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National Transport Master Plan

NATMAP 2050

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ENERGY & ENVIRONMENTAL WORKING GROUP

THE IMPLICATIONS OF GLOBAL OIL DEPLETION FOR TRANSPORT SYSTEMS IN SOUTH AFRICA

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FORUM BUILDING, 159 STRUBEN STREET, PRETORIA, 0001, GAUTENG, SOUTH AFRICA

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Prepared By:	Energy & Environmental Working Group, represented by: • Africon • SSI • Ingérop In association with • The Association for the Study of Peak Oil (SA), Marianne Vanderschuren and Tanya Lane

2. Energy and Transport Status Quo: Demand and Vulnerabilities

A report submitted to the National Department of Transport by

The Association for the Study of Peak Oil (SA)

in association with

Marianne Vanderschuren

and

Tanya Lane

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Executive Summary

Overview of the South African Transport System

- The major transport arteries that provide access for both passengers and freight in South African urban and rural markets are paved and/or unpaved roads. This is the consequence of an ongoing shift away from rail transportation towards road transportation over the past decade or two.

- Half the South African population uses non-motorised transportation (NMT) to move along the country's roads – either by walking or by cycling. Walking is probably a greater mode of transport than cycling. Half the population uses primarily road motorised transport, focused primarily on private cars and mini bus taxis (MBT).

- Freight is moved primarily through motorised road transport.

- Economic and population growth have resulted in increasing transport flows, both in respect of passengers and goods and services. The two most prevalent reasons for passenger movement are work and education, with the former predominating in urban areas and the latter in rural areas. The public transport system in the form of buses and trains is severely underutilised because commuters perceive it to have a low value due mainly to the distances between housing, stations and bus stops. Most commuters perceive greater value in using MBT due to the shorter walking distances. The public transport system is underutilised, severely under-developed and undercapitalized in relation to commuter needs.

- While the volume of freight moved on roads has been steadily increasing in recent years, there have also been reports of supply chain managers looking to rail for relief from the high cost of transportation, following the recent spike in oil – and therefore, petroleum – prices. Currently rail freight appears to be used exclusively for long-haul operations (transporting mainly iron-ore and coal).

Energy Used by the Transport System

- The primary sources of all energy used in South Africa are mainly coal (67%) and oil (20%).

- While the transport sector consumes 27% of all final energy forms, it uses up a significant 78 % of liquid fuels and only 1,6% of electricity, to drive its wheels.

- The transport sector is almost absolutely dependent on petroleum fuels (98%) and South Africa depends for 70% of its oil on imports, mainly from the Middle East.

- Road transport consumes 87% of the energy used by the transport sector as a whole, aviation 11% and rail only 2%.

- The intensity of road transport in South Africa is concentrated in the Durban-Gauteng corridor: reflected by the corridor accounting for the most liquid fuels consumption.

Peak Oil and Its Implications for the Transport System

- Because oil is a finite, non-renewable resource, and because consumption of oil has been growing exponentially with increased world economic growth, production of oil will at some time in the future peak, and then decline. The reason why the peaking of oil can be expected within the next 10 to 20 years is because discoveries of new oil fields have been on a declining trend since the mid 1960s, with few significant finds over the past 35 years. In addition, the remaining oil resources include an increasing proportion of difficult-to-get and highly polluting tar sands; thus international agreements on limiting the burning of fossil fuels could inhibit the usability of known quantities of “dirty” oil.

- There is therefore a critical and urgent need to drive economic production and distribution through power derived from renewable energy sources. However, a fall in consumption trends is also likely as global economic growth slows down and jobs are shed worldwide in the process.[1]

- The life-cycle curve of oil production is roughly a bell curve, and the longer that production is maintained at or above current rates the faster it will fall on the down side of the curve.

- Precisely when the oil production peak will occur is uncertain, as is the likely post-peak rate of oil depletion, whether substitutes will be developed and implemented in time to avoid damaging shortages, and precisely how governments and people will respond when the decline sets in.

- Based on available evidence there is a significant risk of a rapid decline (or cliff) in global oil production at some time in the foreseeable future (i.e. to 2030). In other words we have roughly 20 years within which to have made a critical switching to non-oil-based transportation fuels and greater fuel efficiency if we are going to avert a serious threat to the South African national transportation system, which is currently powered almost entirely from oil-based fuels.

Strengths and Vulnerabilities of the SA Transport System

- The South African transport system is highly exposed to the risks associated with peak oil and fuel price spikes, given the extent to which petrol-driven private cars and MBTs, and diesel-powered trucks, provide transportation for the vast majority of commuters and businesses respectively.

- It is interesting to note that the majority of the South African population uses NMT at present, so that they are not highly exposed to the impact of peak oil on their own transportation.

[1] Should China, which exports 50% of its GDP to the West, be able to decouple from the global economy and develop significant internal consumer markets, this could mitigate the current global economic slowdown

- In the economic context where petroleum products are vital for sustaining economic growth, their jobs could be critically exposed, depending on the industrial sector. This reflects the fact that freight continues to be transported primarily by road, with the volumes moved by rail remaining stagnant, and as oil prices spike and supplies of it deplete economic growth of particular sectors can be expected to stagnate and decline.

- It is important to identify all the vulnerabilities of the South African transport system, as well as the risk posed, as part of a risk analysis and mitigation exercise.

- To lay the basis for a risk analysis and mitigation exercise we may note the following key vulnerabilities in seven transport modes that make up the overall transport system in the country:
  - Aviation transport
    - Sensitivity to fuel price rises
    - Severe environmental impact
    - Only one alternative fuel
    - High capital costs
    - Only set routes
    - Relatively inflexible as a form of transport business

  - Road transport (private passenger)
    - Energy inefficient
    - High environmental costs
    - Wasteful of key resources (steel, oil, coal)
    - High dependencies among certain user groups
    - Reduced demand comes with high economic cost

  - Road transport (freight)
    - High environmental costs
    - Sensitivity to fuel prices
    - High fuel prices and reduced demand

- Road transport (public transport)
  - Reliability will be severely impacted
  - Security of passengers likely to be severely compromised

- Rail transport (passenger)
  - Poorly maintained urban networks – current physical state problematic
  - Limited geographical (spatial) outreach of existing networks
  - High cost of improvements to the stock and the system
  - Loss of skills within the sector
  - Lack of engineering and maintenance infrastructure
  - Long lead times to effect upgrading

- Rail transport (freight)
  - Poorly maintained networks – current state is problematic
  - Poor maintenance
  - Lack of speed in delivery will increase inventory turn-over time
  - Lack of inter-modal facilities

- Water-based transport
  - Low capacity to handle passengers
  - Requires infrastructure from coast
  - Long lead times to improve capacity
  - Lack of speed will significantly increase journey times

Conclusions

- In the short-term there is scope for effecting savings on liquid fuel consumption through more effective use of private cars (car pooling, lower speed limits, other traffic management measures).

- In the medium-term a switching to non-oil-based sources of energy for transportation will have to be effected; electricity appears to hold the greatest potential, especially as such a small part of the system is currently electrically powered.

- Investing in improving and upgrading rail transportation for both passengers and freight in the Durban-Gauteng corridor would likely have maximum impact given the concentration of existing transport intensity and fuel consumption in this geographical space.

- Significant parts of the transport system need to be moved from a liquid fuels base to an alternative fuels base within the next 20 years.

2.1 Introduction

This report is the first of four reports for the National Department of Transport on the implications of peak oil for the National Transportation Master Plan (NATMAP)

2.1.1 Subject of this Report

The subject of this report is the demand for energy from the South African transport system, and the vulnerabilities that the system faces to a significant depletion or rise in the cost of provision of energy.

2.1.2 Background to Investigation

The investigation, of which this report forms a part of, arose from a proposal that was submitted to the National Department of Transport at the invitation of the Deputy-Director General, Mr Situma, who is managing the process of developing the NATMAP. The intention behind this study is to complement the work which has already been commissioned by the Department to develop the NATMAP. To this end ASPO SA assembled a team of people whose combined expertise covers the critical issues that need to be examined so that the NATMAP will consider the impact of global oil depletion on both the South African transport system and space economy.

The objectives of this investigation are, therefore, that:

- It should produce a stand alone strategic set of documents
- These documents should be used as reference works by the consultants employed to develop the NATMAP
- These documents should be used as reference works by the National Department of Transport

- Pending Departmental decision these documents should be made available as public discussion documents
- These documents will contribute to drawing out the strategic implications of oil depletion for the transportation sector and its development over the coming decades until 2030
- These documents will contribute to setting out a number of routes to a likely end state within the time frame of the NATMAP
- These documents will contribute to explicating the implications of these routes in terms of energy alternatives, energy savings and likely investment

2.1.3 Objectives of Report

The key objectives of these strategic documents, of which this specific report is the first, are:

- To highlight the key strategic implications for the transportation sector of global oil depletion
- To identify key principles which should be factored into transportation planning with a long-term time horizon in the light of the depletion of key energy and other resources
- To identify a number of plausible scenarios which arise as a consequence of global oil depletion
- To assess the risks associated with these scenarios to transport planning in the light of the inevitability of oil depletion during the time frame of the NATMAP
- To identify high-level alternative strategies to the current business-as-usual and demand-led approach for different modes of transport in the light of oil depletion

2.1.4 Limitations and Scope of Investigation

The scope of the investigation has been limited to an agreed table of contents for all four documents, between the Department of Transport, the main contrtactor and the ASPO (SA) consulting team.

2.1.5 Plan of Development

Section 2.2 of this report provides an overview of the South African transport system, covering road, rail, air and water-based infrastructure, both with respect to passenger and freight movement; the extent of person-travel and freight-movement is listed in some detail, including pipeline-based freight movement. This lays the basis for Section 2.3, which covers energy used by the transport system.

Section 2.3 covers the primary energy supply for South Africa, and traces the major sources as well as carriers of energy through to the transport system, and demonstrates the contribution of the transport sector to final energy consumption, as well as the sector's share of petroleum and electricity energy consumption. Section 2.3 also provides a trend analysis of transport's consumption of the range of types of liquid fuels over recent years, focusing particularly on the consumption of diesel and petroleum fuels according to provinces as well as economic sectors.

Section 2.4 addresses the global production and supply of oil, which is the primary energy source carried through petrol and diesel to much of the South African transport system. Following the bell-shaped curve of the life cycle of regional oil production – the so-called Hubbert curve – section 2.4 makes the simple point that because oil is a finite resource, at some time in the future the exponentially growing consumption of oil, which characterises economic growth model of the global economy, will deplete the supply oil. The critical point is not the time when the supply of oil finally runs out, but the time when the supply of oil peaks, i.e. when the quantity of oil supplied starts decreasing. The section identifies the likely timing of the peak, the expected trends ion post-peak depletion and finally the likely impacts on agriculture, food, population, social cohesion, technology and transport and mobility in South Africa.

Section 2.5, basing itself on the likely impacts of peak oil on the South African transport system (in respect of aviation, road transport, rail transport and water-based transport), explores the strengths and vulnerabilities of this system.

2.2 Overview of the South African Transport System

2.2.1 Infrastructure Provision

South Africa is a large country with a diverse physical environment. The country's total land area amounts to 1 219 912 square kilometres. South Africa's physical geography is dominated by one feature: a massive escarpment that runs right around the subcontinent, dividing a thin coastal strip from a huge plateau. This escarpment is clearest in the East, where it is marked by the spectacular Drakensberg Mountains (Ballard, 1998).

2.2.1.1 The Road Network

The South African road network started in Cape Town. Land surveyors slowly 'worked their way' inland through often difficult terrain. It was Pieter Potter who discovered the first Roodezand pass in 1658. Since then, people like Governor Sir Lowry Cole, John Montagu, Charles Michell and Andrew and Thomas Bain (the first of numerous father-and-son teams to serve civil engineering in South Africa with great distinction) have built the most beautiful passes. In the Western Cape, travellers can still witness these incredible engineering works. The South African highway system and the main cities are provided in Figure 2.2-1.[2]

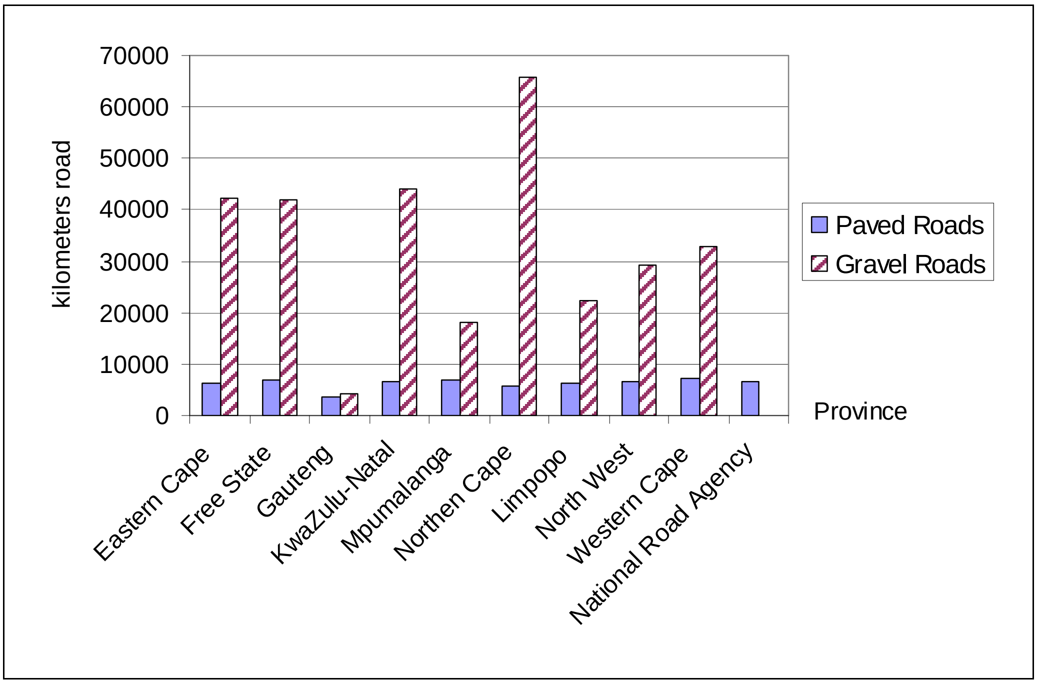
[2] Note: The names of the following South African cities have changed: Buffalo City (previously East London), eThekwini (previously Durban), Mangaung (previously Bloemfontein), Msunduzi (previously Pietermaritzburg), Nelson Mandela Metropole (previously Port Elizabeth), Polokwane (Pietersburg) and Tshwane (previously Pretoria).

Figure 2.2-1: South Africa's Provinces, Cities and Road Transport Network

Source: Vanderschuren, 2006

Although the building of the road network started centuries ago, South Africa still has many unpaved roads. The demand in many rural villages is so low that paved roads are not cost efficient. Figure 2.2-2 provides an overview of the paved and unpaved road network per province and for the South African Road Agency Pty Ltd (SANRAL).

Figure 2.2-2: Length of the South African Road Network



Source: NDOT, 2002

SANRAL is responsible for the national roads. The total of 6 713 kilometres of road under the responsibility of SANRAL is broken down into 239 kilometres of six-lane highways, 1 154 kilometres of four-lane highways, 433 kilometres of four-lane roads and 4 863 kilometres of two-lane roads. Moreover, SANRAL is responsible for a 24 kilometre stretch of gravel road. Cities are responsible for urban roads. In total 170 000 kilometres of – mainly paved – urban roads exist in South Africa (NDOT, 2002).

The breakdown of roads per road category is provided in Table 2.2-1. It needs to be mentioned that, while the data from the national road network are reliable, the provincial data are less reliable and the remaining road data are at best approximations (NDOT, 2008).

Currently, the expenditure on infrastructure in South Africa focuses on the improvement and maintenance of roads, as most connections between cities, as well as the accessibility of urban areas, have been built in the past. Only where villages and cities grow, are new roads required. These roads are generally small and are often financed by urban developers.

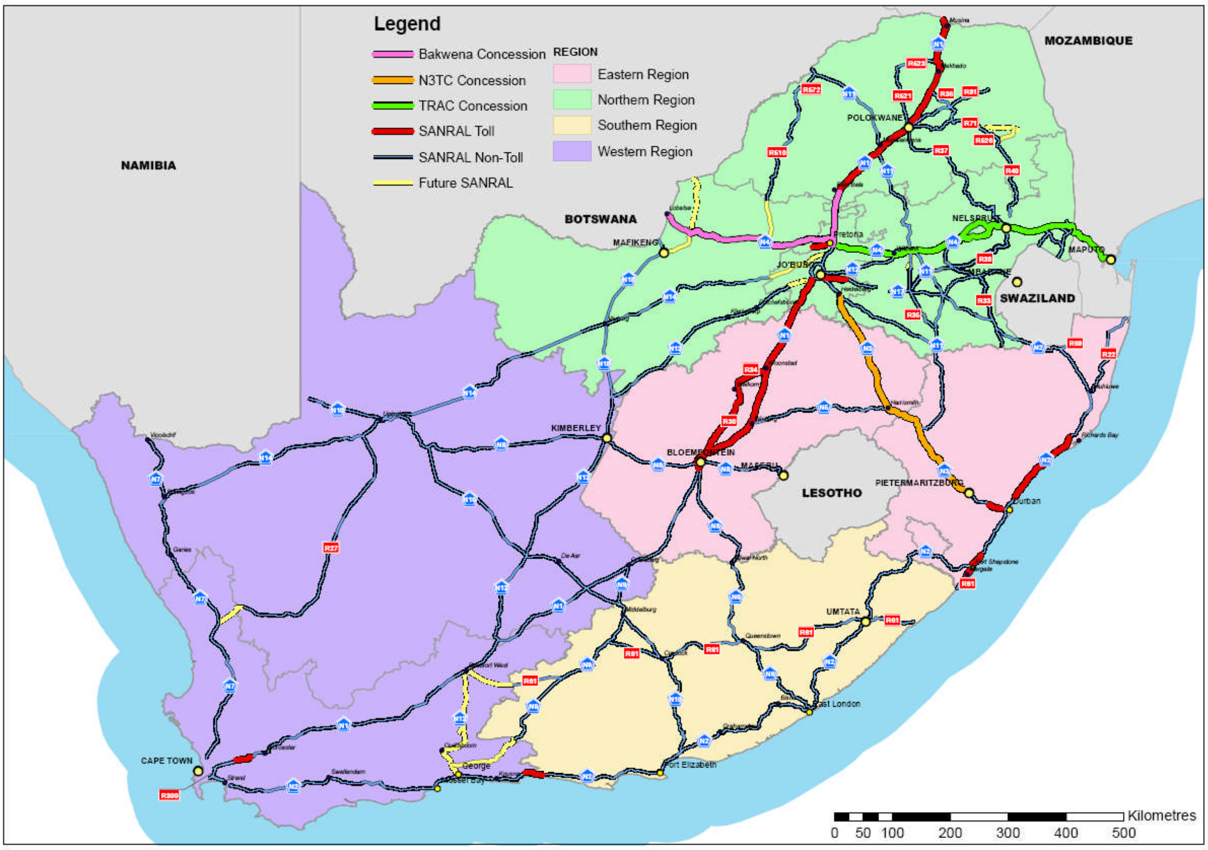
Table 2.2-1: Extent of South African Road Network by Road Classification

Road Authority	Length (km)	%of total road network
National Roads	16,197	2%
Provincial Roads – Paved	47,157	6%
Provincial Roads - Gravel	176,716	23%
Provincial Roads - Access	124,238	16%
Un-proclaimed Rural Roads	221,092	29%
Metro, Municipal and other Roads	168,058	22%
Total	**753,458**	**100%**

Source: SANRAL, 2005

The maintenance of roads is a major problem in South Africa. In the early days, road building and maintenance were financed out of toll collection (see Figure 2.2-3). In 1984, the South African government re-introduced tolls on the national roads. The total length of toll roads grew from 27 kilometres in 1984 to 2 995 kilometres in 2007 (NDOT, 2008).

Figure 2.2-3 SA's National Road Network (Toll and Non-toll Roads)



Source: SANRAL, accessed via NDOT, 2008

The total road network per province was used to calculate the road density of every province, in terms of the length of road per 1 000 population and per square kilometre (see Table 2.2-2) (NDOT, 2008).

Table 2.2-2: Total Extent of Road Network per Province per Capita

Province	Population	Area (km^2)	Road km/ 1000 persons	Road km/km^2
Eastern Cape	6,527,747	169,580	11	**0.43**
Free State	2,773,059	129,480	18	**0.39**
Gauteng	10,451,713	17,010	3	**2.10**
Kwa-Zulu Natal	10,259,230	92,100	10	**1.08**
Limpopo	5,238,286	123,910	4	**0.17**
Mpumalanga	3,643,435	79,490	10	**0.48**
Northern Cape	1,058,060	361,830	55	**0.16**
North-West	3,271,948	116,320	7	**0.20**
Western Cape	5,278,585	129,370	8	**0.32**
Total	**48,502,063**	**1,219,090**	**9**	**0.36**

Source: www.STATSSA.gov.za, 2007

It can be seen that the Northern Cape, the largest province with the lowest population, has the highest road length per 1000 population and least road length per square kilometre in contrast with Gauteng, the smallest province with the highest population, resulting in the shortest road length per 1000 population, but with the longest road length per square km, i.e. the densest road network in South Africa (nearly 7 times South Africa's average road length per square kilometre (NDOT, 2008).

The provincial and national authorities responsible for providing and maintaining roads have an ongoing concern about the levels of overloading recorded all over the country. The development of a successful network of weighbridges, vehicle load monitors and screening devices is needed to resolve this problem (NDOT, 2008).

Finally, it needs to be mentioned that South Africa has adopted the American approach with regard to road design, resulting in car dependency similar to that in the US. Many places in South Africa are only accessible by motor vehicles.

2.2.1.2 The Rail Network

South Africa's rail infrastructure consists of a network covering 20 000km. This represents approximately 80% of Africa's rail infrastructure. There are 80 000 wagons and 2300 locomotives (NDOT, 2008). Rail infrastructure of national importance includes infrastructure that is used for rail freight and for long and short distance passenger rail transport. Long-distance rail infrastructure is owned by Transnet and operated respectively by Transnet Freight Rail (TFR) and the South African Rail Commuter Corporation (SARCC) (i.e. lines used for both goods and passengers). Commuter rail infrastructure is owned and operated by the SARCC, through its operating entities Metrorail and Intersite. These lines are also used for both traffic types (NDOT, 2008).

2.2.1.2.1 The Passenger Transport Network

The South African Rail Commuter Corporation (SARCC) was established as an agency of the National Department of Transport (NDOT) to take responsibility for commuter rail services throughout the country. The agglomerations where the SARCC operates include: Buffalo City, Cape Town, eThekwini, Nelson Mandela Metropole, Tshwane and the Witwatersrand.

Table 2.2-3:SARCC Assets (1990)

Assets	Number
Stations and stops	308
Motor coaches	1 308
Carriages	3 340
Single track km	2 400
No. of suburban trains per day	2 613

At the inception (1990) of the SARCC, rail assets to the value of approximately R5.3-billion were transferred to the corporation (see Table 2.2-3 for details).

The maintenance of rail infrastructure and services is costly. Due to limited funding being available, services have decreased. Moreover, the City of Cape Town estimates that the provision of services will vanish within the next 15 years, due to safety problems if the expenditure on maintenance does not increase.

2.2.1.2.2 New Passenger Transport Infrastructure

The Gautrain project, one of the largest and most ambitious transportation projects in South Africa and indeed Africa, is expected to play an important role in stimulating economic growth and job creation in Gauteng. It will also relieve traffic congestion, promote public transport, tourism and public-private partnerships, and change the culture of public transport usage in South Africa (www.gpg.gov.za).

The Gautrain is a project of Blue IQ - the Gauteng Provincial Government's multi-billion Rand initiative to invest in strategic economic infrastructure. The Gautrain Rapid Rail Link is a state-of-the-art rapid rail network planned for Gauteng. The rail connection comprises two links, namely a link between Tshwane (Pretoria) and Johannesburg and a link between Johannesburg International Airport and Sandton.

Building of the Gautrain project is well on its way. Of the 15 km underground route, almost eight kilometres have been excavated (Venter, 2008). The estimated costs for the Gautrain project have been growing over the last couple of years, currently being more than twice as much as the original estimated amount. The new budget is five times higher than the annual cost for public transport in the country.

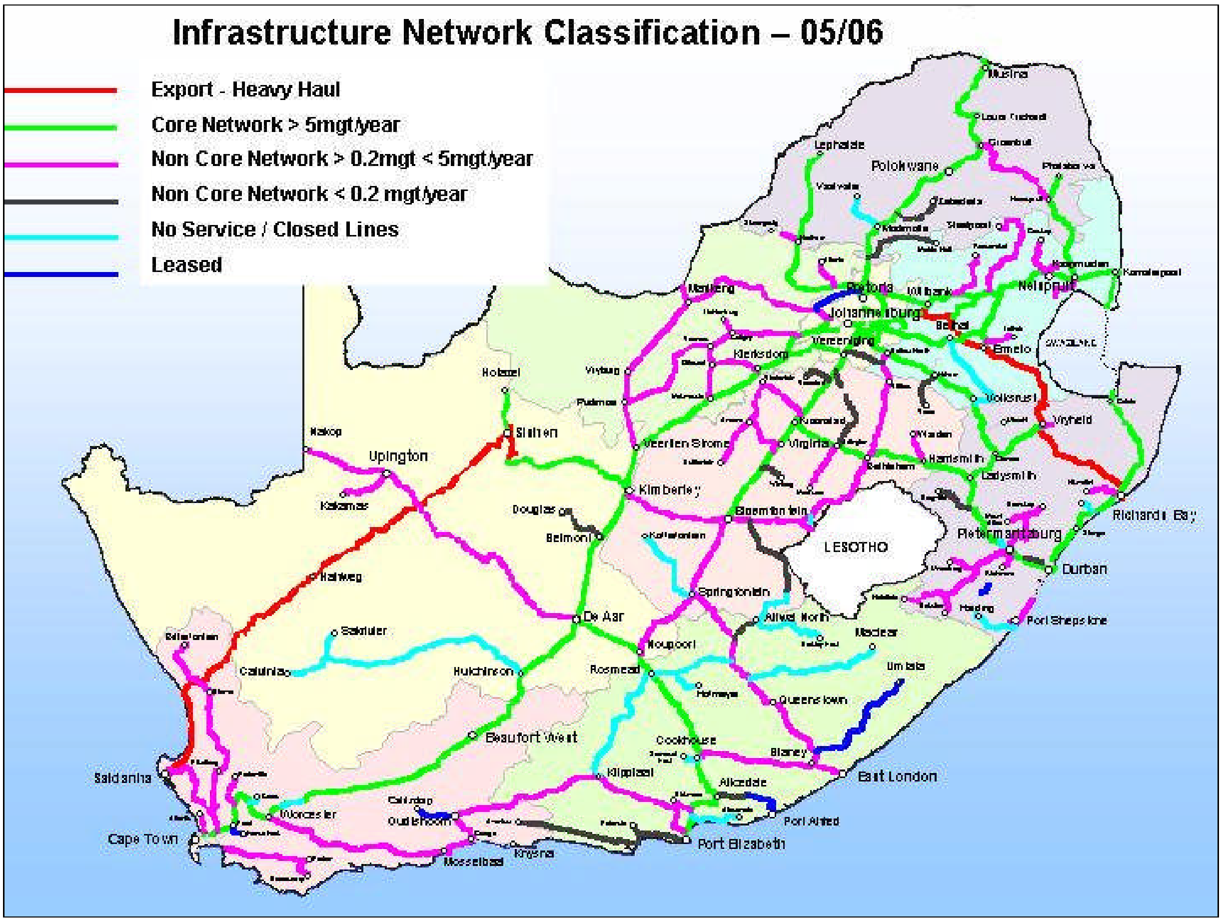
2.2.1.2.3 The Freight Infrastructure Network

The Transnet rail network distinguishes between the heavy haul export lines, the core network, two classes of non-core lines and closed lines. The core network (inclusive of the two heavy haul export lines) represents 43% of the network, with low and light density lines (non-core network) being 42%. The balance of 15% represents infrastructure with no service, closed, and leased lines (NDOT, 2008). The current core network can be classified by use as (see Figure 2.2-4):

- Industrial lines (blue): typically light to medium axle loading for containers, automotive and other general freight goods
- Heavy haul lines (red): specialising in high-axle load bulk products like coal and iron ore
- The green lines: strategic cross-border connections to neighbouring countries

Fryer (NDOT, 2008) indicates that 10 588 km of the Transnet rail network is considered high potential, a further 2 468 km as non-viable lines in operation and 2 147 km as lines where no services are operated. There are various plans to improve and expand the Transnet rail network, providing a potential for growth. From the analysis of freight operations in the Status Quo Report (NDOT, 2008), it would appear that there is sufficient under-utilised infrastructure to permit the promotion of train operator competition over a large proportion of the network. This will require the separation of track provision and maintenance from train operations.

Figure 2.2-4: The National Rail Network



Source: NDOT, 2008

2.2.1.3 Airports and Air-based Routes

South Africa has more than 20 commercial airports, of which many are small and offer limited flights. Some characteristics of the most important airports are as follows (http://www.mapsofworld.com/south-africa/travel/airport.html):

- OR Tambo International Airport (ORTIA), South Africa's largest airport, was established in 1952. According to a report of the United Kingdom transportation research laboratory in 1999 the airport is termed as one of the most cost-effective airports in the world.
- Cape Town International Airport is the second largest airport of South Africa. This airport achieved World Travel Awards for leading airport in Africa for six consecutive years.
- Bloemfontein Airport is the third largest South African Airport and is an important gateway to the Free State.
- Durban Airport is a gateway to KwaZulu-Natal, especially for thousands of tourists.
- East London Airport is a small airport that greatly contributes to the growth of the economy of the Eastern Cape.
- George Airport is flocked by a number of tourists annually.
- Kimberly Airport is located at the heart of the Northern Cape, in a town most famous for the Big Hole (Mining).
- Port Elizabeth Airport is situated five minutes from CBD and is very near to the beach front and other areas of importance in the city.
- Upington Airport is a small airport that does brisk business in cargo.

Figure 2.2-5: South African Airports

The authors realise that Figure 2.2-5 is incomplete. Various airports are not indicated. Nonetheless, this was the best available map.

There are more than 50 airlines operating in South Africa, of which six provide domestic flights. Most of the international flights connect to OR Tambo International Airport in Gauteng. A limited number of international airlines also provide connections to Cape Town International Airport (www.acsa.co.za).

2.2.1.4 Ports and Harbours Infrastructure

There are some 18 ports of note along the 2 954 km long coastline of South Africa, which include eight multi-purpose commercial ports, fishing harbours and other government and private port facilities. The commercial ports are located in KwaZulu-Natal (Richards Bay and Durban), Eastern Cape (East London, Ngqura which is still under construction and Port Elizabeth) and Western Cape (Mossel Bay, Cape Town and Saldanha) provinces, with a total land area of 6 272 hectares (ha). They are all controlled and managed by Transnet National Ports Authority (TNPA), which is a landlord port authority and an operating division of Transnet. The only other province with a coastline is the Northern Cape, which has three small craft harbours (NDOT, 2008).

Figure 2.2-6: Commercial Ports and their Rail Corridors

Source: NPA, 2005

Figure 2.2-7: Commercial Ports and their Road Corridors

Source: NPA, 2005

The commercial ports are the interface between sea and land transport, and are vital to the country's social-economic development, given that over 90% (by value and volume) of international trade is maritime trade (NDOT, 2008). South Africa's ports are also a gateway for transhipment freight to and from the neighbouring land-locked countries and provide hub facilities for coastal shipping services (NDOT, 2008). Figure 2.2-6 and Figure 2.2-7 illustrate the location of the ports and their major freight rail and road corridors, respectively, to the hinterland (NDOT, 2008).

All southern African ports face the challenge of infrastructure development to accommodate the growth in international trade (NDOT, 2008). Many ports that lack sufficient capital to ensure adequate expansion have concessioned terminals to major international port operators and are experiencing success through this measure. Congestion remains a primary concern and in an effort to combat this, ports are developing value-adding activities close to or inside the port boundaries, or attempting to streamline the intermodal transport system to the port. Shippers tend to choose a complete supply chain solution instead of a single port to provide a holistic solution to their transport problem and ports therefore need to make sure they add value to the supply chain in which they participate.

South African ports tend to be product-specific and natural specialisation has resulted in relatively low levels of inter-port competition in South Africa (NDOT, 2008). A major constraining factor to growth in port traffic is the lack of adequate and modern intermodal transfer points between the ports, road and rail; and this situation needs to be improved to accommodate the growth in containerised traffic (NDOT, 2008). The Transnet responsibility for port planning and management issues deters private sector investment and has led to the situation where several ports are badly in need of further redevelopment , investment and modernisation, but are limited by the provision of capital under the control of central government (NDOT, 2008).

2.2.1.5 The Pipeline Network

The main national pipeline network in South Africa currently spans five provinces, namely KwaZulu-Natal, Free State, North West, Mpumalanga and Gauteng. A separate system is found in the Western Cape. Products transported by pipeline include, gas, aviation turbine fuel, crude oil, diesel, alcohol, and various grades of petrol.

The five main long distance pipelines are (NDOT, 2008):

- The refined products pipeline, a 300 mm diameter multi-product pipeline which transports oil products from the coastal (Durban) refineries to the interior refinery at Sasolburg (Free State).
- The crude line, a 400 mm diameter crude oil pipeline which conveys product from the KwaZulu-Natal coast to the Reef storage and inland refinery. A branch from this line enters Mpumalanga north of Vrede and terminates at Secunda.
- The gas line, also known as Lilly Line, is a 450 mm diameter pipeline which transports gas from Secunda through KwaZulu-Natal via Empangeni to Durban.

- The AVTUR (Aviation Turbine Fuel) pipeline, a dedicated 150 mm diameter pipeline which transports aviation fuel from the refinery in Sasolburg to O R Tambo International Airport.
- The Temane to Secunda gas pipeline.

In addition there are refined product pipelines from Secunda to Witbank via Kendal (where there is a base for strategic reserves), Meyerton-Alrode (and the Gauteng and North West network) and to Sasolburg (NDOT, 2008).

The main petroleum product pipeline operations in South Africa is managed by a parastatal organisation knows as Transnet Pipelines (formerly known as Petronet), which has led to very high charges and delayed investment in new infrastructure (NDOT, 2008). Sasol Gas operates and maintains a gas supply network through 2 265 kilometres of pipeline in the Mpumalanga and Gauteng provinces including the 865 km cross-border pipeline linking the gas fields of Temane central processing facility (CPF) in Mozambique to the Sasol Gas network at Secunda in South Africa (NDOT, 2008).

2.2.2 Person Travel

Various data sources have been used to populate the information in the person travel section of this report. Nevertheless, it needs to be mentioned that the most important source regarding person travel is the National Household Travel survey (NHTS). The NHTS provides a standardised format of information obtained through community questionnaire surveys. The NHTS data were collected in 2003 (NDOT, 2005).

2.2.2.1 Road-based Travel

All household members provided information on whether they had made trips on the travel day. Because the NHTS defined the travel day for household members as any weekday between (and including) Monday to Friday, the travel day could be considered to be a “typical weekday”. A typical weekday for most household members would include regular daily activities, such as working and going to school, and some irregular activities, such as going to the doctor. Activities generate travel and understanding the amount and type of trip-making by households was an important objective of the NHTS. The trip purposes for weekday trips were recorded, as were the modes of transport used (NDOT, 2005). Table 2.2-4: People who make one or More Trips on an Average WeekdayTable 2.2-4 reveals that 76% of the population as a whole (35.2 million people) travelled at least once from their homes on an average travel day. While a somewhat higher proportion of metropolitan and urban residents undertook a trip, the actual number of rural people doing so was greater (NDOT, 2005).

Table 2.2-4: People who make one or More Trips on an Average Weekday

Settlement type	% of people making a trip	No. making a trip
Metropolitan	80.5	12 410 000
Urban	78.7	9 417 000
Rural	70.4	13 376 000
RSA	**75.9**	**35 203 000**

Source: NDOT, 2005

Household members were asked for what purpose they travelled. Table 2.2-5summarises trip purposes per province. In the Western Cape, the number of trips to work is the highest; 41% of all household members made a work trip on a typical weekday. The number of trips to work was lowest in the Eastern Cape and Limpopo, where only about 16 per cent of household members made a work trip on a typical weekday. Trips to educational institutions were the major purpose in five provinces: KwaZulu-Natal, the North West, Mpumalanga, Limpopo and the Eastern Cape. Shopping trips predominated in Gauteng, while visiting friends and relatives was the most frequent weekday trip purpose in both the Northern Cape and Free State (NDOT, 2005).

Table 2.2-5: Main Trip Purposes by Province

Province	% of household members naming purpose			
	Education	**Shopping**	**Visiting**	**Work**
Western Cape	33.4	26.0	19.8	41.0
Eastern Cape	49.2	26.9	27.7	16.5
Northern Cape	34.3	28.3	39.7	30.9
Free State	38.2	33.3	42.9	26.6
KwaZulu-Natal	46.4	24.4	20.1	22.7
North West	39.6	23.7	29.5	26.7

Gauteng	29.9	44.1	33.9	39.3
Mpumalanga	41.4	34.0	36.7	23.7
Limpopo	51.2	22.0	27.0	15.9

Source: NDOT, 2005

An important factor regarding person mobility is the mode choice. Table 2.2-6 shows that the most commonly used motorised travel mode in the RSA is the MBT. Some 22% of the population made use of a MBT at least once in the week prior to the survey day. Use of the MBT as a travel mode was higher in metropolitan areas (29%) than in rural areas (14%). Amongst the provinces, minibus-taxi use was highest in Gauteng where 32% of all household members used the mode at least once in the week prior to survey day, and lowest in the Northern Cape where only 13% used a MBT (NDOT, 2005).

The second most frequently used travel mode was the motor car. In the Western Cape, 30% of all household members used a motor car in the 7 days prior to survey day. The lowest incidence of motor car use was in the provinces with more rural settlements, particularly Limpopo and Eastern Cape, where less than 10% of the population made use of a car at least once during the week prior to the survey day (NDOT, 2005).

The only other modes that experienced significant use were trains and buses. Train and bus usage was highest in metropolitan areas, but the use of buses was also significant in rural areas (where 6% of people used a bus during the week before the survey). The provinces with the highest use of bus services by household members were KwaZulu-Natal (9%), Mpumalanga (8%) and North West Province (7%). Metered-taxi and sedan-taxi use was not significant, with only 1% of the population having used metered-taxis and roughly the same number having used sedan-taxis in the week before the survey. It should be noted, however, that 1% of 46 million is a large number and both modes obviously provide a livelihood for operators. The percentage people using other, mainly Non-Motorised Transport (NMT) is also substantial (NDOT, 2005). Better planning for these modes is urgently required.

Table 2.2-6: Modes used by Household Members in the 7 Day Week

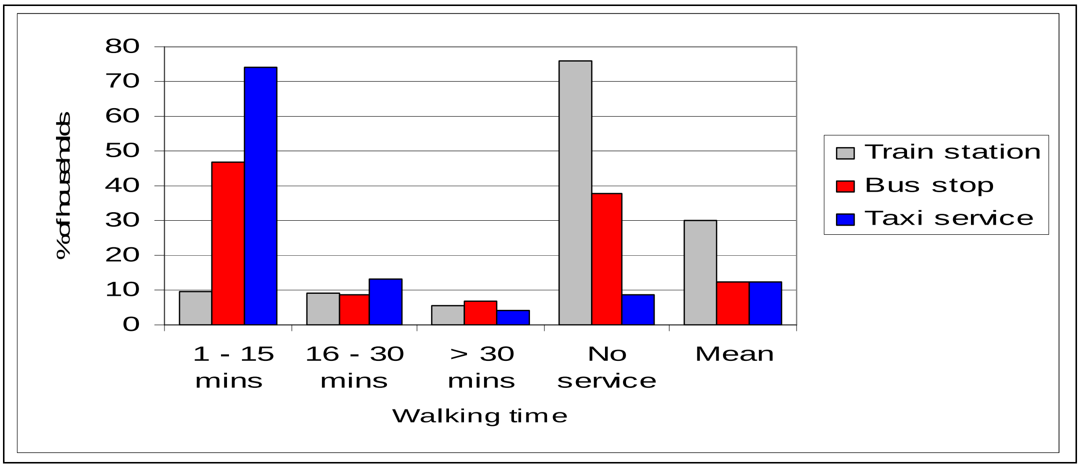
Province	Percentage of all people							
	Train	**Bus**	**Metered taxi**	**MBT**	**Sedan taxi**	**Bakkie taxi**	**Car**	**Other**
Western Cape	7.6	4.6	1.2	19.6	0.8	1.2	29.9	35.1
Eastern Cape	0.7	3.3	0.5	15.9	1.2	4.9	8.6	64.9
Northern Cape	0.3	2.2	0.4	12.7	0.4	0.9	16.1	67
Free State	0.2	3.3	0.9	22.5	1.5	0.6	12.6	58.4
KwaZulu-Natal	1.1	8.7	1.6	20.5	0.9	2.8	11.2	53.2
North West	1.1	6.7	1	22.7	0.4	0.7	11.9	55.5
Gauteng	5.7	3.7	1.6	31.8	0.7	1.1	25	30.4
Mpumalanga	0.2	8.1	1	19.7	1	1.1	11.8	57.1
Limpopo	0.1	5.6	0.6	17.7	0.3	0.7	7.7	67.3
RSA	**2.3**	**5.5**	**1.1**	**21.7**	**0.8**	**1.9**	**15.3**	**51.4**
Metropolitan	5.9	6.3	1.8	29.3	0.8	1.2	24.5	30.2
Urban	1	3.9	0.9	24.4	1.4	1.2	19.8	47.4
Rural	0.3	5.7	0.7	14	0.5	2.9	5	70.9

Source: NDOT, 2005

Although the focus of the infrastructure side of the South African transportation system is car based, the majority of South Africans are dependent on public transport, due to poverty issues. Road based public transport systems that are currently available in South Africa are buses and Minibus-Taxis (MBT). Most services are offered by various bus operators in the urban agglomerations. Nevertheless, there are some long-distance services on offer as well. In December 2002, 26 526 buses, bus-trains and midi-buses were providing the scheduled services in South Africa (NDOT, 2002).

The vast majority (76%) of South African households reported that they do not have access to train services. This and other differences between transport modes are illustrated in the Figure 2.2-8. It is evident from the figure that 38% of households do not have access to bus services (stops). The significance of the taxi mode (minibus, sedan or bakkie) as a convenient form of public transport is also illustrated in the graph. Only 9% of households indicated that there is no available taxi service near their homes. Nearly three quarters of households can reach a taxi service within about one kilometre (less than 15 minutes) of their homes (NDOT, 2005).

Figure 2.2-8: Household Access to Public Transport



Source: NDOT, 2005

The average access times from households to public transport are also depicted in Figure 2.2-8. The relative inaccessibility of trains is evident. On average, households are about half an hour distant from train stations. Bus stops and taxi services can be found within 12 minutes of peoples' homes, on average.

It is interesting to compare these perceived walking times to public transport services to those reported by workers who actually use public transport to travel to work. Figure 2.2-8 shows the average walking times to public transport services reported by users, (including those households that do not use the services).

Transport services in South Africa are clearly not ideal. It needs to be mentioned that the FIFA World Cup 2010 is acting as a catalyst for public transport investments. All major cities are planning improved services that will hopefully leave behind a legacy.

The MBT industry provides unscheduled services. In 2002, 240 427 MBT were operating on South African roads (NDOT, 2002). Services are provided in urban areas, as well as over longer distances. Although the government currently provides licences for routes, it can be concluded that the services are not organised and are often ad hoc. The South African government is trying to include MBT services as a regulated part of public transport.

Table 2.2-7 shows the percentage of all household members who made one, two and three trips per day. It was assumed that each trip from home generated a return trip (NDOT, 2005).

Table 2.2-7: Approximation of Household Trip Generation in the RSA

Settlement type	One-way trips				Average no of trips per person1	Average no of trips per household1
	0	1	2	3+		
Metropolitan	20.1	51.1	13.4	15.4	2.80	9.51
Urban	21.7	50.4	15.4	12.6	2.60	8.92
Rural	29.8	51.1	11.2	7.9	2.08	8.98
RSA	**24.5**	**50.9**	**13.0**	**11.6**	**2.46**	**9.15**
Monthly household income	**One-way trips**				**Average no of trips per person1**	**Average no of trips per household1**
	0	**1**	**2**	**3+**		
Up to R500	28.8	47.4	12.4	11.4	2.34	7.79
R501 - R1000	30.0	48.8	11.7	9.6	2.18	8.41
R1001 - R3000	24.5	51.1	13.0	11.4	2.44	9.89
R3001 - R6000	17.8	54.2	14.3	13.7	2.74	10.74
> R6000	12.5	56.0	15.5	16.0	3.06	10.88

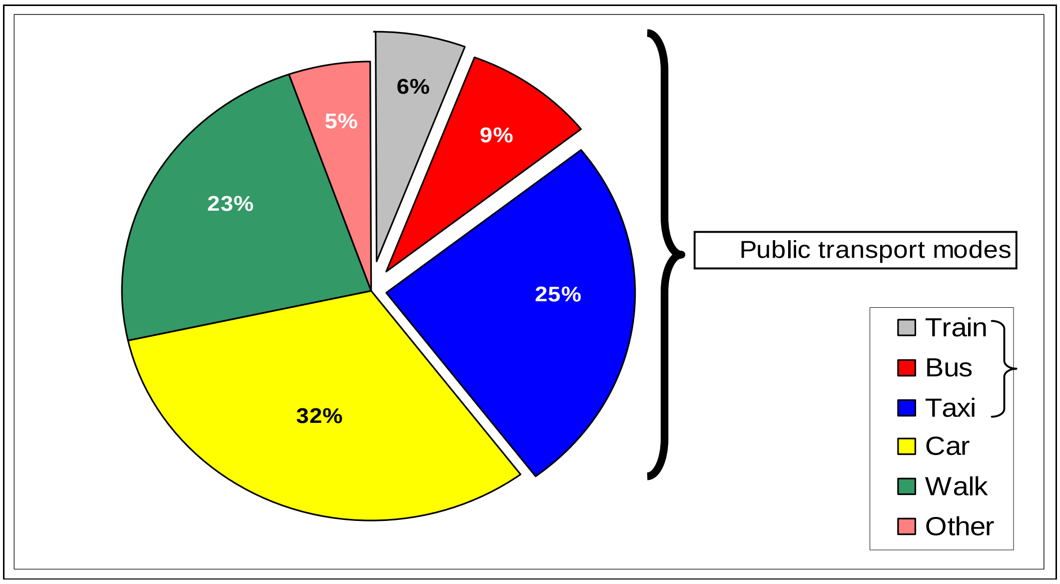
Source: NDOT, 2005

As would be expected, the individuals who made the most trips for many different purposes were found in metropolitan areas (15%) and amongst those earning more than R6 000 (16%) (NDOT, 2005). Given that work and education are two important trip purposes, additional analysis is provided.

2.2.2.1.1 Work Trips

There are about 10 million people who regularly travel to work. The modal share for work trips is depicted in Figure 2.2-9. The modes used vary from province to province, but about a third of all commuters travelled to work by car. Another significant group of commuters (almost a quarter) walked to work (NDOT, 2005).

Figure 2.2-9: Main Mode of Travel to Work



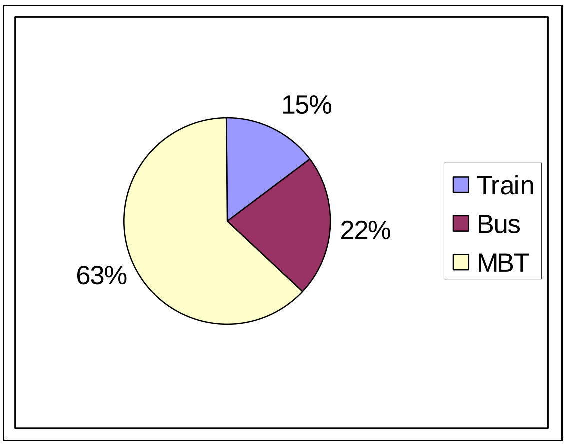
Source: NDOT, 2005

Figure 2.2-9 shows the modes used by the commuters who travelled to work by public transport. The vast majority of taxi users travel in MBTs (over 98%) as opposed to sedan-taxis or bakkie-taxis. The figure differentiates between the settlements types, indicating that train services are significant only in metropolitan areas. Bus services are significant in rural areas but MBT services dominate in all areas (NDOT, 2005).

The reason that MBTs are less dominant in rural areas is because of the long distances between settlements and the generally poor road conditions. MBTs are most dominant in non-metropolitan urban areas. The short distances between residential areas and work places and the relatively lower volumes of passengers in these areas, make MBT the optimum travel mode for reasons of quick loading, fast travel and door-to-door service (NDOT, 2005).

There are approximately 3.9 million public transport commuters. The 2.5 million taxi commuters account for over 63% of public transport work trips. Bus services account for another 22% of public transport commuters and the balance are carried to work by train (NDOT, 2005).

Figure 2.2-10: Public Transport Modes used for Work Trips



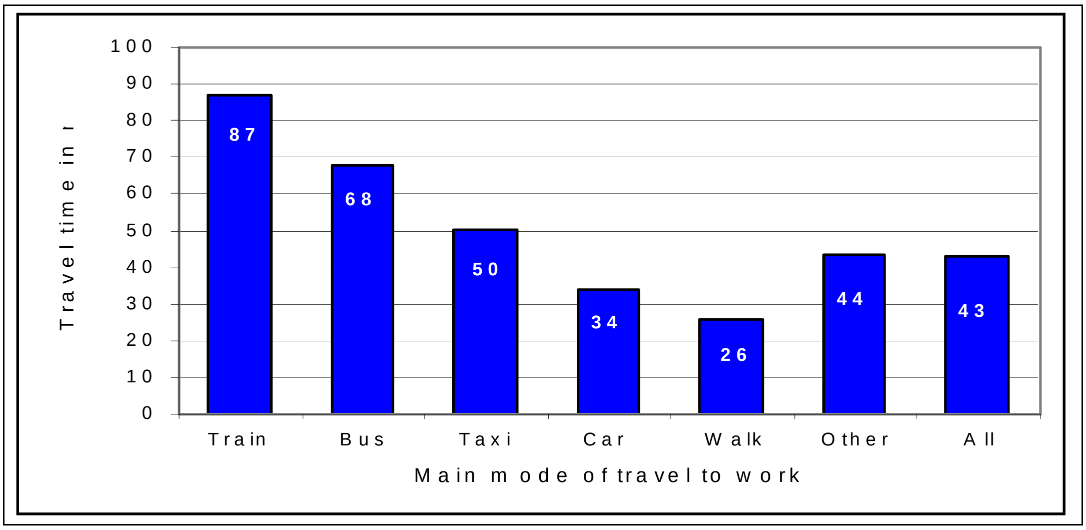
Source: NDOT, 2005

The average reported walking times of workers to public transport modes was nine minutes, with the modal break-down being as follows (NDOT, 2005):

- average walking time to trains was 17 minutes (this applies to train users only);
- bus users averaged 10 minutes to a bus stop; and
- taxi users averaged 8 minutes to a taxi service.

Owing to variable vehicle speeds, as well as pre and post trip travel (see above), the total travel time for commuters differs markedly (see Figure 2.2-11). Train commuters have the longest travel time with 87 minutes, while the average travel time is 43 minutes.

Figure 2.2-11: Average Commuter Travel Times by Mode

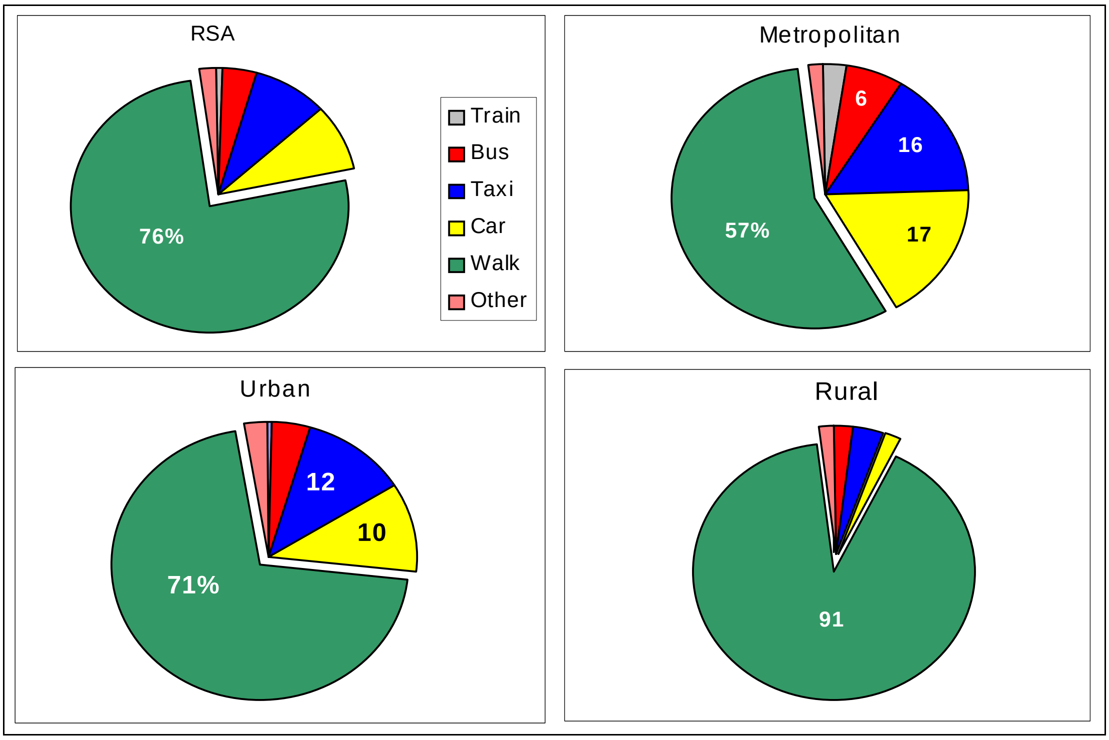


Source: NDOT, 2005

2.2.2.1.2 Educational Trips

Trips to education centres comprise a large proportion of peak hour trips on typical weekdays. The number of education trips is 50% higher than the number of trips made to work (about 15.7 million compared to 9.9 million work trips). It is evident from Figure 2.2-12 that the vast majority of scholars and students walk to their educational destinations (76%). Unfortunately, almost 3 million of those learners spend more than one hour per day walking to and from the education centres. The use of motorised travel is low, with taxis and cars each accounting for around 9% of all trips to education opportunities. There is a large difference between the relative importance of modes used in metropolitan, urban and rural areas, although walking and cycling are the main modes of travel in all areas. In metropolitan areas, about a quarter of learners uses public transport and about 19% use cars or are driven by their parents. In rural areas, 91% of learners walk to education centres (NDOT, 2005).

Figure 2.2-12: Transport modes used to travel to Education Centres



Source: NDOT, 2005

Table 2.2-8 shows the breakdown of the mode used for education trips by the income of the household. It is quite clear from the table that use of motorised transport for education trips is mostly confined to higher income groups (NDOT, 2005).

Table 2.2-8: Transport Mode to Educational Centre by Income of Household

Mode to education - all learners, including pre-school and post-matric							
Monthly household income	Percentage of learners						Number of Learners (millions)
	Walk/cycle	Taxi	Car	Bus	Train	Other	
Up to - R 500	92.5	3.1	1.0	1.8	0.3	1.3	3.5
R501 - R1000	89.3	5.6	1.0	2.3	0.4	1.4	4.0
R1001 - R3000	79.1	9.8	3.1	4.4	1.4	2.2	4.5
R3000 – R6000	56.8	19.6	13.3	6.5	1.7	2.1	1.6
> R6000	27.4	18.5	43.3	6.8	1.3	2.7	1.4

Taxi usage for education trips is far higher amongst those households earning more than R3 000 per month and car usage for households earning more than R6 000 per month. At the other end of the scale, over 90% of the lower income households send their learners to school on foot (NDOT, 2005).

2.2.2.1.3 Vehicle Ownership

As the focus of this study is energy related, it is important to establish the status quo regarding vehicle ownership, use and efficiency. This section provides a summary.

Table 2.2-9: Vehicle Ownership per Vehicle Type and Province (31 July 2008)

Vehicle Class	Province									Total	% of total self-propelled
	GP	KZ	WC	EC	FS	MP	NW	L	NC		
Motor cars and station wagons	2 200 172	741 124	954 783	334 200	246 519	259 993	249 773	184 427	88 633	5 259 624	63.36%
Minibuses	108 933	42 865	36 112	20 746	12 107	18 790	18 878	18 317	3 660	280 408	3.38%
Buses, bus trains, midibuses	13 492	6 718	5 075	3 433	1 867	3 776	2 841	3 481	1 055	41 738	0.50%
Motorcycles, quadrucycles, tricycles	126 266	31 386	67 291	21 189	20 179	18 296	17 888	10 174	7 661	320 330	3.86%
LDV's, panel vans, other light load veh's GVM <= 3500kg	606 806	274 344	270 550	156 629	107 195	140 931	124 417	142 380	58 904	1 882 156	22.67%
Trucks (Heavy load vehicles GVM > 3500kg)	118 503	49 307	34 821	24 381	18 993	23 709	17 507	18 243	8 319	313 783	3.78%
Other self-propelled vehicles	33 221	28 979	29 927	11 924	36 319	20 798	23 410	11 863	6 774	203 215	2.45%
Total self-propelled vehicles	**3 207 393**	**1 174 723**	**1 398 559**	**572 502**	**443 179**	**486 293**	**454 714**	**388 885**	**175 006**	**8 301 254**	
Provincial % of total	**38.64%**	**14.15%**	**16.85%**	**6.90%**	**5.34%**	**5.86%**	**5.48%**	**4.68%**	**2.11%**	**100.00%**	% of total tow vehicles
Caravans	41 290	8 618	16 622	5 866	8 004	9 134	7 691	4 993	2 984	105 202	11.38%
Light load trailers GVM <= 3500kg	263 910	66 976	108 552	42 698	54 137	45 606	46 726	28 432	21 455	678 492	73.38%
Heavy load trailers GVM > 3500kg	47 032	25 619	11 378	11 009	13 005	13 486	9 307	5 979	4 090	140 905	15.24%
Total trailers	**352 232**	**101 213**	**136 552**	**59 573**	**75 146**	**68 226**	**63 724**	**39 404**	**28 529**	**924 599**	
Total provincial % of total	**38.10%**	**10.95%**	**14.77%**	**6.44%**	**8.13%**	**7.38%**	**6.89%**	**4.26%**	**3.09%**	**100.00%**	
All other and unknown vehicles	5 371	3 047	4 759	2 281	4 139	4 132	5 392	2 671	1 202	32 994	
Total number of live vehicles	**3 564 996**	**1 278 983**	**1 539 870**	**634 356**	**522 464**	**558 651**	**523 830**	**430 960**	**204 737**	**9 258 847**	
Provincial % of total	**38.50%**	**13.81%**	**16.63%**	**6.85%**	**5.64%**	**6.03%**	**5.66%**	**4.65%**	**2.21%**	**100.00%**	

Source: www.eNATIS.com

It needs to be mentioned that vehicle ownership has increased over the last couple of decades. The number of cars increased 4.1% annually during the 1980s and 2.2% in the 1990s. The annual rate of growth in the number of cars (2.1%) between 1995 and 2000 is somewhat below the 2.5% annual growth in the nation's human population during the same time period (NDOT, 2008).

Unfortunately, no recent information is available regarding the average use of vehicles. Information for the period 2001-2003 was very stable. The average monthly kilometres per vehicle category was: person car 1,648 km, MBT 2,493 km, buses 3,880 km, motor cycles 995 km, light delivery vehicles (including bakkies) 1,693 km, and trucks 4,196 km per month (www.transport.gov.za).

2.2.2.2 Rail-based Travel

As indicated in Table 2.2-6, only 2.3% of all South African use the train, according to the NHTS (NDOT, 2005). Nonetheless, Metrorail alone runs more than 2.2 million passenger trips every weekday. The Metrorail rail network covers more than 15% of South Africa's rail network and operates more than 470 stations (SARCC, 2008).

According to the SARCC, train schedules have declined in the country, from a high of 793 000 scheduled trains to 717 000 trains over an eight year period (1998/1999 – 2006/2007 (SARCC, 2007). This is indicative of the reduced funding and the budget available over time, as well as the availability of rolling stock. This trend is likely to continue in the short-term, according to the SARCC Annual Report (SARCC, 2007).

The SARCC realises that changes are needed if the company wants to maintain or increase its market share. A Business Plan for 2008/09-2010/11 was developed. Its aim is to increase passenger trips by 6% in 2008/09, 8% in 2009/10 and 10% in 2010/11. The accelerated turnaround strategy of the business is about halting the decline in services. The above initiatives and programmes plan to attain the following targets at the end of the stabilisation phase (SARCC, 2008):

- Train availability at 96%
- 50 stations upgraded
- Predictable service at 90%
- Technical and engineering posts filled at 95%
- Customer satisfaction level at 75%
- Organic fare revenue increase by 5%
- Safety level improvement of 30%

- Crime levels reduced by 15%
- Integrated management system in place
- Unqualified ISO audits.

2.2.2.3 Air-based Travel

The Airports Company South Africa (ACSA) is responsible for operating, planning and maintaining commercial airports in South Africa. ACSA traffic forecasting and analysis take responsibility for the efficient, accurate and timeous dissemination of statistical information about passenger and aircraft movement. The move to an upgraded and integrated system, called Airport Central, will offer even greater benefits. ACSA's (www.acsa.co.za) ten airports handle more than 200 000 aircraft landings and 10 million arriving and departing passengers annually (Table 2.2-10 and Table 2.2-11).

In addition to the tabled information on passenger volumes (NDOT, 2008), passenger volumes from Kruger Mpumalanga International Airport (KMIA) in 2005 were as follows (note no distinction between arrivals or departures):

- Domestic: 173 798
- International: 3 700

Information on passenger volumes from Lanseria International Airport in 2007 (NDOT, 2008) was as follows (also no distinction between arrivals and departures):

- Domestic: approx 91 000
- International: no data available

Table 2.2-10: Passenger Arrivals at Various ACSA Airports (2005)

Airport	Domestic	Regional	International	Unscheduled	Total
ORTIA	**4 481 520**	**295 492**	**3 177 330**	**24 879**	7 979 221
CT International	**2 737 400**	**73 747**	**584 627**	**5185**	3 400 959
Durban International	**1 821 178**	**2 695**	**10 831**	**3 214**	1 837 918
Bloemfontein	**125 429**	**n/a**	**n/a**	**1 559**	126 988
East London	**289 354**	**n/a**	**n/a**	**1 834**	291 188
George	**280 262**	**n/a**	**n/a**	**5 760**	286 022
Kimberley	**51 274**	**n/a**	**n/a**	**6 362**	57 636
Port Elizabeth	**646 170**	**n/a**	**n/a**	**1 466**	647 636
Upington	**14 646**	**n/a**	**n/a**	**2 233**	16 879
Pilanesberg	**2 282**	**505**	**491**	**3 801**	7 079

Source: www.acsa.co.za

Table 2.2-11: Passenger Departures at Various ACSA Airports (2005)

Airport	Domestic	Regional	International	Unscheduled	Total
ORTIA	**4 518 872**	**306 865**	**3 247 068**	**26 414**	8 099 219
CT International	**2 766 290**	**75 742**	**583 034**	**8 148**	3 433 214
Durban International	**1 841 849**	**2 860**	**12 067**	**3 350**	1 860 126
Bloemfontein	**125 967**	**n/a**	**n/a**	**1 850**	127 817
East London	**297 178**	**n/a**	**n/a**	**2 240**	299 418
George	**289 991**	**n/a**	**n/a**	**8 549**	298 540
Kimberley	**51 362**	**n/a**	**n/a**	**6 508**	57 870
Port Elizabeth	**654 804**	**n/a**	**n/a**	**1 307**	656 111
Upington	**13 976**	**n/a**	**n/a**	**2 337**	16 313
Pilanesberg	**2 172**	**772**	**1 264**	**4 855**	9 063

Source: www.acsa.co.za

2.2.2.4 Water-based Travel

In 2005, a total of 125 passenger vessels arrived at South African harbours (NDOT, 2008). Of these, 56 were in Durban, 36 in Cape Town, 11 each in Port Elizabeth and Richard's Bay, nine in East London and two in Mossel Bay.

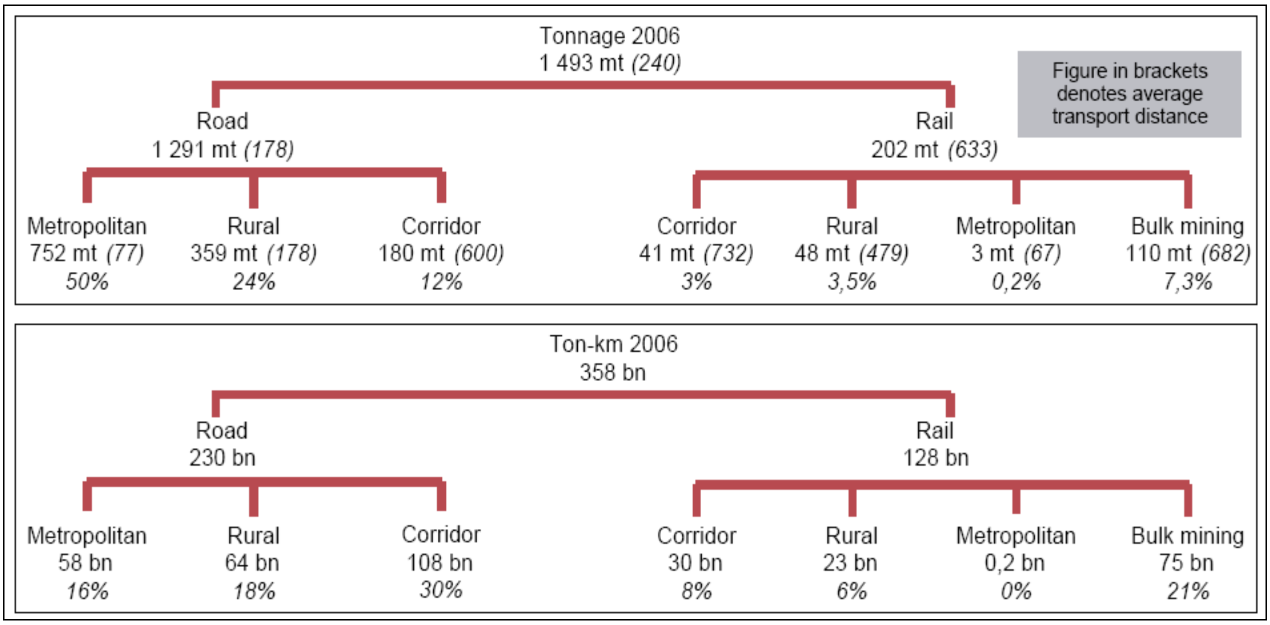
2.2.3 Freight Movement

The annual state of logistics report, produced by the CSIR and the University of Stellenbosch (2007), indicates that total land freight transport in the South African economy amounted to 1.493 billion tonnes shipped in 2006. Total ton-kms amounted to 358 billion. This indicates a 5.5% increase in tonnage and a 1.7% increase in ton-kms from 2005 to 2006. Logistics costs in 2006, as a percentage of gross domestic product (GDP), amounted to 15.7%, of which land transport constitutes 56.9% (CSIR, 2007).

The split between road and rail freight transport is depicted in Figure 2.2-13. Road transport is accountable for 86.5% of total land freight tonnage and for 64.2% of ton-km. There is a great disparity between the average distance hauled for road freight (178 km) versus rail freight (633 km). Rail freight is seen to be almost exclusively used for long-haul operations. Road transport captures the lion's share of land freight transport and freight transport in general. The report indicates that since 1997, virtually all growth in land freight transport has been captured by road transport (Figure 2.2-14). There is a clear need for modal restructuring in the country. The average locomotive travels 7 500 km per month, while the average similar haul road vehicle travels around 18 000 km per month (NDOT, 2008). This performance deficiency also tips the scale in favour of road transport. Moreover, the expansion of the road freight industry is facilitated by the fact that there is sufficient spare road capacity to accommodate the traffic in most (non-metropolitan) areas of South Africa (NDOT, 2008).

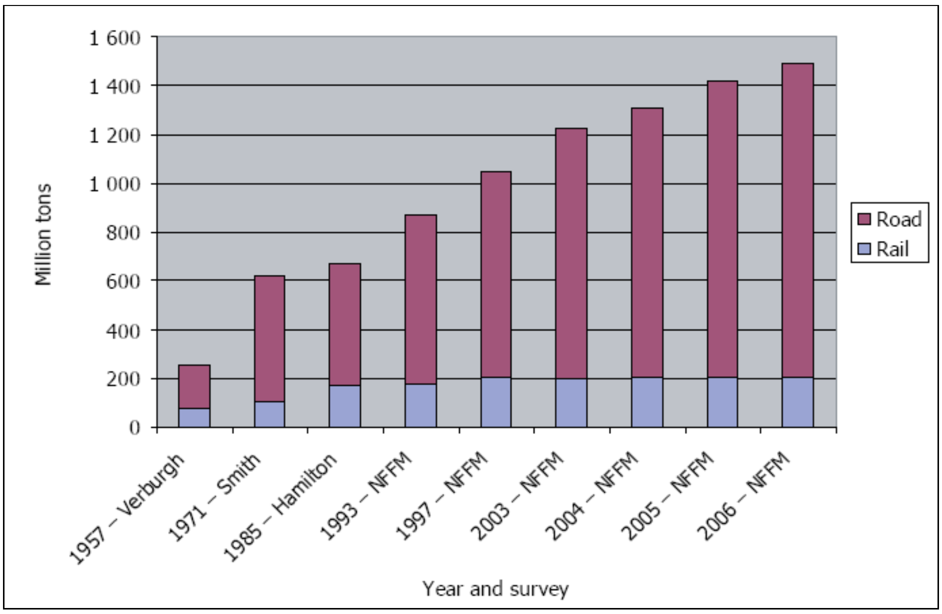
A total of 39% of land freight transport occurs on main corridors, 24% in rural areas, bulk mining accounts for 21% and metropolitan areas carry 16% of freight transport (CSIR, 2007). The major corridors for the movement of goods remain Gauteng–Durban and Gauteng–Cape Town, as also stated in the National Freight Logistics Strategy (NFLS), with almost 40% of all corridor movement taking place on these two corridors (CSIR, 2007). The movement from Gauteng constitutes double the movement towards Gauteng on these two corridors.

Figure 2.2-13: Land Freight Transport in South Africa (2006)



Source: CSIR, 2007

Figure 2.2-14: Historical Land Freight Transport - Modal Split



Source: CSIR, 2007

2.2.3.1 Road-based Freight Movement

In 2006, 1 291 million tons and 230 billion ton-kms were hauled by trucks (CSIR, 2007). The eNaTIS database indicates that there were 313 783 freight vehicles in the South African fleet in July 2008, constituting about 3.8% of the entire vehicle fleet. Approximately 18% of these vehicles are older than 14 years. The tonnages hauled on the various national corridors as indicated in the Status Quo Report (NDOT, 2008), are represented in Table 2.2-12 and the estimated tonnages per commodity group in Table 2.2-13.

In South Africa, modern 400 kW truck tractor-semi trailer combinations haul 38 ton loads at 80 km/h at fuel consumptions of 50 to 55 litres per 100 km (NDOT, 2008). South Africa currently permits some of the largest vehicle combinations in the world for general freight haulage: overall combination length of 22 metres and load heights of 4.3 metres permit a load area of 124 cubic metres and 38 tons; these vehicle carrying capacities and dimensions are undoubtedly a contributory factor in attracting large volumes of bulk commodities to road transport (NDOT, 2008).

Table 2.2-12: Estimated Tonnage Transported on National Corridors

CORRIDOR ORIGIN AND DESTINATION	Tons per annum (Millions)
GAUTENG - DURBAN	41.5
GAUTENG -CAPE TOWN	12.7
GAUTENG - MUSINA	9.8
GAUTENG -LOBATSE	2.3
GAUTENG - RESSANO GARCIA	3.2
CAPE TOWN - NAMIBIA	2.5
CAPE TOWN - PORT ELIZABETH	3.3
EAST LONDON -DURBAN-PONGOLA	7.4
WINBURG - HARRISMITH	6.7
GAUTENG - UPINGTON	2.4
EAST LONDON - BLOEMFONTEIN	1.4
GEORGE - COLESBURG	1.8
BRITSTOWN - NAKOP	0.3
GAUTENG - SWAZILAND	3
THABA NCHU - MASERU	2.76

Source: NDOT, 2008

Table 2.2-13: Estimated Annual Tons of Road Freight per Commodity Group

Commodity Groups	Estimated Annual Tons	%
Crops/Fruit	30,150,000	16.60%
Other miscellaneous	26,840,000	14.80%
Containers	23,672,000	13.00%
Coal	22,860,000	12.60%
Grains	14,670,000	8.10%
Fuel	14,450,000	7.90%
Cement	9,260,000	5.10%
Perishables	7,804,000	4.30%
Iron	7,750,000	4.30%
Wood	7,280,000	4.00%
Agricultural Products	4,930,000	2.70%
Machines-Vehicles	3,686,000	2.00%
Rock -Stone-Ores	3,110,000	1.70%
Drinks	2,910,000	1.60%
Chemicals	2,573,010	1.40%
TOTAL	**181,945,010**	**100.00%**

Source: NDOT, 2008

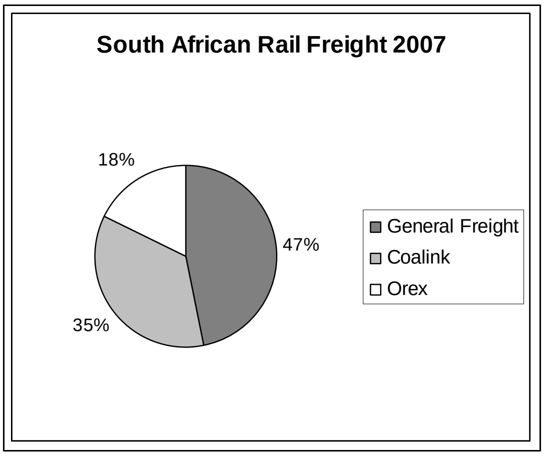
2.2.3.2 Rail-based Freight Movement

From 1980 onwards, rail freight has reduced its participation in general goods transportation and focused activities on the two bulk mining export lines (NDOT, 2008). In 2006, 202 million tons and 128 billion ton-kms were hauled by rail (CSIR, 2007). Rail accounted for only 25% of tonnage moved on the Gauteng–Durban corridor and for 15% on the Gauteng–Cape Town corridor in 2005 (CSIR, 2007). The Coalink and Orex ore export lines form the bulk of rail freight (Figure 2.2-15).

Rolling stock has not been managed efficiently in the past; hence, all the core traffic on offer has not been captured by rail transport (NDOT, 2008). The Status Quo Report (NDOT, 2008) indicates that there is potential for the existing fleet to carry 292 million tons per annum, if it were operated more efficiently. The network infrastructure is able to carry even greater payloads, which would improve efficiency further, but the wagons need to be designed and constructed accordingly. Due to poor wagon fleet renewal practice, old wagons with reduced payloads exist in substantial numbers, limiting the ability to carry extra tonnage (NDOT, 2008).

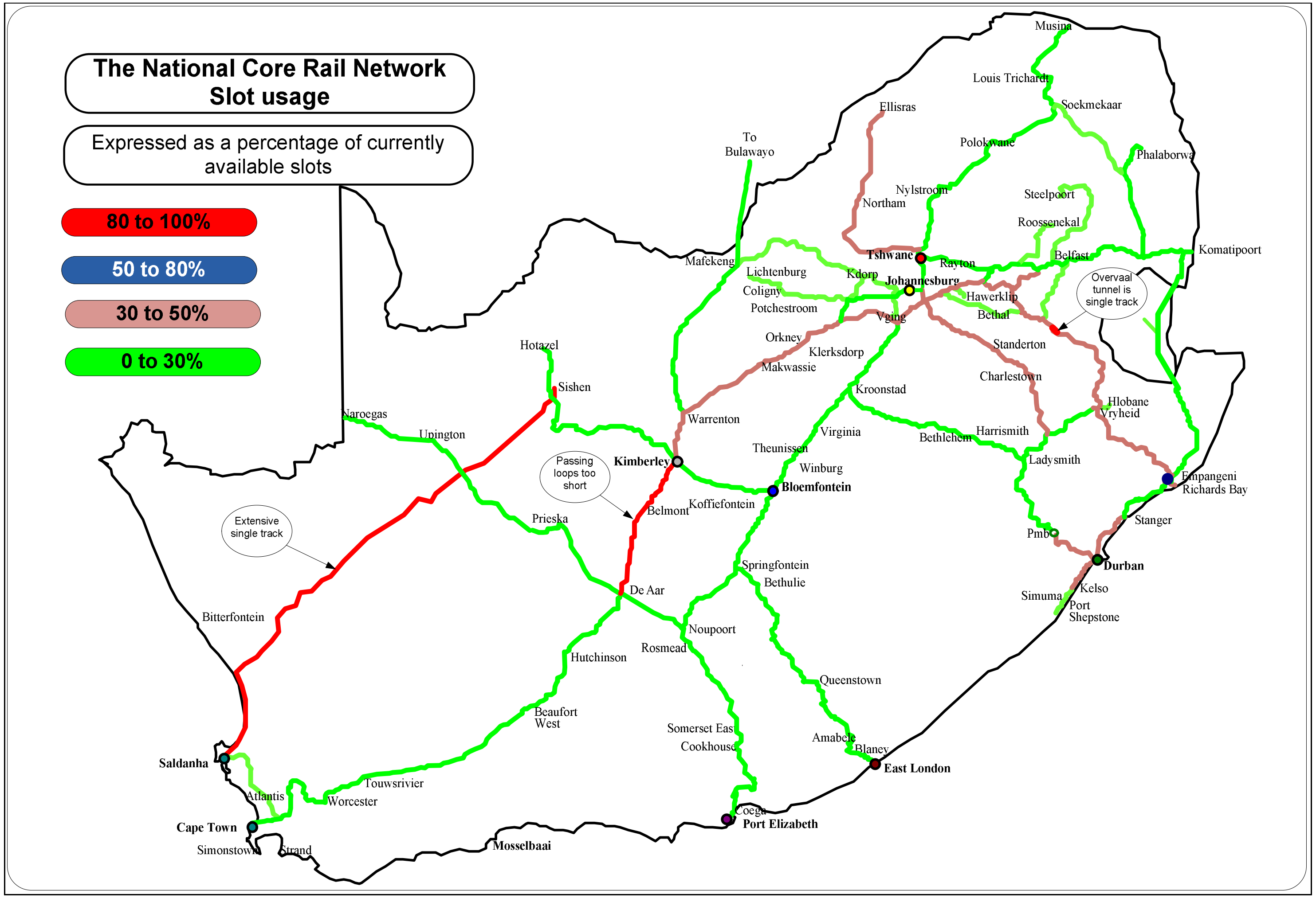
Figure 2.2-16 reveals that there are only three sections of the rail network that are more or less at full capacity; the remainder of the railway network is substantially underutilised (NDOT, 2008).

Figure 2.2-15: Rail Freight in South Africa (2007)



Source: NDOT, 2008

Figure 2.2-16: Slot Usage and National Railway Network



Source: NDOT, 2008

2.2.1.3.3 Air-based Freight Movement

South Africa has six major airports and numerous small regional airports (NDOT, 2008). ORTIA in Gauteng is the most important and busiest airport in the country. Major airports all handle small amounts of cargo that utilises the hold capacity of aircraft on scheduled services. Cape Town International Airport, however, consigns and receives international air cargo, mainly from and to Europe and the Americas (NDOT, 2008). Non-passenger related air freight cargo demand at ORTIA amounts to over 300 000 tons per annum of which two thirds are imports and one third exports (NDOT, 2008). Most of the country's air freight export goods are routed via ORTIA. Air freight cargo traffic is projected to grow 20% over the next five years (NDOT, 2008). Detailed information on domestic air cargo movement is not available; however, an estimation of the air freight cargo tonnages per province is provided in Table 2.2-14.

Table 2.2-14: Estimated Air Freight Tonnages

Province	Tons per annum
Eastern Cape	10,046
Free State	350
Gauteng	300,000
KwaZulu Natal	6,375
Limpopo	Not Available
Mpumalanga	1,125
Northern Cape	170
North West	Not Available
Western Cape	30,000
TOTAL	**348,066**

Source: Adapted from NDOT, 2008

2.2.3.4 Water-based Freight Movement

In 2007, the eight South African ports handled 3.7 million twenty-foot equivalent units (TEUs) of containers and 168 million tons of bulk cargo (Table 2.2-15). Volumes handled in 2007 showed an increase in containerised traffic by 8.6% (NDOT, 2008). In 2006, bulk exports and imports increased by 6% and 4% respectively from 2005 (CSIR, 2007). A decrease of 5% occurred in break-bulk cargo, partially attributable to the growth in containerised cargo. Ngqura is a new port that is not yet operational, but is intended to become the Eastern Cape's primary container port and will probably lead to the closure of Port Elizabeth as a container port (NDOT, 2008).

A major drawback for South African ports is the lack of sufficient inter-modal facilities and this factor needs to be improved to accommodate the growth in containerised traffic (CSIR, 2007).

Table 2.2-15: Annual Containers (TEUs) and Commodity Tons by Port (2007)

Port	Containers (TEUs)	Breakbulk (Tons)	Dry Bulk (Tons)	Liquid Bulk (Tons)	TOTAL (Tons)
Cape Town	764,005	496,778	1,239,966	1,360,377	3,097,121
Saldanha	0	993,060	30,767,716	3,004,865	34,765,641
Mossel Bay	0	92,010	0	898,403	990,413
Port Elizabeth	422,846	1,129,074	3,306,911	161,221	4,597,206
East London	41,986	524,091	260,037	72,758	856,886
Ngqura	0	0	0	0	0
Durban	2,479,232	7,682,830	6,582,013	25,109,212	39,374,055
Richards Bay	4,021	4,477,824	78,425,520	1,339,357	84,242,701
Total	**3,712,090**	**15,395,667**	**120,582,163**	**31,946,193**	**167,924,023**

Source: NDOT, 2008

2.2.3.5 Pipeline-based Freight Movement

Pipelines in South Africa are mainly used to transport liquid fuels. The pipelines have established their place in the transportation system as the most efficient and cost effective means of transporting large quantities of liquids and gases over long distances safely. The cost of transporting bulk liquids by pipeline is lower than for other modes over extended periods, but there is a very high capital investment required for establishing the infrastructure (NDOT, 2008).

Approximately 72 million tonnes of petroleum related products, including gas, were transported by pipeline in South Africa over the 2006 to 2007 period (NDOT, 2008). Transnet indicated in their Annual Report (2005) that a total of 5.99 trillion litre-kilometres were transported on their network in 2005. It must be recognised when analysing the data from pipelines that there are elements of double counting throughout.

The Status Quo Report (NDOT, 2008) indicates the following product distribution of the main pipeline network:

- *Crude oil*: Crude oil is moved from Durban to the NATREF refinery in Sasolburg. Approximately 5 billion litres of crude oil is moved on this pipeline per annum.
- *Refined product:* These include petrol, diesel, and synthetic fuels. Most of these products are transported from Durban to Gauteng – via Ladysmith and the Free State. A total of approximately 9.8 billion litres of refined products per annum is moved.
- *Jet fuel (also a refined product):* Transnet Pipelines uses a dedicated jet fuel pipeline from NATREF to OR Tambo International Airport and jet fuel is also moved from Durban refineries to OR Tambo International Airport. A total of 1.2 billion litres per annum is moved on this line. Approximately 200 million litres of this is moved from Durban refineries to OR Tambo International.
- *Gas:* The gas pipeline runs from Secunda to various places in KwaZulu-Natal, including Newcastle, Richards Bay and Durban refineries via Empangeni. A total of 14 million gigajoules (MGJ) is moved on this pipeline per annum.

In 2006 the pipeline network was operating at capacity – especially on the Durban - Gauteng line, resulting in large volumes of petroleum products having to be transported by road and rail (NDOT, 2008). About 4 to 5 million tons of fuels are being transported by road on the N3 corridor from Durban to Gauteng per annum (NDOT, 2008). A new pipeline has been commissioned, but is due to come online only in 2010.

2.2.4 Conclusions on the South African Transport System Overview

Originally, the rail network in South Africa played a major role for the transportation of goods and people. As rail-based transportation is more energy efficient, it is unfortunate that there has been a steady, continued shift towards road based transport. Many parts of South Africa are, however, only accessible by paved or even unpaved roads.

Globally, as well as locally, transportation flows have been increasing over the last couple of decades and this trend is expected to continue in the future. The ever growing population and recent growth of the South African economy has enhanced this mobility growth. Morning peak traffic flows have increased by up to 5% annually. Car sales have seen record breaking highs between 2005 and 2007. The number of cars increased 4.1% annually during the 1980s and 2.2% in the 1990s. The annual rate of growth in the number of cars (2.1%) between 1995 and 2000 is somewhat below the 2.5% annual growth in the nation's human population during the same time period (NDOT, 2008).

Besides increased car mobility, there has also been an increase in the use of other modes. According to the National Household Travel Survey (NDOT, 2005), only 15% of South Africa's inhabitants used a car in the 7 day survey period. Some 75% of commuters have access to a private car (NDOT, 2005). Although there are differences between the different provinces, within South Africa 21.7% of travellers rely on the MiniBus Taxi (MBT) industry, while a further 3.8% uses other types of taxi service. Train and bus account for 2.3% and 5.5% of trips, respectively, while an overwhelming 51.4% of people rely on other modes, mainly Non-Motorised Transport (NMT).

The low use of formal public transport services (bus and train) is due mainly to the distance between housing and stations and stops. The vast majority (76%) of South African households reported that they do not have access to train services, while 38% do not have access to bus services (NDOT, 2005). Households that have access to formal transport services report distances that are far larger than the acceptable walking distances to MBT services.

The purpose of travel also varies between the provinces. The two main travel purposes are work and education, which each account for between 15% and 52%, depending on the province (NDOT, 2005). More rural provinces record a greater proportion of educational trips, while the more economically active provinces have a larger percentage of work related trips.

Freight transport has also been steadily increasing. The Annual State of Logistics Report, published by the CSIR and the University of Stellenbosch (2007), indicates a 5.5% increase in tonnage and a 1.7% increase in ton-kms from 2005 to 2006 alone. Logistics costs in 2006 amounted to 15.7% of GDP, of which land transport constitutes 56.9% (CSIR, 2007).

Road transport accounts for 86.5% of total land freight tonnage and 64.2% of ton-kms. There is great a disparity between the average distance hauled for road freight (178 km) and rail freight (633 km). Rail freight is seen to be almost exclusively used for long-haul operations and most notably for the two world class bulk mining export lines, transporting iron ore and coal. Road transport captures the lion's share of land freight transport and freight transport in general. Since 1997, virtually all growth in land freight transport has been captured by road freight transport (CSIR, 2007).

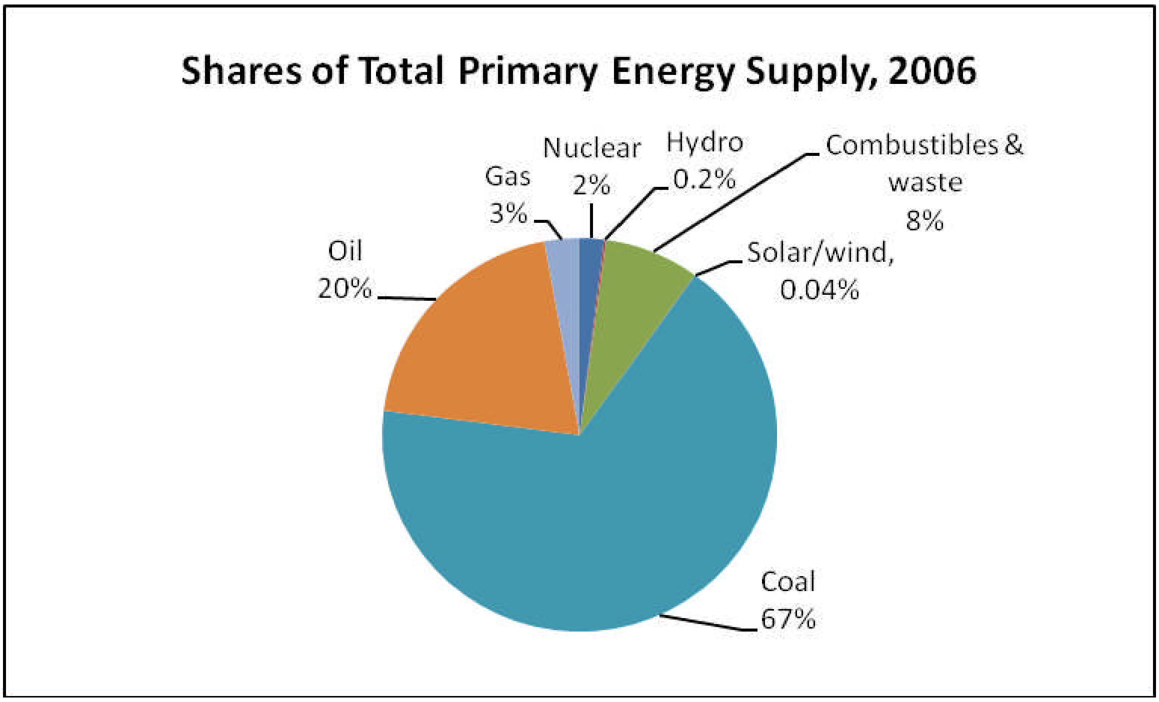
2.3 Energy used by the Transport System

This section first provides an overview of the broader energy context in terms of the total primary energy supply and total final energy consumption in South Africa. This is important as it shows the sources of energy currently available in the country and also the other demand sectors that compete with transport for energy supply. We then consider the demand for energy within the transport sector itself. The penultimate subsection provides comparative evidence on energy efficiency across various transport modes.

2.3.1 Primary Energy Supply in South Africa

According to the Department of Minerals and Energy (DME, 2006), fossil fuels (coal, oil and gas) comprise almost 90 per cent of South Africa's total primary energy supply (TPES). Chief amongst these is coal, which provided 67% of primary energy in 2006 (see Figure 2.3-1). South Africa has the world's sixth largest coal reserves. Approximately one third of the country's annual coal production is exported, and South Africa is amongst the world's top coal exporters. Approximately 57% of the coal that is consumed domestically is used to generate electricity, while another 25% is converted into synthetic liquid fuels by Sasol. In 2006, 20% of South Africa's primary energy needs were met by oil. Natural gas – mostly imported from Mozambique – contributes 3% of primary energy. Combustibles and waste, which comprises wood and other biomass, makes up approximately 8% of TPES. The Koeberg nuclear power station provides just 2% of energy, while renewable energy in the form of hydroelectricity (0.2%) and solar and wind (0.04%) currently contribute negligible amounts of energy.

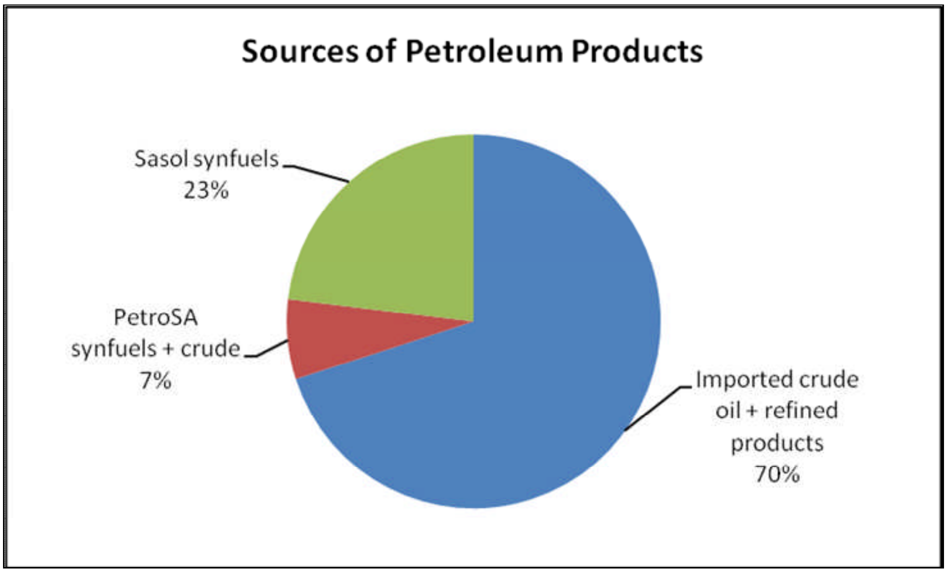
Figure 2.3-1: Total Primary Energy Supply by Energy Source, 2006



Source: DME (2006)

The sources of petroleum fuels are shown in Figure 2.3-2 below. According to the DME (2007), imported crude oil and refined products contribute about 70% of South Africa's annual consumption of petroleum products. The remainder is derived from Sasol's coal-to-liquid (CTL) synthetic fuels (23%) and PetroSA's production of gas-to-liquid (GTL) synfuels plus a small amount of domestic crude oil (7%). South Africa's crude oil reserves stood at a meagre 15 million barrels as of January 2007 (EIA, 2007), and are likely to be depleted within a few years unless substantial new reserves are discovered.

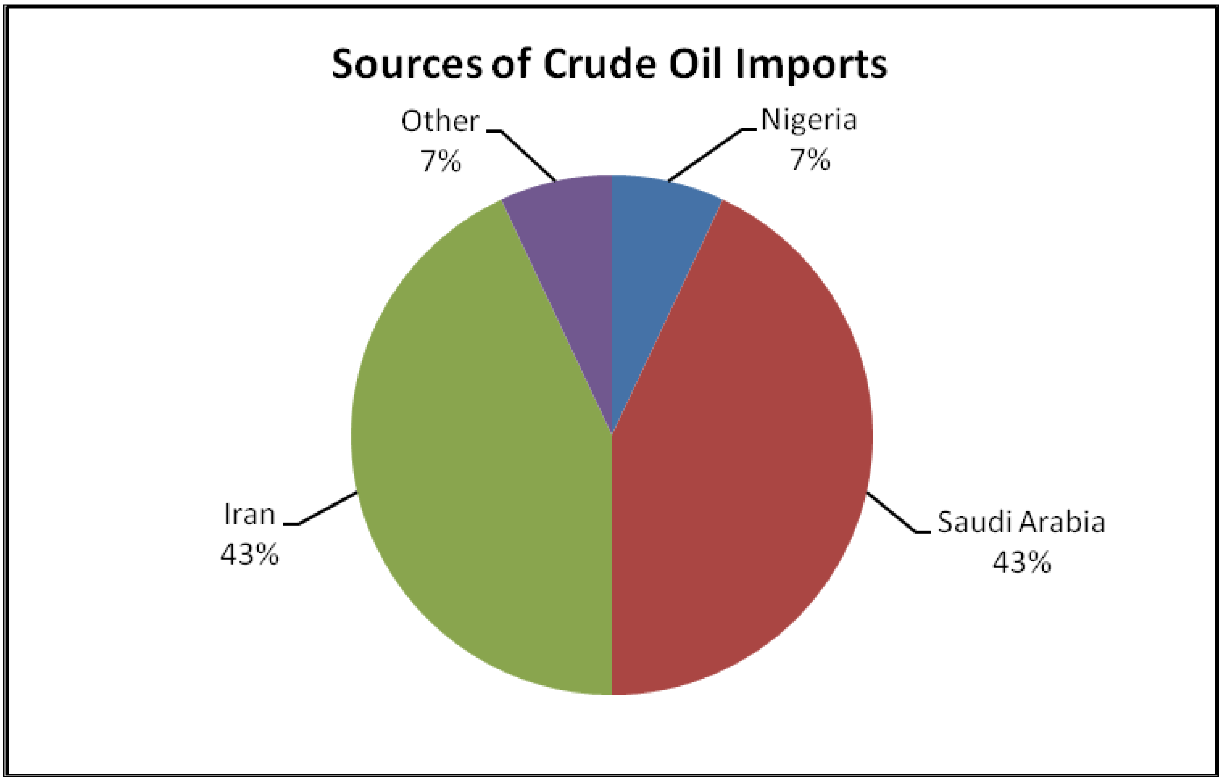
Figure 2.3-2: Sources of Petroleum Products in South Africa



Source: DME (2007)

In terms of crude oil imports, South Africa relies heavily on Middle East suppliers, especially Saudi Arabia and Iran, which together provide at least 80% of our crude oil. Smaller amounts are sourced from Nigeria, Angola, Gabon, Yemen and the United Arab Emirates (see Figure 2.3-3 below).

Figure 2.3-3: Sources of Crude Oil Imports, 2004



Source: EIA (2007)

South Africa has considerable petroleum refining capacity, as shown in Table 2.3-1 below. For many years refined petroleum products have been exported to other countries in Southern Africa. However, demand for refined fuels has in recent years outstripped domestic capacity so that increasing amounts of refined fuels have had to be imported. From 2006, refined petroleum imports have exceeded exports. According to the DME (2006), 88% of the country's refined petroleum products were derived from domestic refineries and the remaining 12% were imported in 2006. Of this total refined product supply, about 10% was exported, 10% consumed by maritime shipping and 80% consumed within SA's borders. The balance between refined imports and exports might change within a few years, as PetroSA is currently planning to construct a 400,000 barrel per day (bpd) refinery at Coega in the Eastern Cape, which it hopes will come on stream by about 2014 (Pringle, 2008). This is discussed in more detail in Section 3.1.

Table 2.3-1: Domestic Oil Refining Capacity

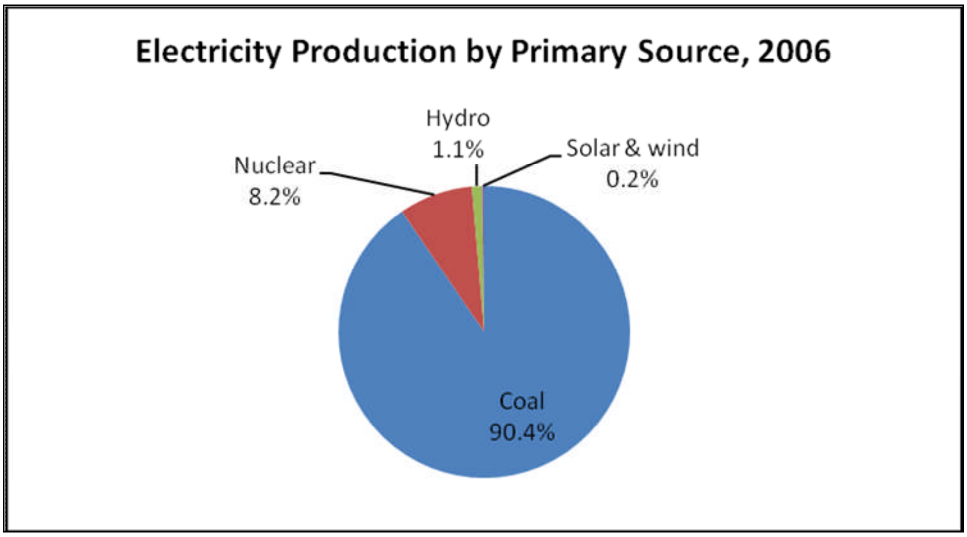
Refinery	Barrels/day	Location	Company
Natref	108,000	Sasolburg	Sasol
Sapref	184,000	Durban	BP/Shell
Enref	125,000	Durban	Engen
Calref	110,000	Cape Town	Chevron
Total crude refining	527,000		
Secunda	150,000	Secunda	Sasol
Mosgas	45,000	Mossel Bay	PetroSA
Total synfuel refining	195,000		
TOTAL	722,000		

Source: DME (2007)

South Africa maintains a strategic petroleum reserve at Saldanha Bay in the Western Cape, with a capacity of 45 million barrels, which translates into about 100 days' worth of crude oil imports. Information on the current volume of oil in storage is not publicly available.

Finally, we consider the primary sources of energy used to generate electricity in South Africa. As depicted in the figure below, the vast majority of the country's electricity (90%) is generated from coal, with nuclear power providing most of the balance (8%) and hydro (1.1%) and renewables (0.2%) contributing minute shares.

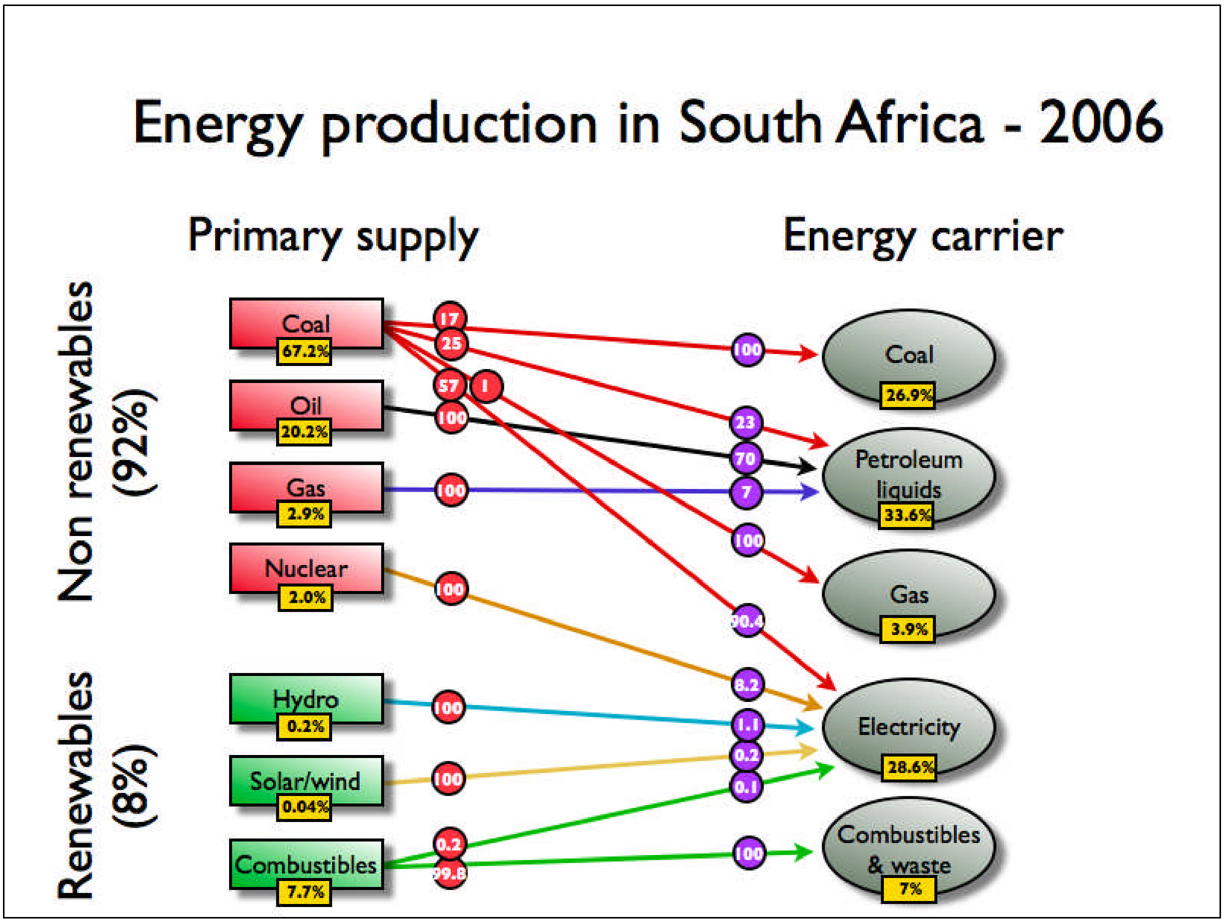
Figure 2.3-4: Production of Electricity by Primary Energy Source, 2006



Source: DME (2006)

Figure 2.3-5 provides a snapshot summary of how South Africa's primary energy sources are converted into final energy carriers (as shown by the arrows). The numbers in the red dots are percentages of the relevant primary energy source that are converted into the various energy carriers. For example, 17% of coal production is burned as is; 25% is converted into petroleum fuels; 1% is converted into gas; and 57% is used to generate electricity. The numbers in the purple dots are the percentages of the energy carrier that are derived from the respective primary energy sources. For example, 23% of petroleum fuels are made from coal; 70% come from crude oil; and 7% is manufactured from gas.

Figure 2.3-5: Primary Energy Sources and Final Energy Carriers, 2006

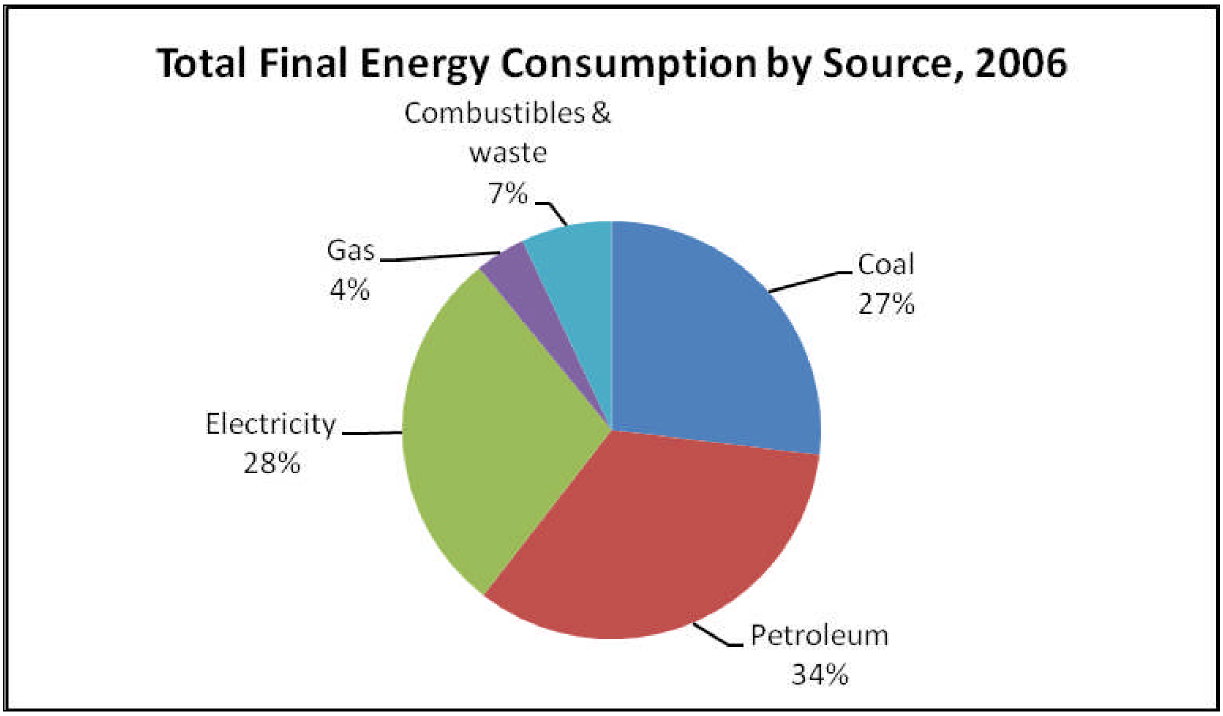


Source: Own calculations based on DME (2006)

2.3.2 Final Energy Consumption in South Africa

Primary energy sources (e.g. oil) are converted into energy carriers (e.g. petroleum fuels) which are then consumed by end users. Figure 2.3-6 below shows the breakdown of final energy consumption by energy carrier. Petroleum fuels constitute the largest share (34%), followed by electricity (28%) and coal (27%). Gas (4%) and combustibles and waste (7%) make up the remainder.

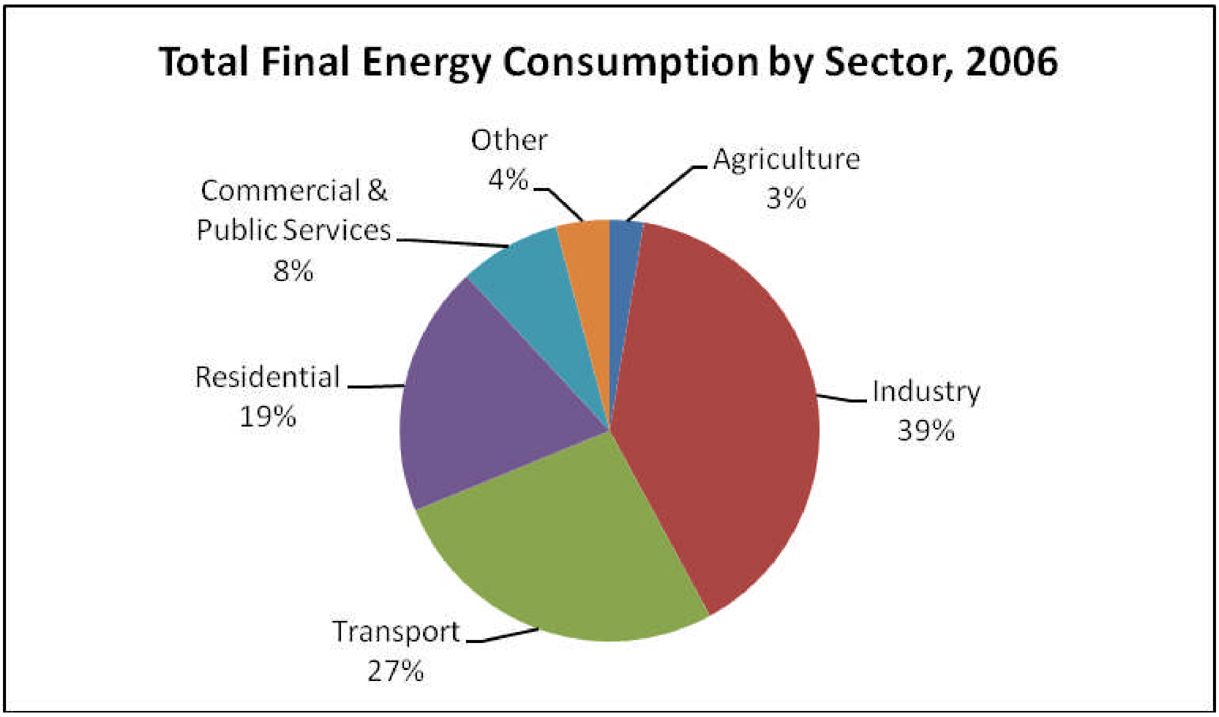
Figure 2.3-6: Total Final Energy Consumption by Energy Source, 2006



Source: DME (2006)

Figure 2.3-7 shows the sectoral shares of final energy consumption in 2006. Industry consumes the lion's share (39%), followed by the transport sector (27%). The residential sector consumes nearly a fifth (19%) of the country's energy, while commercial and public services (8%) and agriculture (3%) consume relatively small shares of energy.

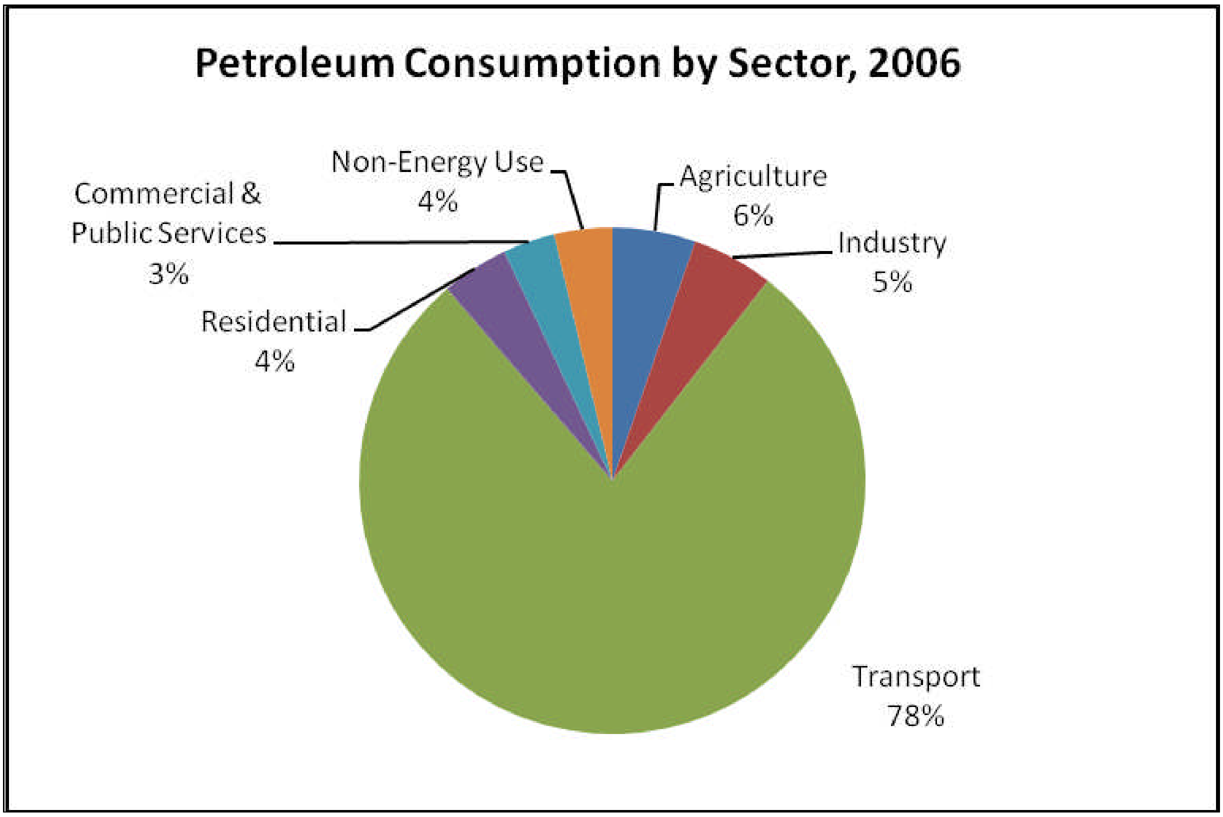
Figure 2.3-7: Total Final Energy Consumption by Sector, 2006



Source: DME (2006)

When it comes to consumption of petroleum fuels, the transport sector dominates with 78%. All of the other sectors consume small fractions of petroleum fuels, with agriculture (6%) being the next largest followed by industry with 5% (see Figure 2.3-8).

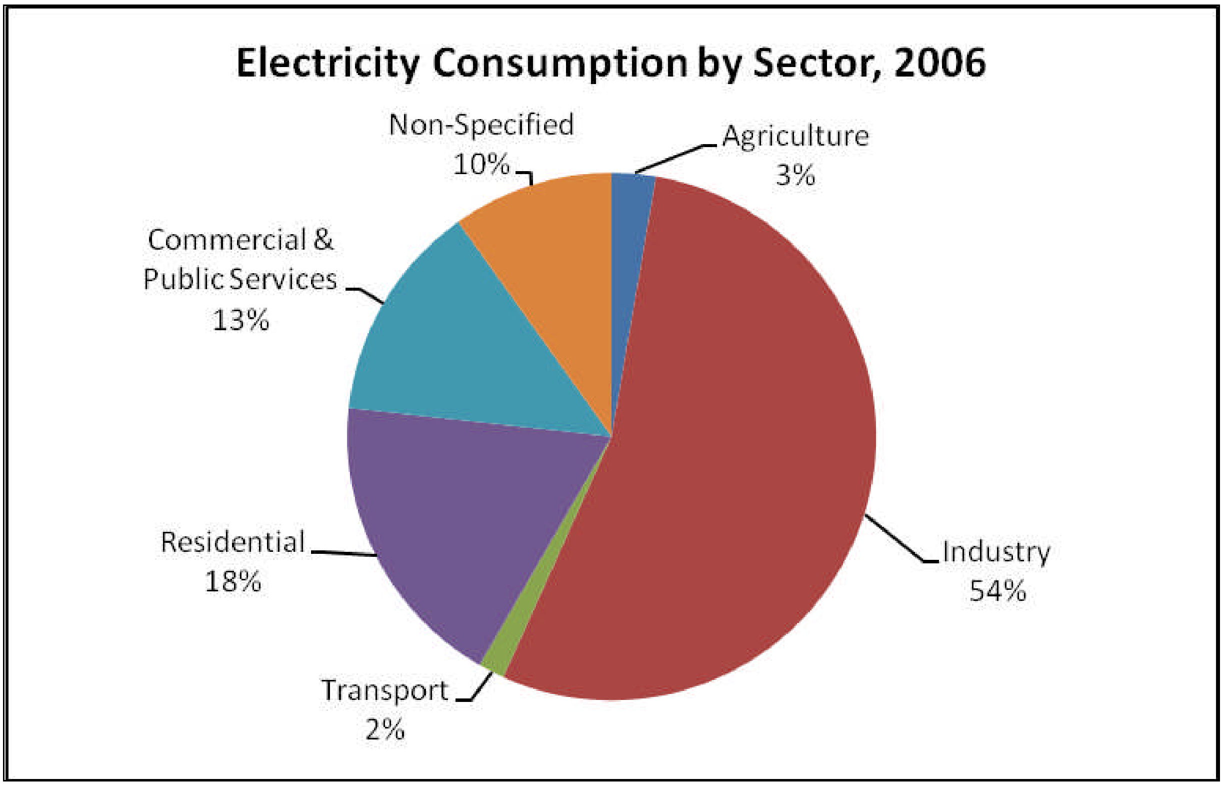
Figure 2.3-8: Sectoral Shares of Petroleum Energy Consumption, 2006



Source: DME (2006)

The consumption of electricity follows a very different pattern. Figure 2.3-9 shows that industry accounts for 54% of electricity consumption, followed by the residential sector (18%) and commercial and public services (13%). Transport uses just 2% of the nation's electrical energy. Clearly, if transport were in the future to consume a greater share of electricity, this would be at the expense of another sector or sectors, such as industry, commerce or households. Eskom has warned that electricity supplies will continue to be under severe pressure until new base-load capacity comes on stream from 2012, so it would be difficult for the transport sector to increase its share of electricity consumption significantly in the medium term without substantial sacrifice or efficiency gains in other demand sectors.

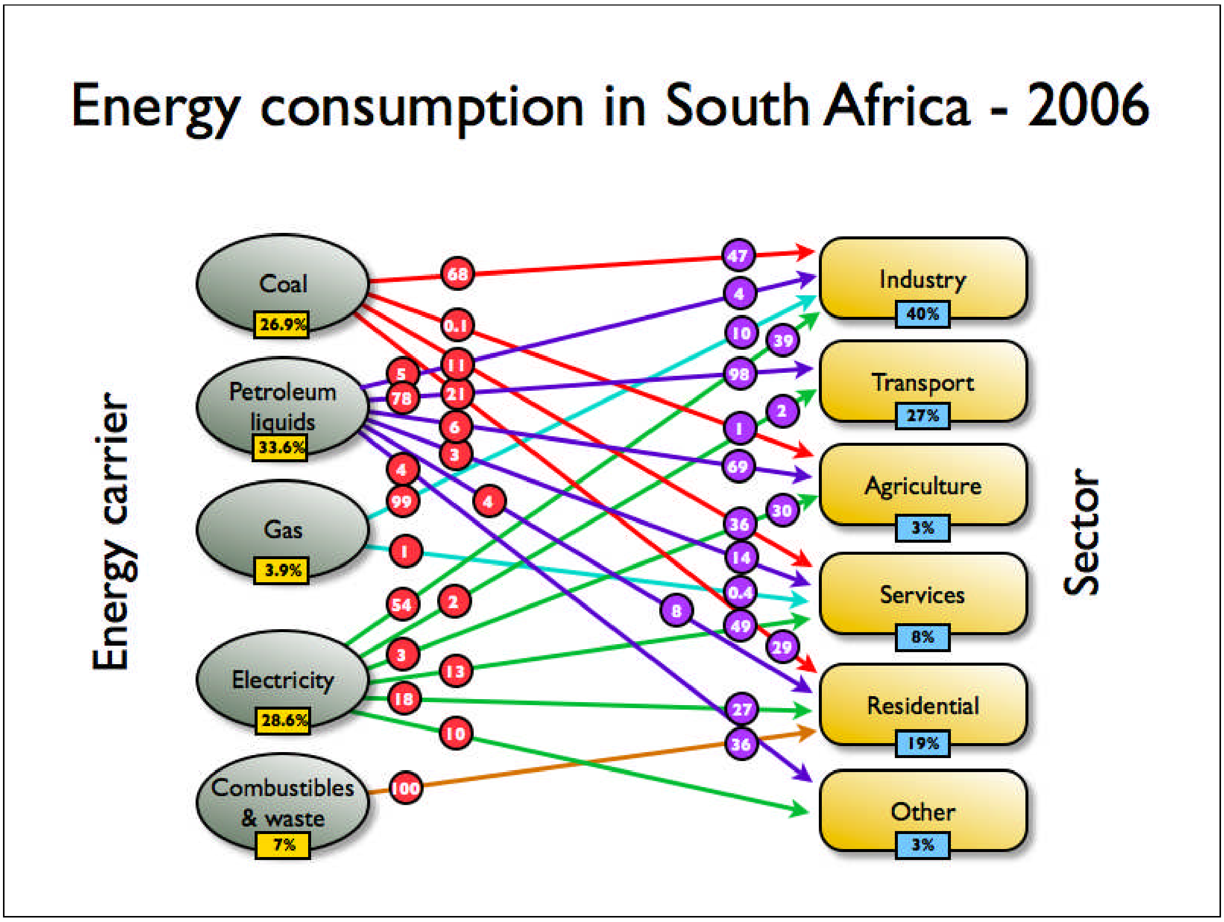
Figure 2.3-9: Sectoral Shares of Electricity Consumption, 2006



Source: DME (2006)

Figure 2.3-10 provides an overview of how the various energy carriers are consumed by the different sectors of the economy. The numbers in the red dots are percentages of the relevant energy carrier that are consumed by the various sectors, as indicated by the arrows. For example, 5% of petroleum liquids are consumed by industry, 78% by transport, 6% by agriculture, 3% by services, 4% by the residential sector and 4% by 'other' users (blue arrows). The numbers in the purple dots are the percentages of energy consumption in the respective sector that are derived from each of the energy carriers. For example, industry obtains 47% of its energy from coal, 4% from petroleum, 10% from gas and 39% from electricity.

Figure 2.3-10: Final Energy Consumption in South Africa: Energy Carriers and Sectors, 2006



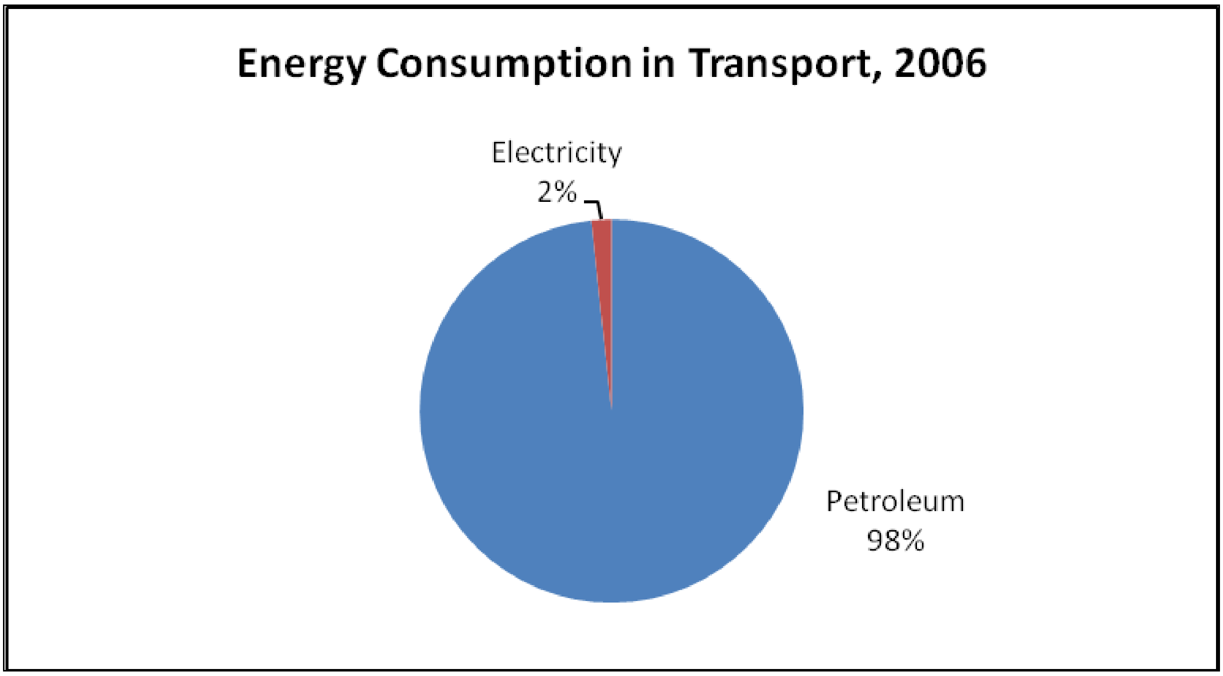
Source: Own calculations based on DME (2006)

Figure 2.3-10 illustrates how vital to the overall economy liquid fuels are. They contribute to all economic sectors but play particularly crucial roles in transport and agriculture. Both of these sectors are important, not only to the economy but to the well-being of both individuals and communities. It is also worth noting that transport and agriculture are interdependent.

2.3.3 Energy Consumption by the Transport Sector

As seen in the previous section, the transport sector utilised 78% of all petroleum energy, 1.6% of all electricity, and 26.7% of total final energy consumed in South Africa in 2006. Within the transport sector itself, 98% of the energy consumed is derived from petroleum products, and only 1.7% from electricity (see Figure 2.3-11). Clearly, the transport sector is overwhelmingly dependent on liquid petroleum fuels.

Figure 2.3-11: Energy Consumption in the Transport Sector, 2006



Source: DME (2006)

Table 2.3-2 shows the consumption of energy disaggregated by energy carrier and by transport mode. Road transport dominates energy consumption with nearly 89% of petroleum fuels and 87% of all energy. Aviation (including international and domestic air transport) accounted for 11% of petroleum consumption within the transport sector in 2006. Rail uses predominantly electricity (94% of electricity consumed by transport) plus a small amount of diesel, but only 2% of total energy.

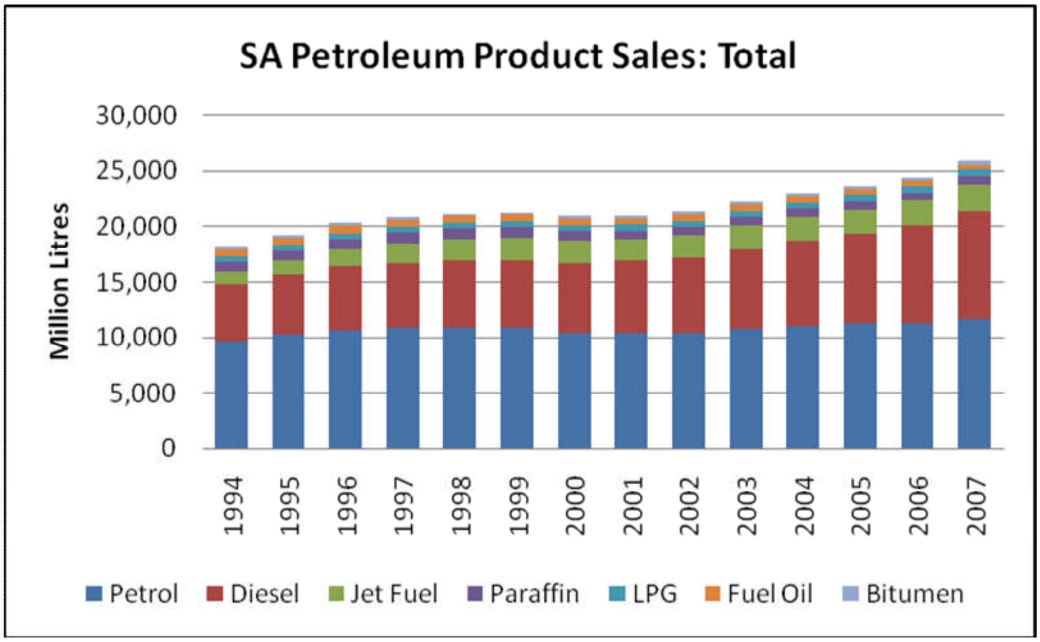
Table 2.3-2: Energy Consumption by the Transport Sector, 2006

Transport Sector	Petroleum		Electricity		Total	
	TJ	%	TJ	%	TJ	%
International civil aviation	35178	4.9	-	-	35178	4.8
Domestic air transport	43510	6.1	180	1.4	43690	6.0
Road	632489	88.6	71	0.6	632560	87.1
Rail	2892	0.4	11810	94.3	14702	2.0
Pipeline transport	-	-	284	2.3	284	0.04
Internal navigation	-	-	181	1.4	181	0.02
Non-specified	-	-	1	0.0	1	0.00
Total	714069	100.0	12527	100.0	726596	100.0

Source: DME (2006)

The consumption of petroleum fuels by the transport sector is now analysed in more detail. Figure 2.3-12 shows the annual sales of all petroleum products for the past 14 years. It should be noted that as yet, biofuels do not contribute any significant portion of liquid fuels; their use is confined to very small-scale operators. The same applies to liquid petroleum gas (LPG) in motor vehicles. LPG sales in the figures below relate mainly to household use for cooking and heating.

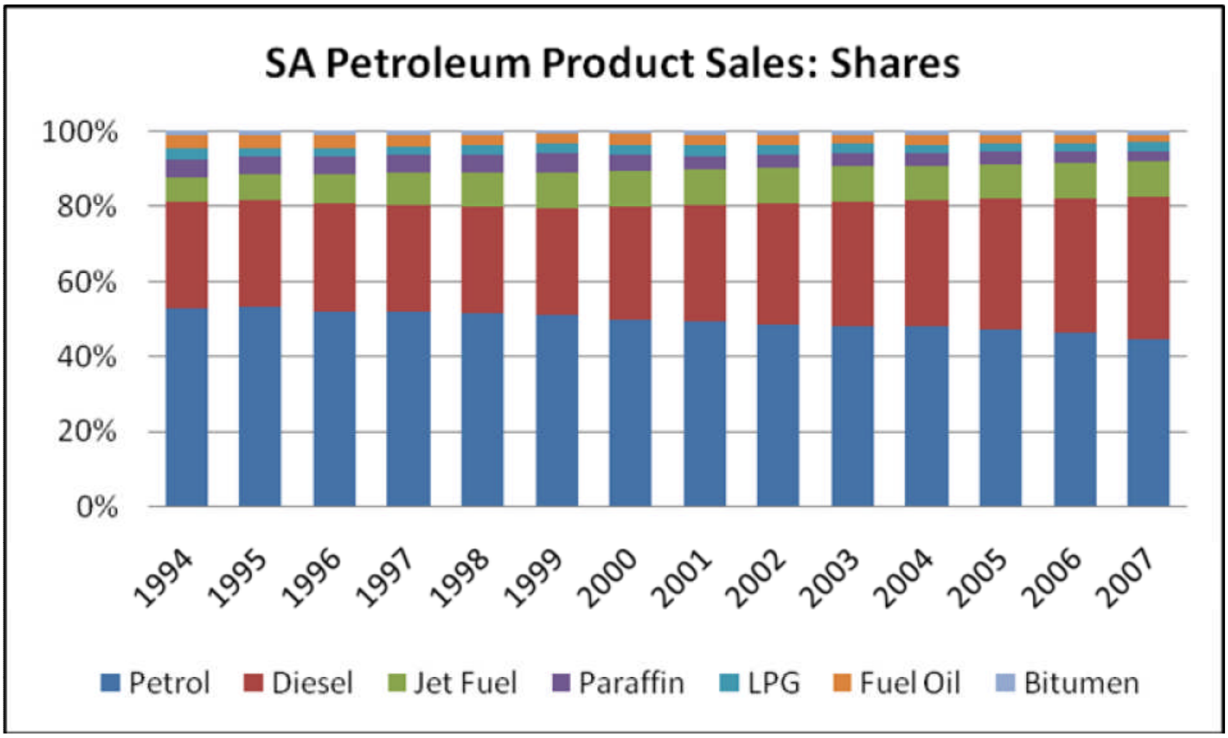
Figure 2.3-12: Annual Liquid Petroleum Product Sales, 1994-2007



Source: SAPIA (2008)

Figure 2.3-13 shows the percentage shares of petroleum product sales by product type. Petrol's share, while still the largest, has declined monotonically over the period. This is mainly due to strong growth in diesel sales. Paraffin sales have declined in relative terms while the proportions of other fuel types have remained more or less constant.

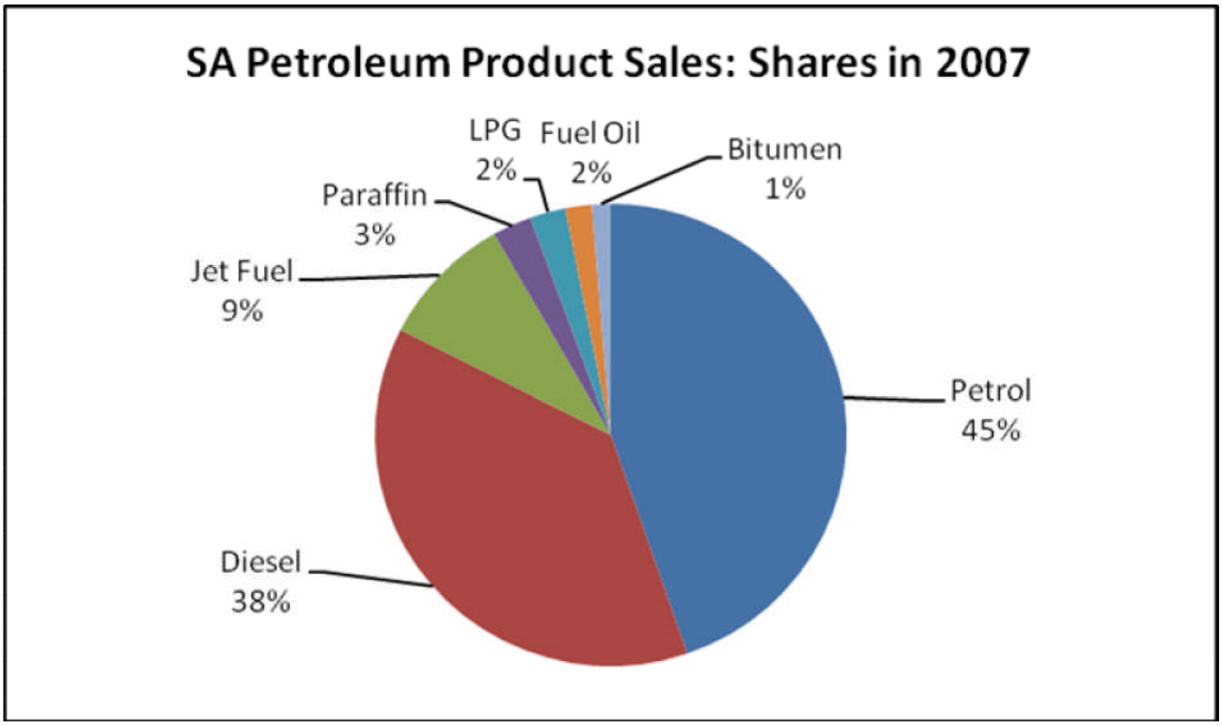
Figure 2.3-13: Annual Percentage Shares of Petroleum Product Sales, 1994-2007



Source: SAPIA (2008)

The dominance of road transport fuels out of total fuel sales is clearly evident in Figure 2.3-14 below. Petrol and diesel together make up more than 80% of petroleum product sales.

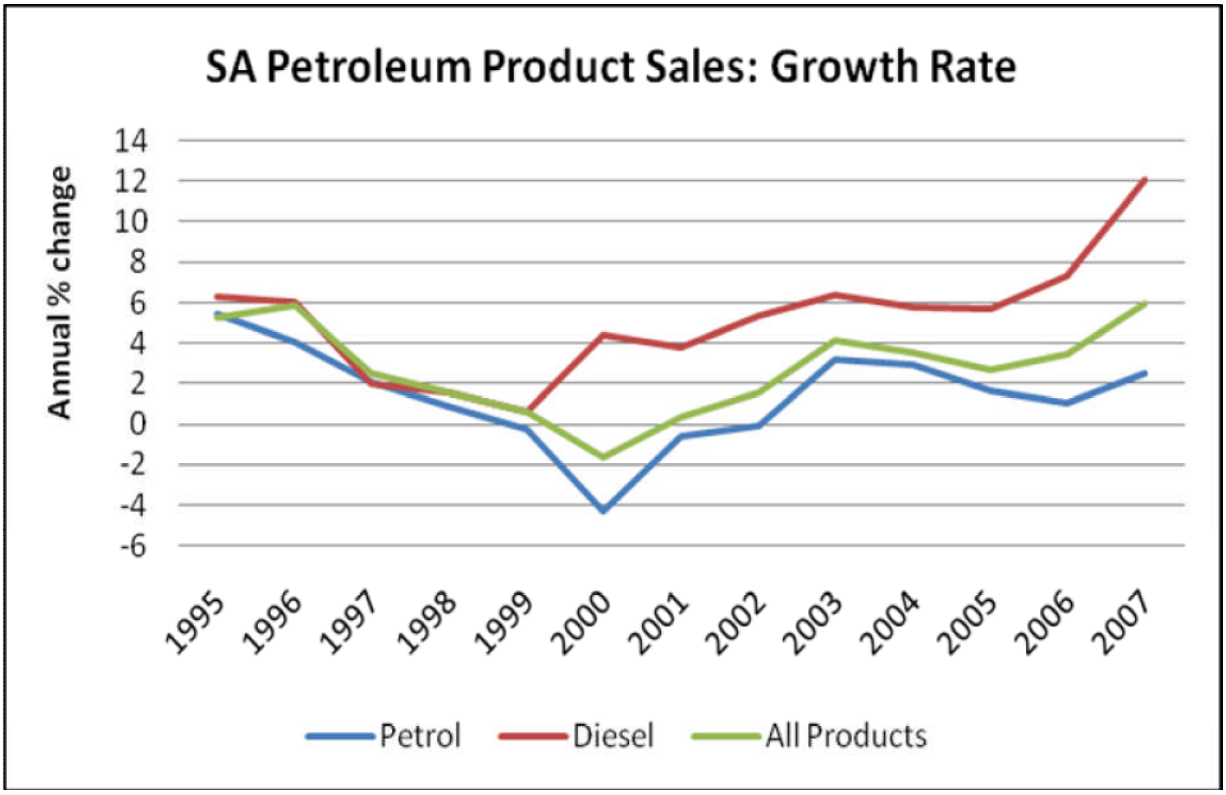
Figure 2.3-14: Percentage Shares of Petroleum Product Sales by Fuel Type, 2007



Source: SAPIA (2008)

Total sales of petroleum products have largely grown in line with the economy over the past 14 years. Growth of diesel sales outstripped that of petrol sales by a considerable margin since 2000, with 2007 recording spectacular growth of 12% relative to 2006. The average growth rate for sales of all petroleum products was 2.8% for the period 1995 to 2007. In that period the average growth rate for diesel was 5.1%, and for petrol, 1.4%.

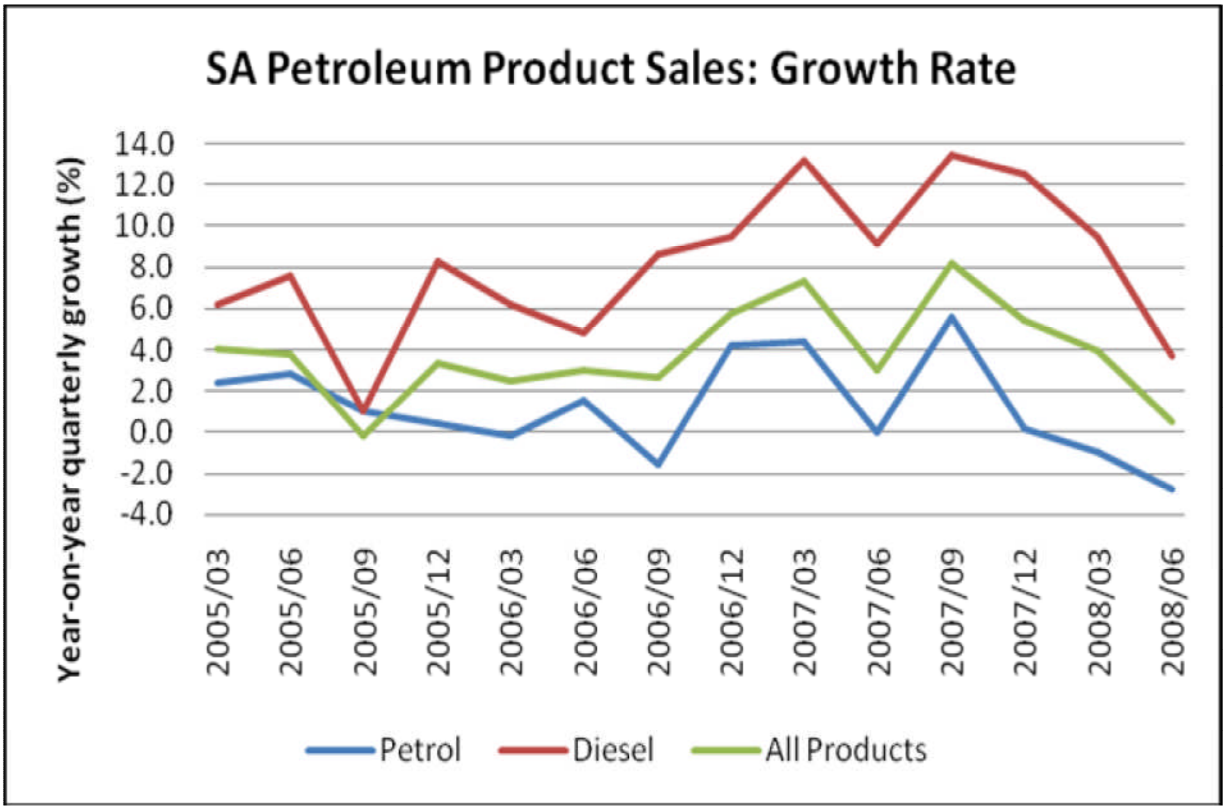
Figure 2.3-15: Annual Growth in Total Petroleum Product Sales, 1995-2007



Source: Own calculations based on SAPIA (2008)

However, these growth rates have fallen steeply in the first half of 2008 as a result of sharply rising fuel prices as well as tighter economic conditions (i.e. rising costs of living and higher interest rates).

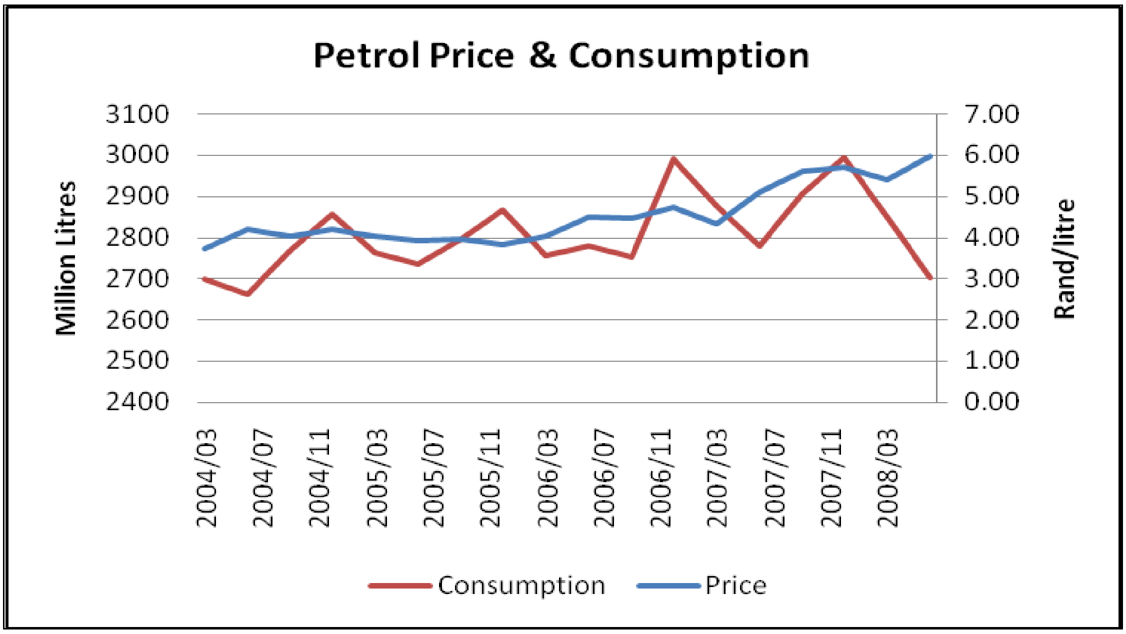
Figure 2.3-16: Quarterly Year-on-Year Growth in Petroleum Product Sales, 2005Q1-2008Q2



Source: Own calculations based on SAPIA (2008)

Figure 2.3-17 and Figure 2.3-18 show consumption and prices for petrol and diesel, respectively, over the past 4 years. Petrol consumption displays a marked seasonal effect, with peak in the December holiday period. Thus the downturn in the first half of 2008 is partly a seasonal effect, and partly a response to rising fuel prices and tighter budgets.

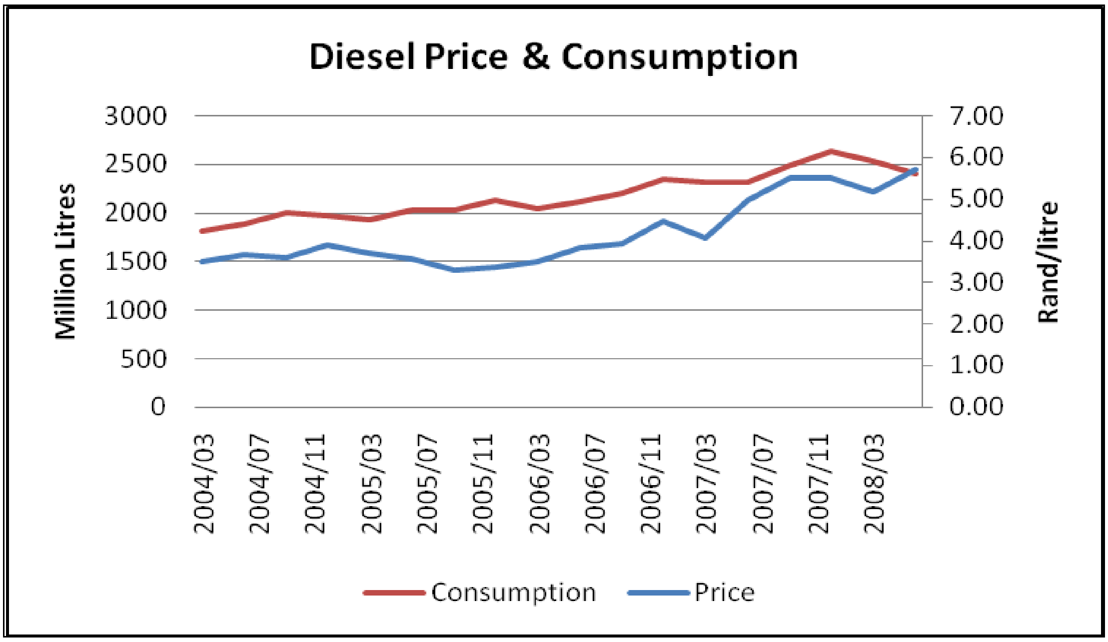
Figure 2.3-17: Price and Consumption of Petrol, 2004-2008



Source: SAPIA (2008)

Consumption of diesel is smoother, although there is a mild seasonal pattern as well.

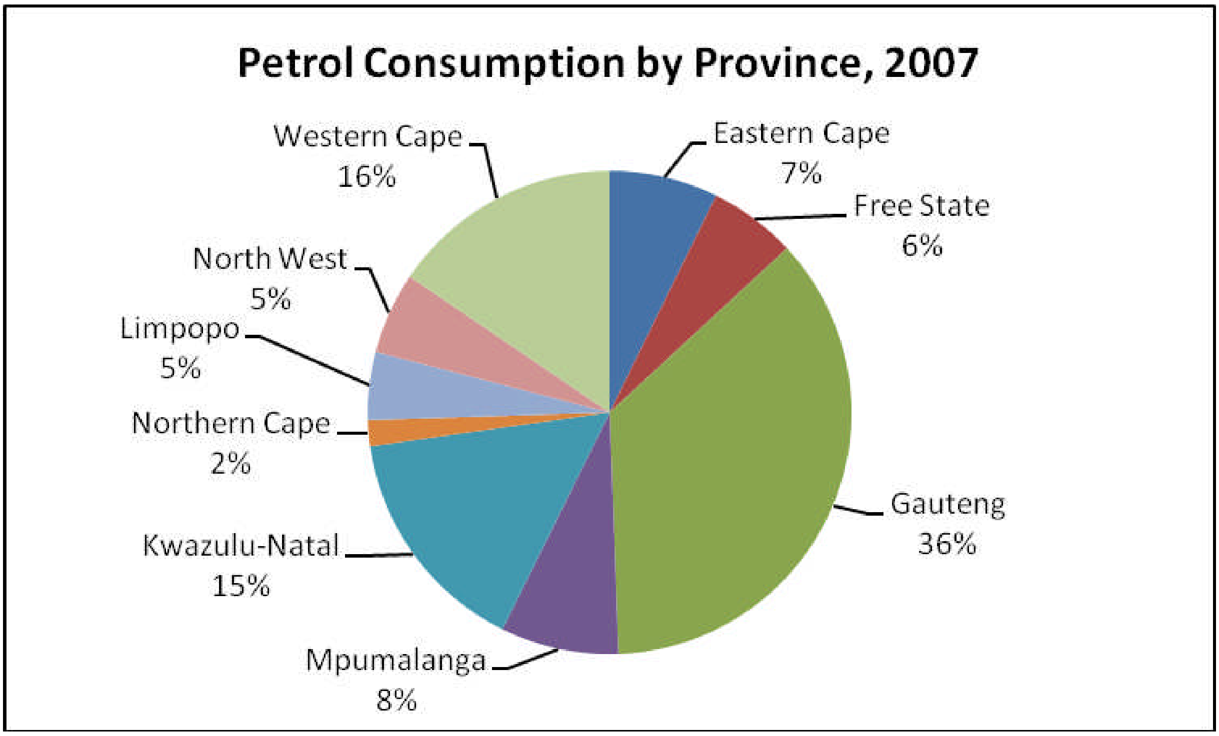
Figure 2.3-18: Price and Consumption of Diesel, 2004-2008



Source: SAPIA (2008)

Figure 2.3-19 shows the provincial breakdown of petrol sales in 2007. Gauteng consumes the largest share (36%), followed by the Western Cape (16%) and KwaZulu-Natal (15%). The shares are related both to population figures and to income levels in the provinces (see Table 2.3-3 below). Car ownership is concentrated in the three wealthiest provinces cited above.

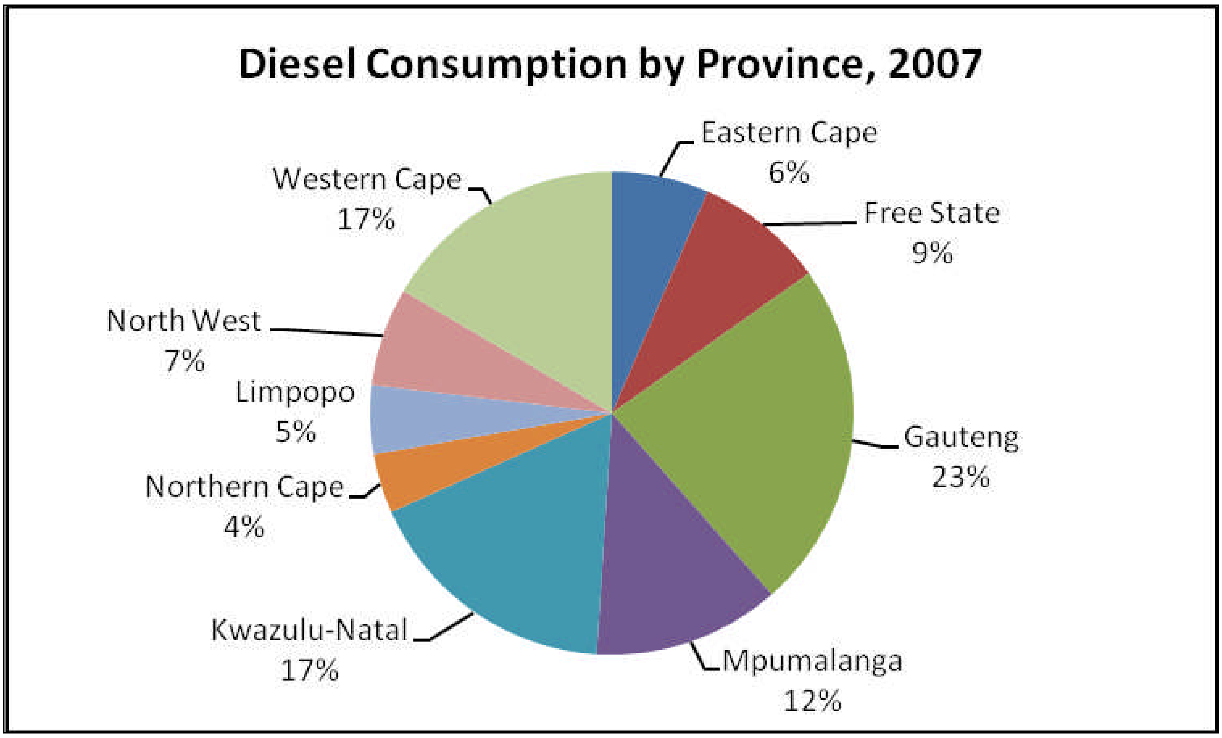
Figure 2.3-19: Provincial Shares of Petrol Consumption, 2007



Source: Own calculations based on SAPIA (2008)

Figure 2.3-20 shows the provincial breakdown of diesel sales in 2007. Gauteng again consumes the largest share (23%), although its dominance is much more muted than in the case of petrol. The Western Cape (17%) and KwaZulu-Natal (17%) also account for sizable shares of diesel usage. The relative shares are determined in large part by freight volumes, but again depend on incomes and population densities.

Figure 2.3-20: Provincial Shares of Diesel Consumption, 2007



Source: Own calculations based on SAPIA (2008)

Table 2.3-3 provides the provincial distribution (percentage shares) of vehicle registrations, petrol and diesel consumption and population, as well as average household incomes per province.

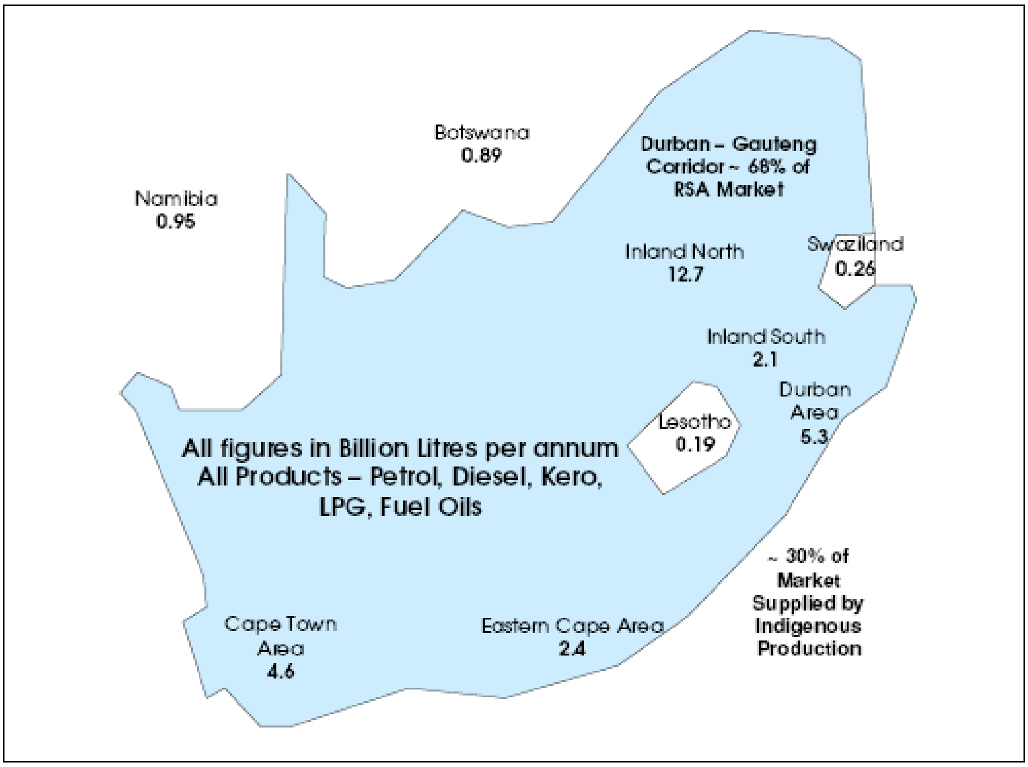
Table 2.3-3: Provincial Distribution of Vehicles, Fuel Consumption and Population

Province	Vehicle registrations %	Petrol consumption %	Diesel consumption %	Population %	Av. household income R/annum
Eastern Cape	6.9	7.3	6.5	14.5	47,930
Free State	5.3	5.9	8.7	6.2	60,700
Gauteng	38.6	36.3	23.3	20.2	111,079
Mpumalanga	5.9	7.9	12.5	7.4	54,562
Kwazulu-Natal	14.2	15.5	17.3	21.0	58,551
Northern Cape	2.1	1.7	4.0	2.4	49,697
Limpopo	4.7	4.5	4.6	11.3	36,386
North West	5.4	5.5	6.6	7.0	56,310
Western Cape	16.9	15.5	16.5	10.0	135,029
Total	100.0	100.0	100.0	100.0	74,589

Source: Own calculations based on eNatis (2008), SAPIA (2008), and StatsSA (2008)

Geographically, fuel consumption is concentrated in certain transport corridors. For instance, 68% of liquid fuels are consumed on the Johannesburg-Durban corridor (DME, 2007). A further 17% is consumed in the Cape Town area and 9% in the Eastern Cape (see Figure 2.3-21).

Figure 2.3-21: Geographical Demand for Liquid Fuels



Source: DME (2007)

Table 2.3-4 provides petrol and diesel sales by customer type. Petrol sales are overwhelmingly at the general retail level. Unfortunately the disaggregation does not fall into private versus public transport. For instance, the 'retail' category includes fuel sold by garages and general dealers, whether to private motorists or to minibus taxi operators. The agricultural sector (co-ops and farmers) consumes nearly 10% of diesel fuel and mining nearly 8%. The proportion of diesel fuel utilised for freight can be approximated by stripping out all sectors apart from retail and road haulage plus Transnet's freight, and assuming that about 10% of the remainder is sold to private motorists (according to NAAMSA, 2007, 10% of private passenger vehicles are diesel and the remainder petrol driven). This yields an estimate of 70% of diesel used for freight transport.

Table 2.3-4: Percentage Sales of Petrol and Diesel by Customer Type

Sector	Petrol	Diesel	Total
Agriculture	1.0%	9.5%	4.9%
Fishing	0.0%	1.3%	0.6%
Mining	0.1%	7.8%	3.6%
Construction	0.0%	2.5%	1.1%
Government	0.2%	0.7%	0.4%
Public Transport	0.0%	1.7%	0.8%
Retail	98.6%	67.4%	84.3%
Road haulage + Transnet	0.1%	9.2%	4.3%
Total	100%	100%	100%

Source: Own calculations based on SAPIA (2008)

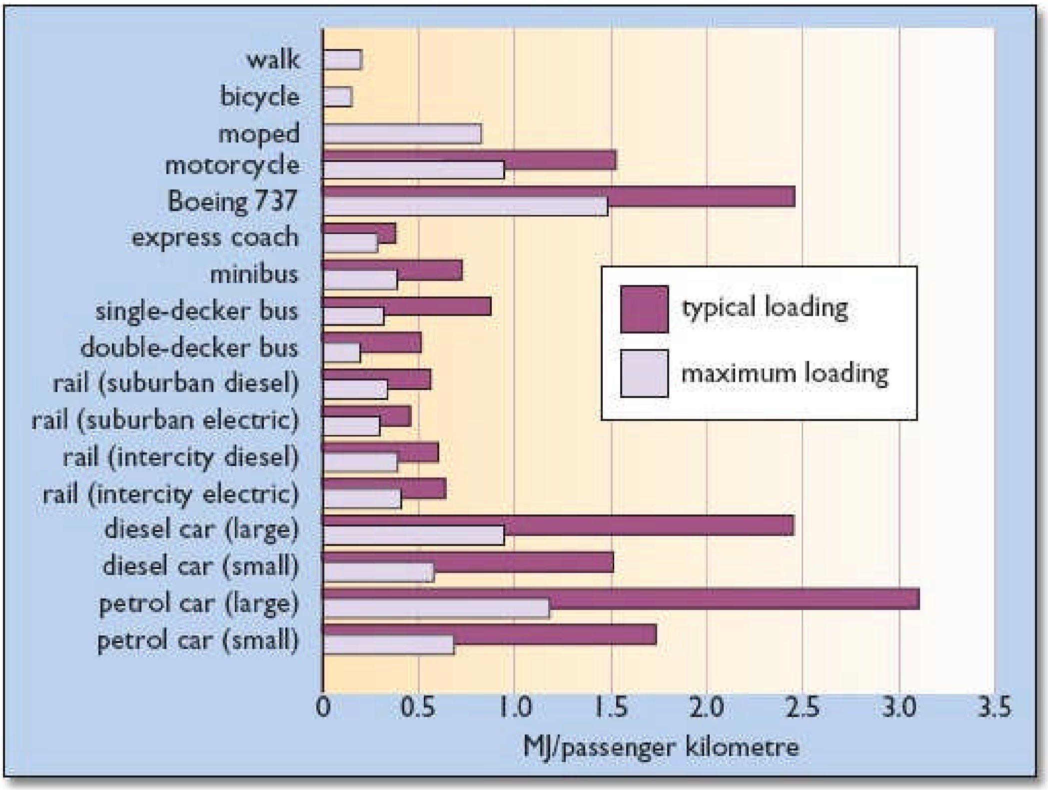
2.3.4 Energy Efficiency of Different Transport Modes

Statistics on the relative energy efficiency of different transport modes (e.g. private car, bus, minibus, train and aeroplane) are not available for South Africa. However, figures are available for some other countries and can act as proxies for the local situation.

Figure 2.3-22 below shows the energy efficiency of transport modes in the United Kingdom in terms of mega joules (MJ) of energy consumed per passenger kilometre travelled. Clearly, efficiencies are higher when motorised vehicles are fully loaded. At typical loadings, the energy efficiency ranking is as follows, in descending order: cycling, walking, rail, bus, car and aeroplane. At maximum loading the ranking stays the same but cars are much more efficient than they are under typical loading. Thus policies which encourage higher vehicle occupancy rates can make a considerable difference to energy consumption. Diesel cars are somewhat more fuel efficient than petrol cars of comparable size. Larger buses are more efficient than smaller buses. There is very little difference in efficiency between diesel and electric trains. At maximum loading the difference between buses and trains is very small. Notably, non-motorised transport (cycling and walking) is more efficient than any form of motorised transport, although this form of transport is clearly limited in terms of distances that can be travelled.

Figure 2.3-22 indicates that the greatest opportunity for achieving energy efficiencies in passenger transport lie in the loading of petrol and diesel driven cars with more passengers.

Figure 2.3-22: Energy Efficiency of Various Transport Modes in the United Kingdom



Source: Open University (2008)

Table 2.2-5 reports energy intensities for passenger and freight transport across various modes for the United States. Interestingly, passenger air travel is more efficient than road – presumably because of the low average fuel economy of the US car fleet in combination with low average occupancy rates. However, air freight is much more energy intensive than road freight, measured in mega joules per ton-kilometre (MJ/tkm). Rail is the most efficient mode in the case of both passenger and freight transport.

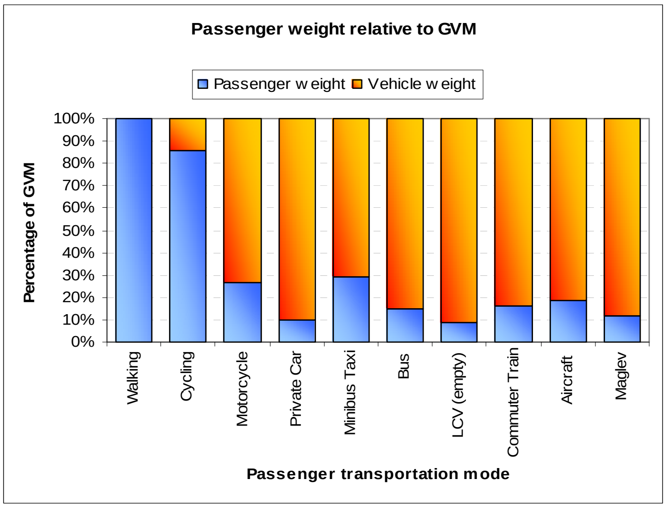
Table 2.3-5: Energy Intensities of Transport Modes in the United States, 2004

Mode	Road	Rail	Air	Water	Pipeline
Freight (MJ/tkm)	2.07	0.21	14.41	0.34	1.57
Passenger (MJ/pkm)	2.29	0.88	1.55		

Source: US Department of Energy (2007)

An examination of the ratio of passenger and freight weight respectively, to vehicle mass underpins the above conclusions. The ratio of passenger weight to vehicle mass is explored in some depth with respect to different vehicle types in the figure below.

Figure 2.3-23: Average Ratios of Passenger Weight versus Tare Vehicle Mass for Different Passenger Transport Modes



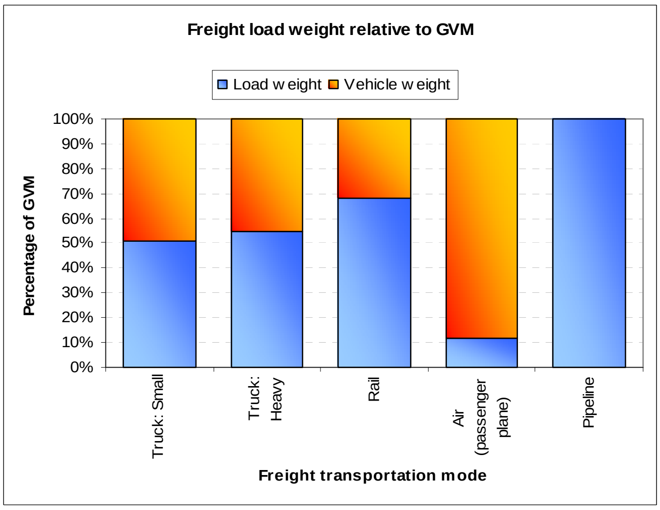
Source: Constructed by the authors Vanderschuren and Lane specifically for this project

Figure 2.3-23 indicates the relative amount of weight contributed by passengers and the vehicles used for their transport. The values are based on average occupancy levels, as well as average passenger and tare vehicle weights (including full fuel tanks). If the passenger to vehicle weight ratio is high (like, for example, in walking or cycling), most of the energy spent is used to propel the passenger forward. This seems to be a more efficient use of energy in terms of transporting passengers, as less energy is exerted on the propulsion of the vehicle itself. The private car and light commercial vehicles (LCVs) used for private passenger transport appear to use almost 90% of the energy to move the vehicle and only 10% to move the passengers.

Passenger transport options like rail, aircraft and maglev are also very heavy compared to the weight that passengers place on the system. When these vehicles are in motion and momentum comes into play they, therefore, become much more efficient than assumed, based on the graph. From this a recommendation for the optimal application of these systems can be deduced: vehicles should be loaded as fully as possible and travel for as long periods possible.

A lot of energy is required to get these heavy systems moving; therefore, the number of times that this should happen needs to be limited. These modes should thus be preferred for long-distance transport and cycling and walking for shorter trips.

Figure 2.3-24: Average Ratios of Freight Load Weight versus Tare Vehicle Mass for Different Freight Transport Modes



Source: Constructed by the authors Vanderschuren and Lane specifically for this project

Figure 2.3-24 indicates that in the case of freight transportation, nearly a 100% of a pipeline's energy consumption has to do with moving the cargo. Air freight transportation uses energy in the least efficient way, due to the massive fuel penalties for extra weight on a plane. Rail vehicles can be loaded to such an extent that about two thirds of the energy is used to actually move the cargo and only a third to move the train. The combined weight of a freight train and its cargo is, however, very high and a lot of energy will be required to set the train in motion. Once in motion, efficiency increases again. Trains are, thus, more efficient than trucks, providing that there are limited interruptions in the transport.

2.3.5 Conclusions on Energy used by the Transport System

South Africa's total primary energy supply is dominated by coal (67%) and oil (20%).

The transport sector consumes 27% of total final energy, 78% of liquid fuels and 1.6% of electricity in the country.

The transport sector depends on liquid petroleum fuels for 98% of its energy, and electricity for 2%.

South Africa imports 70% of its oil, approximately 80% of which comes from the Middle East.

Petrol (45%) and diesel (38%) account for the bulk of petroleum product sales.

For the period 1995 to 2007, the average growth rate of diesel and petrol sales was 5.1% and 1.4%, respectively, and 2.8% for all petroleum products.

Petrol and diesel growth rates have slowed in 2008, partly in response to higher fuel prices.

Road transport accounts for 87% of energy consumed by the transport sector, with aviation using 11% and rail just 2%.

Liquid fuel consumption varies considerably by province according to vehicle ownership, wealth and population density, and is concentrated in Gauteng, KwaZulu-Natal and the Western Cape.

Freight transport accounts for roughly 70% of diesel usage while petrol is consumed mainly by private motorists and minibus taxi operators.

The energy efficiency ranking for alternative passenger transport modes is as follows, in descending order: cycling, walking, rail, bus, car, and airplane. Efficiencies per passenger kilometre vary considerably according to vehicle occupancy rates, especially for private cars. For freight transport, rail is more energy efficient than road.

2.4 Peak Oil

2.4.1 Nature and Timing of Global Oil Depletion[3]

In the 1950s, a petroleum geologist named M. King Hubbert theorised that conventional oil production in any given region would roughly follow a bell-shaped curve, rising to a peak when approximately half of the total oil had been extracted, and thereafter gradually falling toward zero as extraction became progressively more difficult and costly. This production curve would mirror a similar pattern of oil discoveries, although after a substantial time lag. Hubbert applied a logarithmic probability distribution function to historical data on reserves and production in order to forecast the timing of peak production in a region.

Hubbert's model successfully and accurately predicted that oil production in the lower 48 States in the USA would peak between 1966 and 1972 (Heinberg, 2003: 88), based on the pattern of oil discoveries there which had peaked in the 1930s. The actual production peak for conventional oil (which excludes tar sands, oil shales, and heavy oils) occurred in 1970, after which date production has followed a steadily declining trend.[4] Hubbert hypothesised that world oil supply would follow a similar bell-shaped curve, mirroring the pattern of (earlier) oil discoveries. His theory has been the subject of intense debate, particularly in recent years. The debate now centres on when the inevitable peak in world oil production will occur, not on whether it will occur (see Hirsch, 2005). Nobody can credibly deny that production of a finite resource must eventually decline toward zero.

Economists, amongst others, correctly point out that higher oil prices tend to stimulate increased exploration activity. However, more exploration does not necessarily translate into more discoveries: it depends on the extent to which undiscovered oil fields still exist. At some point,

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[3] Parts of this and subsequent sections draw on earlier work by Wakeford (2006 and 2007)

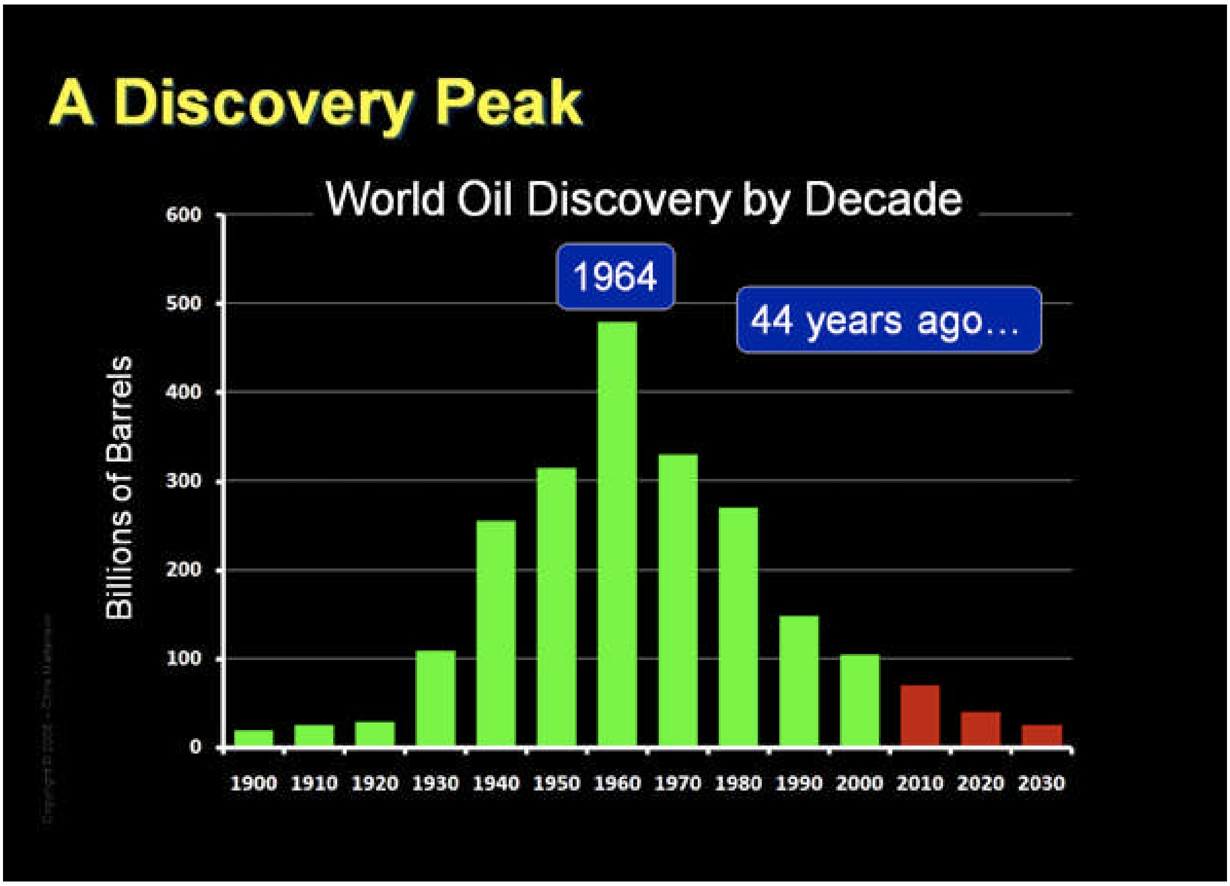
[4] Overall US production never regained its 1970 peak rate despite more recent discoveries in Alaska's Prudhoe Bay and the Gulf of Mexico.

no matter how high the price of oil rises, it cannot overcome the physical limitations of a finite resource.

There is growing evidence that we are nearing the global Hubbert peak:

- Globally, new oil discoveries peaked in the 1960s and have been on a declining trend ever since (see Figure 2.4-1). This is despite spectacular improvements in exploration and recovery technology over the past few decades and the incentives provided by high oil prices in the 1970s and more recently.

Figure 2.4-1: Global Discoveries of Oil

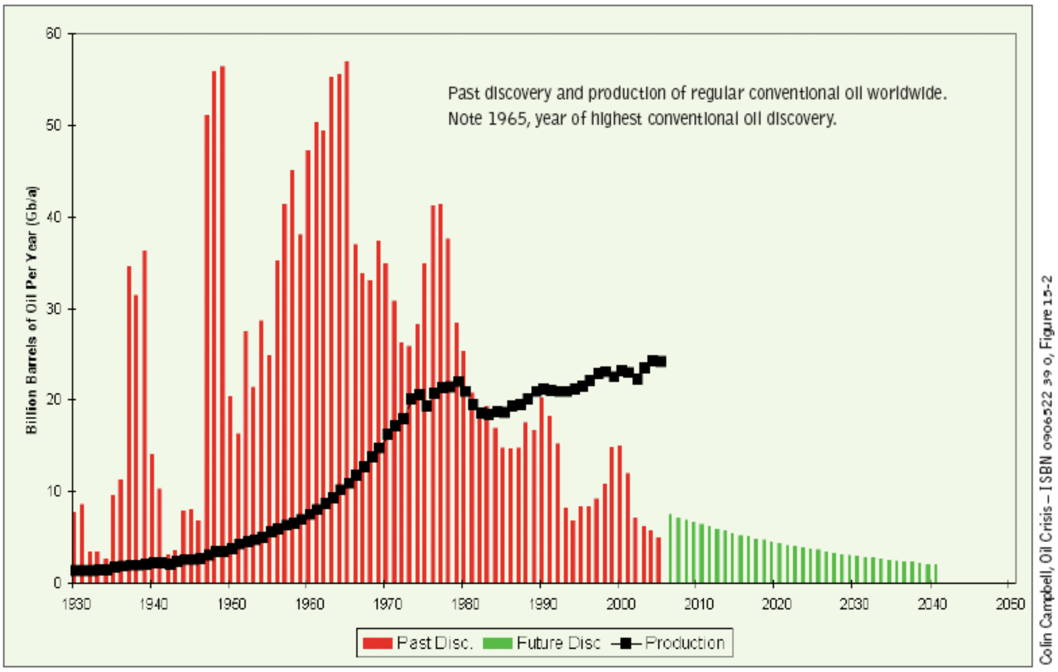


Source: Martenson (2008)

- About half of global oil reserves are contained in the largest 100 fields, almost all of which were discovered more than 25 years ago. Production from many of these super-giant and giant fields is in decline.

- Since 1981, more oil has been consumed annually than has been discovered each year (see Figure 2.4-2). In the past few years, about five or six barrels have been used for each new one found.

Figure 2.4-2: Discovery of Oil Fields and Historical Production



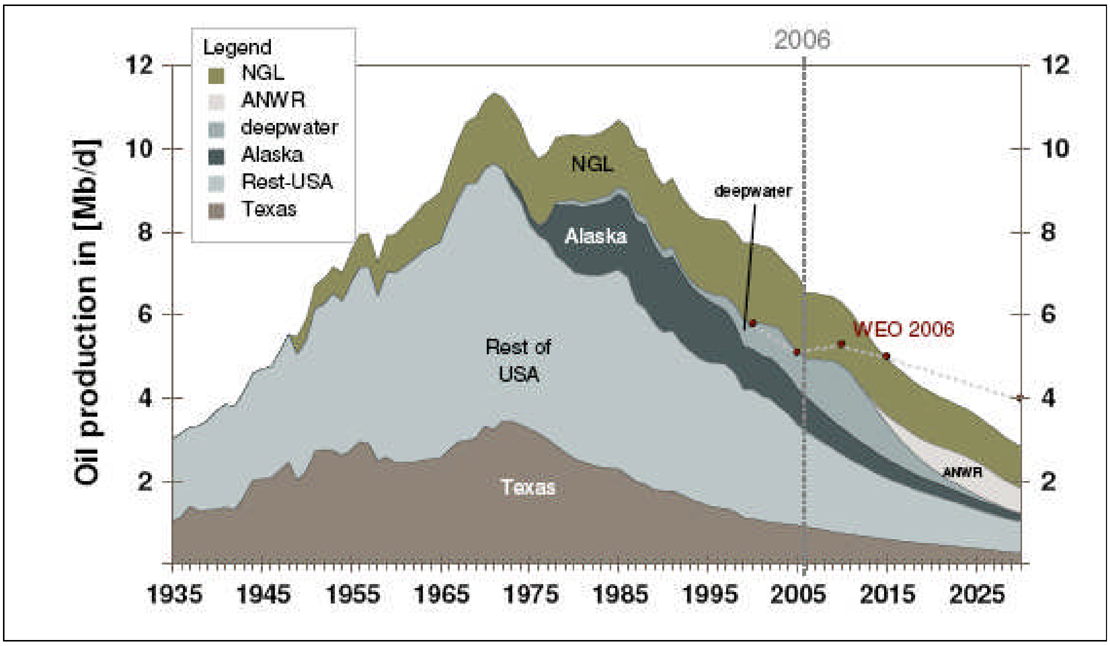
Source: Colin Campbell, ASPO-Ireland

- Thirty-three of the 48 significant oil-producing nations have already passed their individual production peaks (Hirsch, 2005).

2.4.1.1 The Nature of the Peak

It is useful to use the US as a point of reference in this discussion because the data is not contentious. The data in the US is transparent and has been verified through regular statutory audits. In the US, the oil production curve has been largely unimpeded by political influences and determined chiefly by geological and economic factors. This resulted in a 'classic' Hubbert curve profile, with a well-defined, absolute peak being reached in 1970 and a fairly symmetrical shape (in the lower 48 states).

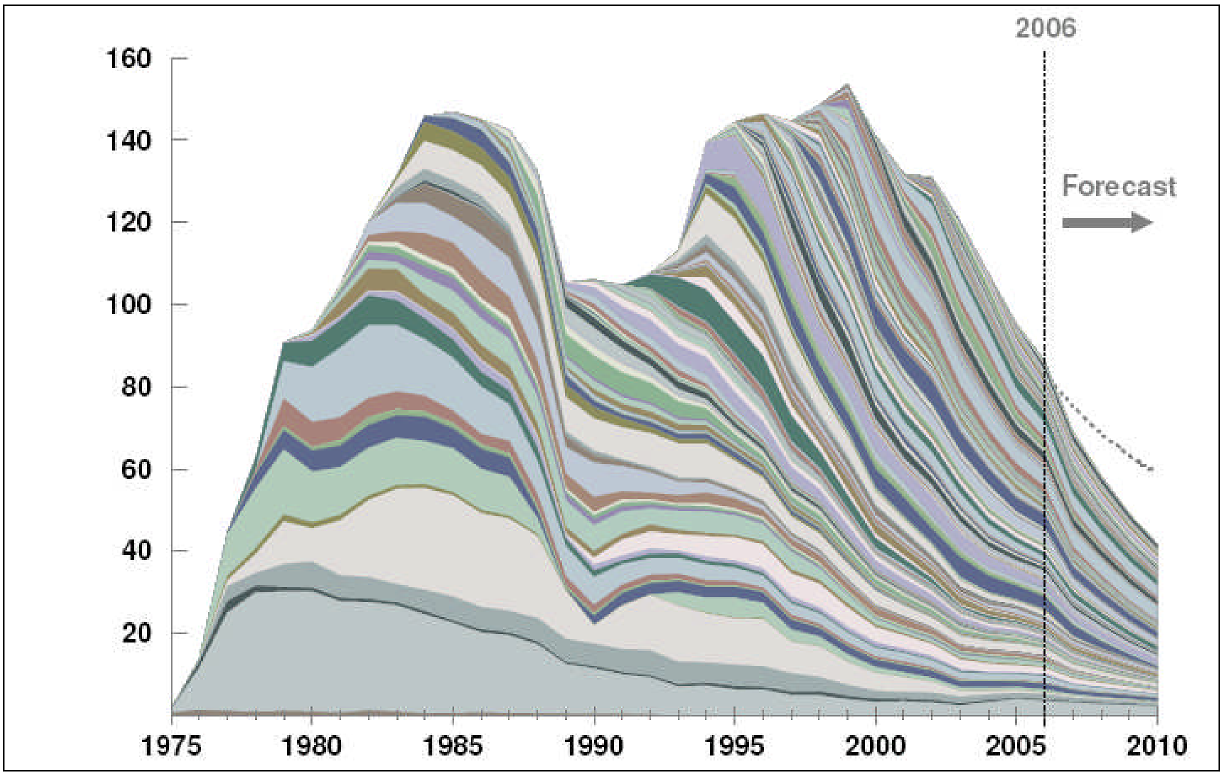
Figure 2.4-3: United States' Oil Production Curve



Source: Energy Watch Group (2007)

Figure 2.4-3 above shows how US oil production has declined despite new discoveries in Alaska and in the deep waters of the Gulf of Mexico. In other countries, however, notably some members of the Organisation of Petroleum Exporting Countries (OPEC) and Russia, production has been more volatile, having been influenced by political decisions or economic turmoil, respectively. Such factors have resulted in two or more local peaks in the production curve of some oil producers. This is well illustrated in the case of the United Kingdom, whose fields in the North Sea passed their aggregated production peak in 1999 and which has also experienced a steady decline. These production figures are also uncontested, enabling us to state with a high level of confidence that peak oil is an observable and empirically verifiable fact.

Figure 2.4-4: Oil Production in the United Kingdom

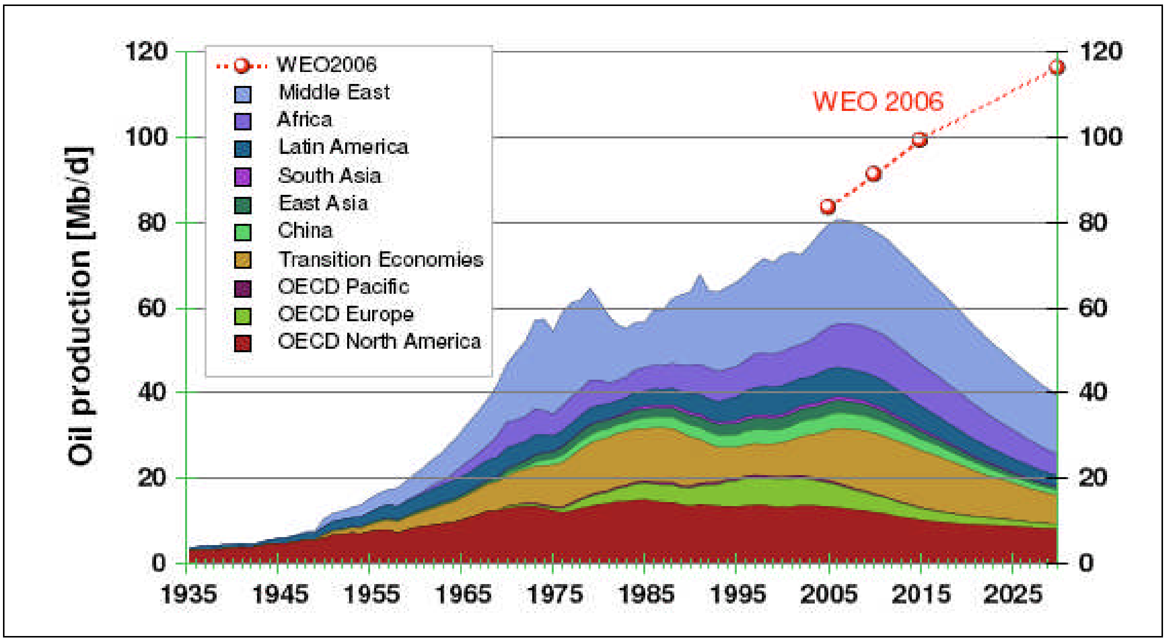


Source: Energy Watch Group (2007)

For the world as a whole, production will not necessarily (or even likely) reach a well-defined, sharp peak. Many experts are predicting a 'bumpy plateau' lasting for several years (Heinberg, 2004: 34-37). The plateau is due partly to the smoothing effect of aggregating national or regional production profiles which peak at different times, while the bumps are expected to result from supply disruptions and subsequent recoveries resulting from political and economic upheavals. However, geologically and mathematically it is clear that production must at some date reach a global maximum (even if it is a plateau lasting several months or years).

Figure 2.4-5 below, compiled by the German based Energy Watch Group, shows the aggregated oil production profile for the world and the projected rate of decline (which it predicted as relatively rapid). It has been divided into the recognized oil producing regions of the world. It also shows a peak in 2006. For the past three years global oil production has remained more-or-less constant. During this period the price has risen from about $50 a barrel to over $120 a barrel. This increase in price would represent a strong incentive to increase production, particularly in the context of rising demand, mainly from China and India, which both have very high economic growth rates. Instead, the rising price and the constant production have given rise to a reallocation of oil consumption from poorer countries to those that can afford the high prices. As global oil production passes its peak and global demand for oil outstrips the ability of oil producing countries to supply it, prices will rise dramatically. There will therefore likely come a point when the South African economy can no longer sustain these prices and we will have to reduce our imports and make do with less imported oil. Our oil supply will then need to be rationed in some way, either through the price mechanism or by government controls, or by a combination of the two.

Figure 2.4-5: Oil Production and Rate of Decline



Source: Energy Watch Group (2007)

2.4.1.2 The Timing of the Peak

Predictions about the timing of the world peak vary amongst individual oil geologists and energy agencies. As can be seen in Table 2.4-1, a significant number of experts expect oil to peak within the next decade. For instance, the latest projection by veteran oil geologist Colin Campbell, founder of ASPO, is that 'regular conventional' oil production peaked in 2005, and that all petroleum liquids (including heavy, deep-water and polar oil, and natural gas liquids) will peak around 2008. In contrast, forecasts by Cambridge Economic Research Associates (CERA) and the US Geological Survey (USGS) are more optimistic. However, these predictions are based on arguably unrealistic assessments of future oil discoveries and an unsound methodology (Campbell, 2005: 39-41). Actual discoveries over the past few years have been considerably below the USGS's F95 high probability forecast, which predicts a world peak in 2016. Thus all of the most credible estimated dates of the world peak lie within the next decade, and many within the next five years.

Table 2.4-1: Predicted Dates of World Oil Peak

Source	Affiliation	Date	Notes
Kenneth Deffeyes	Princeton University (retired)	2005	Regular oil
Richard Duncan	Institute for Energy and Man	2006	Regular oil
	Energy Watch Group	2006	Regular oil
Ali Samsam Bakhtiari	Iranian National Oil Company (retired)	2006-2007	Regular oil
Chris Skrebowski	Oil Depletion Analysis Centre, UK	2007-2008	
Colin Campbell	ASPO-Ireland	2005	Regular oil
		2008	All petroleum liquids
David Goodstein	Cal Tech University	Before 2010	
Michael Smith	Oil geologist & analyst	2011	Regular oil
		2013	All liquid fuels including biofuels
Cambridge Economic Research Associates		After 2020	
US Geological Survey		2016	F95 (high probability) scenario
		2037	F50 (median) scenario

Sources: Campbell (2008); CERA (2005); Deffeyes (2005); Duncan (2003); Energy Watch Group (2007); Goodstein (2005); Hirsch (2005); Smith (2007).

According to Colin Campbell, approximately 90 per cent of crude oil production to date has been regular conventional oil. ASPO's forecast includes so-called 'unconventional' sources of petroleum (heavy oil, oil sands and shale oil, deep water and polar oil, and natural gas liquids), but does not anticipate that these will extend the date of the peak by more than a few years, although they will lessen the steepness of the descent. This is because each of the unconventional sources of petroleum has significant disadvantages and/or limitations: each source has a lower net energy return[i] than regular oil; the costs of extraction are significantly higher; extraction is in most cases technically more difficult; and in some cases the environmental consequences are extremely negative, not least because of their relatively high carbon dioxide emissions.

Matthew Simmons (2005), a prominent energy investment banker and former advisor to the Bush Administration, has argued that Saudi Arabia is much closer to peaking than is commonly thought, and that when Saudi production peaks, the world will peak. Over the past year the Saudi oil production has dropped from approximately 9.5 million barrels per day (mbpd) to around 8.6 mbpd and has more recently risen again to 9.5 million barrels. According to the Saudis, this decline has resulted from deliberate cuts as part of OPEC agreements. But there is speculation that their largest field, Ghawar, could be in a state of collapse – as is Mexico's Cantarell field, the fourth largest field in the world. The rate at which Cantarell is declining will have Mexico stopping its oil exports to the US within the coming three years. The US will then need to find another source of oil equal in size to its current third largest supplier.

It is important to note that depletion alone will not determine the date of the peak. Geopolitical events (such as wars in oil producing countries), extreme weather conditions (e.g. hurricanes in the Gulf of Mexico) and economic factors (e.g. an international recession) could all play a role by influencing either supply or demand for oil.

Ultimately, as Heinberg (2003: 202) points out, the timing of the peak in world oil production may only be apparent several years after the fact. This is partly because there is likely to be considerable supply volatility in the years immediately before and after the peak as a result of economic and political disruptions. Even if the peak occurs after 2012, there may be a further run-up in oil prices before then. According to Leggett (2006), there is a very high probability that new oil production coming on-stream will be insufficient to match the combination of rising demand and depletion of existing oil reserves between 2008 and 2012, resulting in excess demand for oil (even though supply may not yet have peaked).

Attempting to predict the date of the peak is something of an academic distraction. The issue is that it is likely to bring with it considerable disruption to our economy and to our way of life.

2.4.2 The Post-Peak Depletion Rate: Slow or Rapid Descent?

The scale and severity of the oil peak's effects will depend to a large degree on the trajectory of the post-peak decline in oil production. The slower and steadier the decline, the easier it will be for societies and economies to adjust in a more orderly and planned fashion. A faster decline will raise the probability of severe shortages and price spikes. Countries will need to prioritise their energy needs and apportion the available oil accordingly.

Estimates of the world depletion rate vary from one expert to the next, from approximately two per cent to approximately eight per cent per annum (Heinberg, 2006). Colin Campbell, chairman of ASPO International, estimates a world depletion rate (of all petroleum liquids) of approximately 2,6 per cent per annum.

However, political and economic forces are likely to play a significant part in the evolution of oil supply in addition to geological constraints. There are several reasons why the post-peak descent might be rapid, or involve 'cliffs'.

- Post peak depletion rates in many countries that are already in decline have been quite rapid, e.g. Egypt, UK and Norway. In many cases, it was not clear that production was near its peak even a year before the event (Hirsch, 2005).

- High oil prices over the past few years have encouraged many producers to pump at the maximum rate, thereby extending the production plateau but also raising the likelihood of a steep cliff on the far side of the curve.

- Several of the world's largest oil fields are either already in, or are probably near, a state of collapse.

  - Production from Mexico's Cantarell field, the fourth largest in the world, is collapsing.

Production fell 36% over the past year, eroding Mexico's overall oil production and causing a sharp drop in exports. July exports were down 21.7% on year to 1.38 million barrels a day. (ASPO-USA, 2008).

- There is speculation that Saudi Arabia's Ghawar field, the biggest in the world, is in a state of collapse. Saudi oil production has declined by about one million barrels per day (bpd) over the past year. Ostensibly this is due to voluntary production cuts under OPEC agreements, but this may be a political cover for a peak that analysts like Matthew Simmons and Ali Samsam Bakhtiari have been warning of for several years. Since the Saudis keep their reserve and production data as State secrets, it is impossible to know for sure at this stage.

- The Burgan field in Kuwait, second largest in the world, is of a similar vintage to Ghawar and may also be on the verge of collapse.

- North Sea oil fields are contracting at between six and ten per cent per year.

- Production from some new giant oil fields is being delayed, partly as a result of rising costs and also because of shortages of skilled personnel. Production from Kashagan field in Kazakhstan, the largest field discovered since 1990, has been delayed by several years. Russia's Sakhalin II field is also experiencing delays.

- Some oil exporting countries – notably Russia and Venezuela – are nationalising their oil industries and shutting out multinational oil companies. This may constrain the future flow of oil exports as these countries conserve oil for their own use.

- Most oil exporting countries are experiencing high rates of economic growth. This is obviously a function of the considerable wealth that is flowing into their societies and rising living standards that goes with it. With the rise in living standards goes increase internal consumption of oil. This is eating away at the quantity of oil available for export. So even before a peak in global oil production, it is likely that we will see world exports declining. This will obviously primarily affect oil importing countries.

Furthermore, the existence of numerous self-reinforcing feedback loops increases the likelihood that oil production will decline rapidly rather than slowly.

- There will likely be an increasing prevalence of wars and conflict in oil producing regions as competition for dwindling oil supplies increases, and as the revenue stakes are raised (already extensive conflict limits production in Iraq and Nigeria, while the recent events in Georgia disrupted oil deliveries through pipelines).

- As oil production peaks, and the price of oil rises, the costs of extracting the remaining oil – mostly in less accessible areas like deep water – will rise significantly. This reflects the low net energy return of unconventional oil reserves. Already, rising costs are hampering or halting new oil and gas investment projects in many areas. In addition, more volatile oil prices will cause greater uncertainty for oil investors and may further dampen oil exploration and new investment.

- Oil producing nations may voluntarily cut back on supply to conserve oil and to wait for the prices to rise to boost revenues. Saudi Arabia recently announced that some of its fields would remain unexploited in the short term in order to leave some of their endowment for future generations.

- The infrastructure supporting the production, refining and distribution of oil is ageing rapidly. Most of the oil and gas infrastructure is built of steel and is beyond its original design life. This infrastructure has the following features:

  - A high percentage is un-inspectable until leaks happen;

  - "Rust" never sleeps and is corroding it all the time;

  - 80% of current infrastructure needs to be rebuilt (Simmons, 2008).

  The incentives to replace such long-lived capital diminish when oil production is in decline.

This may lead to shortages induced by faulty infrastructure rather than a lack of crude oil itself.

- The oil industry is experiencing an increasingly acute shortage of adequate skills, which is likely to hamper further exploration and production, especially in less accessible oil provinces. The maturity of the workforce is also an issue:

  - A high percentage of the global energy work force is too old and is retiring;

  - The ex-pats around the world are "coming back home";

  - Talent wars and poaching are getting fierce (Simmons, 2008).

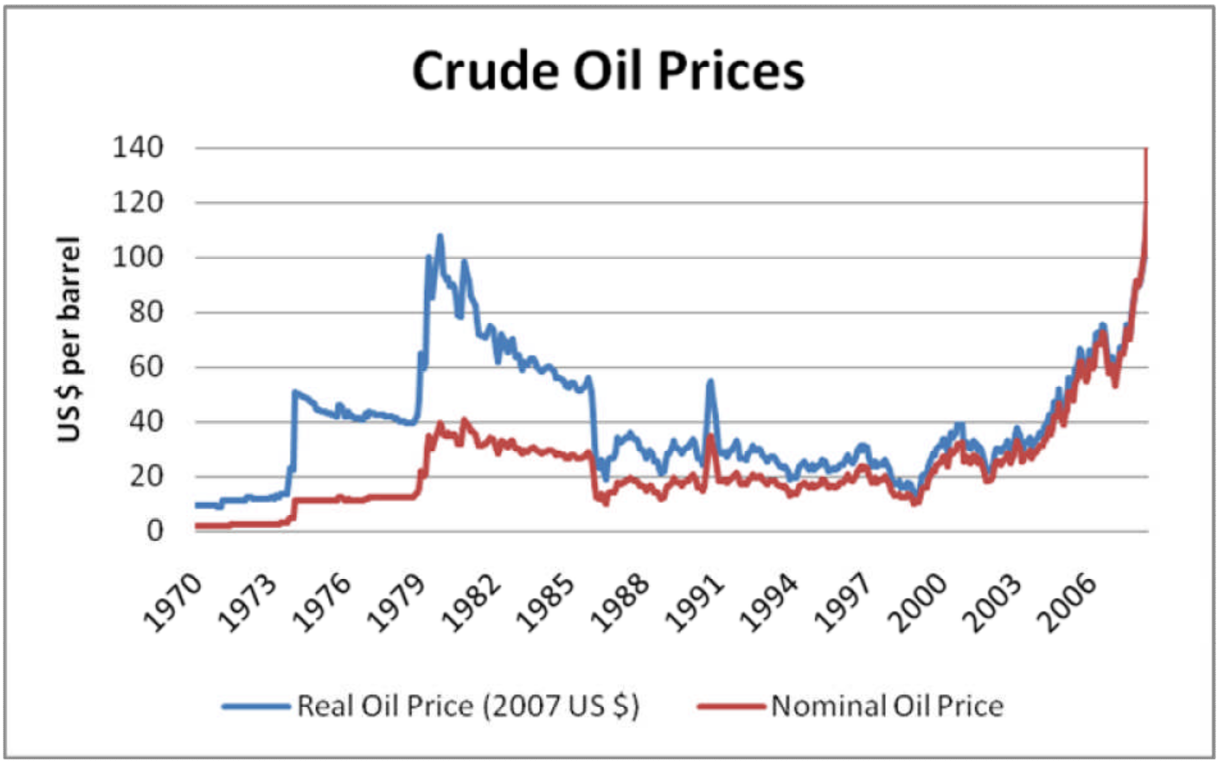
2.4.3 Implications of Peak Oil for South Africa

Humanity has never before confronted the situation whereby supply of its primary energy source declines on a global scale. Therefore it is impossible to predict with any degree of certainty what impact the peaking of world oil production will have on societies and economies. However, on the basis of past experience (including episodes of local energy depletion and previous international oil shocks) and reasoned argument, we can sketch plausible outcomes. Perhaps the most critical point is that the more prepared we are the better. Some people have argued that preparing for peak oil is an exercise in risk mitigation (Hirsch, 2005). With the long-term planning time horizon that the NATMAP envisions, it is important that we identify areas of uncertainty as well as the degree of uncertainty in order to develop plausible scenarios of the future. This will greatly assist in preparations necessary to mitigate the effects of peak oil.

As we saw in Section 2.2 the transport and the agricultural sectors consume the bulk of South Africa's oil. Both of these sectors are important, not only to the economy, but to the well-being of both individuals and communities. It is also worth noting that transport and agriculture are interdependent. Transport is needed to get individuals from their homes to work. In urban areas employment is necessary for basic survival. Farmers rely on transport systems to get their produce to markets in urban areas and to feed urban-based workers.

Figure 2.4-6 shows the history of oil prices from 1970 to the middle of this year.

Figure 2.4-6: Oil Price Trends



Source: IMF (2008)

The price of oil has risen considerably over the last six years. It is now about five times higher than it was in 2002. Over the past three years global production has remained flat while prices have risen from $50 to over $100. This could possibly indicate a peaking of production given that prices would normally be a strong incentive to increase production particularly in the context of rising demand. The international price of oil has meant consistent price rises for fuel in South Africa. These have mirrored the upward trend of oil prices.

Once global oil production starts to decline the world will go from a situation where there has been more oil available on a yearly basis to a world where there is less available year-on-year.

This will represent a paradigm shift requiring the fundamental re-thinking and restructuring of many of the things we currently take for granted. We will attempt to identify some of the implications and to assign a level of certainty to these. This will lay a foundation for the future scenarios we will develop in Section 4. The purpose of identifying uncertainties is to be able to risk analyse the factors that will have a bearing on transport policy and planning in order to lay a solid foundation for timely and strategically sound planning. We will rank levels of certainty on a scale of 1 to 5, with 1 representing high levels of uncertainty and 5 representing high levels of certainty. While the focus of this study is on transport it is important to understand the broader implications because they are likely to affect transport.

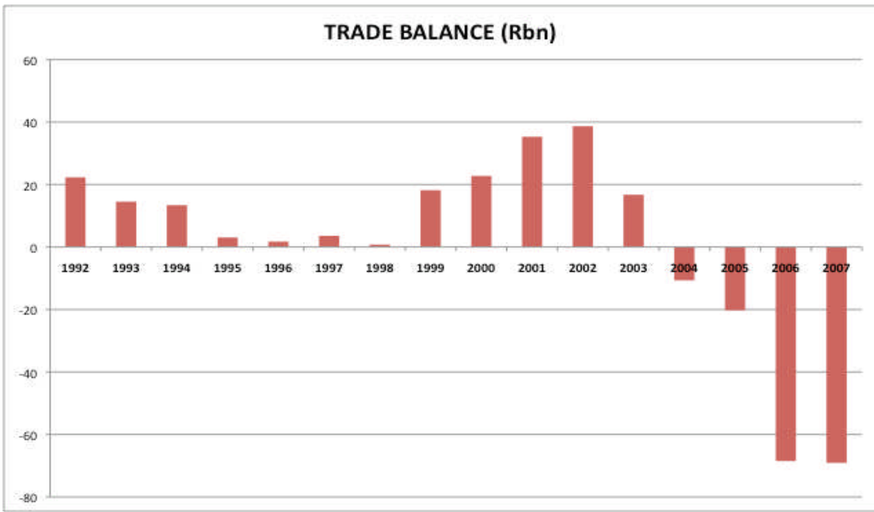
2.4.3.1 Implications for the Economy and Financial Markets

Global demand for oil has been growing for decades as a result of both population expansion and economic growth (at an average rate of approximately 1.5 per cent per annum over the past 30 years). Supply has for the most part risen to meet this demand, aside from two interruptions in the 1970s and a brief one in 1990. The oil shocks of 1973/4 and 1979/80 resulted in rising inflation together with severe recessions and higher unemployment (i.e. stagflation) in the industrialised economies. However, these shocks had political origins and lasted for a few years at most. Peak Oil, being imposed by Nature, will have both short-term and long-term impacts on the economy.

The severity of the short-term economic impact of an oil shock depends on several factors, including the magnitude and rate of the price increase, and whether it is sustained or transient. Rapid, large and sustained price shocks have historically had the biggest impact. After oil output peaks, a gap will open up between demand (desired oil) – which is highly inelastic in the short run – and supply (available oil). As discussed earlier, a conservative estimate of the post-peak depletion rate is about three percent per annum. Considering that oil prices trebled in 1979/80 after a mere five percent reduction in output (Iran's contribution), the potential for runaway oil prices becomes evident.

Figure 2.4-7 below shows the recent trade balance in South Africa. It is notable but not surprising how this has gone into deficit in recent years correlating markedly with the rises in oil price. As oil continues to rise so will the likelihood that the trade deficit will increase.

Figure 2.4-7: South African Trade Balances



Source: DTI (2008)

Another important factor is the monetary policy response of central banks. If central banks allow higher energy prices to work through the economic system, then the increasing scarcity of fossil fuels will manifest appropriately in altered relative prices and act as a stimulus to both energy conservation and investment in substitutes. In the short- to medium-term this new investment could help to offset declines in demand and investment in other sectors. However, most central banks are primed to respond aggressively to signs of rising inflation, especially if oil prices rise rapidly. In this case the likelihood of a recession is increased. Consumers will already be curbing spending as a result of higher energy prices (and second-round price increases for energy-intensive goods and services), and if this demand destruction is exacerbated by higher interest rates, which also depress investment, the economic situation could deteriorate significantly.

Leggett (2005) argues that the crucial timing may not be the actual date of the oil peak, but rather when a critical mass of investors recognises that Peak Oil is unavoidable and imminent. Given the sensitivity of oil prices to news of even small interruptions to supply, this realisation is likely to spark wide-spread panic and hoarding behaviour among investors, leading to a dramatic price spike. Such a spike could have devastating effects on financial markets as investor confidence in the growth economy dissolves.

Indeed, the integrity of the world financial system is deeply dependent on continuous economic growth. This is because new money is created as debt, on which interest payments are required. The only way that the interest can be repaid in future is if more new money is issued, which itself increases the stock of debt. The collateral for this debt is continuous economic growth, which is itself dependent on growing supplies of energy. Should growth fail for an extended period, the financial system may be seriously compromised, compounding the economic adversity.

In the medium term, an economic recession and/or investor confidence crash would reduce global demand for oil and – somewhat perversely – result in the oil price falling again. This in turn could stimulate a partial economic recovery, only for another price spike to be triggered and the cycle to repeat itself.

In the long term, the world faces a virtually endless sequence of supply-side oil shocks on the down-slope of the Hubbert curve. Thus we can reasonably expect a rising oil price trend due to cumulative shocks along with greater volatility as a result of economic and political fallout. Certainly, efforts will be made to conserve oil (and energy more generally), and there will be heightened efforts to find substitutes for depleting oil. However, it will take many years – if not decades – to replace oil as an energy source and the vast infrastructure that currently relies on oil. The problem is that economic conditions will be far less conducive to such investment after Peak Oil as a result of less energy being available, rising costs, and the business environment being characterised by greater volatility and uncertainty.

If no mitigating action is taken, or it is begun too late, the combination of repeated supply-side oil shocks and a major stock market crash could prompt a prolonged economic depression. The US Department of Energy commissioned a report on peak oil by Robert Hirsch et al (2005: 4), who concluded that:

> "The peaking of world oil production presents the US and the world with an unprecedented risk management problem. As peaking is approached, liquid fuel prices and price volatility will increase dramatically, and, without timely mitigation, the economic, social, and political costs will be unprecedented. Viable mitigation options exist on both the supply and demand

sides, but to have substantial impact, they must be initiated more than a decade in advance of peaking."

Table 2.4-2: Possible Economic Implications of the Peaking of Global Oil Production and Levels of Certainty

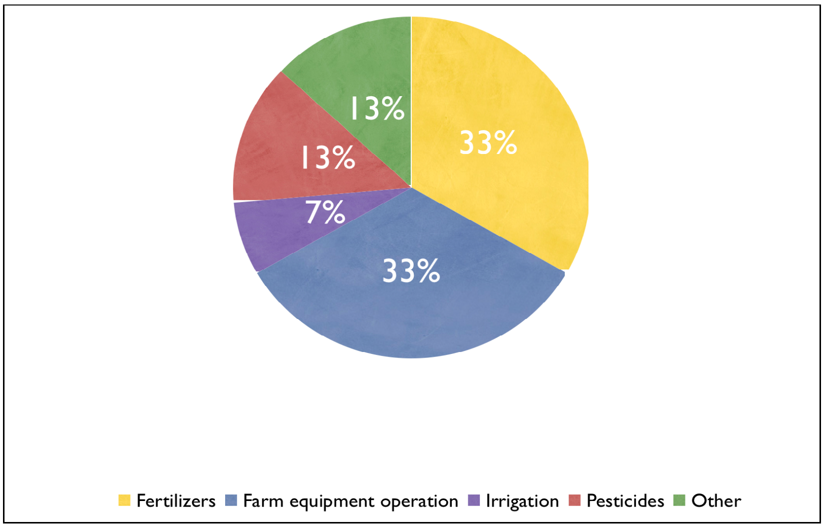
Likely occurrence	Level of certainty
Runaway price rises	5
Higher prices of household goods - inflation	5
Recession (negative economic growth)	4
Rising levels of unemployment	4
Increasing trade deficit	4
Greater investment in energy alternatives	3
High interest rates	4
Stock market crashes	4
Hoarding of food and fuel	5
Collapse of the financial system	3
Short-term boom and bust cycles	4
Growth in the renewables sector	5
Inadequate renewable energy infrastructure	5
Extended economic depression	4
Timely adequate mitigation response	2

2.4.3.2 Implications for Agriculture, Food and Population

Commercial food production is largely oil powered. Most pesticides are petroleum-based, and all commercial fertilisers are ammonia-based and are produced from natural gas. Oil based industrial agriculture is primarily responsible for the explosion in the world's population from 1 billion at the middle of the 19th century to 6.3 billion at the turn of the 21st. Oil allowed for farming implements such as tractors, food storage systems such as refrigerators, and food transport systems such as trucks to become the backbone of the system. As oil production went up, so did food production. As food production went up, so did the population. As the population went up, the demand for food went up, which increased the demand for oil.

Pheiffer (2004) notes that the "Green Revolution", which took place from the 1960s, increased the energy flow to agriculture by an average of 50 times the energy input of traditional agriculture. He shows how in the United States, 1500 litres of oil equivalents are expended annually to feed each American. Agricultural energy consumption is broken down as follows:

Figure 2.4-8: Energy Consumption in Agriculture in the US - 1994



Source: Pheiifer (2004)

Furthermore, the 'Green Revolution', involved the extension of Western farming methods (including fertilizer and pesticide use) and crop varieties to developing countries, massively boosting agricultural yields and thereby supporting rapid growth in their populations. The world population is currently growing by over 70 million people per annum, which implies a growing demand for food.

After oil output has peaked, the world faces the prospect of declining food production and therefore rising world food prices. Some authors suggest that without fossil fuels, the sustainable world population is probably in the region of about two billion (see Heinberg, 2003: 177). Others, however, are optimistic about a larger world population being sustainable. This will however, involve a radical change in the way in which food is currently produced and in the way in which society is ordered. The impact on agriculture of fossil fuel depletion will be exacerbated by soil degradation, depletion of water resources and climate change. Together, these factors pose a significant threat to food security.

In 1900, 40% of the US population were farmers. The industrialisation of agriculture has resulted in many US farmers losing their land to large corporations and moving to cities. There are now only three to four million farmers in the US, less than the number of people in American jails and representing about 1% of the population. The average age of American farmers is 55 years and approaching 60 years. Heinberg (2007) argues that as global oil production declines, so agriculture will inevitably revert to more labour intensive farming methods requiring some 40 to 50 million farmers who will need to be trained.

The concentration of people in towns is only possible because of the industrialisation of agriculture and this has only been possible because of the abundance of cheap energy in the form of oil over the last century. Cheap oil has enabled us to globalise the production of food. Most supermarket shelves are littered with produce from the four corners of the world. And while we are able to do this because we are sourcing our food from the cheapest producers worldwide, it comes with a very high environmental price and is fundamentally unsustainable. In essence, we have built a global system of food production upon which most people in the world are dependent and that is hugely vulnerable because of its reliance on oil.

The pollination of crops is big business. Commercial bee-hivers truck their hives around many parts of the South Africa and other countries on pollination contracts. These are necessary where there are large-scale mono-crops. Because these huge crops require pollination all at the same time, bees need to be imported into the area in large numbers to get the pollination job done. Without this service many large commercial farms would not be viable. The fact that bees have to be transported around farming areas in order to ensure food production makes this form of commercial agriculture even more vulnerable to the effects of oil depletion.

Large areas of mono-crop farming would simply go to waste, were bees not able to be transported by road to these areas.

Another concern is the growing competition between food and fuel. Rising oil prices have prompted governments in several countries (including notably the US and Europe, as well as South Africa) to promote biofuel industries. Together, market forces and government support are making it increasingly profitable for (e.g. maize) farmers to supply their produce for the production of ethanol rather than for food. Growing international production of ethanol from maize and sugar is already pushing up the world prices of these staples, threatening the food security of certain food-importing nations and especially poor, landless consumers.

Table 2.4-3: Possible Implications for Agriculture of the Peaking of Global Oil Production and Levels of Certainty

Likely occurrence	Level of certainty
Runaway price rises of agricultural inputs	5
Scarcity of fuel	4
Scarcity of fertilizers and other chemical inputs	4
Shift to more manual production methods	4
Shift to organic food production	4
More small scale agricultural production	4
Shortages of food	4
Less imported food	5
Lower agricultural yields	5
Urban agriculture	4
Shortages of agricultural skills	4
Local produce markets	5
Lower levels of plant pollination	4
Retraining of farmers	4
Timely adequate mitigation response	2

2.4.3.3 Implications for Social Cohesion

Global oil depletion is likely to give rise to conflicts over resources at global, regional and local levels. As oil production begins to wane after the peak, international competition for remaining supplies will intensify. Given how critical oil is for economic and military power, there is a strong likelihood of further regional military conflicts over energy resources, especially in the Middle East and Caspian region, but also in other significant oil-producing regions such as West Africa and Latin America.

In some cases (Iraq and Nigeria, for example) local conflicts are already deepening, and may possibly descend into civil wars. In addition, the probability of occurrence of war between a powerful consuming nation and a weaker producing state will probably increase (see Heinberg, 2004). Some commentators (e.g. Heinberg, 2006) have argued that such intervention could seed terrorist activity in the future. Regional conflicts could result in a new military rivalry among the US, EU, China and Russia.

This could be a reason for the US policy of positioning and utilising its military forces in order to ensure or control the flow of oil, especially in the Middle East. Russia is now the world's leading oil producer and boasts the world's largest natural gas reserves. Already this resurgent nation has begun to use its energy resources as a political weapon in Europe. China has a voracious appetite for energy, and has been concluding bilateral trade and investment agreements with several oil producing countries (e.g. Angola and Canada).

Escalating geopolitical tensions, outright conflict over energy resources, and terrorism could erode economic confidence, hampering investment and making the transition to alternative energy sources and infrastructure that much harder.

Across the world the effects of rapidly rising oil prices have been varied and widespread. Oil permeates almost every sector and every country. What defines our ability to carry on as before is our ability to pay the going price for the oil we are consuming. We see generalised increases in price as the price of oil rises. The rising price affects the poorest communities first, requiring behavioural change as it moves up the income ladder. People increasingly feel the pressure of higher transport costs as well as generally higher food prices. The question is what do they do under pressure? Around the world we are currently witnessing protests, riots and other expressions of mass discontent. There have been protests and blockades in Spain, protests by fishermen in Brussels, and blockades by truck drivers in the UK. In Portugal, truck drivers have been on strike; in Belgium, workers have protested the rising cost of living; protests are occurring in a number of Indian cities around the high price of fuel as well as increasing transportation costs; and in Indonesia there are protests over the lowering of fuel subsidies. Before that we had food riots in Egypt, Haiti and in other countries, while there have been fuel riots in Nepal and other countries in recent years.

Clearly what we are seeing is people in vulnerable groups whose livelihoods are in some way affected by rising fuel and food costs and who want their voices to be heard. Rising prices puts the greatest strains on the poorer groups in society. How they react to it depends on where the pressure is felt and on socio-cultural factors.

In South Africa, we have had constantly rising fuels costs in response to the oil price rises. This has affected transportation costs and put pressure on people's mobility. Oil pushes up the prices of just about everything and has pushed food prices up too. Rising prices puts a strain on everyone and create the conditions for social tensions and instability. Our dependence on oil has the ability to expose the cracks and fissures in our society as the price rises. In South Africa we have many fault lines, including the divide between rich and poor, between different races, between different cultural groups, between employed and unemployed and between South Africans and non-South Africans.

As we get closer to the peak in global oil production, we are likely to see greater pressures particularly on poorer communities but constantly moving up the income scale. The intensifying pressures are likely to open new fault lines in our society.

At a local level, we are likely to see tensions rising local oil companies and consumers, particularly when high profits are made by oil companies and consumers are saddled with high fuel prices. We have already seen stand-offs between fuel distributors and consumers in a number of countries (eg. Spain and Nepal), between consumers waiting in fuel queues or over rations. In some parts of the world we have seen in sharp rise in the theft of fuel and the emergence of criminal gangs beginning to operate a black market for this valuable commodity. As the price of oil rises further and as oil begins to be rationed we will likely see the growth of powerful criminal gangs wanting to control the underground trade in fuel. The higher the price rises the more likely this will occur. We could begin to see an increase in both land and sea based piracy around the world.

Scarcity of resources places pressures on societies and communities. The more unevenly wealth is distributed in a society the higher the likelihood of social tensions around resources. The higher the price of oil, the higher is the impact on the poorer sections of society. As the price of oil rises there could be other such expressions of frustration and hardship.

Already it is the poor countries that are unable to afford oil at the current levels and have had to make adjustments within their economies in order to cope. Many poor countries have seen food and fuel riots during the course of the past year (e.g. Haiti, Nepal and Egypt). Social tensions could also give rise to political instability and threats to democracy.

While many social tensions are likely to manifest during times of rising fuel prices, cooperation is also a likely outcome. During the past two years there has been huge growth of community based initiatives to mitigate the effects of peak oil. Perhaps the most significant one is the Transition Towns movement in the UK which has grown from nothing to embracing over 250 small towns in the rural parts of the UK during the course of the last two years.

Table 2.4-4: Possible Implications for Social Cohesion of the Peaking of Global Oil Production and Levels of Certainty

Likely occurrence	Level of certainty
Wars between the big powers for energy resources	3
Civil wars in oil producing regions	3
Theft of fuel	4
Growth of organized fuel theft gangs	4
Black market for stolen petroleum products	4
Food riots	4
Fuel riots	4
Rising terrorism	4
Rise of both land and sea based piracy	4
Political instability	4
Rise of authoritarianism	4
Greater levels of social cooperation	5
Local levels actions to mitigate effects	4
Timely adequate mitigation response	2

2.4.3.4 Implications for Technology

Technology is likely to be affected by the peaking of global oil production. As it becomes clear that less oil will be available each year, it is likely that there will be great incentive to find new sustainable sources of energy. Technologies will develop which improve energy efficiencies. Increasingly nature is being used as a model and bio-mimicry is becoming a valid approach to the development of technology. Bio-mimicry has developed through close observation of nature's solutions, processes and products. It has been observed that nature does not produce any waste and has cyclical processes, where the waste of one process becomes an input into another process. Industry is increasingly beginning to view and understand its processes in this way. There are already whole towns that have built along these principles. (e.g. Kalundbourg in Denmark). There are also many new eco-cities presently being planned and built in China, where the city is viewed as a system and is designed to produce zero waste. Technology is likely to move from being metaphysical to becoming biological. Biological systems evolve and respond to real-time feedback they receive.

Technology is also likely to need to adapt to reusing and recycling materials and components in their entirety. Plastics will become increasingly scarce and innovative materials will emerge that have light ecological footprints.

Table 2.4-5: Possible Implications for Technology of the Peaking of Global Oil Production and Levels of Certainty

Likely occurrence	Level of certainty
Bio-mimicry	3
Biological systems	3
Zero waste	3
Adaptive systems	3
Less plastic	5
Long life cycles	4
Reuse and recycling of components	4
Low energy inputs	4
Local solutions	4
Innovation in low energy usage	4
Timely adequate mitigation response	2

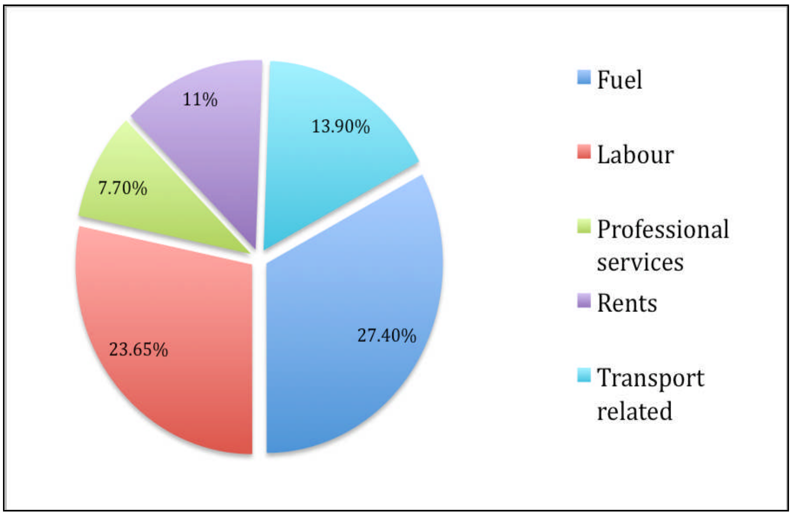
2.4.3.5 Implications for Transport and Mobility

The rapid process of globalisation over the past two decades has been driven by a number of factors, including neoliberal ideology favouring free trade and technological progress (especially with regard to telecommunications). Globalisation has been underpinned by the availability of abundant, cheap oil to fuel the world's transportation systems. With declining supplies of oil, we can expect a partial reverse of the globalisation process in favour of localisation of production and consumption (especially of material goods). With ever higher costs of transport, patterns of movement are likely to become more local. High transportation costs will severely challenge the economics that underlies globalization.

2.4.3.5.1 Aviation

Perhaps the most vulnerable element of the transport sector is aviation. Fuel represents a high proportion of the costs of airlines. As the price of fuel rises so too does the this proportion. Fuel currently can represent up to third of an airline's costs. Bezdek (2007) breaks down the costs of a typical airline as follows:

Figure 2.4-9: Airline Proportional Costs



Source: Bezdek (2007)

It is likely that this will continue to drive the search for conservation and greater efficiencies within the industry. There will be a continued search for synthetic fuels for aircraft. Presently SASOL produces the only alternative synthetic fuel used in the airline industry.

Jet aircraft emissions contribute significantly to global warming so airlines will come under continued pressure in the coming years as new international agreements are implemented to curtail global warming. There are likely to be regulatory pressures as well as shrinking markets as people choose to travel less and as the cost of air travel increases.

Within the aviation industry, the conventional wisdom is that all facets of the industry are likely to grow rapidly in the coming decades. It is projected that growth will come in the following areas:

- Passenger traffic: Regional, domestic, international
- Freight and cargo: Regional, domestic, international
- Charters, business jets, air taxis, etc.
- Aviation miles and revenues
- New aircraft: Small planes, large planes, private jets, etc.
- Airports, airport industrial parks, convention centers, hotels & restaurants, infrastructure, etc.

- Many cities betting their futures on aviation growth
- Airlines planning to expand; new airlines being started

Bezdek (2007) shows, too, that the aviation industry has grown despite higher fuel prices but declines dramatically when GDP falls. In the context of peak oil he foresees the following:

- Aviation will be transformed from a rapidly growing industry to one in decline
- Chaos likely throughout the industry
- Chronic, continuing excess capacity in all aviation sectors
- $100s of billions of investments will be “stranded”
- Some airlines will disappear or may have to be rescued by governments
- Airport and aviation infrastructure projects will be cancelled
- Bonds for airports, airport industrial parks, infrastructure projects, etc. will likely default, cascading throughout financial sector
- Pressure will mount for re-regulation of aviation

A significant decline in the aviation sector will have impacts on other sectors dependent on cheap flights. These include:

- Tourism
- Courier services
- The export and import of fresh produce
- Hospitality

The economic pressures on the airline industry are likely to result in many airlines going out of business. This will mean a surplus of planes on the world market that will also impact on manufacturers. Manufacturers are likely to scale down their operations, forcing many employees into redundancy.

There is likely to be consolidation within the industry as badly run airlines fold. It is also likely that a significant number of airlines could be renationalized as their only means of survival.

2.4.3.5.2 Road Transport

So much of our mobility relies on road transport that the impact of peak oil is likely to be severe. As fuels costs rise and supply begins to decrease, all levels of road transport will be affected. Individuals that rely on public transport will have their transport costs increase. This will affect their disposable incomes. Individuals who rely on private transport for their mobility will see their costs rise too. Rising costs will reduce unnecessary journeys and begin to change mobility patterns. The overall effect is likely to be a reduction of traffic volumes on the roads. It will also drive people into using public transport and other cheaper forms of transport. The rise in the price of oil will also drive freight onto the rail network.

Not only will motorized transport be affected by the oil price, but so too will the roads themselves. Tar used for road construction is an oil based product that will increase in price and become ever scarcer. It could therefore result in the roads that form the national road network falling into disrepair and becoming more and more dangerous to drive on in years to come. Poorly maintained roads affect road safety and journey times.
Moving South Africa (1998) identified and categorized the customers of transportation into various groups related to their transport options and made recommendations for these groups. These were as follows:

- **Strider customers**: (prefer to walk or cycle)
  5.4 million in 1996; projected growth to 6.9 m by 2020
- **Stranded customers**: (no affordable transport available)
  2.8 million in 1996; projected to grow to 3.6 m by 2020
- **Survival customer**: (captive to the cheapest mode of public transport)
  4.1 million in 1996; projected growth to 5.1 m by 2020
- **Sensitive customer**: (captive to the best option of public transport)
  2.1 million in 1996; projected growth to 2.6 m by 2020
- **Selective customer**: (can afford a car, but willing to use public transport)
  4.1 million in 1996; projected growth to 5.7 m by 2020
- **Stubborn customers**: (will only use car)
  3 million in 1996; projected growth to 5.6 m by 2020

Urban passenger customers were segmented on the basis of specific needs, and specific issues were generated in respect of each segment. A large number of "Stranded" passengers were identified, projected to grow to well over 3 million by 2020. Significant system performance gaps were identified affecting other segments as well. The core challenges that emerged were:

- The lack of affordable basic access;
- The ineffectiveness of the public system for commuters and other users;
- The increasing dependence on cars within the system; and
- The impact of past patterns of land use and existing planning and regulation of public transport.

Research into **rural passenger** needs yielded two core challenges: The lack of integrated provision of infrastructure and the absence of a framework for rural roads prioritisation. For **long-distance and tourist customers**, the key strategic challenges were to clarify the transport capacity requirements emerging from the nascent tourism strategy and to prevent transport from bottlenecking tourism growth.

Cutting across all customer segments are the challenges of:

- Building the long term financial sustainability of the roads network,
- Balancing the risk alignment and affordability in the critical areas of environmental concerns and transport safety,
- Enabling the system to create human capacity for new roles in the sector, and aligning training to this, and
- Dealing with the lack of sustainability in the system.

While this study did not identify energy as a specific factor related to the sustainability of the system, it identified some of the key challenges that would still need to be confronted in the context of a globally declining supply of oil. Without being able to quantify more precisely the numbers of consumers in each category (as this lies outside the scope of this work), it is clear that for all categories of consumer, the effect of peak oil will be to drive significant numbers of consumers into categories with fewer transport options. The effect will be to immobilize increasing numbers of transport consumers. Combined with the legacy spatial structuring of urban areas that confined the poorest people to the periphery of the cities, it is clearly the poor that will bear the brunt of this burden. In the context of likely significantly higher food prices and higher rates of unemployment, this has profound implications for social cohesion given the already large numbers of poor people in South Africa.

2.4.3.5.3 Rail Transport

Constraints on the movement of people and goods on the roads is likely to place much greater demand on rail services and require much greater investment to expand the rail network. The longer this investment is delayed the more costly it is likely to become.

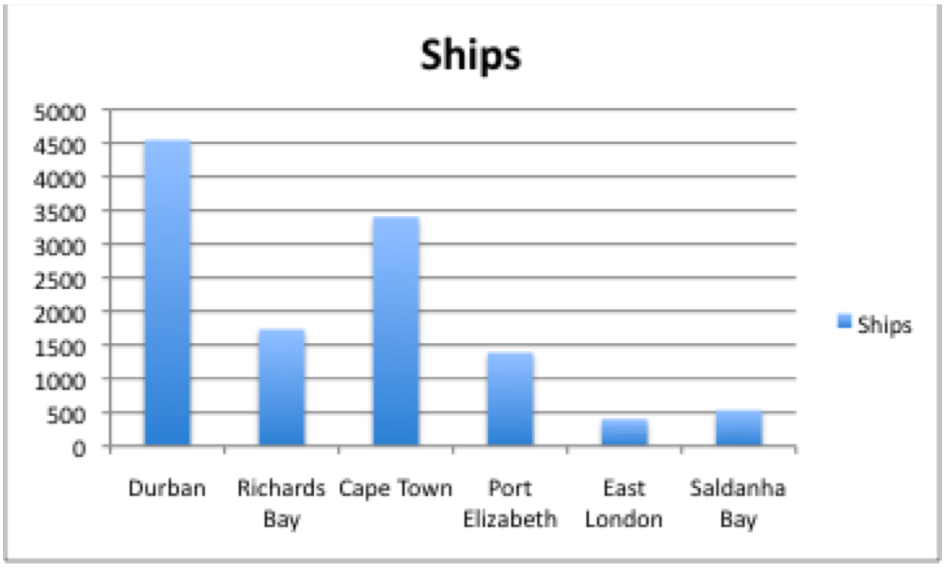
Unfortunately, South Africa's rail network was permitted to stagnate over the past decades and requires considerable effort to restore elements of the infrastructure that have gone into disrepair.

Restoring and expanding the rail network can only be done sustainably if its power comes from renewable sources. There are only limited renewable energy sources that can be utilized to meet the needs of the rail network. Principle amongst these is hydro-electrical power which could potentially come from the Inga Rapids hydro-power project on the Congo River, should this materialize. This would have a positive effect on South Africa's greenhouse gas emissions.

2.4.3.5.4 Sea Transport

The bulk of South Africa's imports and exports are transported to and from the country by sea. Sea transport is vital for trade with Figure 2.4-10 below showing the number of ships being handled by South African ports.

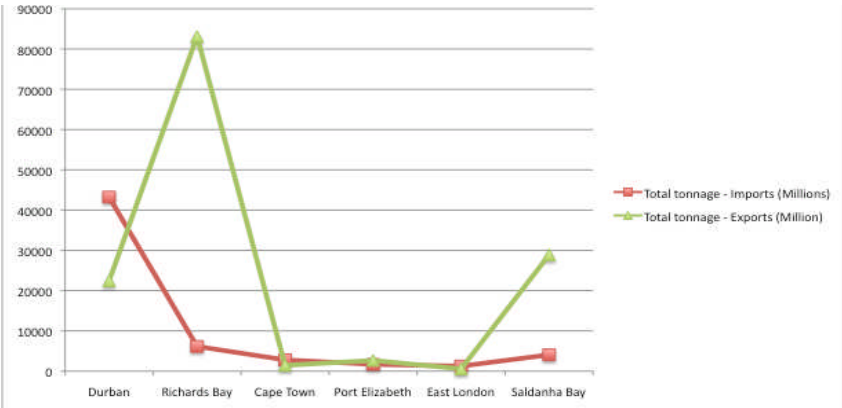
Figure 2.4-10: Number of Ships handled in SA Ports



Source: Ports and Ships (2008

The total tonnage of goods passing through South African is as indicated by Figure 2.4-11:

Figure 2.4-11: Total Tonnage of Imports and Exports passing through South African Ports (2005/06)



Source: Ports and Ships (2008

Given that we have a high level of dependency on ships for the vast majority of our trade, both imports and exports will be affected by rising oil prices. The bulk of South Africa's exports, by tonnage, are handled through Richards Bay and Saldanha Bay. These two ports handle much of the bulk shipments of mined ore and coal. The greatest volume of imports come through Durban and is then routed to Gauteng by road or rail.

It is likely that all of these volumes could drop as the cost of sea transport rises and as economic activity slows as a result of high oil prices and greater scarcity of oil.

Table 2.4-6: Possible Implications for Transportation of the Peaking of Global Oil Production and Levels of Certainty

Likely occurrence	Level of certainty
Greater conservation and efficiencies in aviation	5
More synthetic aviation fuel produced	5
Fall in air passenger volumes	5
Increased prices of both imports and exports	4
Fewer air routes	4
Drop in tourism and related services	4
Lower volumes of people through the airport infrastructure	4
Excess capacity in all aviation sectors	4
High levels of bankruptcy in the aviation sector	4
Re-nationalization of some airlines	4
Increasingly high costs of air travel	4
Increased costs of transporting freight	5
Increased costs of moving people	5
Greater reliance on public transport	4
Deteriorisation of condition of road network	4
Reduction in the transport options for the poor	4
Shift of freight back to the rail network	4
Pressure to expand the rail network and services	5
Lower volumes of both imports and exports	4
Greater numbers of people walking and cycling	5
Shorter journeys	4

2.4.4 Conclusions on Peak Oil

In summary, we can state what we know for *certain* about the depletion of oil:

- Oil must be discovered before it can be produced.
- Oil must be extracted, refined and transported before it can be used.

- On the human time scale, oil is a finite, non-renewable resource.
- The more oil we use now the less we have for the future.
- Exponential growth goes hand in hand with depletion of non-renewable resources.
- Exponential growth in human populations and consumption of physical resources, including non-renewables like oil, is not sustainable indefinitely on a finite planet.
- Production of oil will at some point reach a peak and then begin to decline.
- Petroleum products have the highest energy density of any known portable energy carrier.
- Replacing the current oil-based infrastructure requires time, financial resources and energy.
- The longer we take to change our consumption patterns the more constrained our options will be for doing this in an orderly manner.

Existing research has demonstrated a compelling argument about the life cycle curve of oil production:

- The life-cycle curve of oil production is roughly a bell curve – this is empirically verifiable (e.g. US-48, North Sea, etc.).
- The longer that production is maintained at or above current rates, the faster it will fall on the far side of the Hubbert curve.
- Improvements in extraction technology increase the rate of depletion.

The following is uncertain:

- Precisely when the oil production peak will occur.
- What the post-peak rate of depletion will be.
- Whether sufficient substitutes for oil will be developed, produced and installed in time to avert damaging shortages.
- The scope for conservation and efficiency to offset the decline.
- Precisely how people, countries, and markets will react when the decline sets in.

Based on available evidence, it appears to us likely that:

- Oil production will not increase substantially beyond its current level.
- Between 2008 and 2015, oil output will begin an inexorable decline.
- There is a significant risk of a rapid decline (cliff) in global production at some point.
- Without proactive mitigation well before the peak, shortages will occur causing the price to spike.

2.5 Strengths and Vulnerabilities of South Africa's Transport System

2.5.1 Introduction

In order to assess more fully the likely impact of global oil depletion on transport in South Africa, some of the major vulnerabilities in the current transport system need to be considered. South Africa's overarching vulnerability lies in its twin dependence on imported oil and road transport to move both goods and people, as highlighted in the foregoing sections.

2.5.2 Transport Infrastructure and Systems

South Africa has a sophisticated transport infrastructure that is the envy of many developing countries. This includes an extensive road network, although a major weakness is the deficit in road maintenance in many areas. Minister of Transport Jeff Radebe announced in September 2007 that the country faced a R17 billion deficit for road maintenance over the next five years, covering nearly 15% of the national road network (Fin24, 2007). The national rail network is also extensive, connecting all the major settlements in the country. However, the rail infrastructure has been poorly maintained and is in a general state of disrepair having had little investment in its upkeep for some four decades. Much of the nation's rolling stock is very old and needs replacement soon (Situma, 2007). In addition, the rail lines are narrow gauge, which limits their efficient carrying capacity. The well-developed port infrastructure could serve the economy well if more freight is moved from road to sea. However, since manufacturing production is concentrated in Gauteng, there is limited scope for such modal transfer. Many of the country's airports are currently being expanded, but this will be of doubtful value for the future when air travel is likely to be severely constrained internationally and domestically by rising fuel costs.

According to the National Household Travel Survey (NHTS; DoT, 2003), South Africa had some 10 million commuters in 2003. The major reasons for travel overall were education (41% of household members), shopping (30%), visiting (29%) and work (27%), although the main purpose varied according to settlement type and province. The country's commuters are overwhelmingly dependent on road transport, including minibus taxis (22% of commuters), cars (15%), buses (6%) and other taxis (3.7%). Just 2.3% of commuters reported use of trains. While air travel will be particularly vulnerable to rising fuel prices (since fuel accounts for a relatively high proportion of total costs), business travellers can adapt to some extent by telecommuting. Many of those travelling by air for other purposes (e.g. tourism) are likely to have to shift mode and/or reduce their travel expectations and distances.

Respondents to the NTHS reported a number of concerns, the chief one being lack of access to public transport (50% of households), while 75%, 40% and 75% reported no access to rail services, buses and cars, respectively. Other concerns identified by households included safety (33%), affordability (20%) and security. Thirty percent of households spent more than 20% of their income on public transport (including taxis) in 2003; since then, petrol and diesel prices have more than trebled.

Freight transport is also heavily road-based, with approximately 80% of the country's freight transported by road and the remaining 20% by rail (GCIS, 2006). Mining products, such as coal and iron ore, account for almost half of all freight tonnage, manufacturing for another 45% and agricultural products for just 6%. This presents a major challenge to the economy, both in terms of future fuel supply constraints and the impact of rising costs. The National Freight Logistics Strategy (DoT, 2005: ii; original italics) identifies several other weaknesses: "The freight system in South Africa is fraught with inefficiencies at system and firm levels. There are infrastructure shortfalls and mismatches; the institutional structure of the freight sector is inappropriate, and there is a lack of integrated planning.
Information gaps and asymmetries abound; the skills base is deficient, and the regulatory frameworks are incapable of resolving problems in the industry."

Vulnerabilities can also be identified on a geographical basis. Most obviously, there are substantial distances between major metropolitan areas and towns. Most liquid fuels are consumed in metropolitan areas, due to the high concentration of vehicles found here and the phenomenon of urban sprawl which dictates that urban travel is over longer distances that if there were a more concentrated form of spatial structuring. Townships and informal settlements are highly vulnerable because of their dependence on minibus taxis, the poverty in these areas, and their distance from places of work. Areas in the hinterland that have no rail access are also highly vulnerable, with a danger that both people and assets could become stranded.

Finally, there is the vital social dimension of vulnerability. Of particular concern is the minibus taxi industry, which has demonstrated considerable potential for violence, including intimidation of commuters who choose to use trains and buses. Another group who would be adversely affected by fuel shortages and price rises are truckers. Even advanced countries such as Britain and France have found that striking or protesting truck drivers can bring segments of their economies to a standstill in a short space of time. Thirdly, low-income metropolitan and urban areas could become flashpoints as economic pressures and constraints on mobility intensify.

Table 2.5-1 to Table 2.5-7 below summarise the key strengths and weaknesses of the transport sector by mode of transport. They also assign a certainty factor (CF) between 1 and 5 to the issue, with 1 being highly uncertain factor and 5 being highly certain. In addition to the strengths and vulnerabilities we have considered some of the opportunities and threats that affect our different systems.

Table 2.5-1: SWOT - Aviation

Aviation			
Strengths	**CF**	**Vulnerabilities**	**CF**
Speed of travel	**5**	Sensitive to fuel price rises	**5**
SASOL biggest producer of synthetic jet fuel	**5**	Only one alternative fuel	**4**
Links to all major cities in SA	**4**	No linkages to smaller towns and rural areas	**5**
		High capital costs	**4**
		Consumers reliant on airline schedules	**3**
High safety standards	**4**	Only set routes	**4**
		Inflexible	**4**
		Severe environmental impact	**5**
Opportunities		**Threats**	
Greater use of synfuels	**4**	Economic viability of airlines	**4**
		Higher prices will reduce air-travel demand	4

Table 2.5-2: SWOT - Road Transport (passenger)

Road Transport (passenger)			
Strengths	**CF**	**Vulnerabilities**	**CF**
Flexible usage	5	High dependencies among certain user groups	4
Individual control	5	Energy inefficient	5
		High environmental costs	5
Auto industry is key sector	4	Reduced demand comes with high economic cost	4
		Wasteful of key resources such as steel, coal and oil	5
		Few viable alternative fuel sources	3
		Few alternatives particularly in rural areas	3
Opportunities		**Threats**	
Development of alternative fuel sources and vehicle types	2	Rising fuel prices will make it increasingly unaffordable for poorer users	4

Table 2.5-3: SWOT - Road Transport (freight)

Road Transport (Freight)			
Strengths	**CF**	**Vulnerabilities**	**CF**
Flexibility	5	Sensitive to fuel prices	4
Speed	4	High environmental costs	5
		Road conditions	3
Comprehensive national coverage	4	High fuel prices and reduced demand	4
		Increasing proportion of freight moving onto roads	4
Opportunities		**Threats**	
Implement greater efficiencies	3	Freight likely to move onto rail network as fuel prices rise	4
		Risk of bankruptcies	4

Table 2.5-4: SWOT - Road Transport (public transport)

Road Transport (Public transport)			
Strengths	**CF**	**Vulnerabilities**	**CF**
Energy efficient	4	Security for passengers	4
Flexible	4	Escalating costs	3
Accessible	4	Safety for passengers	3
Lower infrastructure costs	4	Lack of management to run an efficient service	3
		Reliability	4
Opportunities		**Threats**	
To extend and modernize	4	Slow bureaucracy	4
Adopt international best practice	4	Legacy culture of poor service delivery	4

Table 2.5-5: SWOT - Rail (passenger)

Rail (Passenger)			
Strengths	**CF**	**Vulnerabilities**	**CF**
Existing infrastructure	3	Current condition	4
National network	3	Poor urban networks	5
Existing systems	2	High costs of improving	4
A viable alternative to cars	2	Loss of skills within sector	4
		Lack of engineering and maintenance infrastructure	4
		Long lead times to upgrade	4
Opportunities		**Threats**	
Extend in all major urban areas	4	Slow bureaucracy	3
Make more secure	4	Increasing crime	4
Upgrade services	5	Poor management	4
Power the network with renewable energy	3	High costs of installing new infrastructure	5
Reduce CO_2 emissions	3	Only if renewables added to power sources	4

Table 2.5-6: SWOT - Rail (freight)

Rail (Freight)			
Strengths	**CF**	**Vulnerabilities**	**CF**
Existing network	3	Current condition	4
Spare capacity	4	Lack of management	3
Extensive coverage	3	Poor maintenance	4
Cost	4	Speed	4
Opportunities		**Threats**	
Improve	4	Escalating costs	4
Extend services	4	Poor management	4
		Diesel fuel price rise & possible shortages	4

Table 2.5-7: SWOT - Sea Transport

Sea transport			
Strengths	**CF**	**Vulnerabilities**	**CF**
Existing port infrastructure	4	Low capacity to handle passengers	4
		Requires infrastructure from coast	4
		Long lead times to improve capacity	4
		Slow	4
Opportunities		**Threats**	
		High costs	3
		Mindset change required	3
		Sea level rise	3

2.5.3 Conclusion on Strengths and Vulnerabilities of the SA Transport System

While there are strengths to our system, such as the comprehensive road network and the speed and flexibility that road transportation has over other modes, in the context of the global depletion of oil, the energy source upon which most of our national transportation depends, South Africa has high levels of vulnerability relating to the movement of both goods and people. The aviation sector is particularly vulnerable to rising fuel prices and has few viable fuel alternatives.

The road transport system is also vulnerable because it is the predominant mode and because of its extensive dependence on oil. This vulnerability is not evenly spread as people in rural areas have fewer alternatives to mini-bus taxis or buses. In urban areas, some people have reasonable access to trains, while others do not. The most effective and widely available form of transport is mini-bus taxis, which are dependent on liquid fuel for their running. Given that so much of our transport is dependent on road transportation, both passengers and freight, the system as a whole is that much more vulnerable.

Freight continues to be transported predominantly by road while the volumes of freight transported by rail remain stagnant.

The next section of this report examines what alternatives there are for the country as ways of managing and mitigating these vulnerabilities.

2.6 Conclusion

South Africa has an extensive road and rail network. Road transport predominates in respect of both passenger and freight movement. Within road passenger transport the movement is mainly through private vehicles rather than public transport.

The energy consumed to drive the private vehicles, in respect of freight and/or passengers, is entirely from liquid fuels, petrol and diesel, with the former comprising about 60% of the fuel consumed.

Geographically, the intensity of road transport and the consumption of liquid fuels is concentrated in the Durban-Gauteng corridor, which includes transportation within Gauteng and within the Greater Durban region. Freight comprises a significant segment of this transportation and fuel consumption in this corridor.

The limits to the availability of the required supply of petrol and diesel at a price that is healthy for economic growth, are appearing in the form of peak oil, which is an event after which there will be a fall in the supply of oil – and hence petroleum products – as well as steep rises in the prices of these commodities. The impact on the economy and transport systems is likely to take the form of uneven falls in the supply of liquid fuels, which are likely to be unsteady and even cliff-like in their rapidity. Prices are likely to spike. The South African Transport System has no more than 20 years within which to have implemented system change to effect the required shift from liquid-fuels based transport to a situation where the significant volume of both passenger and freight transportation is powered by other, non-petroleum based fuels.

The second report of this investigation will explore the alternative energy sources and fuels to liquid petroleum and diesel, as well as current and likely technologies for vehicular movement in the light of alternative energy sources.

The sustainability of road transport, overwhelmingly dependent on the availability of liquid fuels in sufficient quantities and at an affordable price, will be the part of the national transport system most threatened by the onset of peak oil, and the economic and social impact is likely to be immediately felt in the Durban-Gauteng corridor, with secondary effects through the economy, radiating out from this economic hub

There is scope for savings on the consumption of liquid fuels through decreasing the fuel usage per person by car sharing/pooling; currently it is illegal for car poolers to take payment, meaning that there would be no material incentives for car commuters to alter their behaviour, until forced to do so. The second report in this investigation will also explore other options aimed at enhancing the efficiency of liquid fuel consumption, such as more effective traffic management (e.g. reducing speed).

Given the vulnerability to peak oil of road based, liquid-fuel-driven motor car transportation in South Africa, there needs to be a switching from oil-based fuels to alternative fuels, the full range of which will be identified in the second report of this investigation, as well as alternative types of vehicles and propulsion systems to the petrol/diesel driven vehicles and their internal combustion engines. Whatever the form of alternative energy for transportation in the future, judging by the very limited usage of electricity to power the transportation system, it appears that in the future electrically powered vehicles, including electrified rail, could play a significant substitution role. Given its concentration of transport intensity and fuel consumption, the Durban-Gauteng corridor seems to present an obvious place to begin upgrading and improving existing rail networks in order to provide a more energy efficient alternative means of transporting both people and freight.

Accordingly, the second report of this investigation will also explore the potential for using alternative modes of transportation – like rail – as well as promoting public transport and also non-motorised transport – more than half of the South African population transport themselves on a daily basis through non-motorised forms, i.e. walking and cycling, and are least at risk to the direct transportation implications of peak oil.

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3. Reducing Oil Dependency and Alternatives to Oil-based Liquid Fuel Transport

A report submitted to the National Department of Transport by

The Association for the Study of Peak Oil (SA)

in association with

Marianne Vanderschuren

and

Tanya Lane

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Executive Summary

Alternative Energy Sources

- There are a range of alternative energy sources that could be developed so as to limit the oil import dependency of the South African transport system.

- However, it is not simply a question of switching from oil-based energy to alternative energy sources, because each source of energy has its own strengths and weaknesses from a transport utility perspective, and while each offers unique opportunities for a changed transport system there are inherent risks which could pose threats to the system if not properly managed.

- It is likely that as the price of oil rises after the global oil production peak, the prices of most – if not all – energy substitutes will also rise, thus underscoring the need for energy efficiency as well as diversification of energy supply.

- **Coal-to-Liquids** (CTL) energy is a proven technology, pioneered and owned by Sasol, but as it is reliant on coal it emits high levels of CO2; although there appear to be large quantities of coal available there are the threats of costly infrastructure as well as carbon taxes.

- **Gas-to-Liquids** (GTL) energy is also a proven technology with lower CO2 emissions than coal-to-liquids, but due to depleting domestic feedstock is reliant on imported gas and hence new delivery infrastructure; there are indications of large supplies from Southern Africa but intense international demand for this depleting resource is pushing up prices.

- **Liquid Petroleum Gas** (LPG) is cleaner than petroleum and can be used by vehicles but there is a lack of domestic production and delivery capacity; although there could be a new LPG refinery at Coega the price of LPG has risen considerably in line with global gas/oil price increases.

- **Biofuels** are a renewable energy source that can be used in vehicles and have relatively low CO2 emissions, but a bio-fuel strategy poses a potential (and real) threat to food and water security; small scale diesel is appropriate for farm usage, but as oil is an input into the production of farm crops rising oil prices have had a knock-on effect on biodiesel prices.

- **Electricity** is relatively efficient and already supports rail and pipeline transport, and can be sourced from renewable sources, but there are serious electricity supply constraints until 2013 at least; there are opportunities for electrifying the entire rail network, extending renewable sources and manufacturing electrical vehicles, but at the same time there is the ever present risk of shortage and rising costs. There may be benefits in adopting a distributed systems of electrical production, allowing individuals to produce their own electricity that can be implimented in relatively short time-frames. For example this could be implemented through the installation of solar voltaic panels on the roofs of houses in the country: targets would have to be set over a relatively short time frame, say five years to cover a substantial number, if not the majority, of residential (formal and informal) units.

- **Hydrogen** is a clean burning fuel but a very inefficient carrier of energy, and would require new massive infrastructure with a long lead time; there are opportunities to utilise hydrogen as a carrier of electricity from renewable sources but this could be done at the risk of wasting resources that might be more efficiently applied elsewhere.

Alternative Propulsion Systems and Fuels

- The most suitable propulsion system – or set of systems – for the South African transport system depends on a range of internal and external factors like vehicle purchasing and operating costs, utility of the vehicle, availability and price of corresponding fuel, and the refuelling infrastructure.

- Individual behaviour with regard to transport is seen to be affected more by the maximum travel time per day than by the costs of transportation – this suggests that the adoption of alternative systems and fuels might be very difficult to incentivise.

- Fuels like biodiesel (made from vegetable oils), diesahol (mineral diesel blended with methanol or ethanol), compressed natural gas (CNG), liquefied natural gas (LNG) and hydrogen should reduce heavy vehicle emissions but not necessarily overall energy consumption.

- The application of the preceding fuels to rail would involve substantial modifications to engine and locomotive systems.

- Technically, maglev and tubular freight systems could be the most efficient locomotive systems, but their feasibility and affordability for South Africa requires further research.

Reducing Oil Dependence of the Transport System

- Vehicles can be redesigned to effect energy intensity reductions – this will happen depending on the priorities of manufacturers responding to the vehicle market, including any regulations that are introduced to govern vehicle design.

- Changes in vehicle technology are likely to require large investments and to be rolled out only after a long lead period, dependent on the normal product cycle of vehicle manufacturers.

- In the immediate future the oil dependency of the transportation system could be reduced through:
    - Reduced speed limits
    - Restricted hours for fuel sales
    - Rationing

- Car pooling
- Vehicle sharing
- Measures prompting the purchase of smaller, lighter vehicles

Traffic Management

- Intelligent Traffic Systems represent a cost effective way to improve traffic flows, which in turn reduces energy consumption.

- Two systems have been identified as having the largest impact, namely: (1) optimising traffic controllers, which require investment in human capacity in the municipalities; and (2) variable speed limits, which can be implemented through government investment in highway systems based on Variable Message Signs.

- In freight transport, ITS measures usually lead to improved scheduling and management, which results in energy savings.

Alternative Modes Use

- In principle it is advisable to move passenger and freight transport from less efficient to more efficient modes, but this is not always viable.

- Infrastructure plays a critical role regarding mode shift potentials for person travel and freight movement, and government's role in investing in the infrastructure in terms of a transportation policy is crucial to enable alternative modes.

- It is more cost effective to make better use of existing modes and infrastructure by building on the most energy efficient elements of the present system.

- Investment in new infrastructure and systems will take time and will need to be based on thorough investigation.

Land Use Measures

- Historically South Africa's urban policies of spatial dispersion – and segregation – were made possible by the availability of cheap oil.

- In the present age of expensive oil, urban conurbations need to be compact and integrated with work places, living places and public facilities, all within relatively short distances of each other.

- To increase densities a different land usage, policy will have to be adopted and implemented by the authorities – if not people will adjust their movements to take account of new circumstances, but as this will happen in an unplanned fashion there could be many unintended and negative consequences to land and housing markets.

- Transportation will need to become systematised around the economics of space and the reality of compact living that will be forced on people in their daily lives – it is not clear that the state has the will or the capacity to effect this significant change to its planning policies and practices, which to date have generally allowed residential and commercial property markets as well as the private car industry to dictate a sprawling urbanisation. This has led to significant market distortions in housing with a high value functioning market on the hand, but for the majority dysfunctional housing markets with inadequate accommodation.

Conclusions

- From an analysis of the strengths and weaknesses, opportunities and threats of various energy sources and propulsion systems, it appears that the greatest impact in the short-term would be to develop electricity from renewable resources to power the rail network.

- However, given competing demands for new electricity, the most effective strategy might rather be to focus on efficiency and conservation of oil-based and electrical energy within the existing transportation system.

- Significant efficiencies and energy conservation could be achieved throughprivate passenger transport to mass public transport (road and rail), as well as from road to rail freight on major corridors.

- In the very short-term the authorities need to implement a range of measures that are tried and tested, to reduce fuel consumption through motor transport – in the medium term this would happen also through improved vehicle design.

- A comprehensive strategy to upgrade the rail system, as well as implementing local public transportation stratgeies (i.e. road closures to private motor transport linked to promotion of non-motorised transport, public buses and shuttles) are preconditions for making the critical transport mode shifts that need to be effected from private passenger to public transport and also from road freight to rail freight.

- Local transportation systems will have to align with local economic processes, which means that urban spaces will have to be shaped in ways that are appropriate to the needs of the citizenry and also sustioanbale over the long run. In the medium term land use and spatial planning will have to change to mould local transportation systems to a compact, minimum origination-destination social movement pattern – if this does not happen formally it will happen informally but with greater social and technical costs.

3.1. Introduction

This report is the second of four reports for the National Department of Transport on the implications of peak oil for the National Transportation Master Plan (NATMAP).

Section 2 of this assignment examined the status quo with regard to transport and its energy usage in South Africa. It was made clear that in the context of the peaking and decline of global oil production, the South African transport system is very vulnerable because of its high level of dependency on petroleum-based liquid fuels as an energy source, and the fact that about 70 % of current liquid fuel consumption is met by imported oil. It was also noted that the peaking of global oil production will affect the world and South Africa in numerous ways and that we can expect to face challenging times ahead.

This report looks at tackling some of these challenges head on, particularly as they affect the transport sector. It will begin to answer the question of how South Africa can transition out of this high level of oil dependence and sets out some of the measures our society can begin to adopt. In this sense it goes further than the current DME strategy which focuses on reducing South Africa's dependence on imported crude and refined oil by diversifying sources of imports and further investing in local refining capacity.

According to the DME's (2007: 8) *Energy Security Master Plan – Liquid Fuels*, "[i]ndications are that oil will run out sooner rather than later and a transport strategy that is over 90% dependent on oil is guaranteed to land South Africa in serious trouble in a few years time."

The *Master Plan* recommends that the national petroleum company, PetroSA, procure 30% of all crude oil imports in order to reduce the risks associated with reliance on private oil companies, which currently source more than 80% of South Africa's imported crude oil from the Middle East. The government and PetroSA, the state oil company, have recently concluded negotiations with Venezuelan President Hugo Chavez over access to Venezuelan crude oil

(Business Report, 2008). However, given the global scarcity of oil that will occur after the production peak, the price of oil is likely to rise dramatically no matter where it is imported from.

The *Master Plan* further recommends that at least 30% of refined petroleum fuels continue to be manufactured from domestic raw materials, as is presently the case. Allied to this is a strategy to increase South Africa's oil refining capacity so that there is less reliance on costly imported refined fuels. As mentioned in section 2.2, PetroSA is planning the construction of a new refinery at Coega, dubbed Project Mthombo. This refinery is variously reported as having an intended capacity of 250,000 bpd or 400,000 bpd, possibly rising to as much as 650,000 bpd over time (see Pringle, 2008).

In the context of global oil depletion and the likely imminent decline in world oil exports, the long-term viability of building a new refinery will depend on whether South Africa can secure sufficient crude oil imports at an affordable price. It seems likely that long-term supply contracts will increasingly be based on geopolitical alliances and agreements rather than – or in addition to – market operations. The recent negotiations between the governments of South Africa and Venezuela are a case in point.

3.1.1. Subject of this Report

The subject of this report is reducing oil dependency and alternatives to oil-based liquid fuel transport.

3.1.2. Background to Investigation

The investigation, of which this report forms a part, arose from a proposal that was submitted to the National Department of Transport at the invitation of the Deputy-Director General, Mr Situma, who is managing the process of developing the NATMAP. The intention behind this study is to complement the work which has already been commissioned by the Department to develop the NATMAP. To this end ASPO SA assembled a team of people whose combined expertise covers the critical issues that need to be examined so that the NATMAP will consider the impact of global oil depletion on both the South African transport system and space economy.

The objectives of this investigation are, therefore, that:

- It should produce a stand alone strategic set of documents
- These documents should be used as reference works by the consultants employed to develop the NATMAP
- These documents should be used as reference works by the National Department of Transport
- Pending Departmental decision these documents should be made available as public discussion documents
- These documents will contribute to drawing out the strategic implications of oil depletion for the transportation sector and its development over the coming decades until 2030
- These documents will contribute to setting out a number of routes to a likely end state within the time frame of the NATMAP
- These documents will contribute to explicating the implications of these routes in terms of energy alternatives, energy savings and likely investment

3.1.3. Objectives of Strategic Documents

The key objectives of these strategic documents, of which this specific report is the second, are:

- To highlight the key strategic implications for the transportation sector of global oil depletion
- To identify key principles which should be factored into transportation planning with a long-term time horizon in the light of the depletion of key energy and other resources
- To identify a number of plausible scenarios which arise as a consequence of global oil depletion
- To assess the risks associated with these scenarios to transport planning in the light of the inevitability of oil depletion during the time frame of the NATMAP
- To identify high-level alternative strategies to the current business-as-usual and demand-led approach for different modes of transport in the light of oil depletion

3.1.4. Limitations and Scope of Investigation

The scope of the investigation has been limited to an agreed table of contents for all four documents, between the Department of Transport, the main contractor and the ASPO (SA) consulting team.

3.1.5. Plan of Development

There are several distinct approaches to intervening to address the problem of oil dependency and to identify alternatives to oil-based liquid fuel transport. These approached are explored in the following sections of this report.

The first approach is a supply side initiative to develop alternative sources of energy in conjunction with alternative transportation technologies; these are described in Section 3.1 (which addresses alternative energy sources for the transport sector) and Section 3.2 (which addresses propulsion systems and fuels in the light of alternative energy sources). Section 3.1 covers liquefied natural gas, coal-to-liquid plants, gas-to-liquids, bio-fuels, electricity (fossil-fuel and renewable-source based) and hydrogen. Section 3.2 covers modification of vehicles to run on liquefied petroleum gas, hybrid electric vehicles, electric vehicles and hydrogen cars, as well as magnetic levitation rail and tubular freight systems.

The second approach is a demand driven approach to reduce demand from the bottom up (as explicated in Section 3.3). Section 3.3, which addresses reducing oil dependence of the transport system, covers improving vehicle design, vehicle maintenance and influencing vehicle use and driver behaviour.

The third approach is a top-down management approach to curb demand and to provide the necessary infrastructure that will reduce inefficiencies in the system (Section 3.4). Section 3.4, which addresses traffic management, covers improving road efficiency, reducing speed limits and introducing intelligent transport systems.

A fourth type of measure can be described as a regulatory instrument that authorities can use to discourage excessive travel and to encourage efficiency improvements (Section 3.5). Section 3.5, which covers alternative transport modes usage, addresses public transport promotion, non-motorised transport promotion and mode shifts in freight.

The fifth approach is to alter land use and spatial planning with a view to reducing the need for passenger and freight transport (Section 3.6). Section 3.6, which addresses land use measures, covers the relationship between living and working spaces, and between local economic development and food security. Section 3.6 also identifies spatial planning as the critical context within which transport planning happens.

3.2. Alternative Energy Sources

This section considers the prospects for developing and extending domestic substitutes for imported oil. This descriptive overview of alternative energy sources for transportation will provide the basis for quantitative scenario modelling in Section 4.

3.2.1. Coal-to-liquids

As noted in Section 2.2, Sasol currently supplies in the region of 23% of the country's liquid fuel demand from its coal-to-liquid (CTL) synthetic fuels (synfuels) plant at Secunda. Sasol has already announced plans to expand the Secunda plant by 20% or 30,000 barrels per day (bpd) by 2015. Three quarters of the feedstock will be additional natural gas imported from Mozambique, and the other 25% of feedstock will comprise stockpiled super-fine coal (Mining Weekly, 2007).

Possibly in collaboration with the government and/or PetroSA, Sasol is also conducting a prefeasibility study for a proposed new CTL plant in Limpopo Province. Dubbed Project Mafutha, the plant's capacity has been mooted as 80,000 barrels of liquid fuels per day – slightly more than half of Sasol's current volumes. Sasol has indicated that it would not be the sole investor in such a large scale project, which is estimated to cost in the region of R50 billion. The company is holding investment talks with the Industrial Development Corporation as well as with the departments of Trade & Industry and Minerals & Energy. According to Sasol, Project Mafutha would likely take up to 10 years to complete.

Clearly such a project will proceed only if sufficient coal (or natural gas) feedstock can be secured. This cannot be taken for granted, given the unfolding global energy crunch and Eskom's recent warning that South Africa might face a deficit of coal production of 100 million tonnes (mt) a year by 2017 – compared to total SA consumption last year of about 180 mt (Eskom, 2008). Another risk is continued cost escalation for new plant construction in the energy sector.

If both Project Mafutha and the Secunda extension materialise, Sasol's synfuels would meet about 40% of the country's current liquid fuels consumption (i.e. assuming there was no growth in total consumption). However, this expansion of domestic synfuel capacity would come with a high environmental cost in the form of additional greenhouse gas (GHG) emissions, thereby contributing to global warming. In view of the recent announcements by Marthinus van Schalkwyk, the Minister of Environmental Affairs and Toursim, about the government's climate mitigation plans, Sasol might have to install carbon capture and storage (CCS) technology at any new CTL plant, which would raise its costs considerably. Costs of CTL fuels will also rise if a carbon tax or a carbon trading system is implemented.

3.2.2. Gas-to-liquids

As discussed in Section 2.2, PetroSA produces liquid fuels using natural gas and crude oil as feedstock at its gas-to-liquids (GTL) refinery at Mossel Bay. Current production volumes amount to no more than 45,000 barrels per day, or 7% of South Africa's liquid fuel consumption (DME, 2007).

The existing oil and gas fields in the Bredasdorp basin are rapidly depleting and are expected to cease delivering by 2012 or soon thereafter. The company is thus under considerable pressure to find additional feedstock to maintain its existing capacity. PetroSA is continuing exploration in the region but thus far has not announced the discovery of any substantial new oil or gas fields. Even if new gas and oil fields are discovered off South Africa's western or southern coasts, they would take at least 5 years or so to deliver fuels to the market.

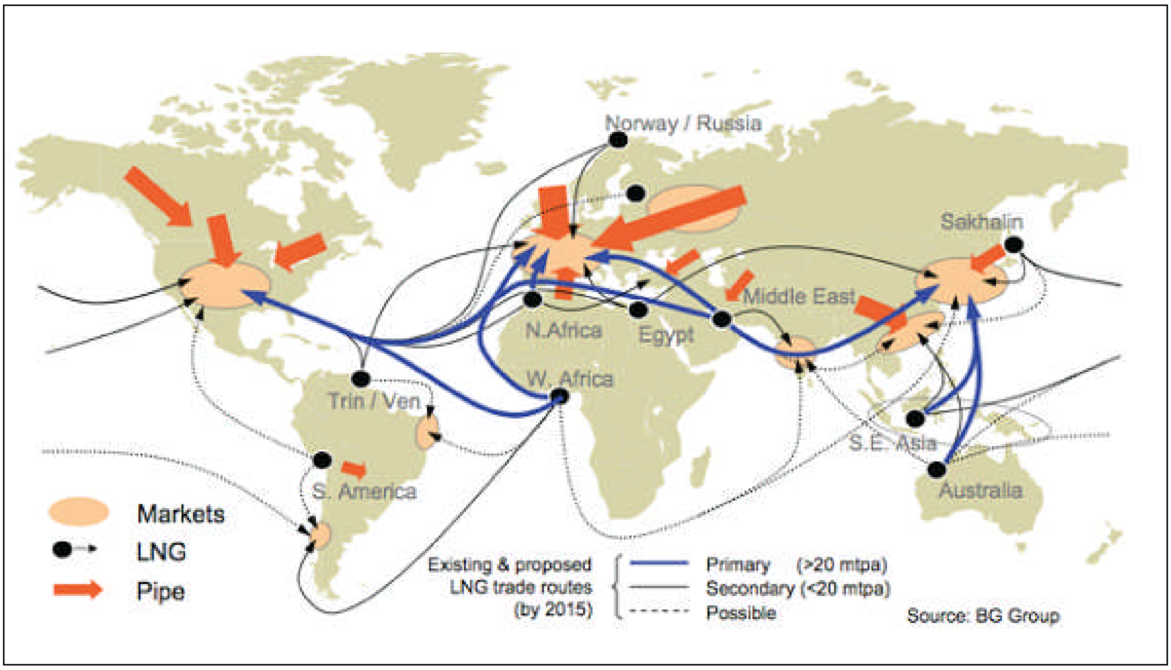
PetroSA has also considered the possibility of **importing gas** from Namibia's Kudu gas field, located offshore just north of the border with South Africa, or from Mozambique. However, in either case gas imports would require the construction of costly additional pipelines (to Mossel Bay in the case of the Kudu gas field).

Another possibility being explored by the DME and PetroSA is imports of **liquefied natural gas** (LNG). LNG has to be transported in special tanker ships and then re-gasified before it can be used onshore, which requires expensive infrastructure. According to the Central Energy Fund

(CEF, 2008), a feasibility study has been conducted for an LNG terminal at Coega. A recent press report suggests that PetroSA and Eskom are considering a joint venture which would provide feedstock to the Mossel Bay GTL refinery as well as to a new gas-fired power station at Coega (Business Report, 2008). PetroSA has apparently issued tenders for the hire of two floating storage and re-gasification vessels to be based at the Coega port.

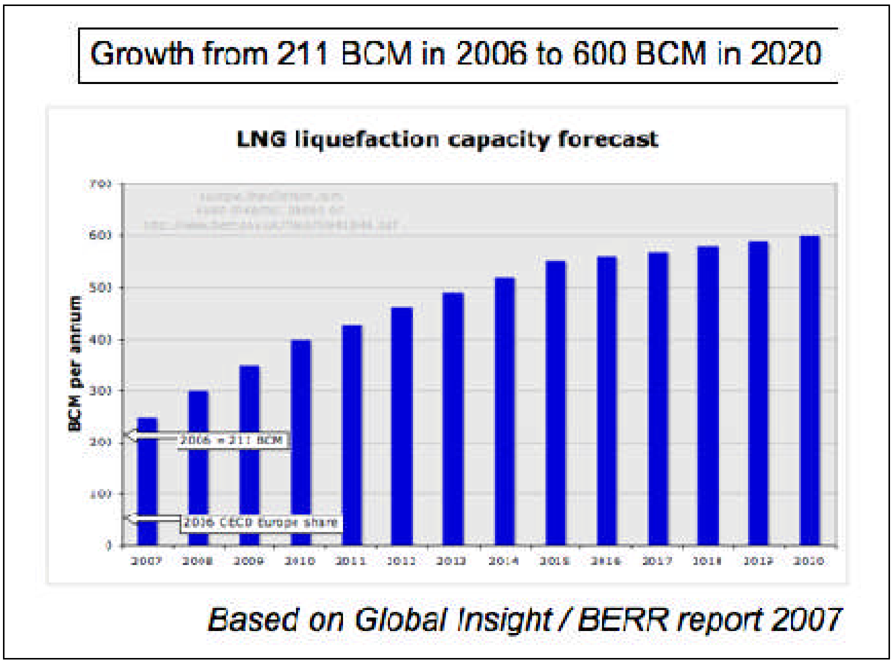
However, global LNG supplies are already under considerable pressure, and are likely to become even more so as the depletion of natural gas reserves continues apace in regions such as North America and Europe. The major existing markets for LNG are Japan, South Korea and Europe, while new markets are developing in the USA, China and India. Europe relies on natural gas (piped and LNG) for 29% of its fossil energy (The Oil Drum, 2008). Thus South Africa will most likely face increasingly stiff competition and much higher prices for LNG in the future; SA is a very small fish in the global gas ocean.

Figure 3.2-1: Current and Proposed Global Natural Gas Markets



Source: The Oil Drum (2008)

Figure 3.2-2: Global LNG Supply Forecast



Source: The Oil Drum (2008)

There is a possibility of **coal bed methane** (CBM) gas being produced in the future. At present there are projects under way in neighbouring Botswana and talk of CBM developments in South Africa (Mining Weekly, 2008). As is the case with all fossil energy projects, there are substantial lead times as well as environmental factors (such as GHG emissions) to consider. At this stage CBM is still in the R&D phase in South Africa.

A final possible source of feedstock for GTL could come from a process called **underground coal gasification** (UCG). Eskom and Sasol are both currently working to develop this alternative technology for extracting the energy from coal. UCG is a process whereby coal is ignited *in situ* underground, fed through a borehole by air or oxygen and yielding a synthetic gas (syngas). The syngas can be used for electricity generation, for the production of synthetic liquid fuels or for industrial uses (e.g. the manufacture of petrochemicals). In addition to this flexibility, several other advantages are claimed for UCG. First, otherwise uneconomical resources can be utilised; Eskom estimates that an additional 45 billion tons of coal could be exploited through

UCG (over and above existing proved reserves). Second, there is no need for traditional mining and associated health and safety risks for miners. Third, indications from a pilot UCG project in Australia indicate that the process has a much lower environmental impact (in terms of groundwater contamination, land degradation and subsidence, and greenhouse gas emissions) when compared to conventional coal mining.

Eskom already has a small pilot UCG plant in operation at its Majuba power station in Mpumalanga, generating 100 kilowatts of electricity. So far, Eskom is optimistic that the costs will compare favourably with those of conventional coal mining and power generation. One must pose the question, however, as to why UCG has not previously been commercialised in South Africa (and other countries, such as the United States), given that the technique has been used since the 1950s in the former Soviet Union. Also, although UCG might produce a smaller volume of GHGs per unit of energy than conventional coal, there are still considerable emissions to deal with.

3.2.3. Liquefied Petroleum Gas

Liquefied petroleum gas (LPG) is one of the by-products of crude oil refining and is also produced synthetically by Sasol and PetroSA from gas and coal, respectively. It can be used as a fuel for conventional petrol motor vehicles after minor modifications have been made (mainly involving the installation of a new tank to store the LPG). As a vehicle fuel it has several advantages over petrol: (1) it is cleaner burning (i.e. it generates less particulate emissions and CO_2); (2) engines running on LPG require less maintenance and last longer.

The DME (2007: 21) states that: “Traditionally LPG in South Africa has, due to high prices and hence limited demand, been supplied only from local refineries. The resulting limited importing capability, coupled with limited LPG storage capacity at refinery level, has left South Africa exposed to significant stock shortages in the event of future demand growth.”

The DME intends to promote wider use of LPG, especially as a household energy source for cooking (RSA, 2007). The DME announced earlier this year that it is investigating regulating the retail price of LPG in order to make it more affordable to consumers.

If the new Coega refinery goes ahead and sufficient crude oil feedstock is secured, and/or the proposed LNG terminal at Coega is built and secures feedstock, the local LPG supply could increase somewhat. Again, however, affordability will be a key factor in addition to feedstock supply issues.

3.2.4. Biofuels[1]

In late 2006 the Department of Minerals and Energy released its *Draft Biofuels Industrial Strategy* for public comment. The Draft Strategy recommended a target of 4.5% of liquid fuels to come from biofuels by 2013, using maize and soya beans as primary feedstocks. However, in the latter part of 2007 the debate heated up as concerns emerged about potential competition between food and fuel and the impact of biofuels on food prices. Subsequently, the Cabinet approved an amended *Biofuels Industrial Strategy* in December 2007, which excludes maize as a feedstock for ethanol, relying instead on sugar cane and sugar beet. The Strategy also proposes that biodiesel be produced from soya beans, canola and sunflower. The target was adjusted downward to just 2% of liquid road fuels by 2013 in an initial five-year pilot phase.

In the future context of fossil fuel depletion and climate change, expanding biofuels production more aggressively would likely have serious negative consequences, especially in terms of food security, but also with regard to water usage and environmental sustainability. The food security concern applies to feedstocks that are food products (e.g. sugar, wheat and soya), as well as to non-food feedstock that is grown on land which could otherwise support food production.

Warnings about the impact of biofuels on food prices and affordability for the poor in low-income countries have been coming thick and fast of late. The International Monetary Fund's Chief Economist, Simon Johnson, says "the world has experienced a substantial inflationary shock in the form of food prices" in the past year and advocates the scrapping of ethanol subsidies in rich countries. The Economist newspaper declared in December 2007 that the world has come to "The end of cheap food", blaming this on rising Asian incomes and subsidies for ethanol in the

[1] Parts of this section are drawn from Wakeford (2008).

United States, where nearly 30 per cent of corn output is being converted into fuel. Lester Brown, President of the Washington-based Earth Policy Institute, has stated that "The competition for grain between the world's 800 million motorists who want to maintain their mobility and its two billion poorest people who are simply trying to stay alive is emerging as an epic issue." Even more emotively, the United Nations Special Rapporteur on the Right to Food recently stated that using arable land for biofuels was "a crime against humanity."

In South Africa cautionary statements about the connection between biofuels and food price inflation have emanated from the National Treasury, the Reserve Bank Governor and the Department of Trade and Industry. This sentiment no doubt contributed to the government's change of stance on maize-ethanol.

Concerns over food security have stimulated interest in non-food crops for biofuels. There has been much excitement in some quarters over the Jatropha plant, which yields oil-bearing fruit that can be turned into biodiesel. Some enthusiasts say that Jatropha can be grown on marginal lands in dry conditions, but others caution that to have yields sufficient for commercial purposes, Jatropha plantations may require irrigation and fertilisers. While Jatropha is presently being cultivated in Swaziland and Zambia, thus far the South African Department of Agriculture has placed a moratorium on the plant while it considers environmental concerns such as water usage and possible invasiveness.

Another future possibility is cellulosic ethanol, which would – if or when the technology becomes commercial – be able to use agricultural 'waste' such as corn stalks and wood chips or other biomass (e.g. switchgrass) as feedstock. The problem with cellulosic ethanol is that there is no ecological 'free lunch': for arable land to remain fertile, a significant proportion of the nutrients contained in the 'waste' must be returned to the soil – the more so when synthetic fertilisers become relatively scarcer and more costly. In any event, it may take a decade or more before so-called second generation biofuels such as cellulosic ethanol are successfully commercialised.

Is seems likely therefore that biofuels will not make a significant contribution to future liquid fuel security, at least in the medium term (10-15 years). The DME's (2007) *Liquid Fuels Master Plan* does not identify biofuels as one of its recommendations to enhance fuel security.

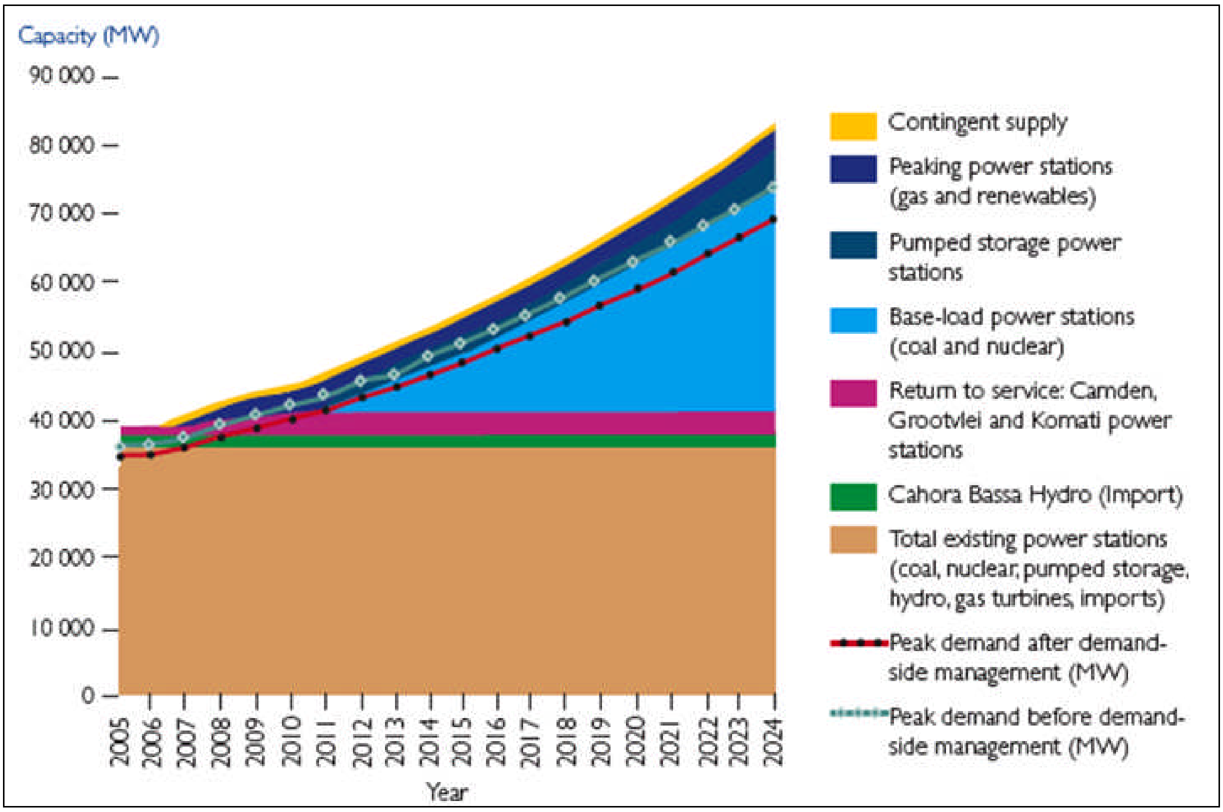
3.2.5. Electricity

As noted in Section 2.2, only about 1.6% of electricity generated in South Africa is currently consumed by the transport sector. Thus at first glance it might seem that there is considerable scope for switching to electricity-based forms of transport, such as electrified rail and electric (or plug-in hybrid) road vehicles.

However, the transport sector will need to compete with other demand sectors (e.g. industry and the residential sector) if it is to expand its share of electrical energy usage. Moreover, there is uncertainty as to whether electricity generation can expand to support extra demand from transport given existing capacity constraints. Demand for electricity is already out-growing Eskom's supply capacity and the utility has warned repeatedly that the country should expect shortages or constraints until at least 2013, when the new base-load coal-fired power station is due to be commissioned.

The Minister of Public Enterprises, Alec Erwin, recently said that South Africa needs to invest R1 trillion in energy infrastructure – approximately half of our annual Gross Domestic Product – in order to avoid future energy scarcity (Business Day, 2008). Eskom has stated its desire to double the country's electricity generation capacity to 80 gigawatts by 2025. Half of the additional 40 gigawatts (GW) is planned to come from new nuclear power plants. Construction has begun on two new coal-fired power stations which, together will three de-mothballed plants, will contribute about another 10 GW of capacity. Eskom (2007) sees renewable energy contributing just 2% of total electricity capacity in 2025. There is also a possibility of South Africa importing more electricity through the Southern African Power Pool if the Inga Dam hydroelectric power station can be expanded sufficiently over time. However, the political situation in the Democratic Republic of the Congo has thus far been a serious obstacle to progress on that score.

Figure 3.2-3: Eskom's projected Expansion of Electricity Generation



Source: Eskom (2007)

However, the future of electricity generation and consumption depends on many factors such as the rate and composition of economic growth, improvements in energy efficiency, the government's climate change strategy, and not least of all the impact of the global oil peak (including its effect on the viability of new infrastructure developments and the prices and availability of primary energy sources).

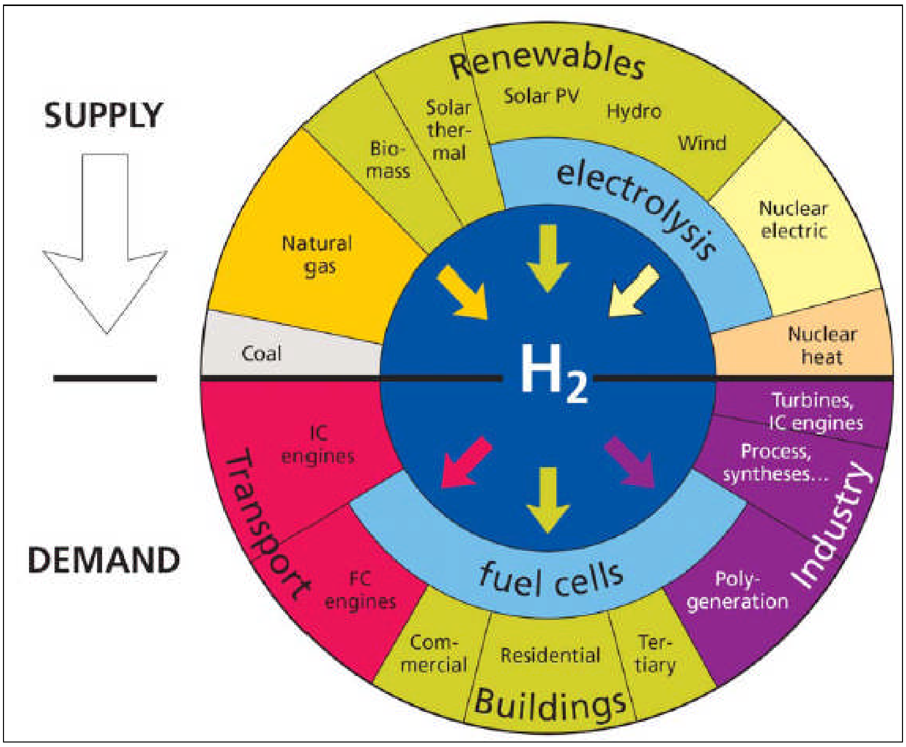
The long lead times required to add new electrical capacity could be reduced if South Africa were to shift from centralised electricity prodcution to a distributed system, enabling individuals to produce their own electricity.

3.2.6. Hydrogen

The National Department of Science and Technology (DST) has identified hydrogen as a strategic focus area and has allocated millions of rands to universities to conduct research into hydrogen energy and fuel cell technology.

Hydrogen is the most abundant element in the universe and it can be burned as a fuel or used in fuel cells to generate electricity. However, hydrogen is not available freely in the physical environment, but has to be split from carbon atoms (bonded in hydrocarbons like natural gas or coal) or oxygen atoms (through electrolysis of water). Hydrogen, like electricity, therefore, is an energy carrier rather than an energy source. Both methods of producing hydrogen require energy inputs and are less than 100 per cent efficient; i.e. more energy is needed as an input than is contained in the resulting hydrogen. On the other hand, an advantage of hydrogen as an energy carrier is that many different primary sources can be used to make it, including hydrocarbons, nuclear and renewable energy (see Figure 3.2-4below).

Figure 3.2-4: Hydrogen Fuel Supply and Demand



Source: DST (2007)

On the demand or consumption side, hydrogen is also very flexible. It can be burned in internal combustion engines, although this requires specially designed and currently expensive fuel tanks. Hydrogen can also be used to power fuel cells, in which hydrogen combines with oxygen to produce an electric current.

If hydrogen were to be used as a transport fuel, it would require a new storage and distribution infrastructure and a new fleet of vehicles, all of which – even if technically feasible – would require massive amounts of capital investment and probably decades to roll out. One of the technical obstacles that would have to be overcome is that leaks of hydrogen gas are very difficult to stem entirely, since the molecules are so small. Since the gas is highly flammable, the storage and distribution issue poses significant safety risks.

Even if these obstacles were overcome, hydrogen as a vehicle fuel may not make sense from an efficiency point of view. The direct efficiency of a hydrogen fuel cell is more than twice that of a conventional internal combustion engine, but overall some 75% of the energy is lost in the process of manufacture, distribution and final use of the hydrogen in the fuel cell so that it is actually less energy efficient than a petrol-electric hybrid car (Strahan, 2007: 87).

Most hydrogen produced in the world today is made from natural gas and other fossil fuels; only 4% is made via electrolysis (Strahan, 2007). This is because electrolysis requires a much higher energy input – 35% of the energy content of the hydrogen product. It would be more efficient to use electricity directly in electric vehicles, especially given the costs involved in building a hydrogen distribution infrastructure.

Moreover, if hydrogen were to be made via electrolysis, then the same electricity supply constraints as discussed in the previous section would come into play. Strahan (2007: 96) calculates the amounts of fossil fuels or renewable electricity that would be required to convert the UK and US vehicle fleets to run on hydrogen, and concludes that “hydrogen as a transport fuel seems to be utterly incapable of mitigating either global warming or the last oil shock.”

3.2.7. Conclusions on Alternative Energy Sources

Table 3.2-1: SWOT for CTL to Table 3.2-6 summarise the discussion by listing each energy source's strengths, weaknesses, opportunities and threats.

Table 3.2-1: SWOT for CTL

CTL	
Strengths	**Weaknesses**
Proven technology owned by Sasol Produces jet fuel as well as road fuels	High CO_2 emissions Reliance on depleting coal resources Competition for coal supplies from electricity demand & exports
Opportunities	**Threats**
Project Mafutha (Waterberg coal field)	Cost escalation for new infrastructure Climate change mitigation (carbon trading or tax) could raise costs substantially

Table 3.2-2: SWOT for GTL

GTL	
Strengths	**Weaknesses**
Proven technology by Sasol & PetroSA Lower emissions than from coal & crude oil	Depleting domestic feedstock Increasing reliance on imported gas requiring new delivery infrastructure
Opportunities	**Threats**
Sasol GTL using gas from Mozambique PetroSA LNG terminal at Coega Gas imports from Namibia's Kudu field	Increasing international competition for depleting global gas reserves High international demand and prices for LNG Cost escalation for new infrastructure

Table 3.2-3: SWOT for LPG

LPG	
Strengths	**Weaknesses**
Cleaner fuel Can be used by modified petrol engines Reduced maintenance & improved longevity of engines	Lack of domestic production capacity Lack of delivery infrastructure Reliance on imported feedstock
Opportunities	**Threats**
Possible new refinery & LNG terminal at Coega	Global gas/oil price rises

Table 3.2-4: SWOT for Biofuels

Biofuels	
Strengths	**Weaknesses**
Renewable energy source Can be used in existing vehicles with slight modifications Lower CO_2 emissions Production can be labour intensive Can be blended with current petroleum fuels	Potential threat to food & water security Partial reliance on fossil fuels as inputs Low net energy return for some feedstocks (e.g. maize)
Opportunities	**Threats**
Small-scale biodiesel, especially for farm use Small (2%) contribution to liquid fuels	Climate change threatening crop yields Rising input costs as oil/gas prices rise

Table 3.2-5: SWOT for Electricity

Electricity	
Strengths	**Weaknesses**
Relatively efficient Multiple primary sources of energy, including renewables Supports rail, pipeline and potentially road transport	Electricity supply constraints at least until 2013 New fleet of electric road vehicles required, taking time and money
Opportunities	**Threats**
Renewable electricity (solar, wind, ocean) Electrification of entire rail network Develop local EV manufacturing	Power outages and shortages Rising costs of rail infrastructure, locomotives & new EVs

Table 3.2-6: SWOT for Hydrogen

Hydrogen	
Strengths	**Weaknesses**
Multiple primary sources of energy, including renewables Clean-burning fuel (no GHG emissions) Indigenous platinum resources for fuel cells	Energy carrier (not source) with efficiency losses Massive new infrastructure required with technical difficulties still to be resolved Likely lead time of several decades Less efficient as a transport fuel than using electricity directly in vehicles
Opportunities	**Threats**
Fuel cell technology development Storage (carrier) for renewable (solar & wind) energy	Risk of wasting resources

3.3. Propulsion Systems and Fuels in the light of Alternative Energy Sources

Government can lead by investing in the required research and development programmes for the adoption of alternative propulsion systems and fuels. Incentives and legislation can also promote the adoption thereof. However, in formulating and targeting its investment strategy, government is dependent on the development of relevant research and development programmes, as well as on the uptake of these systems by consumers.

The focus of this section is on technologies that utilise alternative energy sources to petrol and diesel. However, it needs to be mentioned that fuel efficiency improvements of between 5% and 35% are possible due to current technology transmission optimisation (US Congress, 1991; Immers, *et al*, 1994). South Africa will continue to benefit from international developments in this regard, as its vehicle fleet is between three and five years older than the European and US fleet and it inherits vehicle designs from overseas. The average age of motorcars is 10 years, minibuses 13 years and buses and trucks are generally between 11 and 12 years old (www.grsproadsafety.org). In Section 4 this potential benefit will be incorporated in the Business-as-Usual case.

Apart from conventional combustion engines in road-based transport (mainly for person travel) a large variety of new propulsion systems are emerging, most being at an early concept stage. This is evident when the multitude of alternative fuels is considered alongside the different types of combustion engines. These alternative propulsion systems theoretically offer some potential energy efficiency benefit. The largest benefit (over 40%) is expected from the ceramic gas turbine, but research and development challenges still keeps this system from implementation on a large scale (Utopia consortium, 1998).

Given the expected challenges regarding the provision of traditional energy sources, this section focuses on propulsion systems based on alternative fuels.

3.3.1. Liquefied Petroleum Gas Vehicles

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. 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 shortages in South Africa, it is possible that 5% of petrol could be replaced by 2030.

3.3.2. Hybrid- electric Vehicles

Conventional and electric motor technology comes together in hybrid-electric vehicles. A hybrid's electric motor is energised 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 and Lexus Hybrids already available, hybrid-electric vehicles are expected to constitute a significant portion of new vehicle sales in the coming years, especially because the potential kilometre per unit of fuel output improves by more than 100% (see Table 3.3-1). Based on improved efficiency and expected market penetration, it is estimated that hybrid-electric vehicles will account for a 17% reduction in crude oil demand by 2030 (Vanderschuren, *et al*, 2008). Nevertheless the cost is comparatively high while new car sales growth is dropping. In the Department of Environmental Affairs and Tourism's Long-term Mitigation Scenarios (LTMS), hybrids are one of the most expensive mitigation options per emission/energy unit.

Hybrids attain their greatest efficiency advantage over conventional vehicles in slow stop-and-go traffic, so that very attractive applications might include urban taxicabs, transit buses, and service vehicles such as garbage trucks. Estimates of the fuel economy improvement in slow urban traffic of a hybrid medium truck over its conventional counterpart range from 55% to 124%; a (hybrid) heavy garbage truck could achieve gains as high as 140% (An, *et al*, 2000).

Table 3.3-1: Hybrid-electric Vehicles' Fuel Efficiency Improvements (km/l)

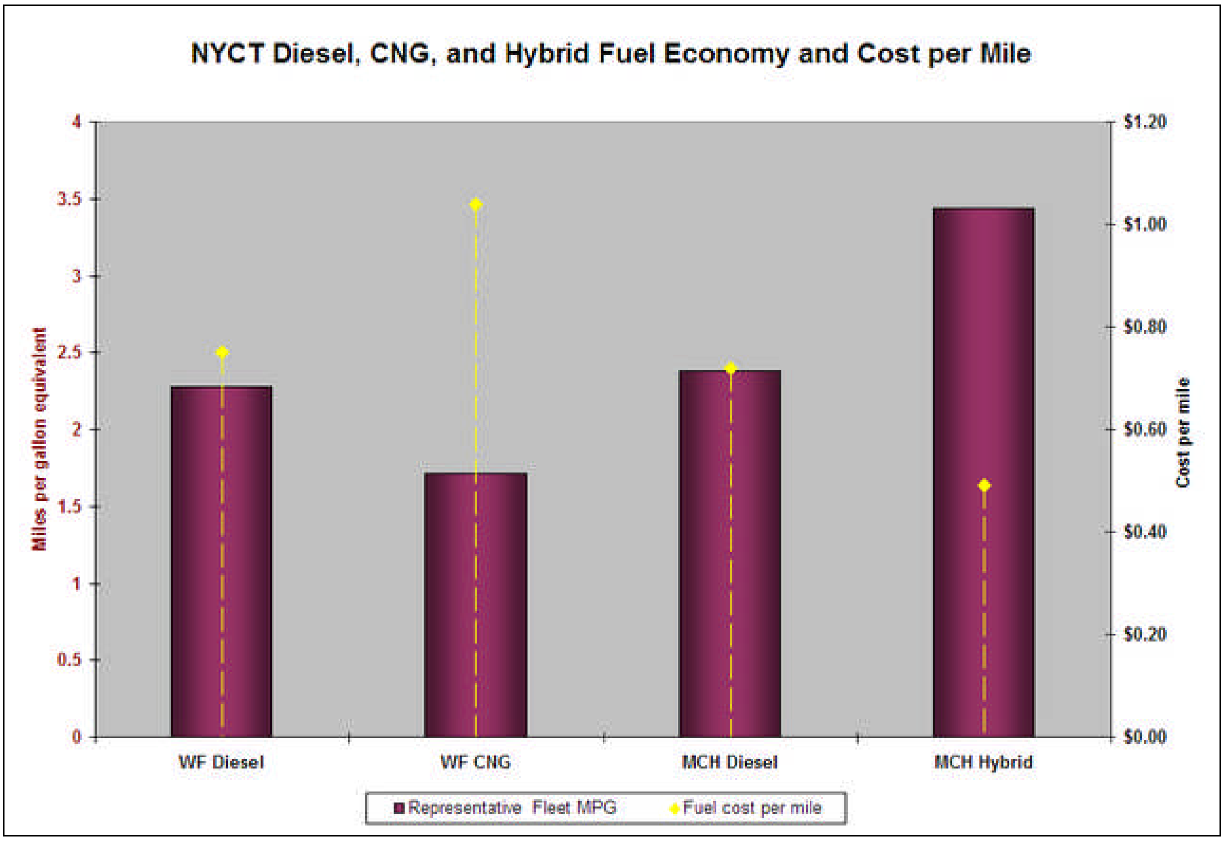
Switching to hybrid vehicles	City (Km/l)	Efficiency improvement (%)	Highway (Km/l)	Efficiency improvement (%)
COMPACT CARS				
Honda Civic Hybrid	***17.3***	63.21	***18.1***	34.07
Toyota Corolla	10.6		13.5	
MIDSIZE CARS				
Toyota Prius Hybrid	***21.2***	105.83	***18.1***	42.52
Nissan Sentra	10.3		12.7	
SPORT UTILITY VEHICLES 2WD				
Ford Escape Hybrid FWD	***12.7***	38.04	***11.0***	3.77
Jeep Compass 2WD	9.2		10.6	

Source: Adapted from EPA, 2007

Improved technology in public transport services can result in a substantial reduction in energy consumption. Orion VII series hybrid buses operated by New York City Transit (NYCT) on the city's most severe duty cycles achieved up to 45% better kilometre per unit of fuel output than diesel buses and 100% improvement compared to comparable natural gas buses on an energy-equivalent basis, according to the results of a study released by the National Renewable Energy Laboratory (NREL, 2008).

Recent improvements in hybrid technology provide even further improvements. Fisher Coachworks' lightweight hybrid bus achieves twice the fuel economy of current hybrid buses, according to the Oak Ridge National Laboratory (Science Daily, 2008). It is estimated that South Africa could have a fuel efficiency improvement as high as 75%, if second generation hybrid buses were sourced.

Figure 3.3-1: Fuel Efficiencies of the New York Bus Fleet



Source: NREL, 2006

3.3.3. Electric Vehicles

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 unless a high proportion of new electricity is generated from renewable energy sources. 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 systems of these vehicles.

Electric vehicles are not as convenient as conventional vehicles - they need to be recharged for 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. Given the current electricity crisis and potential energy inefficiencies, as mentioned in Section 3.2, it is not likely that electric vehicles will be adopted in South Africa in the short-term.

It is possible to estimate the electrical generation capacity required if South Africa's fleet of petrol cars were to be replaced with electric cars. If we assume that the average fuel efficiency of petrol vehicles is 10 kilometres per litre, then the 11.6 billion litres of petrol consumed in 2007 would translate into 116 billion kilometres driven. According to Idaho National Laboratory (2006), a modern electric car requires 0.2 to 0.3 kilowatt hours (kWh) of electricity per kilometre driven; in other words, electric cars are able to drive approximately 4 kilometres per kWh. Dividing the total kilometres driven by 4 means almost 29 billion kWh of power would be required per annum. This would require 3,300 megawatts (MW) of capacity, or 8.25% of Eskom's current capacity of approximately 40,000 MW. The cost of 29 billion kWh of electricity is roughly R6,5 billion, based on Eskom's (2008) average selling price of R0.23 per kWh. This is a small fraction of the R116 billion that would be spent on petrol annually at today's price of approximately R10 per litre. The capital cost of building 3,300 MW of electric power capacity is approximately R60 billion (about two thirds of what Eskom (2008) has budgeted for one of its new 4,800 MW coal-fired power stations). Replacing the diesel vehicle fleet with electric vehicles – even if technically feasible – would nearly double the amount of power needed (diesel consumption in 2007 was 9.8 billion litres, but much of it was consumed in trucks with lower fuel economy).

3.3.4. Hydrogen Vehicles

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 (see also Section 3.2), 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).

As with electric vehicles, if we assume that the average fuel efficiency of petrol vehicles is 10 kilometres per litre, then the 11.6 billion litres of petrol consumed in 2007 would translate into 116 billion kilometres driven. Dividing this by the fuel economy of a hydrogen-fuelled car (88 km/kg) gives 1.3 billion kilograms of hydrogen required. This implies a need for 85 million megawatt hours of electricity, since it requires 65 kilowatt hours (kWh) of electricity to produce a kilogram of hydrogen. This is equivalent to 9,750 megawatts (MW). Thus it would require almost 25% of Eskom's current power capacity of approximately 40,000 MW to produce enough hydrogen as a replacement for petrol vehicles. Note that this is three times as much power as would be needed to replace petrol cars with electric vehicles. Replacing diesel with hydrogen would roughly double the amount of electricity needed. Thus converting the entire (petrol and diesel) vehicle fleet to run on hydrogen would consume roughly half of the new power generation capacity that Eskom is planning to build over the next two decades.

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 regards 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.

When one considers that present day locomotives are electrically driven (via direct overhead wire, third rail, or diesel-generator set electrification), the fuel cell can potentially replace both diesel-electric and electric locomotives if the technology can progress to be physically feasible and economically viable (Stodolsky, *et al*, 2002).

In rail-based transport, the thermal efficiencies of fuel/cell reformer combinations and diesel engines are roughly equivalent, so a direct replacement of one for the other would have little effect on fuel efficiency, until an inexpensive, low-impact H_2 source is developed. The main driving force for fuel cells, of course, is emissions reductions, and their use might eventually produce some additional fuel efficiency if they can be used instead of energy consuming emission-control techniques with diesel engines (Stodolsky, *et al*, 2002).

Marine transportation may ultimately be favoured as the sector that first makes the switch to gaseous fuels such as hydrogen for various reasons (Lovins, *et al*, 2005). First, large non-passenger ships offer a relatively small cargo loss factor in ensuring storage of gaseous fuels. Second, due to rigorous training and licensing, ship operations and management may, at minimal exposure to the public, be particularly well suited to adopting alternative fuels more safely and at lower costs than other sectors. Third, a highly centralised refuelling infrastructure implies transition investments can be low per unit of energy delivered. Fourth, net improved environmental performance may be greater in the less regulated industries such as international and domestic shipping, and converting ships to hydrogen could reduce emissions of traditional pollutants significantly if that were to become a priority. Finally, because of the scale of each ship propulsion system, each ship uses tailored designs with generally similar power systems built one at a time, which makes the process of innovation more effective than for mass produced vehicles such as automobiles.

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).

In terms of energy demand, electric cars have an overwhelming advantage over hydrogen vehicles: there are no large 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).

The authors believe that electric vehicles have more advantages than hydrogen. Nonetheless, it is likely that either one of electric or hydrogen vehicles will be widely adopted, acting like mutually exclusive alternatives. Both require focused planning and infrastructure investments (EVs will need recharge points and possible additional electricity generation capacity that might or might not be ring-fenced for transport). Given the infrastructure requirements, it would not be cost effective to invest in both systems; also economies of scale will be greater if one vehicle type is introduced. Presently, there are too many unknown factors (such as future technological developments, consumer responses, automobile manufacturers' investment decisions, and government decisions on infrastructure spending) to accurately predict which alternative will be preferred by manufacturers and consumers. 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 (Vanderschuren, *et al*, 2008).

3.3.5. Compressed Air Technology

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 and 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.

3.3.6. Maglev Systems

Maglev (magnetic levitation) transportation systems are currently the fastest ground transportation systems in the world, reaching speeds of over 500km/h. Instead of using wheels, maglev systems use magnetic properties to levitate the train above a guideway and to propel it forward. These systems can be used to transport both passengers and freight, above and below ground (Lane, 2008).

Maglevs use narrow-beam, elevated guideways, leaving a much smaller footprint than highways, airports or railroad tracks on the landscape. The elevation of the guideways allows good flexibility to suit the track to various terrain types. Guideways can last up to 50 years or more with minimal maintenance, due to the absence of physical wear and tear and because loads are uniformly distributed, instead of being concentrated at the wheels. Commonly, the magnetic field inside a passenger compartment is less than that of a hairdryer, toaster or electric sewing machine. No negative influences on cardiac pacemakers or magnetic cards (such as credit cards) have been perceived (Lane, 2008).

A great advantage of maglev systems is that they do not directly rely on fossil fuels as a source of energy. These systems are powered by electricity. Maglev systems are very energy efficient – they consume approximately a tenth of the energy required by an average automobile per passenger-kilometre. In low pressure tunnels the average energy efficiency could potentially be increased to around 4000 km/l (Lane, 2008).

Even though the advantages of maglevs seem to outweigh the disadvantages, there are some obstacles to the wide-scale adoption of this technology. Investing in a maglev system can be quite expensive, although Transrapid (German maglev manufacturers who built the Shanghai maglev system) claims that the investment cost of a maglev system is similar to that of modern high-speed railroads. Maglev systems endure very little friction, resulting in low operating expenses (Lane, 2008).

At present no maglev systems are being considered for implementation in South Africa. Internationally, though, maglev systems are steadily becoming a more popular choice. At present there are six functioning maglev systems in the world (in Germany, China, Japan and the USA), although some are only test tracks. New systems are currently being considered in 12 countries and many maglev research projects are underway (Lane, 2008).

3.3.7. Tubular Freight

Under a research programme on advanced freight movement, the Federal Highway Administration (FHWA) with the support of the John A. Volpe National Transportation Systems Center is examining the technical and economic feasibility of tubular transportation systems to address future freight transportation requirements (www.tfhrc.gov).

Tubular freight transportation is a group of unmanned transportation systems in which close-fitting capsules or trains of capsules carry freight through tubes between terminals. All historic systems were pneumatically powered and often referred to as pneumatic capsule pipelines. One modern proposed system called SUBTRANS uses capsules that are electrically powered with linear induction motors and run on steel rails in a tube about two meters in diameter. The system can be thought of as a small unmanned train in a tube carrying containerised cargo (www.tfhrc.gov).

Tube transportation systems have a number of attractive features that make them worthy of evaluation as alternatives for future freight transportation systems. Because such systems are unmanned and fully automatic, they are safer than truck or railroad systems. When traveling down grades, the capsules may be able to regenerate energy for improved energy efficiency (www.tfhrc.gov). Because they are enclosed, they are unaffected by weather and are not subject to most common rail and highway accidents. Hazardous cargo can be more safely transported than on surface systems. The tubes could also be used as conduits for communication cables for the future information highway. Benefits from reducing the number of trucks carrying freight in congested areas by tube freight transportation systems are (www.tfhrc.gov):

- Reduced traffic congestion.
- Reduced traffic accidents, injuries, and fatalities.
- Reduced traffic exhaust pollution and traffic noise.
- Reduced damage to roadways and bridges.
- Reduced petroleum fuel consumption.
- Increased control over delivery schedules.
- Lower freight transportation costs.

Although research and development around tubular freight (and passenger) systems has been emerging for several decades, no final conclusion regarding the feasibility and energy efficiency benefits have been reported.

3.3.8. Alternative Jet Fuels

From a strictly technical standpoint, it appears that coal-to-liquid (CTL) jet fuel produced by the Fischer-Tropsch process is most promising alternative to oil-derived jet fuels. This type of alternative aviation fuel is presently used in some parts of the world, including in South Africa, and extensive operational and environmental impact studies are underway to determine its potential for use in the United States. While experience and advanced research in CTL fuels look promising, the development of any viable alternative to traditional petroleum-based jet fuel should be encouraged because of climate change concerns. Recent studies (www.airlines.org/economics/energy) show that jet fuels made with a CTL product mixed with bio-fuel may result in major reductions in GHG emissions below levels seen in petroleum-based jet fuel. However this assumes that the bio-fuel has a high net energy – the limiting factor is that this is not true of all bio-fuels. Keeping the airline industry going on CTL or a type of bio-fuel that contributes to global warming would be undermining holistic, sustainable transport and settlement strategies[2]. Even if alternative fuels do not prove feasible for near-term use in commercial aircraft, ATA supports their development for other uses. Further research and development is needed to quantify the potential for alternative fuels in the air-based transport industry.

3.3.9. Conclusions on Propulsion Systems and Fuels

It is virtually impossible to give a list of 'most suitable' propulsion systems, because the value for the user depends on various internal and external factors. Among those factors are, for example, vehicle purchasing and operating costs, the utility of the vehicle (which largely

[2] A sustainable transportation strategy needs to be aligned with a set of sustainable human settlement and local economic processes

depends on the kind of propulsion system applied), availability and price of the corresponding fuel and the availability of the necessary refuelling infrastructure, amongst others. In some countries a particular fuel may already be on the market for years, yet in another country it may be very difficult to install the corresponding infrastructure of filling or charging stations. Also, new propulsion systems need well educated service technicians, who may not be readily available.

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). Nonetheless, it is internationally accepted that maximum travel time per day is a larger constraint than costs (Kraan, 1996).

Identified alternatives to diesel as a fuel for heavy vehicles include (Baas & Latto, 2005):

- Biodiesel (diesel made from vegetable oils, can be blended with mineral diesel),
- Diesahol (mineral diesel blended with methanol or ethanol),
- Compressed natural gas (CNG),
- Liquefied natural gas (LNG), and
- Hydrogen.

Although all of these alternative fuels will certainly reduce heavy vehicles' emissions, they will not necessarily reduce overall energy consumption.

Most alternative fuels, with the exception of bio-diesel and oxygenated diesel (oxy-diesel), cannot be used directly in rail transportation, without substantial modifications to engine and locomotive systems, as well as to the refuelling infrastructure (Stodolsky, *et al*, 2002). Natural gas - either as compressed natural gas (CNG) or liquefied natural gas (LNG) - or Fischer-Tropsch fuel and other renewable fuels (such as ethanol, bio-diesel and oxy-diesel) might find application to locomotives, but additional research is needed (Stodolsky, *et al*, 2002).

Maglev systems are currently the most energy efficient systems operating in the world. After 40 years of research and development, commercial systems have started to emerge and the interest in these systems is growing steadily. South Africa should explore the feasibility of maglev systems for this country. Tubular freight (and passenger) systems should also be investigated.

Table 3.2-1 summarises the advantages and disadvantages of the various alternative propulsion systems and fuels.

While the table does not address other non-motorised forms of transport, i.e. cycling and walking, it should be noted that while these are slow forms of movement with limited capacity to carry loads, they nevertheless are relatively oil independent, and are in fact the dominant modes of individual transport for the majority of the South African population. Sailing ships are driven by wind energy, and have not been considered here but might well be an option in the future for international and to a limited extent local trade. Nuclear powered ships were not considered because they are viewed as unrealistic in the long term given limits on the supply of uranium as well as the toxicity of the waste.

Table 3.3-2: Advantages and Disadvantages for Alternative Propulsion Systems and Fuels

Present mode	Vehicular Form/Propulsion System	Alternative fuel	Advantages	Disadvantages	Comment
Aviation	Aircraft	Alternative jet CTL fuel			May result in major reductions of GHG emissions. However bio-fuels could contribute to global warming
Rail	Electric trains	Electricity	Infrastructure mostly in place	State of repair of the infrastructure	Locomotive technology is continuously developing
	MagLev trains	Electricity	Speed and energy efficiency	Cost	Few in existence but increasingly looking like an attractive option, particularly in rich countries.
	Tubular freight containers	Air, and also air generated by electricity	Fully automated with high levels of safety. Energy efficient Unaffected by the weather		No conclusion yet regarding feasibility
Road (Private cars)	Hybrid engines	Conventional fuels	Greater energy efficiency	High embedded energy	Useful in reducing consumption. Not a long-term solution
	Electric cars	Electricity	Infrastructure relatively easy to install Quite	Additional load on electrical networks. Source of electricity is crucial from an environmental perspective	As a realistic option it requires a serious look at where the electricity will come from. The only long-term viable option is for it to come from renewable sources
	Compress-ed air car	Derived ultimately from electricity or liquid fuel driven compressor	Very fuel efficient Infrastructure in place Running costs 80% lower than comparable car. Constructed using light weight materials Pressure vessels have a longer lifetime than batteries used in electric cars. Cost per 100km – Approx. R18 (vs R85 for a small comparable car) 17.5kg of CO_s produced per 100km using electricity derived from a coal fired power station. (vs 23kg for a comarable small car) (Peak Energy, 2007)	Compressed air has a low energy density (320kJ/l vs 33MJ/l for petrol)	Innovative and holds promise, certainly in urban areas

Present mode	Vehicular Form/Propulsion System	Alternative fuel	Advantages	Disadvantages	Comment
			Engine can be scaled up or down depending usage.		
	Hydrogen car	Hydrogen is an energy carrier. Hydrogen extracted from compounds using other energy sources.	None	Energy inefficient Technology decades away from being viable. New distribution and storage infrastructure required.	Technology is still a long way away. Very energy inefficient.
	LPG Vehicles	Gas	Has capability of displacing petrol	Not favoured by DME due to refining complexities and non-contribution to Road Accident Fund	Could replace 5% of petrol by 2030

3.4. Reducing Oil Dependency of the Transport System

Road transport accounts for more than 95% of land based person travel and 86.5 % of land freight transport demand in South Africa. Because it is such a significant component of transport and is responsible for the most energy demand, the measures to reduce oil dependency are largely (though not exclusively) focused on road-based transportation.

Although shifting modes or propulsion systems away from oil-intensive practice are very effective interventions to reduce oil dependency, the measures in this section are measures aimed at improving the current fleet, based on the current technologies and modal split as described in Report 2.[3] The most noteworthy demand side oil dependency relief measures include: improving the vehicle design, vehicle maintenance practice, and Travel Demand Management (TDM). Alternative propulsion systems and modal shifts are discussed in Sections 3.2 and 3.5 respectively.

3.4.1. Improved Vehicle Design

Improving the design of a vehicle in the road, rail and air transport industry aims to address various ways of improving the distance (kilometres) covered per unit of fuel consumed. International research and development efforts have gone into reducing air and rolling resistance, as well as into the use of light weight materials and the design of smaller vehicles. These changes all improve the energy efficiency of vehicles. Furthermore, reducing the energy use of vehicle accessories has also been investigated.

3.4.1.1 Air Transport

In the aircraft industry, airplanes showed a 70% decrease in gate-to-gate fuel use, in idealised normal operations, between 1960 and 2000 (Lovins, *et al*, 2005). This can be attributed to improved engine and airframe design alike. New aircraft are 70% more fuel efficient than 40 year old aircraft and 20% better than 10 year old aircraft (www.iata.org). Historically,

[3] "Energy and Transport Status Quo: Demand and Vulnerabilities"

improvements in aircraft fuel efficiency have averaged between 1% and 2% per year since the dawn of the jet age in commercial aviation (www.enviro.aero). This has mainly been achieved through the incorporation of new engine and airframe technologies. Modern aircraft achieve fuel efficiencies of 3.5 litres per 100 passenger-km (www.iata.org). The Airbus A380 and the Boeing B787 are aiming for 3 litres per 100 passenger-km, which will be a better fuel economy than a single-occupant compact car. Airlines are aiming for a further 25% fuel efficiency improvement by 2020 (www.iata.org) and the Air Transport Action Group (www.enviro.aero) projects this improvement trend to be continued to 2050.

In air transport, auxiliary loads, such as air-handling, space-conditioning, lighting, cooking and electronics, have not yet received the systematic and up-to-date attention they deserve (Lovins, *et al*, 2005). The Rocky Mountain Institute believes that redesigning auxiliary loads could profitably save up to 2% of fuel use, which can save weight and fuel carriage, whilst improving passenger comfort, health and safety (Lovins, *et al*, 2005). The extent to which these improvements can beneficiate freight aircraft is unfortunately not known.

Of all the factors influencing aircraft fuel consumption, weight is undoubtedly the most influential. Reducing the weight of a midsize aircraft by 0.45 kg typically saves 56 kg of fuel a year (Lovins, *et al*, 2005). On average, an aircraft will burn about 0.03kg of fuel for each kilogramme carried per hour (www.enviro.aero). This number will be slightly higher for shorter flights and for older aircraft and slightly lower for longer flights and newer aircraft.

3.4.1.2 Road Transport

Regarding road based transport, Bendtsen (2004) indicates that transmission friction accounts for 7%, air resistance for 4% and rolling resistance for 14% of the total energy consumption in passenger vehicles. Research and development over the last two decades has led to a substantial reduction in *air resistance* of private vehicles.

Ogburn and Ramroth (2007) indicate that in the average long-haul trucking operation, only about 6.5% of the energy in each litre of diesel fuel is used to move the cargo and only 4.5% is used to move the tractor-trailer. The remaining 89% is lost along the way: 56% to thermodynamic effects in the engine, 12% due to idling, 2% to driveline and transmission drag, 19% to overcome aerodynamic forces, and 11% to tyre rolling resistance (Ogburn & Ramroth, 2007).

3.4.1.2.1 Aerodynamic Design

According to the Rocky Mountain Institute (2007), more than 60% of total aerodynamic drag in a tractor-trailer combination truck is due to the trailer. There are three types of panels that can be bolted on to a trailer to improve truck fuel efficiency. The first are called side skirts (fairings that hang down from the bottom of a trailer, enclosing the open space between the rear wheels of the tractor and the wheels of the trailer) and they can save 4% (RMI, 2007), although manufacturers claim savings between 5% and 18% (Ang-Olson & Schroeer, 2002). Secondly, there are base flaps (6%) and then there are gap fairing and nose cones, which can save approximately 2% (RMI, 2007; TMC, 1998). Together, drag is reduced by approximately 20% and a saving of around 12% can be achieved (Ogburn & Ramroth, 2007). Triangular plastic pieces, mounted along the back of the cab and trailer, are designed to create a vortex in the tractor-trailer gap and behind the trailer. This is claimed to result in at least a 4% improvement in fuel economy (Ang-Olson & Schroeer, 2002).

3.4.1.2.2 Materials

Lightweight materials have slowly been introduced in the car industry. The lower the weight, the lower the amount of energy required to move the vehicle. In freight, truck tare weight can be reduced by purchasing tractor and trailer components made of lightweight materials, or by eliminating unnecessary components (Ang-Olson & Schroeer, 2002). The tare weight of a typical combination truck can be reduced by as much as 4.5 tonnes by using lightweight materials and eliminating unnecessary components (TMC, 1998). Most trucks will not be able to achieve reductions this large, in part because of the need for certain accessories or more durable components. Ang-Olson and Schroeer (2002) assume that trucks could achieve a weight reduction of 1.36 tonnes whilst maintaining desired durability and features, which would improve fuel economy by approximately 0.05 l/km at a speed of 105 km/h, or 1.8% (TMC, 1998).

Unfortunately, lightweight materials have a long lead time, as safety risks need to be assessed. South Africa follows international trends in this regard, although it lags international trends by 5 to 10 years.

3.4.1.2.3 Vehicle Size

Regarding the *vehicle size*, the car industry has gone through a full cycle. To make cars affordable to the general public, small vehicles were designed in the sixties and early seventies. In the eighties, the size of vehicles increased, decreasing its energy efficiency. Although research and development efforts in the nineties went into smaller vehicles, consumers the world over did not move towards these more fuel efficient vehicles. Comfort for the whole family was more important than energy efficiency. International trends showed that fuel efficiency improvements were counter balanced by an increased vehicle size in that period and the overall effect energy efficiency effect was neutral (Jansen, 1995).

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

Large campaigns and financial incentives have started to change the consumers' behaviour, mainly in Europe. In South Africa, the trend towards large vehicles still continues. Although South Africa has its own car manufacturing industry, research and design changes are mainly determined overseas. The early production and adoption of small vehicles and vehicles with energy efficient associates is recommended. European drivers have started a shift towards smaller vehicles in recent years and South Africa is expected to adopt this preference. Internationally available small vehicles are often only imported into 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 (Vanderschuren, *et al*, 2008).

The majority of new heavy vehicle engines are electronically controlled - providing a 7% to 15% improvement in fuel economy (Baas & Latto, 2005). Matching engine size to the required task will give the best fuel economy. A 5 horsepower increase in engine size will reduce fuel efficiency by 2% (Baas & Latto, 2005).

3.4.1.2.4 Tyres

In freight, *improving equipment* provides substantial potential to reduce energy consumption. Michael Ogburn, from the Rocky Mountain Institute (RMI, 2007; Ogburn & Ramroth, 2007), claims that between 4% and 8% fuel savings are possible by changing the type of tyres used. Traditional twin tyres that are optimised for fuel economy can save approximately 4%. 'Single-wide' or wide-base tyres save between 4% and 6% of fuel by reducing rolling resistance and reduce the load on the axle by about 90kg per tyre; reducing the tare weight of the truck or allowing for extra cargo to be loaded onto the truck (RMI, 2007). Tests of the Michelin wide-base tyre reveal fuel economy improvements of between 3.7% and 4.9% when compared to the equivalent Michelin dual tyres (Markstaller, Pearson & Janajreh, 2000). Bridgestone claims fuel economy improvements of 2% to 5% using its wide-based tyre (Ang-Olson & Schroeer, 2002).

3.4.1.3 Rail Transport

The Swiss railways, which are very active in terms of research and development and are already rather efficient, foresee large potential savings (up to 60%) from integrating new propulsion concepts (up to 30%), light-weighting (up to 20%), cutting drag and friction (up to 10%), and optimising operations (Lovins, *et al*, 2005). For rail engines, advances have been made in reducing aerodynamic drag and weight, and in developing regenerative brakes (at rail-side or onboard) and higher efficiency motors (IAC, 2007).

3.4.1.3.1 Diesel Power

According to the literature, the diesel engine is the most efficient rail based power source available today. Thermal efficiency of locomotive diesel engines is 40% or higher, which results from high power density (via high turbocharger boost), high turbocharger efficiencies, direct fuel injection with electronic timing control, high compression ratios, and low thermal and mechanical losses (Stodolsky, *et al*, 2002). It is believed that locomotive diesel engine design can be improved to achieve improved thermal efficiencies of 50% to 55%, resulting in a reduction in specific fuel consumption of about 20%. Developments such as advanced materials (e.g., thermal barrier coatings, titanium), new enabling technologies, advanced combustion concepts and advanced analytical tools for optimisation have contributed to, or are likely to contribute to, efficiency gains (Stodolsky, *et al*, 2002). Nonetheless, in South African diesel engines are problematic. An interview with an employee of Transnet indicated that, due to the engineering used in South Africa, there is a significant amount of energy lost by diesel trains. It was recommended in the interview, to prioritise electric powered engines.

Locomotive engines are idled because heating is required to keep the engine coolant from freezing (locomotive cooling water contains no antifreeze, so the engine must be drained of coolant if the cooling-water temperature approaches freezing) and to heat the thick engine oil in order to improve viscosity. For a switcher locomotive that idles 75% of the time (Association of American Railroads switcher duty cycle), 27% of the fuel is consumed and 25% of the NOx emissions are produced at idle. An idling locomotive consumes 13.5 to 20 litres of fuel per hour (Stodolsky, *et al*, 2002). Two approaches to idle reduction are starting to gain acceptance by the industry: automatic start/stop systems and auxiliary power units (APUs). Considering the high percentage of time that locomotives spend idling, it would not be unreasonable to expect idle-reduction technologies to be able to reduce fuel consumption by at least 10% in the long term (Stodolsky, *et al*, 2002).

3.4.1.3.2 Aerodynamic Design

There appears to be little room to improve the aerodynamic design of rail locomotives. However, considerable aerodynamic-drag losses are found for certain car configurations, especially those that include empty coal cars and inter-modal cars. One company has found that aerodynamic drag accounts for about 15% of the round-trip fuel consumption for a coal train, and that fuel consumption is approximately the same for an empty train as it is for a full one (Stodolsky, *et al*, 2002). In an experiment with simple fairings or foils (not a full cover) to direct the air flow over the empty cars, about a 25% reduction in aerodynamic drag was achieved, which resulted in a 5% fuel savings for the round trip. For inter-modal cars (two containers stacked on a flat car), about 30% of the energy loss is due to aerodynamic drag (Stodolsky, *et al*, 2002).

Depending of the reduction of the *rolling resistance* on passenger vehicles, energy consumption can be reduced by between 0.1% and 17% (Bendtsen, 2004). Table 3.4-1 provides an overview of the energy consumption saving proportional to the rolling resistance reduction.

Table 3.4-1: Effect on Total Energy Consumption in % of Rolling Resistance

Change in rolling resistance	1%	5%	10%	25%	50%
Change in total energy consumption	0.14%	0.85%	2.33%	6.41%	16.62%

Source: Bendtsen, 2004

3.4.1.3.3 Wheel-Rail Friction

Regarding rail-based transport systems, a significant fraction of the energy consumed in rail transport is due to wheel/rail friction. The magnitude of the wheel/rail frictional energy losses relative to other losses (bearings, aerodynamic, and grade) depends on the condition of the track (dry or lubricated), whether the track is curved or tangent, truck design, wheel rail profile conformance, truck wear resulting in poor steering, and train speed (Stodolsky, *et al*, 2002). Past studies have indicated that energy savings could be as high as 24% when friction at the wheel/rail interface is properly managed (Stodolsky, *et al*, 2002).

Trains rely on high friction under locomotives to keep wheels from slipping and sliding when power is applied. Friction is also required under braking conditions to control train speed down hills or to bring a train to a safe stop. Much lower friction levels are desirable under normal train operations and can significantly reduce the energy required to pull a train. Therefore, the key is to apply the lubricant just where it is needed and to make sure that it does not cover the track where high friction is needed for traction or braking (Stodolsky, *et al*, 2002).

3.4.1.4 Water-based Transport

In water-based transport, technology options for reducing energy use in the shipping industry include hydrodynamic improvements and machinery; these technologies could reduce energy use by 5% to 30% on new ships and 4% to 20% when retrofitted on old ships (IAC, 2007). Since ship engines have a typical lifetime of 30 years or more, the introduction of new engine technologies will occur gradually.

3.4.2. Vehicle Maintenance

Improved *vehicle maintenance* reduces fuel consumption as vehicles are better tuned. It consists of several different elements. Table 3.4-2 provides an overview of maintenance elements along with their potential fuel consumption reduction. It is assumed that these values, although published for passenger vehicles, are applicable to freight vehicles as well.

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.

Table 3.4-2: Vehicle Maintenance-based Fuel Consumption Improvements

Vehicle maintenance elements	Efficiency improvement (%)
Keep Your Engine Properly Tuned	4%
Check & Replace Air Filters Regularly	Up to 10%
Keep Tyres Properly Inflated	Up to 3%
Use the Recommended Grade of Motor Oil	1%-2%

Source: USDEEE&RE and EPA, 2008

A poorly tuned truck engine can use up to 50% more fuel than a well tuned one (Baas & Latto, 2005). In freight, a clogged air filter can cause a 10% increase in fuel consumption (Baas & Latto, 2005). Lubricants need to be checked and replaced regularly. Worn out engine oil increases engine friction, resulting in increased component wear and fuel consumption (Baas & Latto, 2005). It is important that, as engine repairs are made - specifically the injector pumps - the electronic units should not be replaced with manual pumps. Electronic components result in far greater fuel efficiency. (Baas & Latto).

Maintaining proper tyre pressure reduces the rolling resistance and fuel consumption caused in the freight industry as well (Baas & Latto, 2005). As a rule of thumb, a 10 psi drop in tyre pressure will increase rolling resistance by 2% and fuel consumption by 0.5% to 1% (Ang-Olson & Schroeer, 2002). A 16 km/h increase in speed increases the rolling resistance by between 7% and 10% (Baas & Latto, 2005). The impact of trailer tyre under-inflation is estimated to cause a 0.6% reduction in fuel economy on a typical truck (Taylor, 1999). The fuel savings mentioned could be much larger for trucks that do not frequently check and maintain proper tyre pressure.

Regarding air-based traffic, Flight Sciences International (www.flightsciences.com) indicates that improved maintenance reduces energy consumption between 5% and 10% over the long term.

3.4.3. Travel Demand Management: Influencing Driver-User Behaviour

Travel Demand Management (TDM, also called Mobility Management) is a general term for strategies that result in more efficient use of transportation resources. Most individual TDM strategies have modest impacts, affecting a small portion of total vehicle travel, but their impacts are cumulative and synergistic. An integrated TDM program can often reduce 20-30% of private vehicle travel where it is applied. Some studies suggest that comprehensive implementation of TDM strategies, to the degree that they are economically justified, could reduce total vehicle kilometres travelled by more than a third (www.vtpi.org). TDM measures, such as car/ride sharing, adaptive work schedules, tele-working, tele-learning or tele-shopping can be pursued to decrease energy consumption in the transportation field.

3.4.3.1 Scrappage Policies

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 the more efficient vehicle. Incentives are determined using a sliding scale depending upon the age of the vehicle. The success of such schemes is reported to depend upon how many choose to replace their vehicles and the age of the replacement vehicle (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.

3.4.3.2 Car/ride Sharing

Car sharing or so called ‘Green Wheels’ are systems that make sure that sub-owned vehicles are available to consumers at pre-booked times. A management system makes sure that demand is always met. Small parking garages in neighbourhoods limit walking distances. Most car sharing schemes are introduced in neighbourhoods. Some companies organize ‘Green Wheels’ for their employees to reduce car ownership and use. Car sharing in neighbourhoods were launched in Switzerland in 1987 and later in 1988 in Germany. In 1993 the city of Quebec was the first North American city to introduce can sharing. As of the 1st of January 2008 - based on data provided by Susan Shaheen, University of California, Berkeley - 18 U.S. car sharing programs claim to have 234,483 members sharing 5,261 vehicles, and 13 Canadian car sharing programs apparently have 33,895 members and share 1,499 vehicles (www.carsharing.net).

Ridesharing refers to carpooling and vanpooling. Carpooling uses participants’ own automobiles, whilst vanpooling uses vans that are usually owned by an organization (such as a business, non-profit or government agency) and made available specifically for commuting. Vanpooling is particularly suitable for longer commutes (More than 15 km each way). Ridesharing can be the most cost effective transportation mode. Carpooling that makes use of existing vehicle seats that would otherwise travel empty have very low incremental costs. Vanpooling with 6 or more passengers in a vehicle tends to have the lowest average cost per passenger-km, since it carries more passengers per vehicle than a carpool, and does not require a professional driver or have empty backhauls like conventional public transit services (www.vtpi.org).

3.4.3.3 Tele-working/learning/shopping

Tele-working/learning/shopping involves the use of telecommunications to substitute for physical travel. This includes telecommuting, distance learning, and various forms of electronic business and government activities. According to some estimates, up to 50% of all types of jobs in the US are suitable for tele-working, but the actual portion of trips that can be reduced appears to be much lower, since many jobs require access to special materials and equipment, or frequent face-to-face meetings. Not all employees or employers want to tele-work or have suitable home office conditions (www.vtpi.org).

Different studies have been performed, trying to establish the reduction in commuter car trips due to tele-commuting. The estimates vary between 5% and 24% (Vanderschuren, *et al*, 1993; Handy and Mokhtarian, 1996; Martens and Korver, 1999). A portion of the reduced travel is often offset by additional vehicle trips tele-workers make to run errands and because it allows employees to move further from their worksite. For example: choosing a home or job in a rural area or another city because they know that they only need to commute two or three days a week (www.vtpi.org). The reduction in car trips for households is, therefore, less than the reduced number of work trips (between 1% and 10%) (Vanderschuren, *et al*, 1993; Handy and Mokhtarian, 1996; Martens and Korver, 1999).

A potential reduction in car related mobility has been identified in the literature with regard to tele-learning. Nevertheless, the current experience is not enough to indicate the potential savings in car mobility and energy efficiency (Vanderschuren, *et al*, 1993). In South Africa tele-learning provides possibilities for disadvantaged communities (rural). The introduction of distance learning facilities for these communities will not decrease car mobility. Further research in this regard is recommended.

Woolworths, Pick-and-Pay and other retail companies already provide tele-shopping facilities in South Africa. Tele-shopping will increase in importance over time, partly due to the increase in households with two working adults and to the increased affordability of internet access in South Africa. If catalogue and web based shopping becomes more important, travel is expected to reduce slightly. Nonetheless, the overall energy efficiency effects have not been established yet (Vanderschuren, *et al*, 1993).

3.4.3.4 Travel Demand Management in Freight

A reduction in total freight transport can be achieved by reducing product volumes and unnecessary packaging, relying on more local products, and locating manufacturing and assembly processes closer to their destination markets (www.vtpi.org). Businesses should be encouraged to consider shipping costs and externalities in product design, production and marketing and to rely on more local suppliers. By clustering common destinations together, the total amount of travel required for goods distribution can be reduced (www.vtpi.org).

A New Zealand software company, 4Technology, has created a website which matches empty trucks with one-off shipments. The website, at www.4Freight.net, promotes transport efficiency by providing a way both shippers and carriers can match freighting needs with available services. It is aimed particularly at individuals and companies moving irregular large consignments (ww.vtpi.org).

In urban environments, changing freight delivery times to reduce or avoid congestion can result in reduced fuel demand (www.vtpi.org).

Significant reduction of product volumes through greater reliance on local products has been illustrated through an innovative, multi-disciplinary building approach in the construction industry, 'The Natural Step' principles, advocated by Collis and Cowen (2007). In terms of this approach through mapping of the conventional and unconventional building materials in the region, as well as a mapping of what enters and what leaves a site, residential and non-residential environment.[4] This approach requires a regulatory framework, i.e. local building and

[4] In a sustainable subsidised housing scheme in Mbekweni, outside Paarl, Collis and Cowen made significant use of local material such as stones, timber, slate etc. They also designed the houses as double storey. Another interesting project is an upmarket residential project in Devils' Peak, Cape Town. The clients wanted two separate dwellings on the double erf and although there was an existing house, it was structurally unsound and couldn't be used. The old house was demolished – but carefully, so that much of the materials could be reused. Bricks, sand, timber floors and slate were all reused. In fact, they

planning regulations, in order to have maximum impact. This is an interesting example of linkages between travel demand management and broader local authority developmental strategies and policies.

In rail-based freight operations, consist management is the manipulation of train length, car placement, and locomotive placement based on operating speed, tonnage, and terrain. When multiple locomotives coupled together are operating at less than full power, the total energy consumed can vary considerably, depending upon the relative ratings of the locomotives and the throttle position of each. For example, it may be much more efficient to run one locomotive at full throttle and the others at much lower power levels rather than running all of the locomotives at the same power setting (Stodolsky, *et al*, 2002).

3.4.3.5 Travel Demand Management in Aviation

Aviation is a major source of energy consumption and pollution emissions, is one of the fastest growing transportation sectors, is relatively energy inefficient and tends to stimulate increased travel. High altitude air pollution emissions by jets tend to impose particularly high greenhouse impacts and aircraft cause local air and noise pollution problems. Aviation represents about 10% of current transportation energy consumption in North America (www.vtpi.org). In South Africa this is equal to 10.8% (see Section 2.2).

Although some air travel is relatively price inelastic (which is why airlines can sell high-priced business-class seats), much air travel is highly price sensitive (which is why airlines offer discounted fares), so even modest price increases can reduce air travel. Various policies and management strategies can encourage more efficient, less polluting air travel and shifts to other

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did not allow any rubble removal trucks on site. The end result was not just a beautiful urban house, but a considerable cost saving.

Since traditional building contracts and remuneration schemes are not conducive for this 'fresh' approach, Collis and Cowen (2007) designed their own contracts and work in close partnership with all the contractors and the client. The builder, for example, is incentivised to use 'rubble' from the site and more labour by receiving a percentage of the overall cost saving on material. At the Tsoga Environmental Centre project they used a rubble trench foundation using local waste material and monitored the amount of heavy vehicle kilometres and diesel consumed through this approach, as opposed to going for a traditional concrete slab. The saving was over 90%.

modes, particularly to rail and bus for medium-distance trips (350-1350 miles). These include (www.vtpi.org):

- Eliminate airport infrastructure property tax exemptions, and increase aviation fuel tax rates. Eliminate duty-free shops at airports.
- Increase airport user fees to provide full cost recovery of airport infrastructure investments, air traffic controls and security services.
- Support development of fast and efficient rail transport on busy corridors to compete with air transport for medium-distance journeys.
- Upgrade and replace older aircraft with newer models that reduce fuel consumption, noise and air pollution emissions.
- Improve air traffic management systems to increase operational efficiency.

3.4.3.6 The Marketing of Travel Demand Management

TDM Marketing includes activities that provide consumer information and encouragement to support TDM. Marketing can have a major impact on TDM programme effectiveness. Some TDM marketing programmes have reduced automobile travel more than 10%. TDM marketing includes (www.vtpi.org):

- Educating public officials and businesses about TDM strategies they can implement.
- Informing potential participants about TDM options they can use.
- Identifying and overcoming market barriers to the use of alternative modes.
- Promoting benefits and changing public attitudes about alternative modes.

3.4.3.6.1 Education and Public campaigns

Better driver education and public campaigns provide the possibility to reduce fuel consumption substantially. Aggressive driving (rapid acceleration and braking) wastes energy. In road-based transport, 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 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 rear-window heater off (3-5%).

Where appropriate, these percentages are applicable to both private vehicles and trucks. Several of the mentioned measures interact. It is expected that continued awareness campaigns could reduce fuel consumption by an estimated 15% in South Africa (Vanderschuren, *et al*, 2008).

ATA's Maintenance Council (1998) estimates that the best truck drivers, compared to the worst drivers, can improve fuel efficiency by 35%. This is the extreme case, however, and it can be expected that most fleets would see more modest improvements. Case studies, conducted by National Resources Canada as part of their FleetSmart program, have shown differences of up to 12 litres per 100 km between the best and worst drivers (Baas & Latto, 2005). Ang-Olson and Schroeer (2002) indicate that a variety of other studies have estimated that driver training programs result in fuel savings ranging from 5% to 20%. The main differences between drivers are attributed to speed, gear ratios used and gear change points (Baas & Latto, 2005).

Some of the fuel savings that result from training overlap with other measures to improve fuel economy, such as reduced idling and speed reduction. A 4% fuel economy improvement can be achieved through better acceleration, shifting and route choice practices alone (Ang-Olson & Schroeer, 2002). Large gains are likely for vehicles in urban areas where shifting practices have more influence on fuel economy.

In rail operations, engineers receive extensive education, including in-cab and hands-on computer simulation of train operation, to learn the many details of safe train handling with the diversity of power and loads required over varying terrain and track conditions (Stodolsky, *et al*, 2002). However, fuel usage on the same route can vary among crews by 12% to 20%, according to studies at Union Pacific and Burlington Northern Santa Fe railroads (Stodolsky, *et al*, 2002). A control system that employed innovative optimisation, navigation, and estimation methods would enable train crews to operate as efficiently as consist, track, and traffic conditions allowed. Such a system would have the flexibility to achieve optimal performance on one trip by one train, or to trade off across the fleet to minimize total fuel used (Stodolsky, *et al*, 2002).

The International Air Transport Association (IATA) compiles industry best practices, publishes guidance material and establishes training programs for member airlines to improve existing fuel conservation measures (www.iata.org). A comprehensive checklist on fuel efficiency best practice exists, enabling member airlines to assess their operations in this regard. These practices should also be adopted and adhered to, in South Africa.

3.4.4. Conclusions on Reducing Oil Dependence of the Transport System

Energy-intensity reductions are possible beyond the level that is cost-effective for users; however, vehicle design changes that offer large reductions in energy intensity also are likely to affect various aspects of vehicle performance. Achieving these changes would thus depend either on a shift in the priorities of vehicle manufacturers and purchasers, or on breakthroughs in technology performance and cost.

Where energy-intensity reductions result from improved vehicle body design, GHG mitigation may be accompanied by a reduction in emissions of other air pollutants, where these are not controlled by standards that effectively require the use of catalytic converters. On the other hand, some energy-efficient engine designs (e.g., direct fuel injection and lean-burn engines) have relatively high emissions of NOx or particulate matter (SAR II, 21.3.1.1).

Changes in vehicle technology can require very large investments in new designs, techniques, and production lines. These short-term costs can be minimized if energy-efficiency improvements are integrated into the normal product cycle of vehicle manufacturers. For cars and trucks, this means that there might be a 10-year delay between a shift in priorities or incentives in the vehicle market, and the full results of that shift being seen in all the vehicles being produced. For aircraft, the delay is longer because of the long service life of aircraft, and because new technology is only approved for general use after its safe performance has been demonstrated through years of testing.

A number of strategies can be developed which aim to change the functioning of the car itself. These include the following:

- Changes to car body design. The aerodynamic efficiency of a car is related to its body shape. Its efficiency is measured by its drag coefficient. Aerodynamic forces are proportionally related to the square of an object's speed (when the speed is doubled, drag quadruples). The exact speed at which a vehicle achieves its highest efficiency varies based on the vehicle's drag coefficient, frontal area, surrounding air speed, and the efficiency and gearing of a vehicle's drive train and transmission.
- Changes to car engine design.
- Changes to the engine combustion chamber design.
- Changes to the fuel/air mixture.
- Introduction of statutory fuel efficiency standards. This requires government expertise in setting of these measures and there may be resistance from manufacturers.

Strategies to reduce fuel consumption

The beauty of these strategies is that they are easy to implement and can be done very quickly. Historically they have been shown to be effective, provided that they are enforced.

- Reduced speed limits. This reduces overall fuel consumption which rises considerably as speed increases.
- Restricted hours for fuel sales. This has the effect of discouraging superfluous travel and for people to become more conscious in their journey planning.

- Rationing by providing a quota to all vehicle owners. This divides the available fuel or a specific target equitably amongst road users. To take account of usage pattern differences it requires a mechanism enabling people to trade their quotas.
- Car pooling and other measures to increase car occupancy.
- Vehicle sharing.
- Measures that encourage changes to car purchasing preferences with an emphasis on smaller, lighter vehicles. This can be effected through means of a tax which increases with engine size. In the longer term this will encourage car manufacturers to produce smaller more fuel efficient cars.

3.5. Transport Management Measures

The measures described in this section are classified as top-down measures – measures which need to be implemented by regulatory authorities. They mainly pertain to infrastructure provision that will improve overall transport efficiency. The focus is on so called Intelligent Transport Systems (ITS).

ITS is a very broad field. It varies from traffic light control to incident management, from enforcement to passenger information and from driver assistance to intelligent speed limit enforcement. Structuring a broad field like ITS measures is difficult, as each structure can be challenged.

ERTICO (www.ertico.com), the European equivalent of ITS America (www.itsa.org), splits ITS measures into three groups:

1. **Intelligent Traffic Management Systems** measure and analyse traffic flow information and use ITS measures to reduce problems. These measures consist of computerised traffic signal control, highway and traffic flow management systems, electronic licensing, incident management systems, electronic toll and pricing systems, traffic enforcement systems and intelligent speed adaptation.

2. **Intelligent Passenger Information Systems** improve the knowledge base of driver and consist of passenger information systems, in-vehicle route guidance systems, parking availability guidance systems, digital map databases and variable messaging systems.

3. **Intelligent Public Transport Systems** include ITS measures that aim to improve public transport performance. They consist of intelligent vehicles, Intelligent Speed Adaptation, transit fleet management systems, transit passenger information systems, electronic payment systems, electronic licensing systems, transportation demand management systems and public transport priority systems.

A field that is not well researched internationally is ITS measures for freight. Moreover, rail-based and air-based traffic uses very specific ITS systems. In this document, freight- and rail- and air-based systems are included as separate subsections.

Intelligent Transport Systems (ITS), including traffic management, can contribute towards achieving various outcomes: safety, mobility, efficiency, productivity, energy and environmental improvement and customer satisfaction (Mitretek Systems, 2001). Two important traffic management measures that assist in energy management are road efficiency improvement and speed management measures.

3.5.1. Intelligent Traffic Management Systems

Improved road efficiency measures and traffic speed management are two systems that have been identified as important Intelligent Traffic Management Systems.

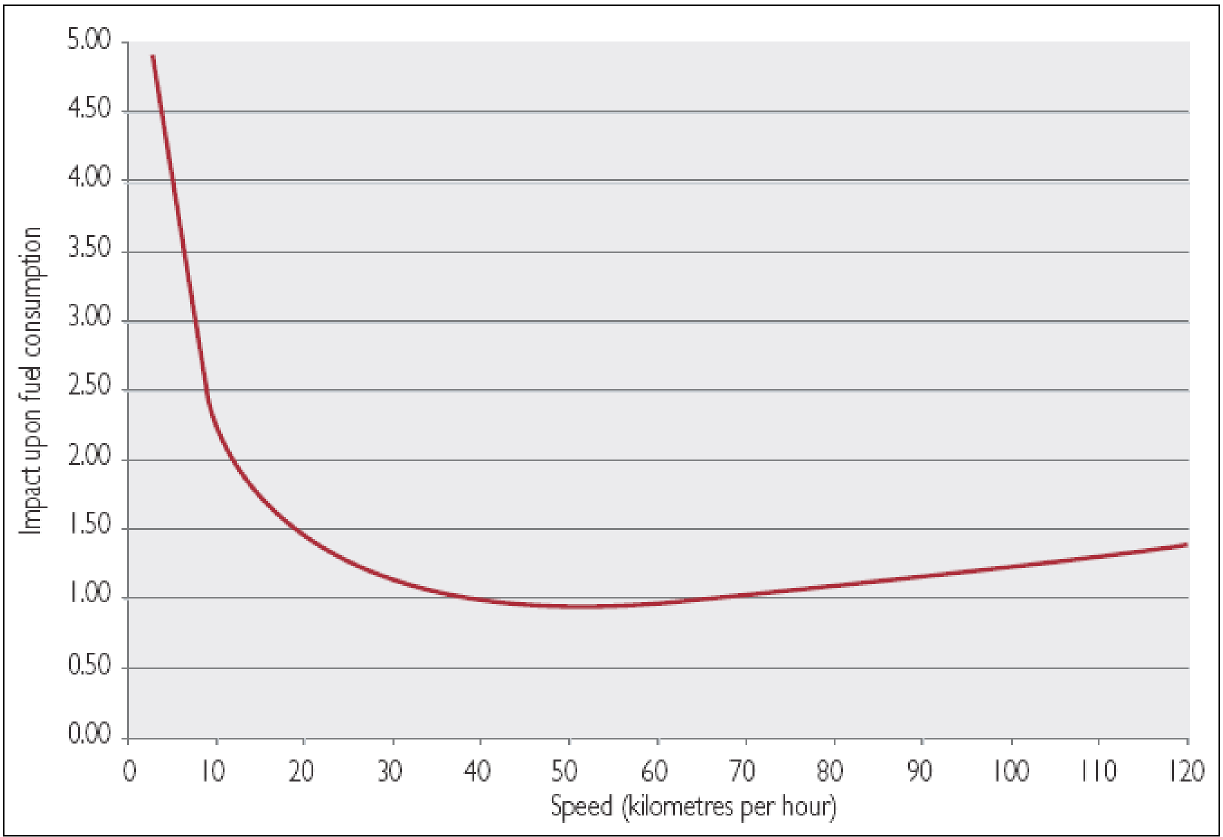
3.5.1.1 Improving Road Efficiency

The main improvement to road efficiency results from the implementation of traffic control systems. Traffic controllers are used to regulate traffic flows at intersections. According to the ITS Handbook (PIARC, 2004), traffic controllers (or Adaptive Traffic Signal Control Systems) have various benefits. The findings, based on several implementations in Oakland and Toronto, are:

- A reduction in travel time by 7% to 8%,
- A reduction in the number of stops by 22%,
- A reduction in CO and HC emissions by 4% to 5%, and
- A reduction in fuel consumption of 6%.

It has been demonstrated that techniques which improve traffic management, adopted internationally, reduce fuel consumption by between 5% and 20% (Willekens, *et al*, 2008; 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 (Figure 3.5-1).

Figure 3.5-1: Fuel Efficiency related to Speed



Source: Hutton, 2008

South African cities have elected to adopt the Split, Cycle and Offset Optimiser Technique (SCOOT). The SCOOT (Split, Cycle and Offset Optimizer Technique) adaptive traffic control system was developed in the United Kingdom by three companies, Ferranti, GEC, and Siemens, under the supervision of the Transportation Road and Research Laboratory (TRRL), and is employed extensively in Great Britain. SCOOT is intended to control the operation of systems of signals rather than isolated intersections. The system works via a central computer system and aims to optimise the network performance. Unfortunately, SCOOT systems are not used optimally in South Africa. In Cape Town, for example, human resources in the municipality allow only 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 (www.scoot-utc.com).

Public Transport Priority (PTP) can also be promoted via traffic control systems. PTP systems minimise the negative impact of traffic lights for public transport. Many traffic control systems, such as SCOOT, are able to give public transport priority at intersections. It is, however, necessary that public transport vehicles can be identified, via tags or Geographical Positioning Systems (GPS). In the same manner, freight vehicles can be given priority at intersections. Nonetheless, given the large number of operators, it is much more difficult to organise the required communication systems in the fleet.

Optimising traffic control systems in South Africa is expected to reduce energy consumption by at least 10% (Vanderschuren, *et al*, 2008). This is expected to benefit private cars, public transport and freight.

3.5.1.2 Traffic Speed Management

Traffic flow theory indicates that optimal throughput is achieved around 70 km/h (TRB, 2000). This is also when modern vehicles maintain maximum efficiency (Vanderschuren, *et al*, 2008). There are two possible systems to reduce speed on the road network:

- *Variable Speed Limits (VSL)*: Variable Message Signs (VMS) are mostly used to apply VSL on a road, and

- *Intelligent Speed Adaptation (ISA)*: ISA is a collective name for systems in which the speed of a vehicle is continuously monitored within a certain area. When the vehicle exceeds the speed limit of the area, the speed is automatically adjusted or a warning is provided to the driver.

VSL are mostly applied during peak hours on highways. The aim is to reduce the speed before congestion appears, which will result in a more homogenised traffic flow. Less stop-and-go occurs, and hence, efficiency is improved and energy consumption reduced. An average speed reduction (and, therefore, reduced energy consumption) of 10% was found in the literature (Vanderschuren, 2006). Homogenising traffic flows via VSL does not always result in more homogenised traffic on a highway system, at least not with the modelled maximum speed limit of 90 km/h (Stemerding, *et al*, 1999). The total throughput in this study decreases by two percent, while more traffic is using the secondary road network. Moreover, the number of stops increases, which is negative from an energy consumption point of view. Analysing the details, Vanderschuren (2006) indicated that the limits of the software used might have influenced the results. Recently, Willekens (Willekens, *et al*, 2008) found a fuel efficiency benefit of 20% at a regulated speed of between 65 km/h and 70 km/h.

The main aim of ISA is an improvement in road safety. Lui and Tate (2000) estimated the benefits of a mandatory ISA models over a voluntary systems. They found, in the before situation, that 34% of drivers exceeded the speed limit. It can be concluded that ISA could be promoted to reduce speeds on South Africa's roads. Nonetheless, government has less influence on the implementation of ISA systems than VSL systems. Moreover, the ISA system is more receptive to vandalism and fraudulent use.

Various Cruise Control (CC) systems are on the market already. Manual systems make sure that the speed limit is not exceeded. Moreover, more intelligent systems, such as Adaptive Cruise Control (ACC) become like an auto pilot (also reducing potential stop-and-go). In a study carried out by Ludmann (Ludmann, *et al*, 1999), 100% of vehicles were equipped with ACC. Estimates were done for highways, as well as urban traffic. Two different systems were tested (the second one reacted slightly smoother). The changes in speed and throughput were calculated. The average speed in the first scenario decreased by 13%, while the speed increased by six percent in the second scenario.

In a study for a highway link Vanderschuren (Vanderschuren, *et al*, 2000) demonstrated that the effect of Autonomous Adaptive Cruise Control (AACC). [5] on speed, travel time and throughput (traffic flow) is minor. Despite the minor effects on speed, travel time and throughput, a phenomenal reduction in shock waves was estimated, which is an indication of an improvement in road safety and energy consumption. A study by Marsden (Marsden, *et al*, 2000) indicates that there is an optimal percentage of penetration with ACC. If 40% or more of the vehicles have ACC, the average speed (and, therefore, energy consumption) decreases. Unfortunately, it is

[5] Autonomous Adaptive Cruise Control is the second generation ACC

too early to estimate overall energy consumption benefits. Nonetheless, government should promote CC systems as effects are expected to be positive.

Given the extent of speeding on the South African road network, it was estimated that an energy consumption reduction of at least 10% can be expected in South Africa (Vanderschuren, *et al*, 2008). Further analysis revealed that this benefit will be mainly for private vehicles. Freight and public transport vehicles already drive slower. A lesser energy reduction of between 3% and 5% is, therefore, expected for these vehicles.

It needs to be mentioned that in water-based transport, reducing the speed would also have this effect (IAC, 2007). It has been estimated that the average energy intensity of shipping could be reduced by 18% in 2010, and by 28% in 2020, primarily via reduced speed and eventually new technology (IAC, 2007).

3.5.2. Intelligent Passenger Information Systems

The main uses of intelligent passenger information systems are to provide current, accurate real-time information regarding traffic flows to drivers. Many in-vehicle systems use Global Positioning Systems (GPS) to track their location, although other systems have also been explored over the years.

3.5.2.1 Traffic Information Flows

If traffic information centres collect enough information regarding the traffic flows, real-time information on congestion, delays, incidents and events can be provided, which can inform route selection and trip timing. Similarly, if information regarding the use of parking garages is collected, parking guidance can be provided, reducing unnecessary searching for vacant bays (therefore, reducing energy consumption). Modelling studies estimate that, if between 20% and 40% of road users are fully informed, network efficiency improves with up to 10%. Nevertheless, if 100% of road users are fully informed, network efficiency decreases, due to instability (Mahmassani, 2004). More recently, the University of Delft established that the network performance could reduce with a penetration rate as low as 15% to 20% (Lint, 2008). Although these systems are available on the market, no large scale research studies have investigated penetration rate, delay times and fuel efficiencies.

The information gathered by the traffic information centre can also be provided to in-vehicle systems, such as navigation systems (electronic in-vehicle systems that provide road information to the (co)driver). Although energy efficiency benefits are expected, no accurate estimate of the benefits can be provided at this moment in time.

3.5.2.2 Fuel Efficiency Information

The vehicle industry provides various systems that improve drivers' experiences. Warning systems refer to in-vehicle systems, such as anti-collision systems (using sensors), weather systems (via radio, navigation systems etc.), congestion warning and fuel efficiency systems (the so called econometer). Fully automated driver assistance systems can save up to 23% (Van der Voort, 2001). The introduction of fully automated systems is, unfortunately, not expected in the near future.

3.5.3. Intelligent Public Transport Systems

Intelligent Public Transport Systems have the following characteristics (Wright, 2007):

- Low-emission vehicle technologies,
- Low-noise vehicle technologies,
- Automatic fare collection and fare verification technologies,
- System management through centralized control centre, utilising applications of Intelligent Transport Systems (ITS) such as automatic vehicle location, and
- Signal priority or grade separation at intersections.

3.5.3.1 Fare Collection

Fare collection and verification systems represent a range of technology options that vary by cost and feature. The versatility of smart card systems has prompted many leading bus operators to adopt this technology option. Intelligent fare collection has two major benefits related to energy consumption. Firstly, smart cards often reduce the idling time, making the system more efficient. Secondly, the cards provide accurate Origin-Destination information that can be used to reduce trip length or number, vehicle size etc. on routes with less demand or at times that routes are less in demand. Optimisation of the fleet and schedule is therefore possible. Quantified information regarding this improved energy efficiency is currently not available.

3.5.3.2 Signal Priority

Active, or real-time, priority techniques change the actual traffic signal phasing when a bus rapid transit (BRT) vehicle is observed to be approaching the intersection, thereby reducing unnecessary deceleration and acceleration, idling or stopping. At an even higher level of sophistication, the priority phasing can be based on observed traffic levels for both the BRT vehicles and the general traffic. The importance of traffic signal priority on BRT vehicle speeds tends to be greatest in systems with fairly low bus volumes, particularly with bus headways longer than five minutes. When BRT vehicle headways are less than 25 minutes, it is generally difficult to implement active signal priority at all (Wright and Hook, 2007).

However, even with high bus frequencies, measures such as green phase extension and red phase shortening can be used, particularly at less important cross streets, yielding benefits on the order of a 4 percent to 10 percent reduction in traffic signal delay (Wright and Hook, 2007).

The development of a BRT system can also present a unique opportunity to upgrade the traffic signal technology along the same corridor. A new BRT system will imply several changes that will affect traffic signal technology. These changes include (Wright and Hook, 2007):

- New priority treatment for public transport vehicles,

- New exclusive lanes,
- New turning movements for public transport vehicles, and
- New restrictions on private vehicle turns.

With new electronic signalling technologies and software programmes now available, an upgrade of the traffic signal system should be integrated into the BRT planning process. The appropriate synchronisation of traffic lights often does not currently exist in developing cities. A readjustment of phase lengths and synchronisation should be undertaken with a special focus on smooth public transport vehicle flow. Some type of priority for buses can be introduced, such as “green extension” or “red shortening”. In these options vehicle detection, either using the GPS or fixed detectors (e.g. transducer), is required at the intersection. Information on arriving buses is given to the signal controller which can increase the green time or shorten the red time to not stop the buses. Green extension or red shortening is limited by certain constraints, so as to not affect signal synchronisation and the overall performance of the signal network. As indicated, priority signal technology is an option, but is not always feasible in high-frequency systems (Wright and Hook, 2007).

3.5.4. Freight-related Management Systems

Fleet management systems are based on navigation technology with feedback links to the operators. Operators are able to follow the vehicle, analyse driver behaviour and take steps if behaviour is unsatisfactory. 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% (Baas & Latto, 2005; Vanderschuren, 2006).

A specific freight based measure is the implementation of so called road trains, a measure explored in Europe. Vehicle-to-Vehicle communication allows trucks to platoon in a very efficient way. The modelling exercises clearly show that freight can be transported using road trains without any negative effects to the speed, travel time or safety of other road users (Hoogvelt, *et al*, 1996). Ludmann (Ludmann, *et al*, 1999) estimates an increase in throughput of between 10% and 14% on a two-way highway. In this study, a fuel consumption reduction of 34% was calculated as well. Road-train technology is still in a research and development stage. If at all, the introduction of road trains in South Africa will only happen in the medium- to long-term.

3.5.5. Rail-based Management Systems

Opportunities exist for improving train scheduling with information-based technologies. Often referred to as Intelligent Railroad Systems, they consist of sensors, computers, and digital communications to collect, process, and disseminate information to improve the management, planning, and safety of train operations (Stodolsky, *et al*, 2002).

Digital data-link communications networks provide the means for moving information to and from trains, maintenance-of-way equipment, switches, wayside detectors, control centers, yards, inter-modal terminals, passenger stations, maintenance facilities, operating data systems, and customers.

Positive train control (PTC) systems consist of digital data-link communications networks, continuous and accurate positioning systems, computers with digitized maps on locomotives and maintenance of way equipment, in-cab displays, throttle-brake interfaces on locomotives, wayside interface units at switches and wayside detectors, and control-center computers and displays. PTC systems also may interface with tactical and strategic traffic planners, work-order reporting systems, and locomotive-health reporting systems. PTC systems issue movement authorities to train and maintenance-of-way crews; track the location of the trains and maintenance-of-way vehicles; have the ability to intervene to prevent any violations of the movement authorities; and continually update operating data systems with information on the location of trains, locomotives, cars, and crews (Stodolsky, *et al*, 2002).

In addition to providing a greater level of safety, PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running-time reliability, higher asset utilisation, and greater track capacity. They will assist railroads in measuring and managing costs and in improving energy efficiency (Stodolsky, *et al*, 2002).

3.5.6. Air-based Management Systems

Improvements to the air transportation system and logistics (mainly due to information technology) can save an additional 5% to 10% of system fuel demand, both in the air and on the ground (Lovins, *et al*, 2005). Moreover, up to 18% of international aviation fuel is wasted as a result of inefficient infrastructure and operations (www.enviro.aero). The aviation industry has already developed and uses many operational measures to minimise fuel usage. Operational improvements could provide a further 6% overall fuel saving (www.iata.org). ITS systems play a major role in achieving this improvement.

The route a plane takes, the height it flies, and the weather it flies through all affect the amount of fuel it burns (www.enviro.aero). These factors are managed by air navigation service providers (the companies that provide air traffic control services). ATM enhancements could improve fuel efficiency and reduce CO_2 emissions by up to 12% (www.iata.org).

Taxi time is affected by the distance between the runway and the terminal building, by air traffic management and by congestion on the ground (www.enviro.aero). Traffic delays negatively impact fuel consumption and service levels. Improved design and expansion of airport facilities, along with more efficient use of air routes, will help ease the congestion experienced at some airports and thus reduce fuel demand.

Because of capacity constraints at airports and in the air over major hubs (when there are large numbers of aircraft trying to use the same runway or airspace), air traffic control will queue flights and allocate slots to land in safely (www.enviro.aero). This results in the aircraft circling the airport for a variable period of time, wasting fuel. All sectors of the air transport industry are working together to reduce the amount of time that flights have to circle through more efficient landing approach techniques, flight paths and on-the-ground operational programmes to clear runways more quickly (www.enviro.aero).

3.5.7. Conclusions on Traffic Management

Intelligent Traffic Systems represent a cost effective way to improve traffic flows, which in turn reduces energy consumption. Two systems have been identified as having the largest impact, namely: (1) optimising traffic controllers, which require investment in human capacity in the municipalities; and (2) variable speed limits, which can be implemented through government investment in highway systems based on Variable Massage Signs. In freight transport, ITS measures usually lead to improved scheduling and management, which results in energy savings.

3.6. Alternative Modes Use

In the second report the status quo regarding transport in South Africa was examined. The energy status quo reported clearly supports the view that certain modes are much more energy efficient than others. The overall efficiency of road, air, and rail transport depends on the extent of utilisation; higher occupancies for buses, trains and airplanes result in lower energy consumption (and emissions) per passenger-km. Potential mode shifts are very different for person travel versus freight movement, therefore person and freight trips are handled separately.

3.6.1. Potential Mode Shifts in Person Travel

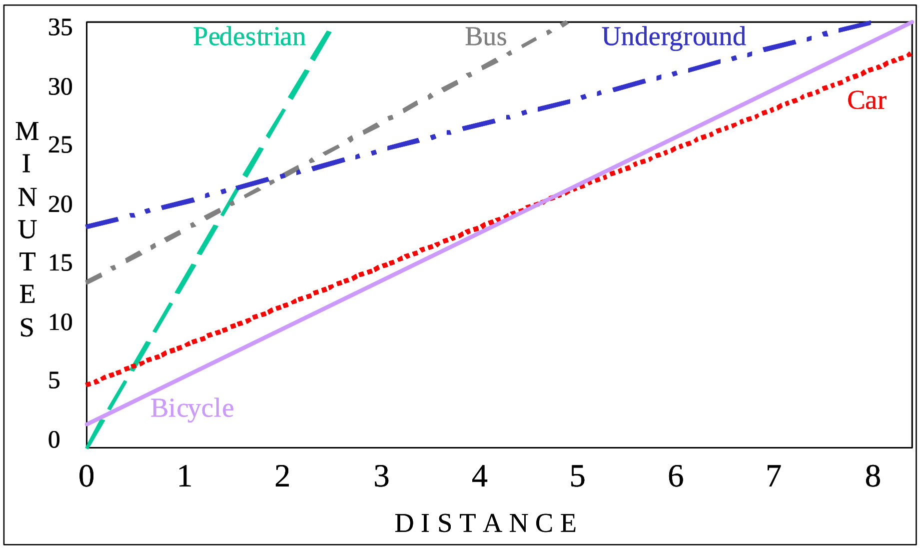
The general aim of mode shifts is to reduce the number of private vehicle trips and, more importantly, distances travelled in private vehicles. To do so, a shift towards collective modes (public transport, including air travel) and Non-Motorised Transport (NMT) is required. It needs to be mentioned that private car users in South Africa are considered to be the urban wealthy. A total of 74% of households (NDOT, 2005) do not have access to a private car and are, therefore, dependent on public transport and NMT in any case.

3.6.1.1 Encouraging a Shift towards Collective Transport Systems

Across the world, the average person travels between 60 and 70 minutes a day (Kraan, 1996). For commuter trips, this means that a 35 minute journey is considered acceptable. Pre-trip travel and waiting times hamper the competitiveness of public transport.

Based on average travel speed and pre-trip travel/handling time in European urban areas (epp.eurostat.ec.europa.eu/), it is possible to establish a time-distance diagram (see Figure 3.6-1). In Europe the average pre-trip time for bus is 14 minutes and for underground (train) 17 minutes (see also Figure 3.6-1). In South Africa, pre-trip times are quite similar- 9 minutes for bus and 17 minutes for train (see Section 2.1). Within the 35 minute acceptable trip time, a bus can provide approximately a 5 km distance while the underground/train can cover a 7.5 km distance (see Figure 3.6-1). Given the convenience of and the distance covered by car (8 km), it is unlikely that large shifts from the private car to public transport will happen for trips less than 8 km.

Figure 3.6-1: Time Distances based on Pre-trip and Journey Travel Time



Source: Vanderschuren, 2001

For medium distances (within urban areas, but longer than 8 km) upmarket public transport systems should be able to attract car owners. It has been established that speed, reliability, status, safety, security, convenience, comfort and costs are of utmost importance to choice travellers (Wright and Hook, 2007). The implementation of Bus Rapid Transit systems in urban areas using busways 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 (Vanderschuren, *et al*, 2008). It needs to be noted that a shift from car to other modes, might unlock so called latent demand, leading to an increased energy demand.

The effectiveness of policies in shifting passengers from cars to buses and rails is uncertain. The literature on elasticity with respect to other prices (cross price elasticity) is not abundant and likely to vary according to the context (Hensher, 2001). The Transport Research Laboratory guide showed several cross price elasticity estimates with considerable variance in preceding studies (TRL, 2004). Goodwin (1992) gave an average cross elasticity of public transport demand with respect to petrol prices of +0.34. Jong and Gunn (2001) also gave an average cross elasticity of public transport trips with respect to fuel price and car time of +0.33 and +0.27 in the short term and +0.07 and +0.15 in the long term.

For long distances, the demand for air travel already provides proof that the urban wealthy are willing to use collective transport based on travel time gains. Although air travel (excluding take-off and landing) is energy efficient over long distances, the pollution is unacceptable. The establishment of competing public transport modes, such as high speed trains and maglev systems, should, therefore, be investigated. The identified speed, reliability, status, safety, security, convenience, comfort and costs requirements (Wright and Hook, 2007) are also valid for long distances.

3.6.1.1.1 Taxes and Subsidies: Incentivising Shifts to Public Transportation

There are various ways of taxing road users. Most commonly, localised taxation is used around the world. Road Pricing is the term commonly used, which means that motorists pay directly for using a particular roadway or driving in a particular area. Road Pricing can be implemented as a demand management strategy, to fund roadway improvements or for a combination of these objectives. Economists have long advocated road pricing as an efficient and equitable way to pay roadway costs and encourage more efficient transportation. Road pricing should also be considered as a way of prompting car users to make greater use of public transportation; however, this will presuppose an effective and efficient public transportation system. Specific types of road pricing are (www.vtpi.org):

- *Toll Roads* are a common way to fund highway and bridge improvements. This is considered more equitable and economically efficient than other roadway improvement funding options

- *Congestion Pricing* (also called *Value Pricing*) refers to road pricing used to reduce peak-period vehicle travel

- *High Occupancy Toll (HOT)* lanes are High Occupancy Vehicle lanes that also allow access to low occupancy vehicles if drivers pay a toll. This allows more vehicles to use HOV lanes while maintaining an incentive for mode shifting, and raises revenue

- *Cordon (Area) Tolls* are fees paid by motorists for driving in a particular area, usually a city centre during weekdays. This can be done by simply requiring vehicles driven within the area to display a pass, or by tolling at each entrance to the area

- *Vehicle Use Fees,* such as mileage-based charges can be used to fund roadways and reduce vehicle travel.

All EU countries apply VAT to the purchase of motor vehicles and transportation fuel. This is a general tax applied to all goods (with a few exceptions) throughout the EU, and is used to raise revenue. In addition to VAT, 12 (out of a total of 15) EU countries have a vehicle registration tax (i.e. a tax or charge with a revenue raising function) payable at the time of first registration of a vehicle. These tend to be focused on passenger cars, motorcycles (12 countries), buses (7 countries) and trucks (6 countries) and are reduced for buses and trucks. In addition, some Member States also levy a registration fee payable on registration with the national vehicle register (Vanderschuren and Jobanputra, 2005). All these measures are trying to reduce vehicle ownership, which in turn hopefully will reduce vehicle use.

Fuel Taxes are often considered a road user fee, which can be increased to recover more roadway costs. Carbon Taxes are taxes based on fossil fuel carbon content, and therefore a tax on carbon dioxide emissions. Fuel tax increases are an effective way to reduce energy consumption and carbon emissions, but is less effective at reducing other emissions or other mileage-related costs. *Raising fuel price* has two effects, it causes modest reductions in vehicle mileage and over the long term encourages motorists to choose more fuel-efficient vehicles. A 10% price increase typically reduces fuel consumption by about 3% within one year and 7% over a five to ten year period. About one-third of the long-term energy savings is due to reduced driving, while about two-thirds results from consumers shifting to more fuel-efficient vehicles (www.vtpi.org).

Company cars and travel allowances in South Africa 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, *et al*, 2002; IEA, 1996).

3.6.1.2 Encouraging a Shift towards Non-motorised Transport

Non-Motorised Transport (NMT) is only a viable option for short distance trips. Figure 3.6-1 clearly provides an indication that acceptable (commuter) distances for pedestrians in Europe are about two kilometres. Cycling is acceptable up to eight kilometres.

In Section 2.1 it was established that more than 50% of South Africans use 'other' modes of transport, mostly NMT. The majority of these trips are on foot. Walking is much more important in South Africa than in Europe and other developed world countries. Moreover, due to financial constraints, many commuters walk much longer than would be acceptable for Europeans, up to three hours each way (Behrens, 2002).

In South Africa, walking is seen as a poor person's mode of transport. Moreover, given the high crime and road safety risk (about 40% of road fatalities are pedestrians according to Botha and van der Walt, 2006), it is unlikely that affluent car drivers will start walking, even if it is for less than the established acceptable 35 minutes.

Given the large number of cyclists participating in South Africa's cycle tours, the bike seems to be more acceptable as an NMT mode of transport for the urban wealthy. Nonetheless, to shift car commuters to the bicycle for anything other than recreational activities, will need more than just the availability of the vehicle. Weather conditions and topography have a severe influence on the likelihood for commuters to cycle. Moreover, the lack of infrastructure and road safety concerns hinders the unlocking of cycling's potential. Currently, only splinter infrastructure development is occurring, although various municipalities are trying to address this (i.e. COCT, 2005). It is concluded that, without large disincentives to using cars (such as very high fuel prices and/or taxes), it is not expected that car owners will move to NMT as a mode of transport (Vanderschuren, *et al*, 2008).

3.6.2. Potential Mode Shifts in Freight

Internationally in freight transportation, the least energy efficient mode is air freight and the most efficient mode is rail, followed by water-based transport and pipelines. Road transport is the second least efficient mode of freight transportation. The preferred modal shift is thus to increase the modal share of rail, water and pipeline freight transport. Several barriers to achieving this shift exist.

Not all freight transportation or commodities are suitable to all modes. It is generally accepted that shorter distance haul prefers road transport and long distance rail. If the commodity transported is time-sensitive or has an extremely high value to weight ratio, air transport is generally preferred. The transport network can, however, be structured around these constraints, by using an intermodal platform. Intermodality allows the use of the most suitable and efficient mode for each stage of a journey, for example trucks to transport products from the manufacturer to a hub, rail from one hub to the next and trucks again for local delivery.

South Africa has one major inadequacy when compared to both developing and developed countries, namely the lack of modal integration (CSIR, 2007). Intermodal transport has become very important, especially with the rise of containers as a freight solution. South Africa lacks the intermodal terminals and interchange facilities that can improve the logistical system by consolidating cargo, thereby increasing efficiency and simultaneously reducing logistics costs (CSIR, 2007). Several studies have promoted different regions or cities as logistics hubs. Each proposal has its merits, but what is required is an effort from national government in conjunction with the private sector to identify a suitable location for one or more logistical hubs based on predetermined criteria (CSIR, 2007).

For rail to obtain a greater share of freight transport, it would have to be competitive in terms of cost, speed, reliability, safety and convenience and would have to be able to accommodate supply chain strategies such as just-in-time manufacturing[6]. Improvements to rail and marine transportation infrastructure and services are needed to make these modes more competitive with trucking. Nonetheless, reducing shipping costs may lead to an increase of total freight traffic volumes, which in turn might lead to increased energy consumption (www.vtpi.org). Perhaps new systems, such as tubular freight and maglevs, hold the key to providing viable alternatives to trucks and the current rail system.

The creation of "freight villages" (areas within which activities related to freight transport, logistics and goods distribution are coordinated, including shippers, warehouses, storage areas, public agencies and planners, businesses, etc.) might act as a catalyst for modal shift and integration. To encourage intermodal transport, a freight village should be served by multiple modes (road, rail, waterways and air transport). This integrates the functions of freight handling and transfer to maximise efficiency (www.freight-village.com).

Pedal Express is an example of NMT in freight transport. It is a human-powered cargo delivery service in the San Francisco Bay area (www.vtpi.org). A fleet of cargo bicycles, capable of carrying up to 315 kg in watertight containers, is operated. Common deliveries include meals and baked goods, books, packages and post office box mail (www.vtpi.org).

3.6.3. Conclusions on Alternative Modes Use

Moving passenger and freight transport from less efficient modes to more efficient modes is, generally, a good strategy to reduce transport energy demand. However, this is not always viable. Governments and authorities are tasked to create conditions that will make these modal shifts viable through infrastructure development, incentives and disincentives. It is important to note that there is a ceiling to the achievable extent of mode shift.

It needs to be mentioned that infrastructure availability plays a crucial part regarding mode shift potentials for person travel, as well as for freight movement. In the short term (5-10 years), the transportation system will be relying on existing infrastructure. Moreover, reallocation of existing

[6] However, recent press reports (cf. Business Day, 07/08/08) note that South African Supply Chain managers are looking to rail for cheaper freight transport, albeit slower, and commenting that the costs of holding greater inventory stocks will be justified in a period of hyperinflation of oil and petroleum prices.

infrastructure, as happened during the implementation of the Bus Minibus Taxi (BMT) lane on the N2 in Cape Town, can support mode shifts. The total number of commuters (general commuters and BMT commuters) increased by between 24% and 29% during the morning peak period (Tichauer and Watters, 2008), due to the infrastructure reallocation. It needs to be mentioned that the improved level of service for MBTs increased the frequencies, which also contributed to the shift. Moreover, the increased commuter numbers did not only come from private cars, but also from other existing public transport facilities. Special lanes can also be created for freight, as is the case around the harbour of Rotterdam.

It is more cost effective to make better use of existing modes and infrastructure and to build on the most energy efficient elements of the present system, than to invest and introduce new systems. Given the time-span of the NATMAP, the investigation of new systems should be incorporated in the analysis.

3.7. Land Use Measures

3.7.1. Introduction

Most of South Africa's cities experienced their growth during the course of the 20th century. In large part, our cities were structured through the lens of segregation and apartheid so that black people were excluded from urban amenities and functioned to service the mines, factories and homes of whites, and were confined to ghettos on the urban edge or beyond. The evolution of our cities is also intimately bound up with the prevalence of abundant cheap oil that enabled individual mobility to, from and within urban areas. As the motorcar evolved and was mass-produced, it afforded individuals greater mobility, so the structure of our cities expanded horizontally into the form of urban sprawl that we have today. Urban sprawl as an urban form only works with high levels of mobility as it enables people to work, school their children, access medical care, recreational facilities and social services in different parts of the city. In South Africa, we rely for our mobility on the private car as well as busses, trains and taxis, particularly in black residential areas.

As oil production passes its global peak, we will need to consider seriously how appropriate our city models and structures are in an oil constrained and hence mobility constrained world. As has been shown previously, not only will the price of oil continue to rise substantially and become more volatile, there will be less of it to go around. This situation will not be a temporary one, but rather one that becomes increasingly severe putting relentless pressure on our current lifestyles and our urban transport systems, including the movement of goods and food.

Land use management has the greatest potential to reduce vulnerability to rising oil prices in the medium to long term. Travel demand is in large part a function of land use patterns and access to a variety of destinations, markets and services. Changes in land use development that improve accessibility by alternative modes will therefore reduce the need to travel by private vehicle and thus improve resilience to sustained high oil prices.

Transportation research in the 1990s began to question the ability and utility of public infrastructure providers to continually react to developer-led growth. Thus for the past decade, a desire to coordinate the provision of public infrastructure in advance of private development has led to increasing attempts to avoid urban sprawl with urban containment. Infrastructure-led development recognises that uncontrolled development on the fringe of urban areas incurs large infrastructure costs while also imposing high external costs on society in terms of environmental effects, such as vehicle accidents, air pollution, and noise (Jakob, *et al*., 2006, MOT, 2005b).

Awareness of the need to integrate land use planning with transportation is growing. It is important that this begins to be codified into both our land use and transport planning practices so that investment in the requisite transport infrastructure can be provided in a timely and efficient fashion.

A pertinent example of a spatial development strategy that reflects sustainable human settlement has been developed and proposed to the Stellenbosch municipality (Sustainability Institute and Probitas, 2008). To be sustainable, urban housing and/or transportation strategies need to be embedded within a sustainable spatially defined system of interdependent settlements which are linked to regional economies, but defined in ways that establish limits to growth. This is precisely what has been formulated as a strategy for the Stellenbosch municipal area. In practice this requires an unconventional approach to spatial planning where in contradistinction to existing town planning practices which lay down a predetermined spatial grid and identify sectoral linkages, the plan proposed for Stellenbosch reflects the principles of sustainable human settlement. The spatial linkages are the transportation routes and nodes and the modes of transport are aligned with the objective of sustaining human settlement for the majority of the people in an area. In practice this means that spatial transportation and settlement plans need to enable opportunities for the urban and rural poor (hence, to be pro-poor, and facilitate housing, transport and labour markets that work for the poor). In the case of Stellenbosch, the implications for a transport strategy that will align with and reinforce the sustainable settlement strategy, are public transport through bus and/or rail shuttle within the town and immediate peripheral precincts, with private vehicle car parking on the fringes. The logic also militates against the building of ring roads around the town, as a solution to the congestion of through traffic, as this withholds the flow of cash and resources to the town and its inhabitants. In a word this means that an effective transportation policy requires an appropriate, integrated spatial development framework, and should be embedded within that framework.

3.7.2. Living and Working

Municipal land use and transportation planning decisions directly influence whether people and businesses will have mobility choices that allow them to save energy and money.

How appropriate are our cities and the way they are structured to cope with the pressures of ever increasing oil prices? As the price of oil rises it is becoming increasingly difficult for people to live, work, school their children, engage in recreational activities and access health and other social amenities, particularly when these activities are spatially separated. Most people will need to use some form of mass transportation such as a bus, a taxi or a train to be able to fulfill the activities that make up their lives. Presently people with higher incomes merely get into their cars and drive to wherever they need to be.

Our suburbs and townships are going to need to become much more integrated and will need to work at a much smaller scale. Densities will need to increase placing pressure on existing service infrastructure. People will need to be able to access all the things they need without making long journeys. New modes of transport (or rather quite ancient ones) will dictate the structure just as the current structure has been made possible by cheap oil. High fuel prices and poor access to public transport will force many people to do much more walking and cycling to access amenities. Work related opportunities are going to have to find their way into the townships and the suburbs. More walking will bring with it the need for more security, particularly in our crime ridden areas. Security concerns are likely to increase as high oil prices will affect employment and affordability of staple foods. Increasingly we will need to create sustainable urban communities that require low levels of mobility and transportation.

Our big metropoles will need to be divided up spatially in ways that make economic and social sense and which enable urban living but on a much smaller scale. These areas will then need to be connected by fast, efficient and reliable public transport to facilitate the movement of goods and people between them. This will require a dramatic increase in investment in new appropriate public transport infrastructure. All of this will require high levels of coordination and planning in time frames that are becoming shorter by the day.

3.7.3. Local Economic Development and Food Security

Municipal economic development initiatives are opportunities to encourage development in low-energy, zero-carbon directions, by both incentive and example. As oil production begins to decline and there is less available on a yearly basis, so people will be forced to reduce their journeys and to travel less. Supply lines, too, will start to decrease and instead of an expanding global market we will begin to see a contracting one. As this process continues, we will see economies becoming much more local again. Raw materials will need to be procured locally, components will need to be manufactured locally, products will need to be assembled and distributed locally. This will provide an impetus for the development of a robust local economy. Building strong local communities will become more and more necessary in order to build local community resilience to reduce the effects of oil depletion. This form of local economic development needs to go hand-in-hand with initiatives to use less energy and to begin to develop the renewable energy infrastructure.

In its strategy to manage the decline in global oil production the city of Portland in the US state of Oregon has recognised that perhaps the most profound change that is likely to emerge from the peaking of oil production is that economies will need to become much more local (City of Portland, 2007). Our globalised economic relationships will be put under pressure as increased oil prices affect air and road transport dramatically, seriously challenging current business models. This will mean changing both economic and spatial arrangements so that local economies flourish. Importing and exporting (and anything that requires long distance transportation) will become much more expensive and will place huge strain on the economic relations that underlie these models. Like Portland, we too, will need to look at strategies to maintain business viability and employment in an energy constrained environment. The kinds of changes necessary will bring with them opportunities that could have positive social and economic impacts as we begin to spend less on imported fuel and redirect our money into local economies.

Food is a big concern as its production and distribution are highly dependent on oil. We will need to think about ways of producing food within our cities and distributing it locally to reduce the dependence on food produced using highly mechanised means with the use of fertilisers and pesticides which are fossil fuel by-products. The need for urban agriculture will require the need to utilise unused land in creative ways.

But what size of population can be sustained on urban agriculture? Will this place pressure on people to move to rural areas which will themselves be under pressure to convert their production to more labour intensive methods?

The following responses present different tools to assist with the transition to integrated land use patterns that efficiently reduce the need to travel by private vehicle.

3.7.3.1 Parking Regulations and Management

A recent study by the New Zealand Transport Authority (NZTA, 2008) has noted that parking regulations have had a huge and often overlooked impact on urban form, and have significantly contributed to sprawl and vehicle use. Indeed, parking may be the single most important transport – land use connection. In a review of parking policies Marsden (2006) describes parking as the "glue between the implementation of land use and transport policies."

Parking requirements are usually based on standards that assume each individual commercial, office or business development should provide on-site parking to cater for its peak demand for free parking. Parking demand is assumed to be generated by the size and type of land use, which ignores other (more relevant) factors such as ease of access to the site by other modes and existing capacity on nearby sites that have complementary peak demand hours. The cost of providing the land to meet parking requirements is not charged directly to the users of car parks, but is bundled in the cost of the development, thereby favouring single occupant vehicle trips over other modes. This generalized practice sets a norm for developments which then make it difficult to break the cycle because it would alter the commercial viability of new developments, making them less attractive to potential lease holders.

Some authors regard this practice as a form of inefficient subsidy which ends up making driving cheaper than its real cost, and therefore encourages driving (NZLA 2008).

In addition to subsidising single occupant vehicle trips and increasing the vulnerability of the transport system to high oil prices, minimum parking requirements have a wide range of negative impacts including: inflated demand for land and increased costs of living, particularly for medium to high density dwellings; increased costs of redevelopment in existing urban areas, particularly town centres and historic buildings; reduced urban densities that result in an autocatalytic cycle of motor vehicle dependence (Litman, 2006, Shoup, 2005).

Local authorities need to be aware that their parking regulations are a significant driver of low density urban sprawl, out-of-centre retailing, traffic congestion, and low alternative transport mode share. Minimum parking requirements have been responsible for a large portion of the compliance costs for redevelopment of urban areas and have driven many large developments to the fringes of urban area where land is cheaper, thereby undermining compact city development (Cervero, 1985).

As oil prices rise there will be greater pressure on local authorities to roll back subsidised parking provisions. This then begins to make way for a context in which public transport is encouraged and greater urban densities begin to take shape, creating more rational urban structures that lend themselves more easily to alternative transport use.

3.7.3.2 Flexible Zoning and Urban Containment

Zoning is a planning instrument that has traditionally been used to separate land use activities so as to minimise many of the negative external effects of commercial and industrial activities, such as pollution and noise. Many zoning regulations now place a large number of restrictions on land use activities, particularly type of activity, bulk of building, and density.

In attempting to manage the negative external impacts of development, some zoning regulations have contributed to a need for increased vehicle travel. One of the unintended consequences of zoning for single land use activities is the need to use vehicles to get from wholly residential areas to access the goods, services, employment, education and recreation provided in wholly commercial areas. Zoning for low density and single development inhibits the provision of efficient public transport services to these areas, by creating dispersed land uses.

This has in turn created a vicious circle, in that because of the urban sprawl, private vehicles are required to get around, and because private vehicle become assumed, no public transport is seen to be necessary. If it is seen to be required, it comes at a high cost because of the distances involved. So ironically, much of the noise and air pollution generated in urban areas is now directly attributable to the use of vehicles – in other words zoning regulations have partly perpetuated the very issues that they were designed to solve.

High fuel prices can be expected to generate demand for higher density and more diverse urban areas, and local authorities should be encouraged to create more flexible zoning regulations that allow for higher densities and a variety of uses to occur in developed areas.

It is acknowledged that density and diversity alone cannot ensure sustainable settlements. Urban design standards, noise and light regulations, and sufficient green space requirements will need to be introduced concurrently with mixed-use zoning to ensure that urban areas are developed in a way that preserves or improves standards of living and general amenity, to address the negative effects of development.

Industrial uses also have specific demands and thus may be better isolated from some land uses. Another instrument to be used in conjunction with flexible zoning is that of urban containment. That is, limiting growth to current urban areas or adjacent to planned transport nodes, such as rail stations. This will likely be necessary to transition from a low to a high oil price environment.

3.7.3.3 Investment in Public Transport Infrastructure

To incentivize commuters to change from a private car or other form of liquid fuel transport mode to a public (train or bus) mode of transportation will require the investment of sufficient public and private funding to make public transport a viable alternative mode, that is effective, efficient, timeous, secure and well maintained. This means that all tiers of government need to place the upgrading and improvement of public transport infrastructure on their agendas as priorities. It is critical that the transportation webs within cities as well as between conurbations are aligned with and supportive of the spatial development frameworks within which they would be embedded.

3.7.4. Spatial Planning: The Inter-relationship between Transport and Land Use

Dowthwaite, *et al*, (2007) argue that most people do not readily recognise the important linkages between transport, and land-use factors. Yet they contend that the two are deeply interconnected. The type of transport system chosen profoundly affects the type and character of land-use decisions that follow and the way in which residents end up commuting and attaining their daily needs. A decision to build a motorway, for example, creates pressures to convert (or re-zone) farm land into housing estates or retail outlets. Recent evidence suggests that when this development occurs it tends to follow a car-oriented form of land development similar to what is currently found in suburbs in the U.S. New growth around motorways in South Africa is usually designed using American style Euclidean Zoning. Euclidean zoning's main characteristic is the segregation or separation of uses. Shops, schools, and other amenities tend to be separated from residential zones and often best accessed by car.

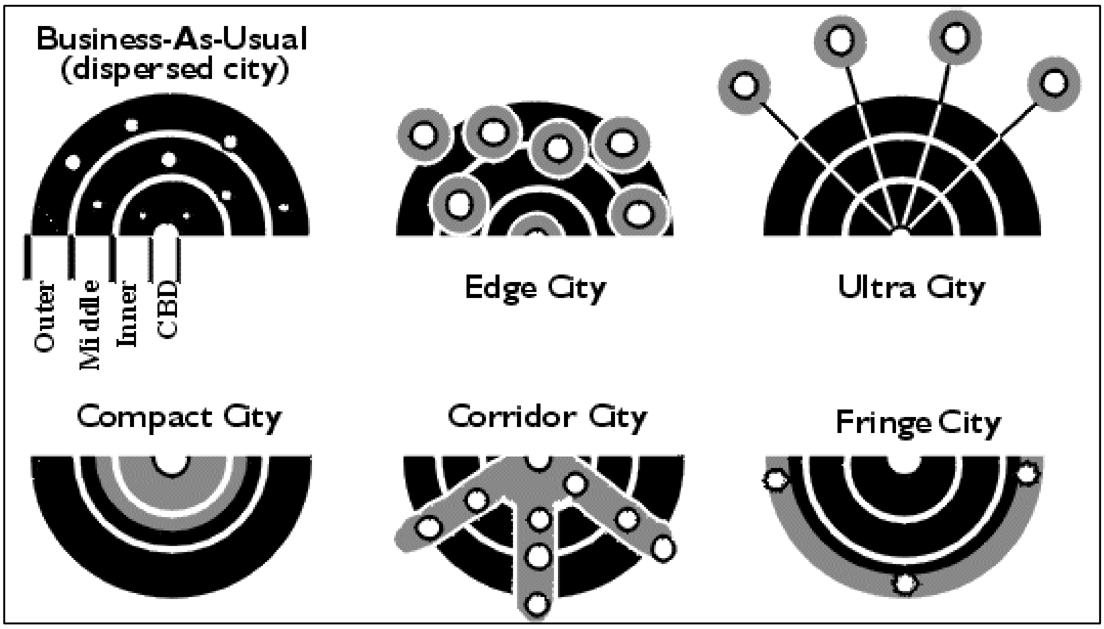
They argue that car use is typically a requirement due to distances and the lack of connectivity between suburbs. Transport planning efforts that emphasised public modes of transport typically have a very different impact on land-use planning and the built environment. Transit-oriented development of village oriented development uses public transport to deliver commuters to community, neighbourhood, or village centres where residents can walk or cycle to their homes and to attain their daily needs in neighbourhood shops, thus seriously reducing the need for a car. Land-use densities are also affected in part because residential density is needed to enhance the viability and efficiency of public transport.

The main parameter characterising the form of a city is its density, which has significant effects on travel distances and the modal split. Planners have investigated several growth patterns for cities over the years. In literature (Newton and Manins, 1999), at least six urban growth theories (Figure 3.7-1) can be found, of which examples exist around the world.

The business-as-usual city

In the business-as-usual city, new developments occur rather autonomously in any open space. From a transport planning point of view, transport infrastructure (in particular the road network) develops along the predict-and-provide method: supply follows demand. Business-as-usual cities generate dispersed settlements and long travel distances. Provision of public transport in this type of city is difficult. The private car has, therefore, a prominent role. This approach is not considered to be sustainable.

Figure 3.7-1: Growth Patterns for Cities around the World



Source: Newton and Manins, 1999

The edge city

The edge city features growth in population, housing density and employment at selected nodes and increased investment in freeways linking these nodes. The edge city is considered more sustainable than the business-as-usual city, as the nodes provide higher levels of services closer to home and, therefore, decreased travel distances. The main negative aspect is the distribution of activity nodes, limiting the possibilities for viable public transport. Most edge cities can be found in America. Local densities in these cities are higher than in the business-as-usual city. Nevertheless, the overall densities of cities are still low.

The ultra city

The ultra city features growth in regional centres within a 100 kilometres of the central business district. High-speed trains link the regional centres to the heart of the city. Although high-speed trains are a sustainable mode of transport, the ultra city development itself is not considered sustainable. Valuable open land is used for development, which could have been realised in (or closer to) urban areas.

The compact city

Compact cities utilise open spaces within the city. An increase in the population is realised within existing suburbs, therefore the densities increase. In general, compact cities are considered to be a sustainable way of extending cities and public transport is generally a viable option.

The corridor city

The corridor city tries to avoid the negative impacts of the edge city. Growth arises from the central business district and existing radial links (public transport) are upgraded. The corridor city is considered to be a sustainable city.

The fringe city

The fringe city has its growth predominantly on the outskirts. Large Australian cities are known to have distinctive rural-urban fringes and densities are low.

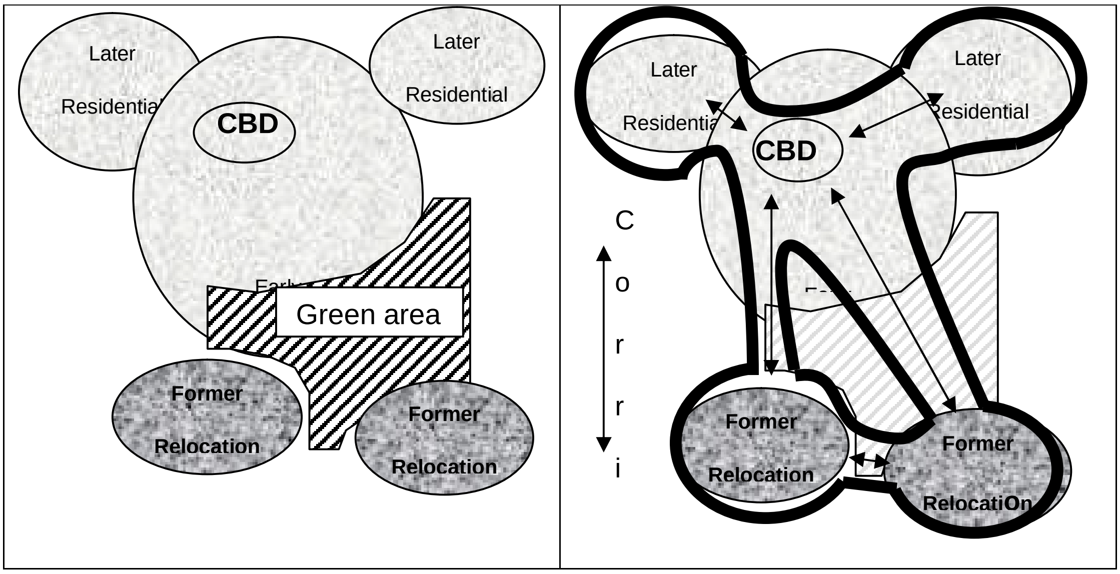
During the apartheid era (1948-1990), South African cities were also developed as fringe cities. Whites stayed in the developed areas, close to all facilities, while Blacks lived in the townships[7] far away from the developed areas. Public transport used to act as commuter service to take Blacks to their workplace early in the morning and bring them back in the evening (Vanderschuren and Galaria, 2003).

7 These areas were not considered part of the city though a big portion of the population lived there.

Figure 3.7-2 illustrates an example of the historical South African city structure. The northern parts of the diagram represent the areas where the wealthy urban live. The bulbs on the southern parts of the diagram represent the townships where the male workforce used to live (women often stayed behind in the homelands). The green areas were buffers creating a planned mobility barrier. The poor Black and Coloured workforce was not allowed to move out of their district on their own. As mentioned, people were transported for work purposes only.

With the end of apartheid, there are no longer restricted areas based on racial classification. Thus, freedom of movement has become possible and mobility for all people is encouraged. This brings with it the increased need for transport (Vanderschuren and Galaria, 2003).

Figure 3.7-2 : SA Traditional and Corridor-planned Cities



The South African National Department of Transport (NDoT) has adopted the corridor city approach (Minister of Transport & Department of Transport, 1999) as its focus (see Figure 3.7-2). Considering the historical layout of South African cities, this appears to be a sustainable way forward. It could also be argued that many South African cities have evolved and now have Edge City characteristics. For example, Johannesburg, used to have a clearly defined CBD and has now evolved to having a number of nodal centres around the city. These would include

Rosebank, Sandton, Soweto and Bedfordview. Cape Town, too, has a similar structure, with the CBD, Claremont, Bellville, Tyger Valley, Mitchell's Plein and Blaawberg.

The critical question that arises in the context of global oil depletion, is how to create sustainable neighbourhoods that reduce the need for road travel and where residents have all of their needs located within a small radius and can make use of non-motorised transport options. Sustainable neighbourhoods need to provide residents with work, schooling, health services and other public services as well as have provision for the production of food through urban agriculture. The issue from a transport planning perspective is how to link a series of sustainable neighbourhoods with fast, reliable and safe (public) transport?

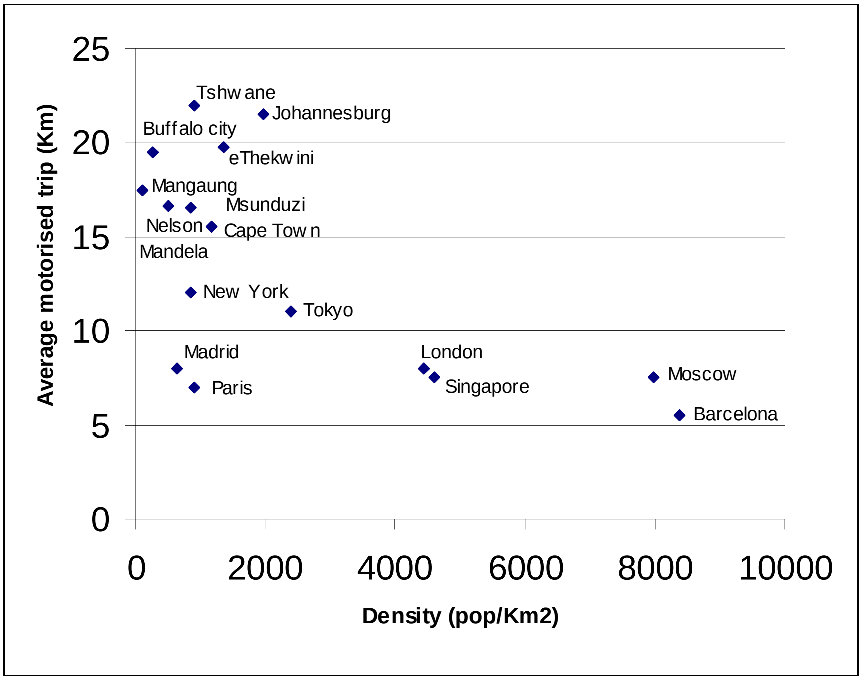
Unfortunately, the starting point for the new (democratic) government is difficult. On top of unsustainable land-use planning during the apartheid period, the general trend in South African cities was a reduction of densities. In Cape Town, for example, densities decreased over the last 100 years from 115 persons per hectare in 1904 to 39 persons per hectare in 2000 (Gasson, 2002).

Densities obviously vary for different agglomerations in South Africa. Figure 3.7-3 provides an overview of the densities per region. The figure clearly shows that Gauteng (Johannesburg and Tshwane), Cape Town and eThekwini have the highest densities.

As mentioned, densities in South African cities have been declining. Lower densities generally lead to larger distances travelled. Figure 3.7-3 shows that European cities and Singapore have a structure that reduces the need for motorised travel (even if the densities for the total agglomeration of Madrid and Paris are low). The main reason is that non-motorised travel is much more common in Europe than in other parts of the developed world, due to the more compact way of building. Moreover, Europe traditionally provides non-motorised transport infrastructure, which is often lacking in other parts of the developed world.

In New York, the average motorised trip is about five kilometres longer than in European cities. South African cities show even longer average motorised trips of up to 22 kilometres. It is clear that land-use patterns created during the apartheid era have had a negative impact on transportation; i.e. the need for motorised travel is unsustainably high.

Figure 3.7-3: Average Motorised Trip Length versus City Densities



Sources: Kenworthy and Laube, 1999; SA cities network, 2004, and estimates by the authors based on the NHTS[8], 2003

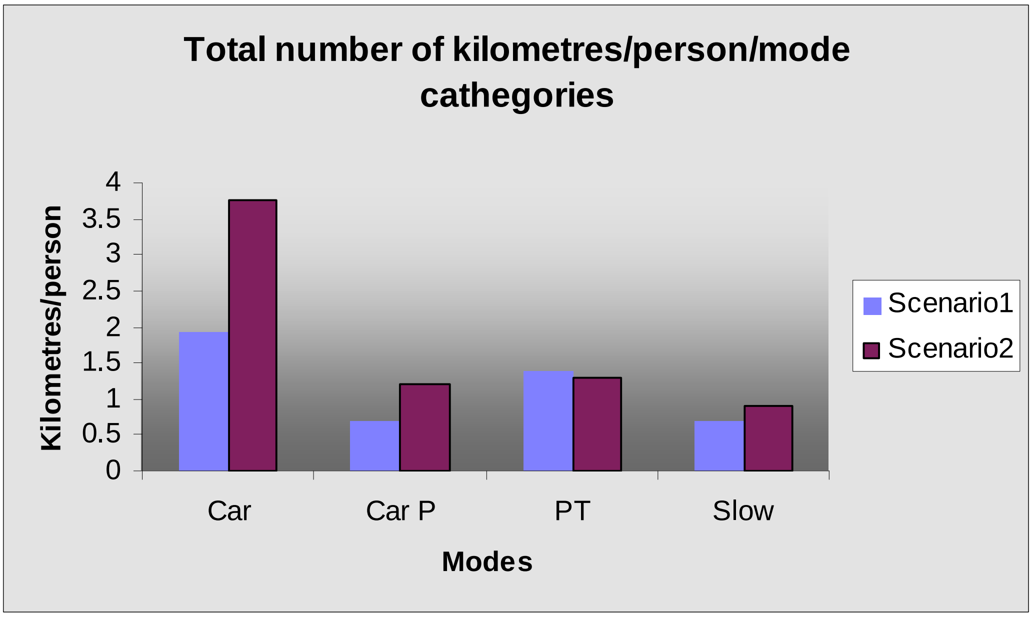
Given the correlation between vehicle kilometres travelled and energy use, it can be concluded that densification will reduce fuel dependency, and contribute to South Africa's preparedness for Peak Oil. Establishing the potential energy saving is beyond the scope of this study, as it requires extensive modelling.

3.7.4.1 Person Travel

Molai and Vanderschuren (2003) explored the reduction of vehicle kilometres for two case studies in Cape Town. A total of 600 housing units were planned in Kenilworth Central (Scenario 1) and Hannover park (Scenario 2). Figure 3.7-4 demonstrates the type of results obtained from the analysis of the two different settlements. It shows the total number of kilometres per person per mode.

[8] NHTS = National Household Travel Survey

Figure 3.7-4: Total Estimated Trip Kilometres/Person/Mode for Scenario 1 and 2



Although the demand (number of trips) for both settlements is equal, the model provides evidence that Scenario 2 (Hanover Park West) produces more trip kilometres (42% less private car km) per person than Scenario 1 (Kenilworth Central) for almost all modes. In this case it will be environmentally and economically wiser to build in Kenilworth, since it is more central and not on the periphery, where Hanover Park West is located. This brings us back to the point noted earlier that housing or rather new settlements, should not be built on the periphery of cities as it has major impacts on the existing transport systems, but that existing settlements should be densified instead.

3.7.4.2 Freight Movement

South Africa can be described as spatially challenged in a logistical sense due to the agglomeration of major industries in Gauteng in the centre of the country, which increases logistics costs when competing in the global market. In a global benchmarking study done by the World Bank, which compared the logistics performance of countries, South Africa was ranked 24th out of 150 countries (CSIR, 2007). This is a remarkable achievement considering that South Africa was ranked 124th based on domestic logistics costs. The high logistics costs are due to the high transportation costs of goods, which will continue to increase in the short term, firstly due to the geographical nature of South Africa's market and secondly, due to global factors such as higher oil prices. To exacerbate the spatial challenge, the movement from Gauteng constitutes double the movement towards Gauteng on the two main corridors (CSIR, 2007).

Environmentalists all over the world are advocating that the food miles should be reduced. It is suggested that choosing food that is local and in season means it does not have to travel so far. Bon Appetit Management Company, a US based food service contractor that serves 80 million meals a year, is planning to reduce its energy consumption by 25%. It will cut beef and cheese purchases by at least 25% and commit to buying only those meats raised in North America; it will stop purchasing any air freighted seafood and buy only local or frozen-at-sea fish; push for composting and less food waste and stop using any imported water.

Reducing food miles can have a dramatic effect on reducing energy consumption. Readers need to realise, though, that transport is not the only activity using energy in the food production and distribution process. In the US the energy consumption allocated to transport is 11% of the total energy consumption in the food chain (Weber and Matthews, 2008), while it is 9% in the UK (Practical Action, 2008). Although the reduction of food miles (kilometres) reduces energy consumption in transport, it is recommended to analyse the complete food supply chain.

3.7.5. Conclusions on Land Use Measures

Land use and planning play a significant role in determining the energy efficiency of our cities. Historically, South African cities expanded horizontally because this was possible due to the prevalence of cheap oil. This led to the evolution of inefficient transport systems. As we enter into an age of expensive oil, our cities will need to evolve so that they are far more energy efficient. This will require changes to the way in which we use urban land. Urban areas will need to increase their densities, adopt more mixed uses in areas which are more integrated so that fewer journeys are required and alternative modes of transport are encouraged. This will happen to some extent organically as residents adjust their lifestyles to take account of new circumstances, and needs to be complemented by regulatory measures.

3.8. Conclusion

This report has considered a range of measures that can be taken on both the supply side and the demand side to mitigate South Africa's dependency on imported oil and the likely impact of peak oil.

Supply side interventions involve the development of alternative and indigenous energy sources that can power existing and new motorised transport technologies. South Africa has a history of developing alternative fuel sources to oil. Sasol was established with the express purpose of reducing South Africa's dependence on imported oil. Since its establishment, it has been a pioneer in the commercial conversion of coal-to-liquid (CTL) fuels. Sasol is now the world's leading CTL producer and the group's technology and know-how are sought around the world. Unfortunately, this technology is both energy intensive and produces high levels of greenhouse gases. CTL conversion obviously relies for its feedstock on coal, which is itself a finite resource subject to depletion. Controlling emissions aside, CTL does not offer South Africa a long-term solution to its liquid fuels vulnerabilities.

South Africa is also a leader in the conversion of gas to liquids (GTL), despite the fact that South Africa does not have vast gas reserves. Relying on imported gas is risky in terms of security of supply and affordability. It was argued that biofuels are unlikely to significantly contribute to security of liquid fuel supply given the limitations on arable land and potential competition with food production.

Perhaps the greatest effort needs to go into developing electricity from renewable sources to power the rail network, as part of a comprehensive strategy to significantly upgrade the rail system. Phasing over from petrol and diesel to electrically-driven vehicles could also be a useful strategy provided there is a concomitant expansion of renewable electricity generation. With current technology, hydrogen powered vehicles are less efficient users of energy than electric vehicles and would require a new infrastructure system for delivery.

On the demand side, there is an extensive range of measures that the transport authorities could implement in order to reduce liquid fuel consumption. Some of these, such as fuel rationing and reduced road speed limits, were introduced in response to the oil shocks of the 1970s and are therefore tried and tested. Many of the traffic management systems and measures to influence driver behaviour have proved to be successful in limiting excessive fuel consumption and vehicle emissions in other countries. There is also considerable scope for reducing oil consumption through improved vehicle design.

Of particular importance to reducing liquid fuel consumption will be transport mode shifts: firstly a shift from private passenger to public and non-motorised transport; and secondly from road freight to rail freight. In respect of the latter, maglev systems show great promise in terms of energy efficiency, although infrastructure costs are likely to be high.

For the long term, transport planning should ideally happen in conjunction with sensible land use and spatial planning, both aiming to reduce transport distances and oil dependency.

The third report will develop quantitative scenarios of possible trajectories for (both imported and domestically produced) liquid fuel supplies as well as the fuel savings that could be achieved through a variety of the demand management techniques discussed in this section. These quantitative projections will form the basis for several descriptive scenarios relating to various combinations of future energy supplies and government/consumer responses.

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4. Transport Scenarios under Peak Oil, to 2030

A report submitted to the National Department of Transport by

The Association for the Study of Peak Oil (SA)

in association with

Marianne Vanderschuren

and

Tanya Lane

Glossary of Terms

Passenger road transport efficiency measures

Bio-fuels:	Liquid fuels (diesel and petrol) produced from dry organic matter or combustible oils produced by plants, which can be blended into traditional liquid fuels to substitute oil-based products.
Car pooling:	The shared use of a car by the driver and one or more passengers.
Company cars & travel allowances:	Company sponsored trips or vehicles. It is assumed that drivers are more prone to driving if they do not bear the full cost of travelling.
Driver assistance systems:	Real-time systems providing information to drivers on their fuel consumption.
Driver behaviour:	Driving techniques (for example gear shifts and acceleration/deceleration habits) that can, depending on the actual application, either improve, or decrease, fuel efficiency.
Electric or Hydrogen vehicles:	Alternative propulsion systems that use either electricity or hydrogen as the primary fuel source.
Hybrid-electric vehicles:	Hybrid propulsion systems that switch between a battery and a traditional internal combustion engine.
Integrated TDM:	Integrated travel demand management (TDM) measures such as telecommuting and ride sharing that have the effect of reducing the amount of physical travel required to achieve the same ends.
LPG vehicles:	Liquefied petroleum gas (LPG) vehicles use LPG as an alternative fuel source to petrol or diesel.

Maintenance:	Improved vehicle maintenance (such as proper tyre inflation or filter replacement) reduces excessive fuel demand.
Node:	A node is used in modeling tools to include intersections and junctions. If the tool focuses on public transport, a node might be used for a transfer point.
Pub. transport (PT) priority systems:	Intelligent transport measures that adjust traffic signal settings for public transport priority. This reduces the amount of idling of public transport vehicles. This can also include dedicated road infrastructure for public transport.
Road efficiency measures:	Optimised traffic signal settings and variable message signs that improve throughput and reduce idle time, reduces fuel consumption in vehicles using the road.
Smaller vehicles:	Smaller engines and lighter vehicles have better fuel consumption than heavier ones. If the average vehicle size in the car fleet is reduced, total fuel demand will also decrease.

Freight road transport efficiency measures

Aerodynamic fittings:	External covers and fairings to improve vehicular aerodynamics by covering the open spaces that decrease aerodynamic performance. Improved aerodynamics results in reduced fuel consumption.
Driver behaviour:	Driving techniques (for example gear shifts, idling and acceleration/deceleration habits) that improve fuel efficiency.
Fleet vehicle tracking systems:	GPS based systems that track vehicles and collect data on route choices and fuel consumption, which can be used as a very effective tool to manage driver performance in a fleet and detect vehicles in need of maintenance.

Hybrid-electric buses and trucks:	Hybrid propulsion systems that switch between a battery and a traditional internal combustion engine.
Lightweight materials:	The tare mass of a vehicle affects its fuel consumption. Replacing heavy materials with safe, lightweight materials will lead to improved fuel consumption.
Maintenance:	Improved vehicle maintenance (such as proper tyre inflation or filter replacement) reduces excessive fuel demand.
Road efficiency measures:	Optimised traffic signal settings and variable message signs that improve throughput and reduce idle time, thereby reducing fuel consumption in vehicles using the road.
TDM:	Travel demand management (TDM) measures such as load consolidation and vehicle routing that effectively reduce the amount of travel required to deliver the same amount of goods.
Tyres:	There are fuel efficiency gains if traditional twin tyre sets are replaced with wide-based tyres.

Rail transport efficiency measures

Aerodynamic fittings:	External covers and fairings to improve vehicular aerodynamics by covering the open spaces that decrease aerodynamic performance. Improved aerodynamics results in reduced fuel consumption.
Consist management:	The make-up of the train (sequence of trucks) can affect fuel efficiency if it is not optimal.
Engineer training (driver behaviour):	It has been recorded that different engineers achieve different fuel economies. Better training should result in improved fuel economies in general.

Idle reduction:	Idling consumes fuel without being productive; reducing idling will reduce unnecessary and unproductive fuel demand.
Regenerative braking:	A technique through which energy usually lost in the braking process is captured and used to charge a battery.
Rolling resistance:	Higher rolling resistance requires more fuel to propel a train forward. If rolling resistance is reduced, total fuel consumption will also be reduced.

Air transport efficiency measures

Air traffic management:	The scheduling of flight departures and arrivals has a great influence on aircraft fuel demand, as it affects the amount of time that aircraft circle the airport on approach and the amount of idle time on the ground. Managing this effectively can result in large fuel savings.
Aircraft improvement:	Improvements to aircraft aerodynamics will lead to improved fuel economy.
Infrastructure and operations:	The design of airports can lead to reduced fuel demand if taxi and idle time is kept to a minimum.
Maintenance:	Improved engine and aircraft maintenance reduces excessive fuel demand.
Redesigning auxiliary loads:	Auxiliary loads indirectly draw power from the engine. Ensuring that these loads are as energy efficient as possible will have positive fuel impacts.
TDM:	Air travel demand management (TDM) measures try to eliminate unnecessary travel and typically include routing and consolidation of flights.

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Executive Summary

This report is the third of four reports for the National Department of Transport on the implications of peak oil for the National Transportation Master Plan (NATMAP). This report identifies a number of plausible scenarios which arise as a consequence of global oil depletion. It builds on the information contained in the two previous reports in this series, namely: “Energy and Transport Status Quo: Demand and Vulnerabilities” and “Reducing Oil Dependency and Alternatives to Oil-based Transport.” The report considers how transport efficiency improvement measures, and alternative fuels, propulsion systems and transportation modes could be implemented within the context of different scenarios for the timing of peak oil and subsequent rates of oil depletion, over the next 22 years (i.e., to 2030).

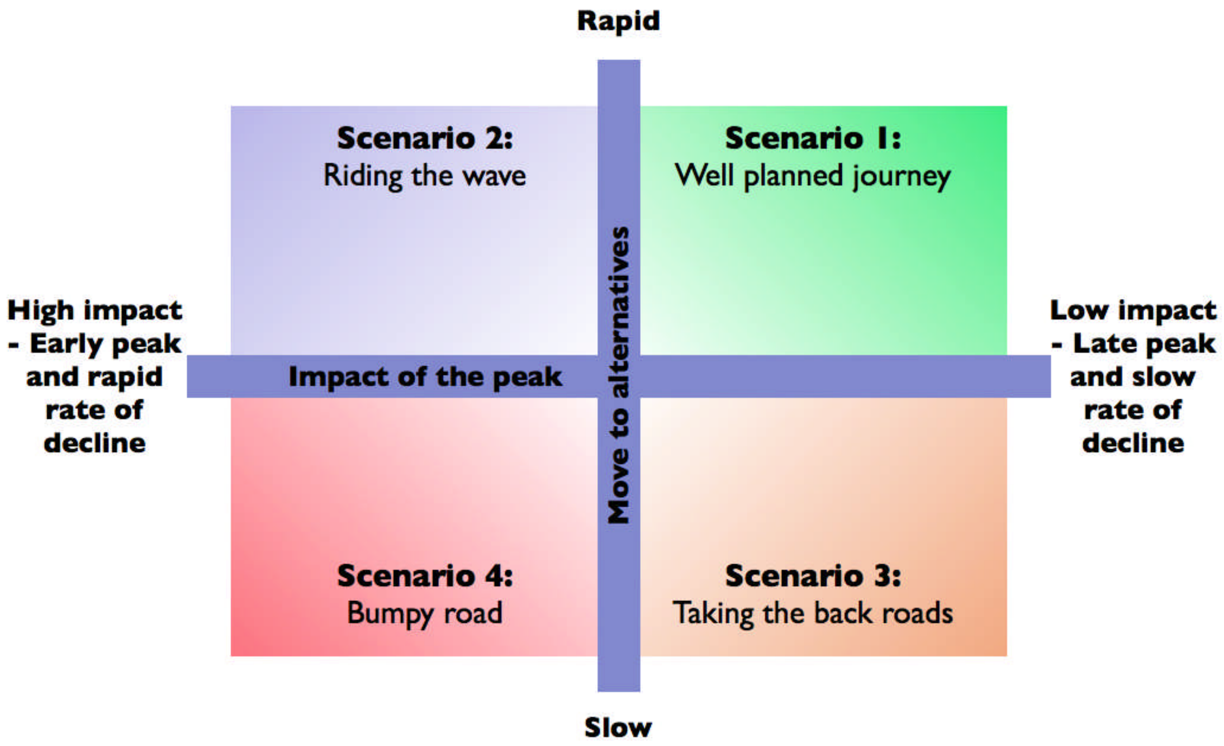
Scenario methodology

The focal question for the scenario analysis is:

“How long will it take for South Africa to reduce its dependence on imported oil and how can it make the transition to a sustainable transportation system?”

In the opinion of the study team, there are two sets of uncertainties that will have the most significant impact on the national transport system. The first set of uncertainties concerns the impact of the oil peak, in terms of how soon it occurs and how fast global oil production rates decline after the peak. For the purposes of developing these scenarios two possibilities were considered. Firstly, a low impact where there is a late peak and a slow rate of production decline. Secondly, there is a high impact set of circumstances, where there is an early peak with a rapid rate of decline in production. The second set of uncertainties relates to the speed at which alternative fuels, new propulsion systems and demand side transport efficiency measures can be developed and implemented, with government taking the lead. At one extreme there is a proactive response by government, whereas at the other extreme the response is limited or late.

These two areas of uncertainty can be plotted on two axes, which are then intersected to form a two-by-two matrix framework consisting of four scenario quadrants (see figure below).


Rapid
Scenario 2:
Riding the wave
Scenario 1:
Well planned journey
High impact
- Early peak
and rapid
rate of
decline
Impact of the peak
Move to alternatives
Low impact
- Late peak
and slow
rate of
decline
Scenario 4:
Bumpy road
Scenario 3:
Taking the back roads
Slow

Scenario 1: Well planned journey

In this scenario, there has been an early move to improving transport energy efficiency and to developing alternative energy and transportation fuels and systems, while the peak is late with a slow decline, providing everyone with an opportunity to be better prepared for the events as they unfold. By beginning to reduce oil dependence in advance of the peak, an orderly transition to alternatives is possible.

The quantitative projections contained in the following figure show that a combination of passenger and freight road transportation efficiency measures can reduce demand sufficiently to bring it in line with available supply in this scenario.

Scenario 2: Riding the wave

In this scenario, although there has been an early move to improving transport energy efficiency and to developing alternative energy and transportation fuels and systems, the onset of peak oil occurs almost simultaneous to the pro-active response. The early peak reinforces the response in an upward "virtuous" cycle but with a great deal of stress on the transportation system because there is little time for planning and implementation.

In addition to fuel efficiency measures, the riding the wave scenario requires modal shifts for both passenger and freight transport (see figure below).

Scenario 3: Taking the back roads

In this scenario there has been a hesitant move to improving transport energy efficiency and to developing alternative energy and transportation fuels and systems; fortunately there is a late peak and a slow decline with consequences less severe than first feared. The slow adoption of alternatives hampers decisive progress and creates unexpected events to catch planners and policy makers by surprise.

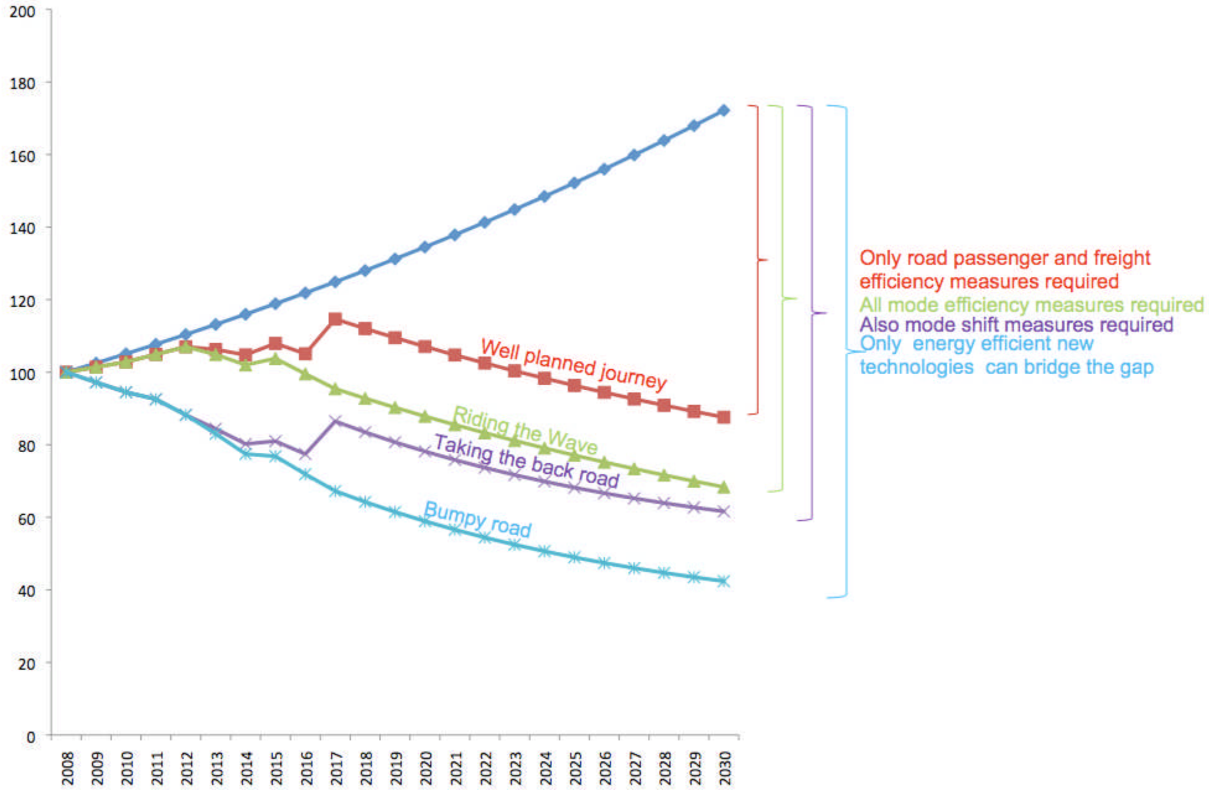
Although this scenario describes a situation in which there is a limited government response to the oil depletion challenge, for illustrative purposes the interventions that would be required for liquid fuel demand to match supply are calculated and shown in the following figure: transport interventions on all modes (road, rail and air) are required.

Scenario 4: Bumpy road

In this scenario the state, markets and civil society have generally continued practicing 'business as usual', while the impact of peak oil is severe, with an early peak and a rapid decline rate. This requires drastic measures to be taken that have often not been well thought through, causing many unintended consequences.

The bumpy road scenario assumes that the response to peak oil by government leaders and authorities is muted. However, for illustrative purposes the interventions that would be required for liquid fuel demand to match supply are calculated and shown in the following figure. The suite of efficiency measures and mode shifts is insufficient; this scenario would require new technology to bridge the gap between supply and demand.

These scenarios can be summarised in the following diagram which shows the accumulated effect of the measures taken and how closely they meet the ongoing demand curve:



During the assessment of potential measures to improve energy efficiency in the transportation system, clear packages of measures emerged. If the "Well planned journey" scenario materialises in the future, South Africa can rely on the improvement of road based transport, while in the case of the "Bumpy road" scenario, new technology is required to bridge the gap between the demand for and supply of oil. The following table provides a summary of the findings.

Peak oil projections	TRANSPORT INTERVENTIONS			
	Road based measures only	Road, rail and air based measures	Mode specific measures and mode shifts	Move to new technologies
Well planned journey	Entirely sufficient (Index: +10.9)	Not required	Not required	Not required
Taking the back roads	Insufficient (Index: -8.3)	Barely sufficient (Index: +0.1)	Not required	Not required
Riding the wave	Insufficient (Index: -11.9)	Insufficient (Index: -3.5)	Sufficient (Index: +3.3)	Not required
Bumpy road	Insufficient (Index: -64.2)	Insufficient (Index: -64.2)	Insufficient (Index: -64.2)	Entirely sufficient (Index: +10.1)

Conclusions:

- It is critical to start investing in measures now, as many of them have long lead times, where benefits are only realised after several years.
- It is possible to manage the process of making a transition to more sustainable transport systems. This will require authorities to begin to implement all interventions across all modes immediately.
- It should be kept in mind that although the scope of this study only extends to 2030, there is no definite reason why the trends will cease after this time (although the associated degree of uncertainty rises as one moves further into the future). With this in

mind, it seems to be a much better investment to construct a maglev system now, as benefits will extend beyond the study period.

- There are very distinct differences in the responses to the various scenarios, providing quite a strong message as to the risk posed by oil depletion.

4.1 Introduction

This report is the third of four reports for the National Department of Transport on the implications of peak oil for the National Transportation Master Plan (NATMAP).

The first report (i.e. Section 2) of this assignment examined the status quo with regard to transport and its energy usage in South Africa. It was made clear that in the context of the peaking and decline of global oil production, the South African transport system is very vulnerable, because of its high level of dependency on petroleum-based liquid fuels as an energy source, and the fact that about 70% of current liquid fuel consumption is met by imported oil. It was also noted that the peaking of global oil production will affect the world and South Africa in numerous ways and that we can expect to face challenging times ahead.

The second report (i.e. Section 3) looked at tackling some of these challenges head on. From an analysis of the strengths and weaknesses, opportunities and threats of various energy sources and propulsion systems, it appears that the greatest impact in the long-term would be to develop electricity from renewable resources to power most transport.[1] However, given competing demands for new electricity, the most effective strategy might rather be to focus on efficiency and conservation of oil-based and electrical energy within the existing transportation system, at least in the short- to medium-term. Significant energy conservation could be achieved through a shift from private passenger transport to mass public transport (road and rail), as well as from shifting freight from road to rail on major corridors. In energy management it is always preferable to improve efficiency first, as this is usually the least costly and least disruptive solution. Therefore, in the short term the authorities need to implement a range of measures that are tried and tested, to reduce fuel consumption through motor transport. In the medium term this would happen also through improved vehicle design. A comprehensive strategy to upgrade the rail system, as well as implementing local public transportation

[1] An interesting point is that the electrification of transportation should not simply be focused on rail (most railways in SA are electrified already). This report also clearly showed that rail is not the panacea it was once believed to be.

strategies (i.e. road closures to private motor transport linked to promotion of non-motorised transport, public buses and shuttles) are preconditions for making the critical transport mode shifts that need to be effected from private passenger to public transport and also from road freight to rail freight. Local transportation systems will have to align with local economic processes, which means that urban spaces will have to be shaped in ways that are appropriate to the needs of the citizenry and also sustainable over the long run. In the medium term land use and spatial planning will have to change to mould local transportation systems to a compact, minimum origination-destination social movement pattern – if this does not happen formally it will happen informally, but with greater social and technical costs.

This report identifies a number of plausible scenarios which arise as a consequence of global oil depletion.

From the first two reports (referred to above) we know that the future of energy supply and demand as well as transportation fuels and systems will be fundamentally different from the primary energy sources, fuels and systems that have underpinned our economy over the past 75 years. It is a reasonable expectation that there will be significantly less oil-based liquid fuel available, and that this will be sold at a significantly higher price than today. It is also reasonably certain that conventional means of transportation – mainly road motor transport driven by petrol or diesel fuelled internal combustion engines – will be greatly constrained owing to the cost increases of this form of transportation, making it less affordable for significant numbers of the population, and also owing to the fact that there is likely to be less fuel available to meet the demand. In short, the depletion of liquid fuel supplies, with concomitant price rises, means that we are going to have to change the ways in which we transport passengers and goods. The challenge is to formulate alternative forms of transportation, based on alternative fuels and propulsion systems, that will be sustainable in the long run, with the added imperative that this should not exacerbate South Africa's carbon footprint, i.e. the country needs to limit its contribution to global warming.[2]

[2] The precise nature of these commitments needs to be clarified. Under the terms of the Kyoto Protocol South Africa is regarded as a developing nation, implying that it does not yet have a fixed target for emission reductions. However a successor to the current Protocol is due to be agreed upon at the end of 2009, to take effect after 2012, and is likely to include emission reduction targets for developing countries, albeit less stringent than for countries with developed economies.

The second report identified alternative energy sources to fossil-based energy as well as alternative fuels and propulsion systems and transportation modes. It is uncertain when the production and supply of oil will peak, and how rapid the post peak depletion will be – yet the timing of the peak and rate of depletion are critical as a basis for deciding on alternative energy sources, fuels, propulsion systems and transportation modes. Likewise, the response of government, the markets and society to the timing of the peak and the rate of post-peak depletion is uncertain, but is also a critical factor that could enable or constrain policy-driven, market-driven and social practice interventions aimed at securing alternative fuels, propulsion systems and transportation modes. Any attempt at defining interventions needs to take account of the extent of the these two uncertainties.

To take account of the extent of these uncertainties this report aims to rehearse the future through *scenario thinking* (GBN, 2007: 4). Trends identified in the first two reports are used in conjunction with scenario planning as a tool for initiating new thinking about managing energy sources more strategically, identifying appropriate alternative fuels, propulsion systems and transportation modes in the face of inherent and increasing uncertainty – shaped by a wide range of geopolitical, environmental, economic and social forces. GBN (2007: 6) notes that: "Scenarios help us make sense of our emerging future. They are not predictions, nor are they strategies. They are stories, with a beginning, middle and an end. Scenarios outline, and then add colour and dimension, to plausible futures in which we might find ourselves. They enable us to rehearse the future, to test current strategies, and to generate novel approaches and options when it comes to making decisions today to prepare and plan for tomorrow. Scenarios also help us to discover robust strategies for a range of possible futures, and by so doing highlight the risks and opportunities inherent in each of these future worlds."

4.1.1 Subject of this report

The subject of this report is the sketching of how transport efficiency improvement measures, and alternative fuels, propulsion systems and transportation modes could be implemented within the context of different scenarios for the timing of peak oil and subsequent rates of oil depletion, over the next 22 years (i.e., to 2030).

4.1.2 Background to investigation

The investigation, of which this report forms a part, arose from a proposal that was submitted to the National Department of Transport at the invitation of the Deputy-Director General, Mr Situma, who is managing the process of developing the NATMAP. The intention behind this study is to complement the work which has already been commissioned by the Department to develop the NATMAP. To this end ASPO SA assembled a team of people whose combined expertise covers the critical issues that need to be examined so that the NATMAP will consider the impact of global oil depletion on both the South African transport system and space economy.

The objectives of this investigation are, therefore, that:

- It should produce a stand alone strategic set of documents
- These documents should be used as reference works by the consultants employed to develop the NATMAP
- These documents should be used as reference works by the National Department of Transport
- Pending Departmental decision these documents should be made available as public discussion documents
- These documents will contribute to drawing out the strategic implications of oil depletion for the transportation sector and its development over the coming decades until 2030
- These documents will contribute to setting out a number of routes to a likely end state within the time frame of the NATMAP

These documents will contribute to explicating the implications of these routes in terms of energy alternatives, energy savings and likely investment

4.1.3 Objective of strategic documents

The key objectives of these strategic documents, of which this specific report is the third, are:

- To highlight the key strategic implications for the transportation sector of global oil depletion

- To identify key principles which should be factored into transportation planning with a long-term time horizon in the light of the depletion of key energy and other resources
- To identify a number of plausible scenarios which arise as a consequence of global oil depletion
- To assess the risks associated with these scenarios to transport planning in the light of the inevitability of oil depletion during the time frame of the NATMAP
- To identify high-level alternative strategies to the current business-as-usual and demand-led approach for different modes of transport in the light of oil depletion

4.1.4 Limitations of scope of investigation

The scope of the investigation has been limited to an agreed table of contents for all four documents, between the Department of Transport, the main contractor and the ASPO (SA) consulting team.

4.1.5 Plan of development

There are several distinct phases to developing scenarios of interventions to address the problem of oil dependency and to quantify alternatives to oil-based liquid fuel transport. These phases comprise the following sections of this report.

The first phase (section 4.2) is an introduction to the scenario approach, which involves:

- Defining (or identifying) the focal question
- Considering five key forces (or force trends) that will impact on how the above question is answered (namely, social, technological, economic, environmental and political)
- Identifying key forces that are inevitable (or pre-determined)
- Identifying key forces that are most likely to define (or significantly change the nature or direction of) the scenario
- Defining the forces that are the most critical uncertainties

On the basis of the above, four plausible scenarios will be defined, which explore the timing of peak oil and the rate of post-peak decline, its impact on oil-based fuel as well as the move to alternative fuels, propulsion systems and transportation modes.

The second phase (section 4.3) will explicate the assumptions for oil and liquid fuel production both globally and locally, as well as the assumptions underlying efficiency measures in various aspects of the transportation system (i.e., road passenger transport, road freight transport, rail transport and air transport) and the modeling of these efficiencies.

The third phase (section 4.4) will develop the identified four plausible scenarios into composite scenarios, i.e. showing the systematic interlinkages of social, technological, economic, environmental and political factors, quantifying and comparing the projected transportation efficiencies against the energy and fuel available for transportation, and narrating the timing (beginning, middle and end), characters and plots. This phase will conclude each scenario with a plot that indicates the outcomes for different social agents (e.g. winners and losers) and also the transport system as a whole (e.g. crisis in the transportation system and the ability of the state, markets and society to response adequately to this crisis). These scenarios will lay the basis for thinking through the most likely future for energy, fuel and transportation in South Africa, and on that basis, in the fourth (and final) report to develop and risk analyse practical recommendations for interventions.

4.2 Introduction to scenario approach

GBN (2007) and Ogilvy and Schwartz (2004) are interesting examples of the utilisation of scenario planning as an approach to plotting the possible trajectory of events under conditions of climate change and energy depletion, on which we have based our scenarios.

GBN (2007: 6) notes that "Scenario thinking simultaneously considers a number of different possibilities in order to make better-reasoned choices and to rehearse today's decisions against a variety of futures. Such rehearsing often leads to decisions that are more likely to stand the test of time, create distinct competitive advantage, and produce robust strategies. By recognising the signs anticipated in scenarios, decision-makers can also gain advantage through flexibility, avoid surprises, and act effectively and proactively."

Likewise, Ogilvy and Schwartz (2004: 2) observe that "Scenarios are narratives of alternative environments in which today's decisions may be played out. They are not predictions. Nor are they strategies. Instead they are more like hypotheses of different futures specifically designed to highlight the risks and opportunities involved in specific strategic issues."

GBN (2007: 7) emphasises that in order to be useful scenarios must be focused, i.e. they need to be anchored by a focal question.

4.2.1 The focal question

From the work that was undertaken in Section 2 it was identified that the South African transportation system is highly dependent upon oil and is therefore vulnerable in the context of decreasing global supplies of oil. In this light, the critical question that needs to be asked is:

"How long will it take for South Africa to reduce its dependence on imported oil and how can it make the transition to a sustainable transportation system?"

This question encompasses the key issues that need to be considered in planning for the likely events that will shape the coming decades. Related to the question of time, the "how long" part of the question, are the investment decisions and their timing. Typically, infrastructural investments have long lead times as well as long life spans. The question of time also enables planners to structure interventions into different time horizons. Thus, short, medium and long-term measures need to fit with the programme's overall objectives.

The issue of our "dependence on imported oil" encapsulates the vulnerability of the transport system as was identified in Section 2. Our transport system is highly reliant on oil because of the high proportion of goods and people that are reliant on road transport for their movement.

"Transition" recognises that there will be a process of moving from where we are at present to where we need to be by building a sustainable transport system.

In answering this question we are explicating the implications of the impact of peak oil on the transportation system. The first report in this assignment described the powering and movement mechanisms as they currently exist and noted limits that oil depletion and oil pricing are likely to place on powering and movement mechanisms. The second report of this assignment explored alternatives to the conventional oil-based fuels and internal combustion engines (or movement mechanisms), as well as transport energy efficiency improvement measures, through which dependency on oil-based liquid fuel could be lessened. In the current report, knowledge of the status quo as well as insights into less oil-dependent fuels and transport technologies are combined and applied to develop scenarios that shed further light on the focal question.

4.2.2 Key forces impacting on the focal question

Based on the focal question the forces of change in the world that could have a significant impact on the issue in question need to be identified. Following GBN (2007: 7) the focus was placed on the following ten critical areas of uncertainty that are thought to comprehensively reflect the social, technological, economic, environmental and political forces that will impact on the events to be explored:

- The timing of the peak in global oil production

There has been much discussion amongst a variety of researchers and commentators as to when the peak is likely to happen. No one can say with precision when this will occur. There are many indications that the peak is likely to occur within the coming decade. The timing of the peak will greatly affect how much time there is to prepare for it. The level of preparation will affect how well or badly societies cope with the impact.

- The rate of decline of global oil production

  Whether the rate of decline is rapid or slow will have a significant bearing on how well societies are able to cope with the changes that the peak in global oil production will bring about.

- Advances in global energy supply and use technologies

  This is a reference to the state and development of technological forces. The third report in this assignment identified alternative energy sources (e.g. of which coal to liquids appeared to be the most promising alternative to oil-based liquid fuels), as well as propulsion systems based on alternative fuels (e.g. LPG vehicles, hybrid-electric vehicles, electric vehicles, etc.).

- Shifts in South African energy and transportation policies and regulations related to climate change (especially the impact of carbon dioxide emissions), fuel conservation and renewable energy sources and renewable energy-related transportation technologies.

  This refers to guidelines and regulations promulgated in terms of energy and transportation-related laws that impact on vehicle and aerodynamic design, driver-user behaviour and education, traffic speed management, transport modal shifts and public education campaigns.

- Public and stakeholder perceptions of climate change and energy depletion

  To a large extent these perceptions arise independently of policy makers' interventions, although public information, education and awareness campaigns can also influence consumer and stakeholder responses to a range of spontaneous occurrences and public policy interventions in the fields of energy and transportation.

- Shifts in financial markets that impact energy markets

  The current unwinding of global financial imbalances, which is manifesting as an extreme credit crisis, is a pertinent example of the interplay between global financial and local energy and transportation forces. Notwithstanding the structural shortages of oil and therefore of oil-based liquid fuels, in the present conjuncture where a lack of credit is pushing all the major developed economies into recession, there has been a significant fall in the price of oil over the past weeks (September-October 2008). This is providing temporary relief to energy markets by bringing down the cost of oil as the primary energy source for most economies, and presently placing a downward pressure on liquid-fuel prices. However this temporary easing of price inflation in oil-based liquid fuel-driven transportation markets should be interrogated rather than simply accepted at face value, because it could hide a longer-term upward trend in oil prices.

- Changes in energy commodity supplies

  This refers to the availability and supply of energy in the form of oil, liquid gas, electricity, uranium, etc. The quantity of energy commodity supplies depends partly on the reserves of that form of energy as well as the ability to commodify energy (i.e. add value and bring it on to the market). Conjunctural events, such as trade relations (including trade wars), as well as real wars over energy supplies could temporarily disrupt the supply lines of energy commodities, while regional alliances (like between South Africa and Venezuela) could enhance the supply of specific forms of energy (in this case, petroleum).

- International political and economic patterns around energy

  Geo-political alliances around energy have been cemented many years ago, for example between the United States and the elite ruling classes of certain Gulf States, while geo-political wars have, since 11 September 2001, became more frequent (Afghanistan, Iraq and possibly still Iran). In the former cases there has been a clear military move by the United States and Britain to safeguard their oil-based energy sources. In contradistinction to the alliances led by the United States is the emerging South Alliance of states grouped around Venezuela, which are favouring the use of oil energy sources for the development of local economic opportunity and social services for the majority of the population.

- Growth in energy efficiency

  This refers to intelligent traffic management systems, improved road efficiency, traffic information flows, fuel efficiency information, other transport-related systems as well as ways to shift to alternative and more efficient transport modes, referred to in the third report of this assignment.

- New business opportunities arising from energy and climate change

  Depletion of oil-based energy sources will lead to shortages as well as higher prices: in market-based economies the recent price spike in oil has already prompted the emergence of a plethora of alternative products, purporting to show the way forward. Peak oil, oil and liquid petroleum fuel depletion should, through the price mechanism, prompt a move of venture capital to other, non-oil-based, energy alternatives, and this would have an impact on the fuelling of transportation systems.

All the above factors will impact on, and, therefore, contribute to shaping the ways in which the South African transportation system will be powered between now and 2030, and also the transportation mechanisms and modes through which passengers and goods will be moved during this period.

4.2.3 Inevitable key forces

The factors referred to above are all significant determinants of the scenarios that will be explored. The extent to which each of these factors will have a greater or lesser impact is unknown. To simplify the scenarios, and also make them more useful as illustrative tools, it is necessary to narrow down the broad range of factors listed above. This is first done by asking which key forces seem inevitable or pre-determined (Ogilvy and Schwartz, 2004: 5); in other words, which trends are already in the pipeline that are unlikely to vary significantly in any of the scenarios. It is assumed that the development of new oil resources is likely to be such a slow changing phenomenon (e.g. the agreement between Venezuela and South Africa giving Petro SA access to exploring Venezuelan oil fields) that its impact can be safely discounted. The opinion is that advances in alternative energy supply and use technologies will be slow in coming, given the required research and development investment initially required and the typical long lead times to implementation; after implementation the impact could be stronger. In the opinion of the study team, the two uncertainties that have the most significant impact on the national transport system are the impact of the oil peak (in terms of how soon it occurs and how fast global oil production rates decline after the peak) and the rate at which local alternatives can be developed. For the purposes of developing these scenarios two possibilities were considered. Firstly, a low impact where there is a late peak and a slow rate of production decline. Secondly, there is a high impact set of circumstances, where there is an early peak with a rapid rate of decline in production. The other set of uncertainties relates to the speed at which alternatives can be developed and implemented. This brings together both the development of technology and the speed with which government can implement energy saving measures. The elasticity of the key forces referred to therefore needs to be kept in mind in each of the scenario narratives.

4.2.4 Key forces that can change the scenario trajectory

Which of the factors referred to are most likely to define or significantly change the nature or direction of the scenarios (Ogilvy and Schwartz, 2004: 5)? This assessment should be measured by two criteria – how uncertain is the outcome of a particular factor, or force, and how important is the impact of that force on the powering and working of the South African transportation system. Clearly, the impact of the oil peak will have a dramatic effect on both the ability to prepare adequately and on the consequences of either having been well prepared or not. The timing will have global implications that will have local consequences.

Other factors, which are likely to have a high impact but where the likelihood of occurrence is very uncertain, include: public and stakeholder perceptions and responses (e.g. will the taxi owners intensify their already sometimes violent completion or will they tend to be more co-operative under crisis conditions?) and international geo-political processes (e.g. will the US or Israel launch a military strike on Iran?).

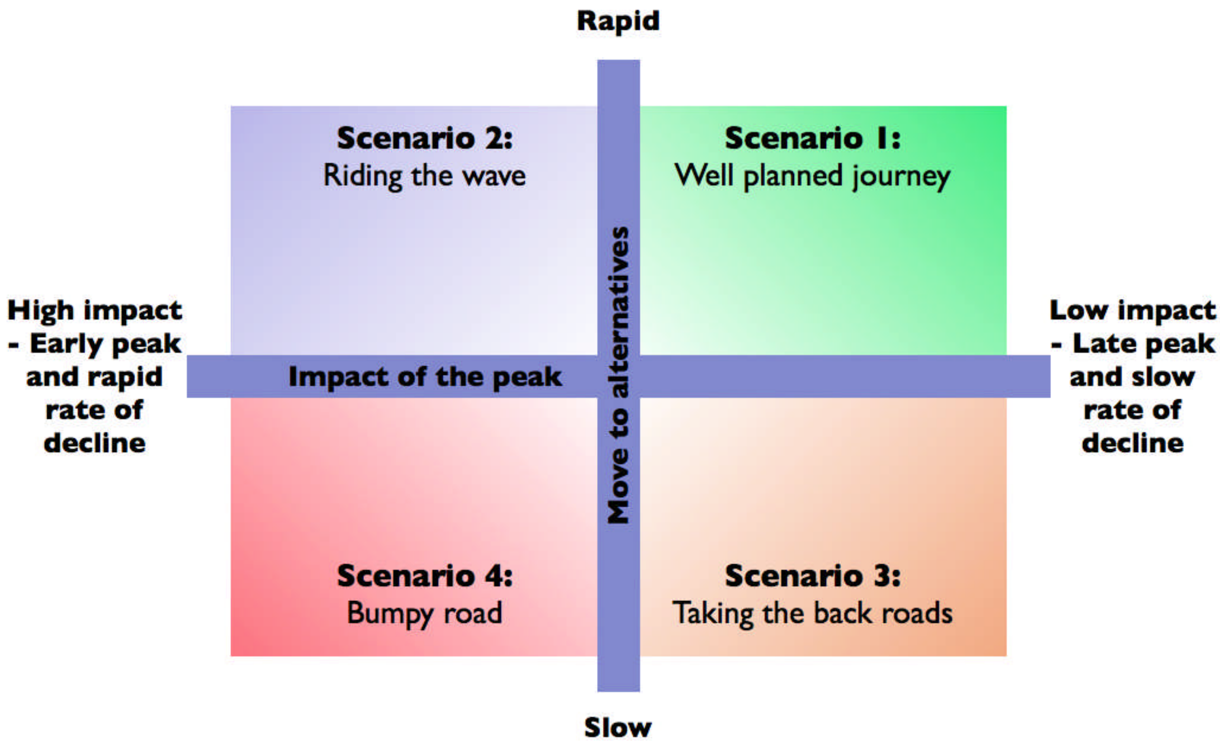
4.2.5 Most critical and uncertain factors

GBN (2007: 8) makes the point that the above uncertain factors need to be further whittled down to the two that simultaneously seem the most uncertain and most critical to the focal question. These two factors are then overlain on axes where the end points represent extremes of how that uncertainty might play out.

The first most uncertain yet critical impact factor is defined as “the impact of the oil peak”, with an early peak and a rapid rate of decline giving one extreme, giving less time to prepare while a late peak and slow rate of decline will give more time to prepare and more time to put in place the measures that will wean South Africans off this critical resource in an orderly manner.

The second most uncertain yet critical impact factor is defined as the rate at which alternatives can be implemented. The rate of deployment of alternatives will determine the depth of the changes that will be required across society. Prices on world markets will reflect the balance between demand and supply, and will be a partial function of the extent to which countries have been able to reduce their dependence on oil. The lower the dependence on oil, the better societies will be able to withstand the pressures of price and international supply constraints. High levels of dependence and slow rates of transition will keep demand high while lower dependence will reduce demand and hence prices.

These two axes are then crossed to form a two-by-two matrix framework consisting of four scenario quadrants (see figure below).



Scenario 1 is referred to as a "Well planned journey" because in this scenario, there has been an early move to improving transport energy efficiency and to developing alternative energy and transportation fuels and systems, while the peak is late with a slow decline, providing everyone with an opportunity to be better prepared for the events as they unfold. By beginning to reduce oil dependence in advance of the peak, an orderly transition to alternatives is possible.

Scenario 2 is referred to as "Riding the wave" because in this scenario, although there has been an early move to improving transport energy efficiency and to developing alternative energy and transportation fuels and systems, the onset of peak oil occurs almost simultaneous to the pro-active response. The early peak reinforces the response in an upward "virtuous" cycle but with a great deal of stress on the transportation system because there is little time for planning and implementation.

Scenario 3 is referred to as "Taking the back roads" because in this scenario there has been a hesitant move to improving transport energy efficiency and to developing alternative energy and transportation fuels and systems; fortunately there is a late peak and a slow decline with consequences less severe than first feared. The slow adoption of alternatives hampers decisive progress and creates unexpected events to catch planners and policy makers by surprise.

Scenario 4 is referred to as a "Bumpy road" because in this scenario the state, markets and civil society have generally continued practicing 'business as usual', while the impact of peak oil is severe, with an early peak and a rapid decline rate. This requires drastic measures to be taken that have often not been well thought through, causing many unintended consequences.

Within each of these scenarios the rate of depletion of oil and transportation fuels and also the extent of the move to alternative transportation fuels and systems have been quantified and these measures have been captured in the graphs that accompany the scenarios. The quantitative projections of energy supply and demand, as well as the extent of energy savings through efficiency measures, alternative transportation fuels, mechanisms, propulsion systems and general traffic mechanisms, is explicated in the following section.

4.3 Assumptions underlying quantification of energy supplies and transportation efficiencies

Certain assumptions were presumed, which underlie quantification of the energy scenarios as well as the impact of a range of transportation efficiency measures, which could be applied within the context of each energy scenario. These two sets of assumptions, as well as an explanation of the mechanism for projecting the impact of transportation efficiency measures, are explained in the following two sub-sections.

4.3.1 Liquid fuel scenario assumptions

This section explains the assumptions on the basis of which quantitative scenario projections have been developed for future liquid fuel supplies for South Africa. The projections include future oil imports and domestic liquid fuel supplies (derived from coal-to-liquids [CTL], gas-to-liquids [GTL] and biofuels) under various assumptions, which are spelled out in detail below. Liquefied natural gas is not included here, but is rather included in the transport energy demand projections in the next section. Electricity supply is also excluded from the projections of alternative fuels because the demand and supply of electricity in the country are determined by so many factors and are therefore subject to a great deal of uncertainty (see the discussion in Section 3.1). Demand sectors other than transport (e.g. industry, commercial services, residential and agriculture) account for the vast majority of electricity consumption, while transport uses less than 2% of the country's electricity. In Section 3, estimates were presented of the amount of electrical power that would be required for a conversion of the existing road vehicle fleet to either electric or hydrogen vehicles; those figures provide an indication of the amount of electrical energy that would be required for private passenger transport.

4.3.1.1 Units of measurement

The unit of measurement for the initial quantitative projections is barrels per day of refining capacity. This unit was chosen because available information on future petroleum product supply (such as expansion of CTL production) has been quoted in terms of oil-equivalent barrels per day of capacity, rather than say litres of refined product. Refining capacity is not the same as production volumes of transport fuels, since the refining process also produces other petroleum products, such as LPG, paraffin, fuel oil and bitumen. However, it is assumed for simplicity that the proportional split between transport fuels (petrol, diesel and jet fuel) and the other products out of total refined petroleum products remains constant over time, so that the refining figures can be used as a proxy for transport fuel volumes. What is important for the projections is the trajectory over the long term, rather than the unit of measurement. The total fuel supply figure in the various scenarios is then converted into a unit-free index, with a value of 100 in the base year 2008. This facilitates easy comparison and interpretation of the figures, as well as the addition of transport demand efficiency measures, which are considered in Section 4.3.2.

4.3.1.2 Prices, supply and demand

The prices of liquid fuels and their impact on demand and hence consumption is not explicitly included in these projections. However, the supply trajectories do indirectly indicate the possible impact of energy (especially oil) prices in the following manner. As global oil production declines after reaching its peak, the prices of oil and other liquid fuel substitutes will have to rise sufficiently to bring global demand down in line with available supply (this process is termed ‘demand destruction’ by economists).

These rising world prices of oil can also be expected to dampen demand for fuels in South Africa. Currently, indigenous fuels are priced according to an import parity pricing formula; i.e. CTL and GTL fuel prices are benchmarked on international refined fuel prices. Demand for transport fuels in South Africa might also fall because of worsening economic conditions (such as falling real incomes and rising unemployment) in the wake of the oil peak, as described in

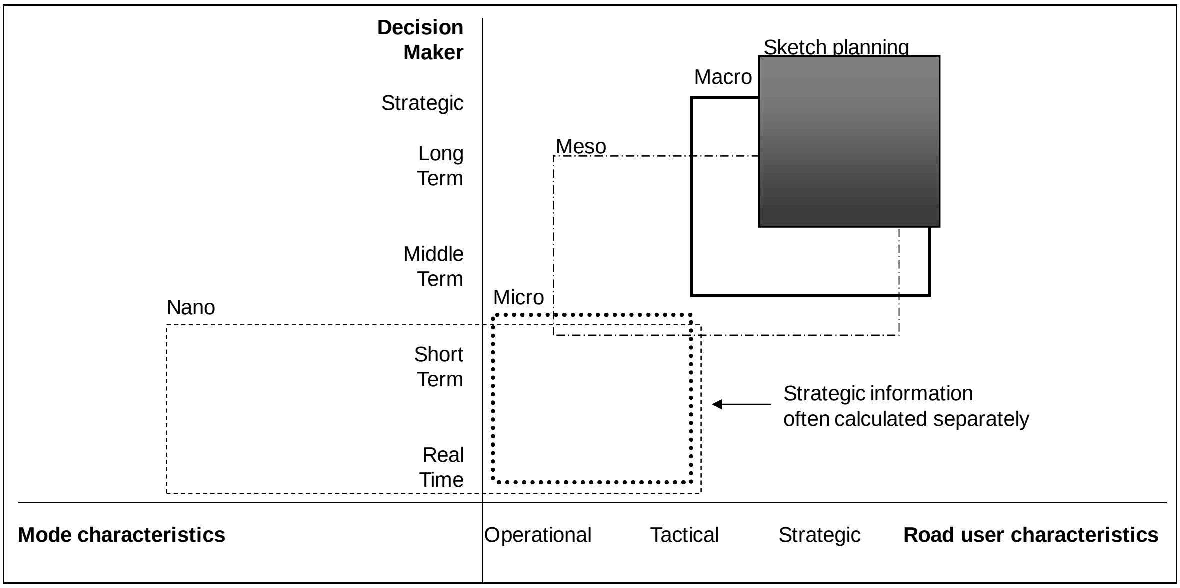
Section 2.3. Therefore projecting possible future oil prices is not necessary for this exercise, as supply limitations will arguably be the primary factor driving oil prices. In a sense then, the liquid fuel supply projections give an indication of how much fuel South Africans will demand given current transport infrastructure and given that prices are expected to rise over the long term, reflecting declining supply.

4.3.2 Transportation efficiency measure assumptions

Decision makers, who typically use projections of transportation efficiency measures, operate at different levels. Historically, conventional transportation planning has required medium- to long-term decision making, a planning horizon for which the four-step model (or, traditional macroscopic model) was developed. In recent years, the planning horizon of decision makers has changed and they have been increasingly required to make strategic decisions (like changing fuel levies): tailor-made sketch planning models have been developed to calculate projections regarding the expected effects of strategic decisions.

At the same time there has been an increasing awareness that the predict-and-provide approach will not by itself result in a sustainable transportation system, because of unknown causative factors and the unintended effects of known factors. Consequently, ways to utilise existing infrastructure capacity more effectively has emerged as one of the principal aims of a new approach to transportation planning. Intelligent Transport Systems (ITS) are an example of the types of measures that are currently explored to achieve greater effectiveness as well as higher levels of efficiency of existing systems. To estimate the effectiveness of ITS measures real-time or short-term models with high levels of detail (microscopic simulation models) are needed. Figure 4.3-1 provides an overview of the type of models available.

Figure 4.3-1: Trade-off between the decision horizon and model characteristics



Source: Vanderschuren, 2006

Based on the flow and traffic dynamics representation, transport models can be divided into five types:

- Although based on the four-step transport model theory, **sketch planning models** are tailor-made for specific questions. In general, a higher aggregation level is chosen when using this approach to model the impact and effectiveness of transportation efficiency measures.

- **Macroscopic models** are based on the four-step transport model. Individual vehicles are not recognised in macroscopic models. The network representation is based on links, nodes and attributes. Aspects such as traffic controllers are included as a node delay.

- **Mesoscopic models** include a representation of individual vehicles (or small 'packages' of vehicles with similar characteristics). Traffic dynamics are based on fluid approximation and queuing theories. The network representation is link and lane based. Traffic control systems are detailed models based on aggregated capacity equivalents.

- **Microscopic models** include a representation of individual vehicles and traffic dynamics through vehicle interaction and movement. Driver behaviour is included in a more detailed way (often via driver classes). Departure times of vehicles are available for every one to five minutes.
- **Nanoscopic models** are micro-simulation models that also include vehicle dynamics, such as turning radius and acceleration power.

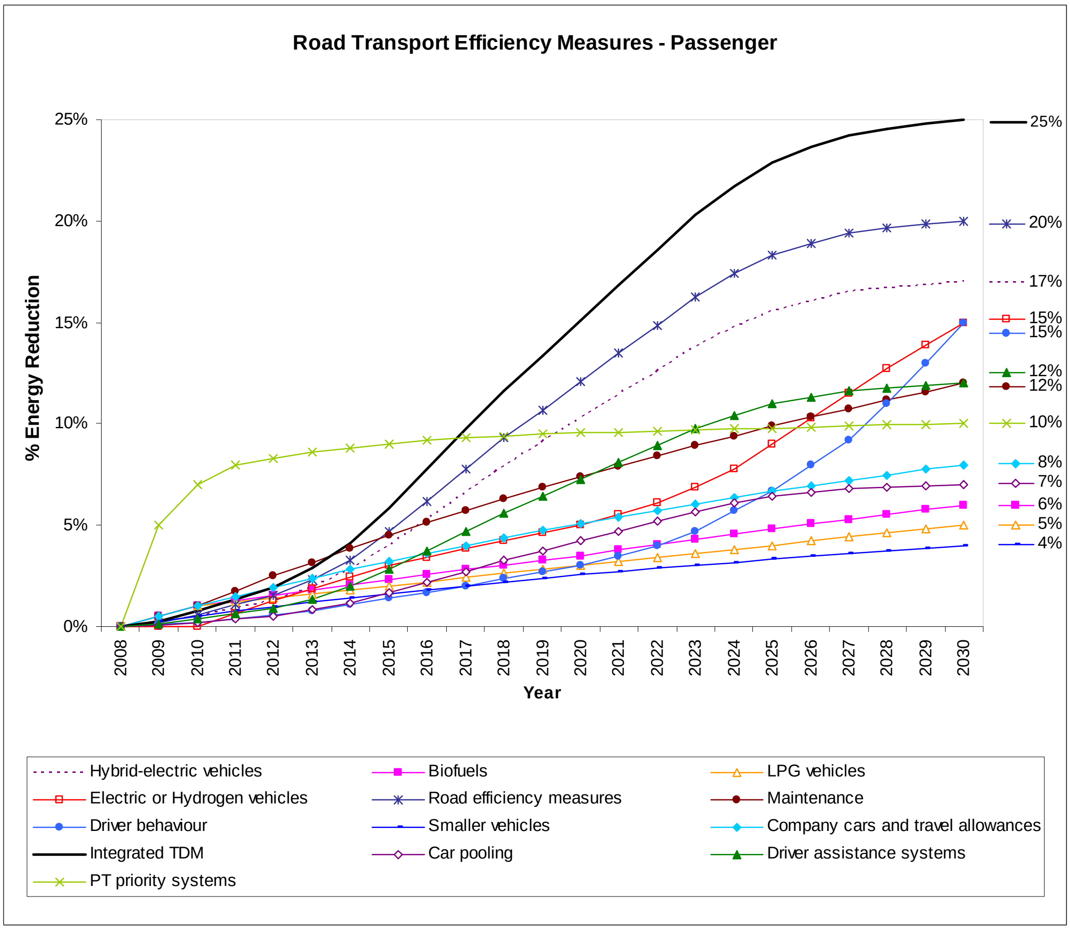
Due to their specific nature, each of the models referred to is usually applicable to different geographical scales. Sketch-planning models have been developed to calculate national, provincial or metro-wide changes. Macroscopic models were developed for main road networks (highway systems and other primary roads). Mesoscopic models are mostly used for corridors and include, as mentioned, traffic controller calculations, as well as secondary roads. Microscopic and nanoscopic models are generally used for any type of road or corridor where knowledge of the interaction of vehicles is needed. Generally, the research area will be smaller than for macroscopic and mesoscopic models.

A custom-made sketch planning tool was developed for this assignment, on the assumption that the government's aim is to plan transportation measure mitigation processes that can close the predicted gap between supply of and demand for conventional oil-based liquid fuels.

The second report of this assignment refers to and describes various energy efficiency improvement measures across all modes of transport. The following charts indicate the expected penetration rates, as well as the total energy saving potential that can be achieved by implementing each measure individually, based on the sketch planning tool's outputs. It should be noted that these benefits cannot simply be added up, as measures interact with each other and sometimes overlap with or eliminate other measures. The values shown are an indication of the maximum expected percentage oil demand reduction that can be achieved by implementing each measure by itself.

4.3.2.1 Passenger road transport efficiency measures

Figure 4.3-2: Passenger road transport energy efficiency improvement measures



See also Appendix 1

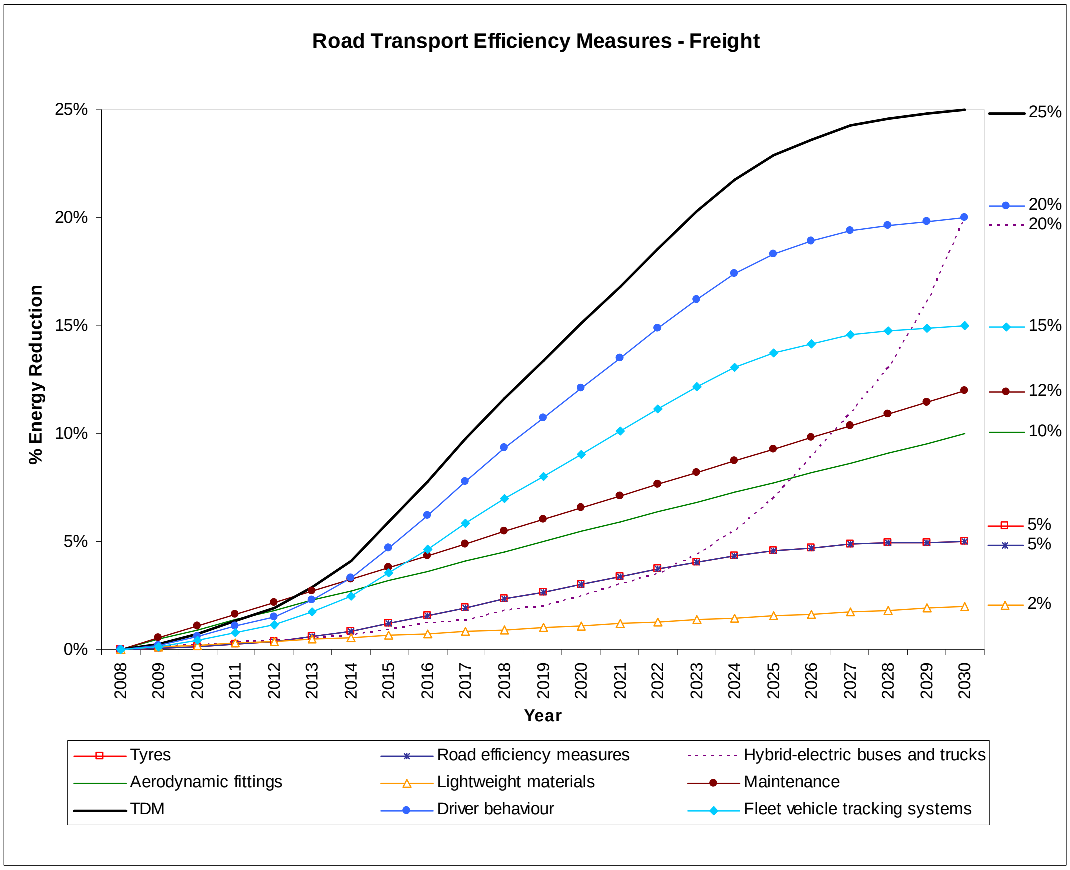
Public transport priority systems are currently being implemented in various cities across the country, aiming for first phase completion by 2010 (for the FIFA Soccer World Cup). It is assumed that once these systems are up and running, no additional benefits will be realised.

The shift towards either electric or hydrogen vehicles, as well as driver behaviour change is expected to start slowly and pick up sharply towards the end of the period. Driver behaviour change, for example, starts off with only a few drivers, then those drivers each influence other drivers and change progresses rapidly, but eventually most drivers are operating as efficiently as possible.

Driver assistance systems, TDM, road efficiency measures, hybrid vehicles and car pooling are all expected to follow an s-curve. That is, the impact on energy use starts off slowly, picks up the pace and shows massive gains and then tapers off towards the end of the period, once saturation has been reached.

4.3.2.2 Freight road transport efficiency measures

Figure 4.3-3: Freight road transport energy efficiency improvement measures



See also Appendix 2

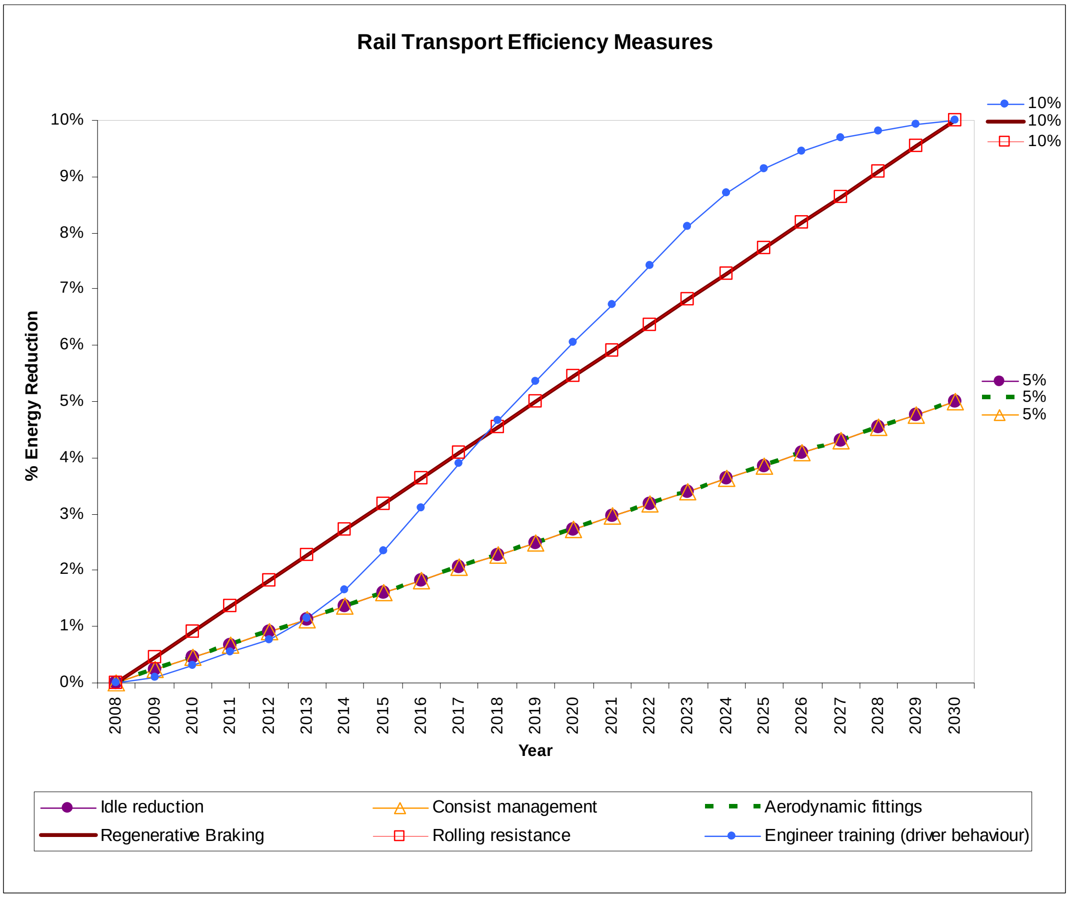
Hybrid-electric buses and trucks are not expected to be adopted widely for many years, but once they become popular the prevalence of these vehicles will likely be high.

It is expected that TDM measures, driver behaviour changes, fleet vehicle tracking systems road efficiency measures and a shift towards more fuel efficient tyres will all start off slowly, then pick up in terms of effectiveness and taper down before the end of the period (following an s-curve).

Vehicle maintenance, the installation of aerodynamic fittings and use of lightweight materials are expected to increase gradually over time.

4.3.2.3 Rail transport efficiency measures

Figure 4.3-4: Rail transport energy efficiency improvement measures

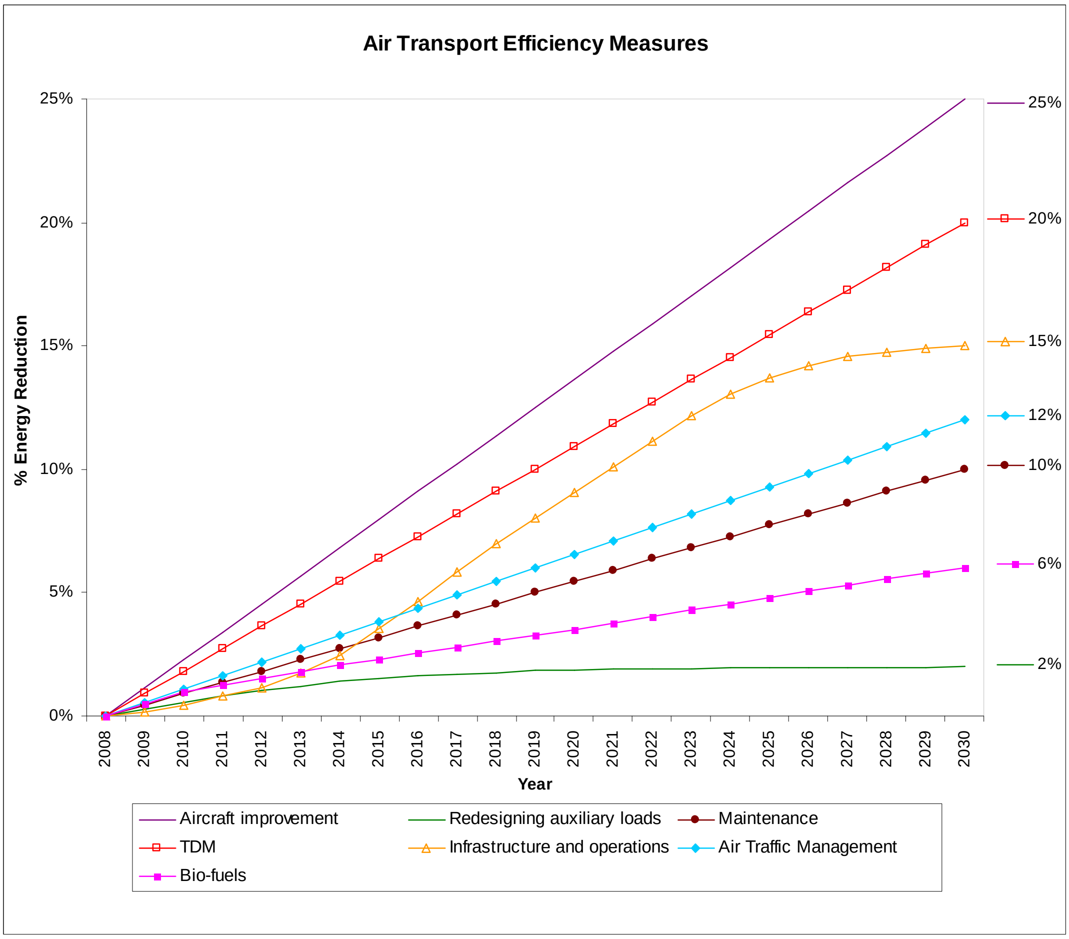


See also Appendix 3

The only rail efficiency improvement measure following an s-curve is driver behaviour. All other rail measures are expected to increase penetration gradually over time.

4.3.2.4 Air transport efficiency measures

Figure 4.3-5: Air transport energy efficiency improvement measures



See also Appendix 4

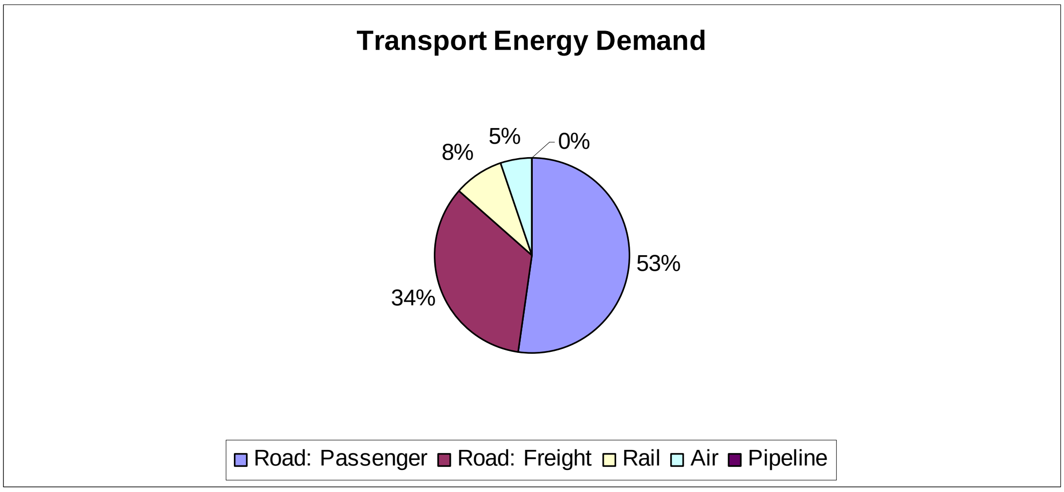
Virtually all air transport measures also increase linearly with time, except for the redesign of auxiliary loads, which is currently underway and is not deemed a continuous process. The other exception is infrastructure and operational changes at airports; this category follows an s-curve because once the changes have been made, no further changes are expected.

4.3.2.5 Conclusion

As mentioned earlier, the modelling of the above projections in the context of each of the four scenarios referred to assumes that measures are neither mutually exclusive nor that the full potentials of measures are likely to be achieved across the board. This has been taken into account in the projections, where measures have been grouped together and adjusted accordingly. Both the feasibility of and interaction between measures have been incorporated into the calculation of the projections.

Calculations of total energy demand per mode reveal that passenger road transportation consumes more than half of all transport energy in South Africa (See Figure 4.3-6: Transport energy demand). It was, therefore, decided to prioritise passenger road transport in the implementation of measures in the projections. The 13 road passenger efficiency improvement measures are grouped into 6 intervention strategies. The intervention strategies are: local government interventions (public transport priority systems and road efficiency measures), ITS (driver assistance systems), driver participation (driver behaviour and maintenance), alternative fuels or propulsion systems (bio-fuels, hybrid-electric vehicles, electric or hydrogen vehicles and LPG vehicles), vehicle size (smaller vehicles) and travel demand management (TDM).

Figure 4.3-6: Transport energy demand



Source: Own calculations based on Report 2 "Energy and Transport Status Quo: Demand and Vulnerabilities"

The first two reports of this assignment as well as the graphed impact of the various transport efficiency measures suggest that efficiency improvement measures are as important in impact, and therefore probably more effective in the short-run, than new technology and mode shifts. Not only are efficiency improvement measures the most cost-effective and least disruptive, they appear able to significantly address the gap between supply and demand, without any new technology or explicit mode shifting. In fact, these are probably the most valuable solutions, because they are ready to be implemented and they highlight the amount of inefficiency currently in the system. There is little point in changing an inefficient system to new technologies that will inherit the same inefficiencies. This needs to be improved first and then the new technology can be introduced into an effective and efficient network. Also, if the price of oil spikes, there will be a natural reduction in travel demand and these efficiency measures will be even more effective than indicated. Efficiency improvement measures can therefore facilitate the reduction of dependency on oil, because less oil would have to be imported and less substituted with other energy sources. In addition, local production might be sufficient to supply the market if demand is kept low.

4.4 Energy and transportation scenarios to 2030

Four energy scenarios are presented below, each of which combines the timing of the peaking of oil production and supply with its post-peak rate of decline, and the improvement of transport energy efficiency, as well as moving to alternative forms of fuel and propulsion systems. As explained earlier, these scenarios explore the unfolding of socio-political events as well as transportation projections in the four quadrants created by the intersection of the liquid fuel supply axis and the speed of movement to alternatives axis:

- a scenario with a relatively late peak/low peak impact (i.e. relatively slow rate of post-peak decline) and rapid move to alternative energy sources and transport systems (the “well planned journey” scenario)
- a scenario with a relatively early peak/high peak impact (i.e. relatively rapid rate of post peak decline) and rapid move to alternative energy sources and transport systems (the “riding the wave” scenario)
- a scenario with a relatively late peak/low peak impact (i.e. relatively slow rate of post-peak decline) and slow move to alternative energy sources and transport systems (the “taking the back roads” scenario)
- a scenario with a relatively early peak/high peak impact (i.e. relatively rapid rate of post peak decline) and slow move to alternative energy sources and transport systems (the “bumpy road” scenario).

The energy projections and the projected impact of the transportation efficiency measures are described initially for each scenario and in turn summarised in the respective tables and figures. The *combined* effect of specific categories of transportation efficiency measures (i.e. passenger road transportation and freight road transportation) is illustrated graphically in the first scenario; thereafter, the combined effect of additional batches of transportation efficiency measures is applied in each consecutive scenario, and within each scenario the effect of adding the impact of each batch is illustrated graphically.

The global credit crisis of 2008 is the context within which all the following four scenarios play themselves out. As already witnessed, millions of indebted American consumers are unable to meet their repayment obligations, and this has triggered foreclosures on home loans. Scores of small lenders in the US have become insolvent, putting pressure on the major banks, one of whom (Lehman Brothers) has gone insolvent, while several others have been bailed out by the Federal Government. The $700 billion "rescue package" to ailing banks from the US Federal Government, as well as the aid from the United Kingdom Government to UK banks has effectively (partially) nationalized the United States and UK banking industry, so drastic is the financial crisis. It is assumed that the beginning phase of each of the four scenarios will happen in the context of a global recession. As it becomes clear that the US economy is sliding into recession, equity investors take fright. The US stock market plunges, as does the over-heated Chinese bourse, triggering similar losses around the world. Trillions of dollars of wealth are wiped out over a few months. Faced with such loss of wealth, consumers restrain their expenditures further, compounding the economic contraction. The value of the US dollar reaches record lows against other major currencies as confidence in the US economy erodes.

For the purpose of the economic context of each scenario, it is assumed that the global economy slides into recession, from which it does not recover before 2015. After a time, the destruction of demand for oil results in the oil price dropping. This helps some economies to begin to recover, including the South African economy, but once again the lowering supply ceiling acts as a constraint and forces the oil price upwards, repeating the economic cycle of contraction. For the South African economy this becomes more noticeable after the 2010 World Cup.

For scenarios 2 and 4, where peak oil has happened early and the rate of post peak depletion is rapid, the following economic conditions are assumed to prevail. Global oil production has peaked and begun to decline. It becomes apparent that despite their promises, oil producers are not able to meet the demand. In the face of inelastic demand, and driven by hoarding behaviour, the oil price spikes to over $150 per barrel. Consumers all over the world are hit by sharp rises in the costs of transport. Soon, the prices of all goods and services that depend on oil-powered transport begin to rise, sending inflation rates to new highs.

In South Africa, the petrol price rises to R12 per litre and inflation refuses to decrease below 10%. The Reserve Bank raises the repo rate by a further three percentage points. Many sectors and businesses begin to realise how dependent on oil they have been and that they have very little flexibility to adapt. Where possible, they pass on higher production costs to consumers, but many are forced to lay off workers. Still the infrastructure investment mitigates the extent of layoffs and therefore of unemployment. Part of this urban based infrastructure is the bus rapid transport systems implemented by Johannesburg, Bloemfontein, Cape Town, Port Elizabeth and Durban in time for the 2010 World Cup. This takes significant pressure off the urban working classes and employees, enabling them to get to work on time and generally has a significant economic savings effect during the beginning phases of these scenarios. In the first and third scenarios, where peak oil occurs later and there is a slow rate of post peak depletion, there are similar economic pressures but they are less extreme and they start to manifest later.

The wild card is whether the United States and China will wage war in order to secure their oil supplies. It is assumed that within the period ending in 2030 the high price of oil and its increasing scarcity increases global, regional and local conflicts. It is also assumed that within this period both China and the US have passed their own oil production peaks and have been roaming the world to secure their primary interest from a wide range of sources. As the scarcity of oil intensifies so too does the competition to control the global supply. These conflicts are centred in the Middle East, Central Asia and the west coast of Africa. An all-out war might erupt in the Middle East and continue to disrupt oil supplies. A US led bombing campaign against Iran might lead to the closure of the Straits of Hormuz and an Iranian retaliatory missile attack on the Saudi Arabian oil fields. If this were to happen and if oil were diverted across Saudi Arabia using the pipeline to the Red Sea, this could provoke an increasing number of attacks on the pipeline because of the anti-US backlash that would probably sweep through the Middle East. In response China and Russia might conclude an alliance that pits them against the US over control of the central Asian oilfields. Nigeria might descend into a civil war as ethnic factions fight to control oil reserves. If these (or similar) events occurred there is great likelihood that South Africa's oil supply could be further disrupted.

4.4.1 Scenario 1 – "Well planned journey"

4.4.1.1 Basic setting

This is a setting where there is recognition of the reality of peak oil and of the need to prepare for this eventuality with a series of well-planned measures. These are approached in earnest and handled in a systematic and coordinated manner and there is a concerted effort to mobilise alternatives.

This scenario assumes that the global oil production peak is reached in 2016, but that the peak in world oil exports is reached earlier, in 2012. It is further assumed that South Africa's oil imports peak when world oil exports peak. Oil imports initially rise at 2% per annum (p.a.) until 2012. The post-peak rate of decline is initially relatively mild (2% p.a.) and after three years quickens slightly (to 4% p.a.). This profile is a simplification of the rough bell-curve shape assumed by most experts who construct oil production forecasts.

The assumptions about domestic liquid fuel supplies are based on recent statements made by the relevant producer companies or government authorities about possible or likely future production capacities. Thus Sasol proceeds with the planned 20% expansion of its Secunda CTL plant, and also builds a new greenfields CTL plant (Mafutha). PetroSA manages to maintain production at its GTL plant using either new oil or gas discoveries or imports, or is replaced by a facility using inland gas reserves. This scenario assumes that even if a new crude oil refinery and/or LNG terminal were constructed, as has been proposed by PetroSA, the price of feedstock (oil and gas) would rise sufficiently high so as to depress domestic demand for liquid fuels to a large extent. There is clearly much uncertainty about the prospects for acquiring affordable oil and gas imports, especially considering the possibility of geostrategic alliances with oil producing countries (see Section 3.1 of the *Reducing Oil Dependency* report). Another wild card is the potential for substantial new discoveries of oil and gas, particularly in off-shore regions of the western and southern Cape coasts; this is not explicitly included in the scenarios due to its speculative nature at this stage. It is assumed that biofuel production rises to 2% of liquid fuels by 2013 in line with the target stipulated in the Department of Minerals and Energy's

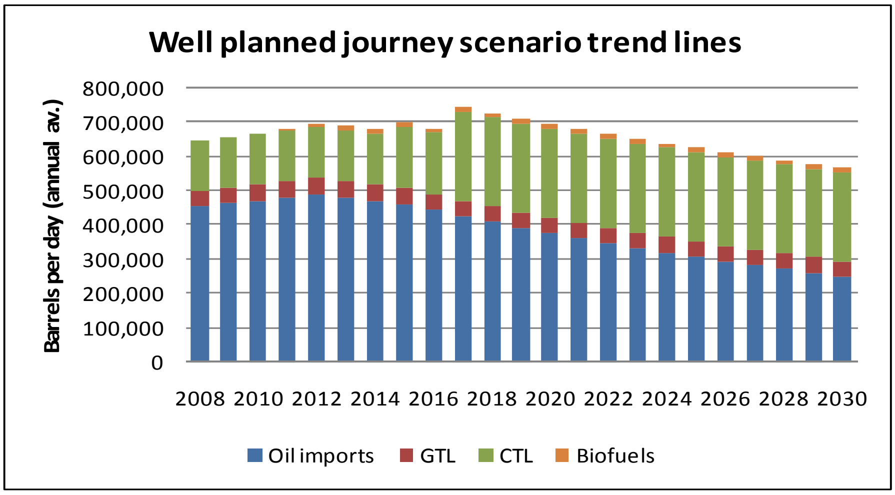
Biofuels Industrial Strategy. Further expansion of biofuels is assumed to be constrained by adverse climate changes (e.g. droughts) and related food security concerns.

Table 4.4-1: Well planned journey scenario assumptions – Late peak, slow oil depletion & mobilised alternatives

Source of liquid fuel	Assumptions
Oil imports	• rise by 2% per annum (p.a.) to 2012 • decline by 2% p.a. from 2013 to 2015 • decline by 4% p.a. from 2016
CTL	• Sasol maintains existing production of 150,000 barrels per day (bpd) at Secunda plant • Sasol adds 30,000 bpd to Secunda in 2015 • Sasol adds 80,000 bpd Mafutha plant in 2017
GTL	• PetroSA maintains existing production of 45,000 bpd at its Mossel Bay plant till 2015 using existing offshore gas and oil reserves, and thereafter from alternative sources (e.g. new offshore oil or gas discoveries or gas imports such as LNG) • alternatively, from 2016 the Mossgas production is replaced by GTL based on coal bed methane and/or underground coal gasification
Biofuels	• rise to 2% of liquid fuels (13,000 bpd) by 2013 in line with the DME's Biofuels Industrial Strategy; thereafter constant

The quantitative projections resulting from these assumptions, and using the latest available figures (see Section 3.1) for the base year (2008), are shown in the figure below. Supply fluctuates somewhat until it reaches a peak in 2017 (when the new CTL plant begins production), after which it declines steadily so that by 2030 it is slightly less than the initial level.

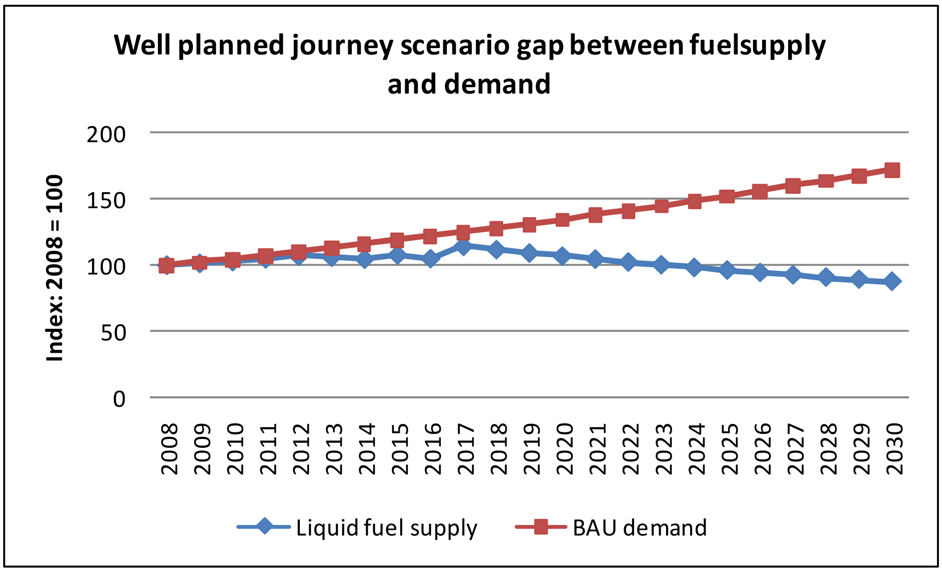
Figure 4.4-1: Well planned journey scenario – fuel supply trend



See also Appendix 5

For benchmarking purposes, a business-as-usual (BAU) or desired demand growth trajectory is projected into the future. It is assumed that BAU demand grows at 2.5% per annum, which is slightly below the average rate of growth of petroleum product sales of 2.8% recorded for the period 1994 to 2007 (see the Energy and Transport Status Quo Report). The resulting gap between BAU demand and available supply under the assumptions outlined above is shown in the following figure.

Figure 4.4-2: Well planned journey scenario –fuel supply/demand gap



See also Appendix 5

4.4.1.2 The beginning of the well planned journey (2009 –2014)[3]

During this period there is strong political will to mobilise all relevant government departments behind this effort. Political leaders at all levels of government understand how important it is for the long-term benefit of the country to strive for energy independence. This scenario starts with leadership from the top: the State President drives a credible and convincing mitigation programme based on visionary leadership which leads by example.

The mission is defined as a course which aims in the short- to medium-term to reduce dependence on imported oil by embracing energy conservation and efficiency and by developing indigenous fuel sources. The longer term goal is energy independence and sustainability through the increasingly widespread adoption and use of renewable energy sources. Strategically, South Africa targets its imported oil consumption on the anticipated world oil depletion rate of around three to five per cent per year. The President and his Cabinet colleagues and senior civil servants have all bought into the vision and mission. Through leading by example the state secures the buy-in of the other vital sectors of society (e.g. business and civil society) that need to contribute to the effort. The national, regional and local transportation systems are identified as key areas of intervention because transportation is the life blood of the economy, enabling trade and access to food and work opportunities.

Local governments are critical stakeholders in this regard. Without the buy-in and support of the local tiers of government, the impact of the state's intervention on enhancing the sustainability of local transportation would be severely curtailed. As it would be vital that city leaders began to embrace the inevitability of change, the Presidency would concentrate on prompting the emergence of leadership by city officials. This would demonstrate that they mean what they say and are prepared to walk their talk. This builds on the commitment already made by several major metropoles to bus rapid transport (BRT) systems – the emphasis now is to ensure that the BRTs are sustainable in terms of fuel.

[3] Periodisation of the well planned journey scenario draws partially on the renaissance scenario explored by Hendler, Holiday, Ratcliffe and Wakeford (2007: 45-48).

The Presidency and national government have undertaken an exercise to position the country and the economy strategically and on the basis of this have formulated a comprehensive set of mitigation plans that cascade to the local tier of government. The effect of these plans is that the nation is set on a mobilised sustainability footing to achieve lasting sustainability. Some of the plans would comprise the following government initiatives through a comprehensive energy saving and awareness campaign in terms of which:

- All government departments would have energy saving targets.
- Legislation to prevent the private sale of national strategic assets: coal would be declared a strategic asset.
- A national energy efficiency plan is implemented for transportation, which effectively introduces a raft of energy efficiency measures in respect of passenger road-based as well as freight road based transportation:
    - Intelligent transport systems
    - Travel demand management (such as vehicle routing and load consolidation)
    - Changed driver behavior techniques (in respect of idling, braking, etc.)
    - Local government interventions (e.g. adjusting traffic signals to reduce idling time)
    - Penalisation of usage of large vehicles and incentives for the usage of smaller vehicle sizes and those with alternative fuels and propulsion systems
    - A carefully crafted nationwide information and educational campaign that explains why and how the previous patterns of transportation and fuel consumption are unsustainable and need to change. This is a key element in a strategy to shift the national consciousness, particularly in respect of alternative types of vehicles, propulsion systems and driver behavior that would be more fuel efficient.

Politicians appeal to their constituents to join hands and contribute to a range of measures to reduce energy usage. They are collaborative and purposeful. Politicians have also ensured that society as a whole has been drawn into this effort. Leadership of government, business and civil society are in broad agreement about what needs to be done and all are playing their parts within their spheres of influence. A comprehensive public awareness campaign is undertaken that involves the President and other key ministers travelling around the country garnering public support for what is thought will be a long period of energy constraint.

Fuel consumption continues to rise in the initial period as new infrastructure is put in place. The global economy has taken seven years to recover from the financial crash of 2008 and a new realisation has been broadly accepted that economic growth cannot be at the expense of the environment, which ultimately sustains all human activity. Resource and environmental sustainability is the bottom line with regard to most development and a sound legal framework ensures this. The late peak provides a sufficient window of opportunity for people to prepare themselves psychologically for the changes ahead. Families plan ahead and make adjustments to their lifestyles that are in alignment with government policies. The Treasury has committed money to incentivising the more efficient usage of freight road transportation systems in all provinces, as well as to the development of transport systems based on alternatives to oil-based fuels. The focus on upgrading and building new rail infrastructure has helped turn the economy around after the 2008 downturn.

4.4.1.3 The middle of the well planned journey (2015 - 2022)

South Africa is able to scale up its clean coal technologies to make a significant impact on the supply situation. The planning and preparation that all government departments and all sectors have taken begins to show results. South Africa's dependence on imported oil begins to drop but overall there is still a gap between affordable and available supply and the BAU growth trajectory. A declining global oil supply pushes prices up and inevitably causes demand to fall. Because people are well aware of the issues, most people have taken proactive steps to reduce their need to travel. This brings demand down to manageable levels. Many new organizations have sprung up to advise people on ways to reduce their fuel consumption and live sustainably. The combined efforts of all bear fruit. South Africans as a whole are constantly focused on new ways of doing things that reduce fuel consumption. Amongst white collar employees, working from home is generally accepted and the need to meet people face-to-face has declined because the sophisticated video conferencing services readily available on the internet enable people to work collaboratively without the need for travel. Newspapers run daily stories on ways of reducing energy and have prominent scorecards of how the nation is doing in its efforts to cut its oil dependency. As far as possible, many people choose to move to homes near to their places of work in order to reduce their travel distances. Cycling has taken off dramatically as people take advantage of cycle lanes created by city councils. There is great camaraderie on the roads amongst cyclists as people enjoy the exercise and the open air as well as the lack of cars on the roads and associated air pollution.

The measures advocated and regulated by the Department of Transport are having a real impact. The Minister of Transport is widely revered for the proactive stance he took in 2008 to put the country's transport systems on to a sustainable path. Interestingly the fuel efficiency measures in road transport have resulted in a new growth in vehicles sales, although the types of cars on the road are different from before 2009 – most are smaller and many are either hybrid-electric or electric. Hydrogen cars have not taken off in the vehicle market due to some of the technical difficulties with hydrogen as an energy carrier (referred to in the second report of this assignment) and the high costs of associated infrastructure. The motor manufacturing industry has adapted to the new energy efficiency requirements and has managed to grow its turnover thereby creating many jobs and making up partially for those that were lost as the car industry downsized during the period 2007 to 2012.

The savings generated through road transportation efficiencies has enabled the global airline industry and with it the tourist industry to minimize contraction although there has been rationalisation: by 2017 many individual airlines (including South African Airways) have fallen by the wayside and been replaced by about 5 international alliances (like the Star Alliance etc). This has improved aircraft utilisation and profitability enough for the industry to survive oil depletion. Only low-cost carriers are operating to accommodate domestic air travel.

Road passenger transportation measures like intelligent transport systems, travel demand management, driver participation and local government interventions proliferate during the middle phase of this scenario, and their positive impact contributes to a virtuous cycle. In addition the very important investments are made to shift the centre of gravity of transportation towards non-oil fuels and also electrified power. For quite some time now many people have been choosing smaller cars and motorcycles to get around, in order to save fuel and to reduce wastage. Various fiscal incentives are in place to encourage more efficient forms of transport.

After some years of planning Transnet reveals its sustainable transport systems powered largely by electricity (some of which is generated from renewable resources), as well as from biofuels that do not compete with food production. The central government implements and manages heavy electric rail, essential for bulk transport and freight between cities and towns. Electric road vehicles also have a place in the transport mix. Telecommuting becomes a significant way of reducing transport needs, as do home delivery services. The savings effected through these transportation energy efficiency measures have enabled the economy to stabilize after the global recession, and limited the shock to the working population by keeping many of them in employment. Minibus taxi operators have cooperated with government authorities – for instance in BRT systems – so as to maintain a relatively safe and efficient mass transit system for lower income people.

4.4.1.4 The end of the well planned journey (2023 - 2030)

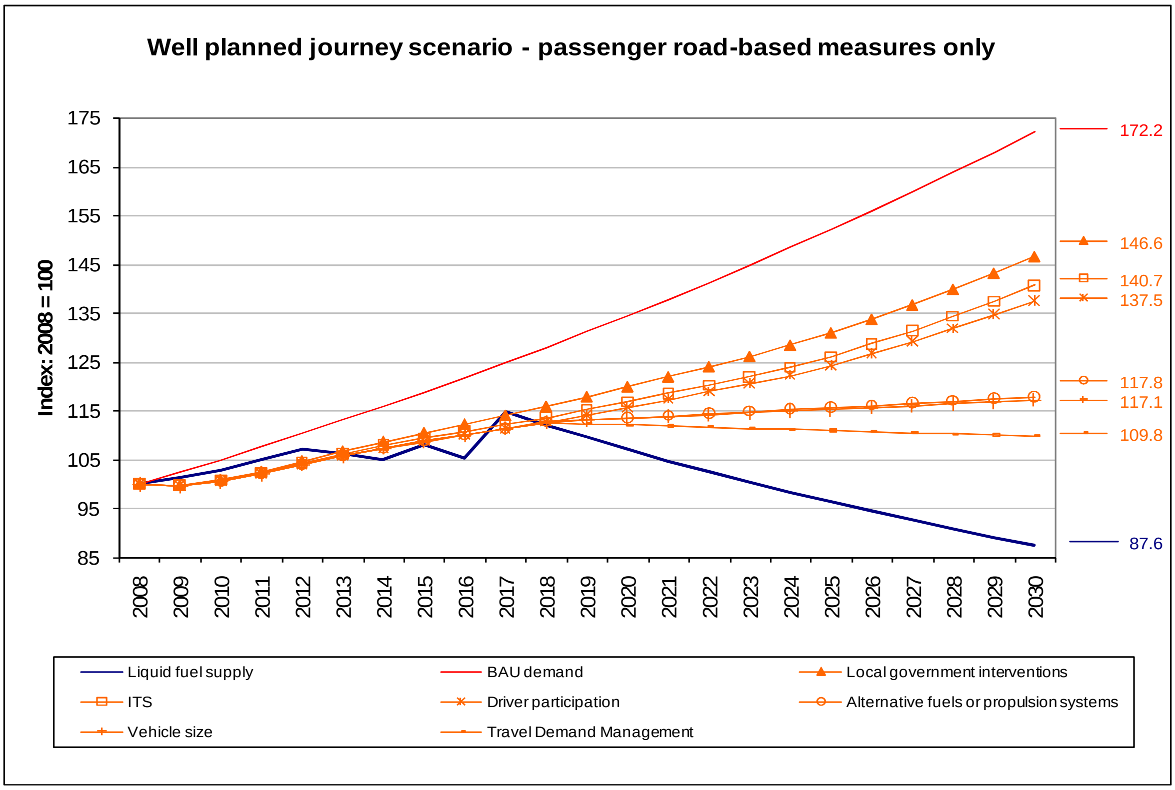
After 15 years of concerted effort to reduce oil dependency through increased road transportation efficiency, few people even discuss the need for alternative fuels as it is taken for granted. It is now the norm that energy is conserved, travel happens only when necessary and people have restructured their lives taking resource limits into account. No longer is there a need to convince people to change, the change has occurred and people have integrated a low carbon and low oil dependency outlook into their lives.

In the cities rapid bus transportation systems work so well that there is less need for use of private cars. Cities have attempted to introduce new forms of spatial planning to restructure themselves into self-sustaining neighbourhoods linked by rapid public transport. Already the majority of people are able to work in their neighbourhoods, do the shopping, school their children and have access to a range of social services within walking distance of their homes. The need for long-distance road transport has decreased considerably as local economic development has grown and led to industry clusters that have little need for materials and resources from far off places. This brings about further savings of oil-based liquid fuels. Sustainable urban communities with higher densities requiring low levels of mobility and transportation, some of which have already emerged in inner city social housing projects, have started to take root. The new planning models intend to divide up metropoles spatially in ways that make economic and social sense and which enable smaller scale urban living. All these areas would be connected by fast, efficient and reliable public transport to facilitate the movement of goods and people between them, following a significant increase in investment in new appropriate public transport infrastructure. In practice citizens are already doing much more walking and cycling to and from amenities and work related opportunities shift to the suburbs. More walking requires more security, particularly in what is often a crime ridden environment. Security problems therefore pose a challenge to the emerging decentralised forms of non-motorised (as well as road) transportation.

4.4.1.5 Well planned journey – impact of transportation efficiency measures

Figure 4.4-3 indicates that even if all six passenger road strategies are implemented, BAU demand still exceeds supply. Additional measures will have to be implemented to rectify the situation by introducing greater fuel savings.

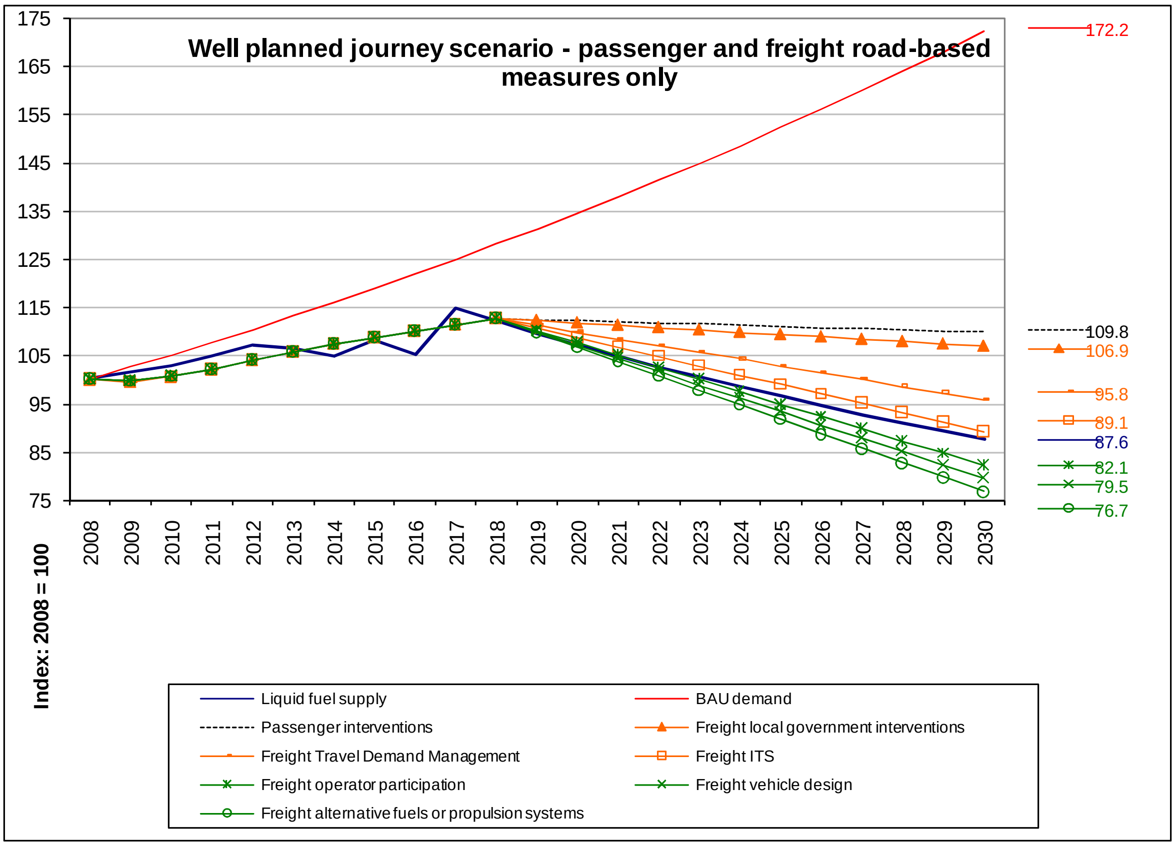
Figure 4.4-3: Well planned journey – road-based efficiency measures (passenger only)



See also Appendix 6

The next greatest consumer of transport energy is road freight transportation; hence these measures are included next (Figure 4.4-4). The freight transport interventions are: local government interventions (road efficiency measures), travel demand management, ITS (fleet vehicle tracking systems), operator participation (driver behaviour and maintenance), vehicle design (changing tyres, aerodynamic fittings and lightweight materials) and alternative fuels or propulsion systems (hybrid-electric buses and trucks).

Figure 4.4-4: Well planned journey – road-based efficiency measures (passenger and freight)



See also Appendix 6

It can be concluded that only a combination of passenger and freight road transportation measures can reduce demand sufficiently to bring it in line with available supply in this scenario.

4.4.2 Scenario 2 – "Riding the wave"

4.4.2.1 Basic setting

The "Riding the wave" scenario assumes that the global oil production peak is reached in 2010, but that the peak in world oil exports is reached earlier, in 2008. World oil exports have in fact been on a horizontal (zero growth) trend for the past three years already, so this assumption is not unrealistic. It is further assumed that South Africa's imports peak when world oil exports peak. The post-peak decline is initially moderate (4% per annum) and after three years quickens to 8% p.a. This faster rate can be interpreted either as rapidly declining oil import availability, due to a higher underlying rate of depletion from oil fields and/or the result of various negative feedback effects (as described in Section 2.3), or to the impact of high oil prices, or both.

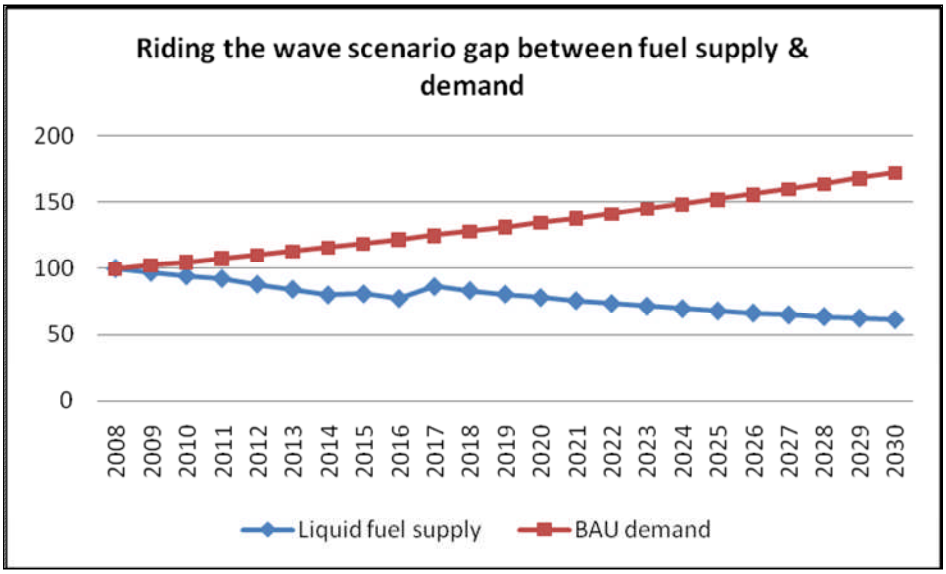
In terms of the domestic alternatives, this "Riding the wave" scenario can be viewed as proactive intervention by relevant authorities in mobilising new investments within the context of the current growth economy. Sasol continues with its extension to Secunda and also constructs the proposed new CTL plant called Mafutha. PetroSA is able to secure new feedstock to maintain production at its Mossgas plant. Further expansion of biofuels beyond the DME's target for 2013 is assumed to be constrained by climate changes (e.g. droughts) and related food security concerns.

Table 4.4-2: Riding the wave scenario assumptions – Early peak, rapid oil depletion & mobilised alternatives

Source of liquid fuel	**Assumptions**
Oil imports	• decline by 4% p.a. from 2009 to 2011 • decline by 8% p.a. from 2012
CTL	• Sasol maintains existing production of 150,000 bpd at Secunda • Sasol adds 30,000 bpd to Secunda in 2015 • Sasol adds 80,000 bpd Mafutha plant in 2017
GTL	• PetroSA maintains existing production of 45,000 bpd at its Mossel Bay plant till 2015 using existing offshore gas and oil reserves, and thereafter from alternative sources (e.g. new offshore oil or gas discoveries or gas imports such as LNG) • alternatively, from 2016 the Mossgas production is replaced by GTL based on coal bed methane and/or underground coal gasification
Biofuels	• rise to 2% of liquid fuels (13,000 bpd) by 2013 in line with the DME's Biofuels Industrial Strategy; thereafter constant

The quantitative projections resulting from these assumptions are shown in Appendix 7 and in the figures below. Fuel supply falls slightly during the years to 2013, and more rapidly thereafter, with a slight (but temporary) increase in 2017 when the new CTL plant comes on line. Supply is less than half of its current level in 2030, but still significantly higher than in the "bumpy road" scenario.

Figure 4.4-5: Riding the wave scenario – fuel supply/demand gap



See also Appendix 7

4.4.2.2 The beginning of riding the wave (2009 - 2014)[4]

The beginning phase of "Riding the wave" is marked by several key economic, transport, food, security and governance issues. The leadership qualities of state officials, as well as private initiatives in the markets and society with respect to fuel and transportation, are symptomatic of a greater social awareness of the financial, energy and climate-change issues facing the world and this nation, and a growing skepticism about the sustainability of the current economic growth route of the South African economy. There is a growing consensus by both public and private sector leadership around a vision of a sustainable future for South Africa. This vision enables rapid planning, which galvanises further action and leads to a virtuous cycle of activity

[4] Periodisation of the riding the wave scenario draws partially on the renaissance and fragmentation scenarios explored by Hendler, Holiday, Ratcliffe and Wakeford (2007: 45-48).

aimed at reducing oil dependence and developing alternative fuels and propulsion systems. Fortunately some of the worst effects of the global financial and economic downturns are mitigated somewhat by the ongoing state investment in infrastructure, partly related to South Africa's hosting of the 2010 FIFA Soccer World Cup.

The result from a transportation perspective is that in addition to passenger road transportation fuel efficiency measures being implemented, there is also a significant set of measures in the area of freight transportation – particularly mode shifts in strategic economic corridors. This means that in this scenario the society manages to balance transport fuel supply and demand over the longer run although the balance is often out of equilibrium in the short run due to the early onset of peak oil and the rapid decline of oil-based fuels.

Likewise, plans are implemented to shift freight transport in the significant economic corridors to electrified rail. A significant effect of implementing these modal changes in freight is that they ensure that goods and services continue to be distributed throughout the economy. Food price rises are therefore contained as a result of more effective and efficient transportation and therefore transport costs are significantly minimised. In the global recessionary environment of the years prior to the World Cup many members of the middle class have to cut back their expenditure on discretionary items, and some have to sell their houses, contributing to a decline in house prices that was triggered by the stock market crash. However, proactive energy and transportation policies and their implementation slows down the inflation in fuel prices and thereby assists the sustainability of business in a number of key sectors, including transportation, tourism, food, construction and import/export, which would otherwise face mounting difficulties resulting from the high price of fuel.

The global airline industry is in serious trouble as its operating costs rise dramatically. Many large airlines worldwide need to be saved from bankruptcy through state intervention. Many privately owned airlines struggle to stay aloft as high fuel prices cripple their profitability. International tourism declines markedly after 2010, hitting South Africa's balance of payments hard. Domestically, due to the continuing shift of freight from road transportation to rail, increases in transport tariffs are contained and the cost of moving goods rises slowly and incrementally. Between 2011 and 2015, when the liquid fuel supply drops and the new modal shifts have yet to be completed, there is a very tight balance between fuel supply and demand,

and particularly in these years there are sudden fuel price spikes. However, this situation starts easing somewhat thereafter as the modal shifts take increasing effect.

There is increasing appreciation of the Department of Transport for having invested heavily in public transport between 2008 and 2014. This has resulted in the rail network being upgraded – at the same time there has been ongoing maintenance and old lines have been resuscitated. Commuter services are also slowly extended over this same period, and with the ever increasing cost of oil-based fuel passenger and freight rail emerge as viable alternative services to road transportation for both passengers and business. The initiative by the SA Rail Commuter Corporation (SARCC) and the Department of Transport means that investments were made before the costs of upgrading and expanding public transport rose dramatically. South African Airways however, incurs ever greater losses despite instituting fuel economy measures, much to the annoyance of both government and taxpayers. Airline tickets rise to their highest levels since the airline was founded, which dampens demand.

4.4.2.3 The middle of riding the wave (2015 – 2022)

By 2015 the beneficial effects of the World Cup on the South African economy are fading. Nevertheless the restructured transportation system is connecting people and businesses and thus facilitating economic activity. This slows down the increase in unemployment: the official unemployment rate starts rising slowly, breaching the 25% mark, while the broad unemployment rate (which includes discouraged workers) reaches 38%.

International geopolitical developments reduce the supply of oil coming to South Africa, resulting in shortages, especially in smaller cities and the interior. Fortunately, alternatives to liquid petroleum fuels are coming on to the market and are being scaled up to meet the shortfall. As consumers downscale their consumption of petrol and diesel, they also have access to a growing public transport system based on BRT. In addition, car pooling becomes commonplace for the middle income car owners for whom train travel is an inconvenience. Many other private car owners switch to using public transport, which at times becomes over-subscribed; however, because the investment in the modal shift was made almost 5 years earlier there is sufficient momentum to supply more coaches and buses etc. to meet the demand, albeit only a bit later;

i.e. bottlenecks cannot be avoided. Many commuters opt to work from home whenever possible, and businesses allow more flexible working hours; local government authorities relax residential zoning regulations to enable commercial activities to take place in suburban areas.

The national government makes a policy decision to conserve fuel as a priority national resource through measures to limit fuel consumption, limiting speed limits on national roads and introducing fuel rationing. The demand for motor cycles and smaller cars increases in relative terms, but overall the automotive industry is hard hit as consumers postpone new vehicle purchases indefinitely. Cycling becomes increasingly commonplace in urban areas, and the local authorities move to adjusting traffic regulations to facilitate cycling and cycling tracks in some of the cities and larger towns. Members of the taxi industry stage protests at the high fuel prices, and there are incidents of violence. Yet these remain the exception rather than the rule because of the inclusion of the sector in early negotiations and plans around the restructuring of transportation from 2008. The modal shift also enables the state to save on road maintenance, the cost of which has soared, since asphalt is a by-product of oil refining and the costs of operating machinery have risen steeply. Because there are significantly fewer cars and trucks on the roads there is also less wear and tear and hence lower maintenance costs.

4.4.2.4 The end of riding the wave (2023 - 2030)

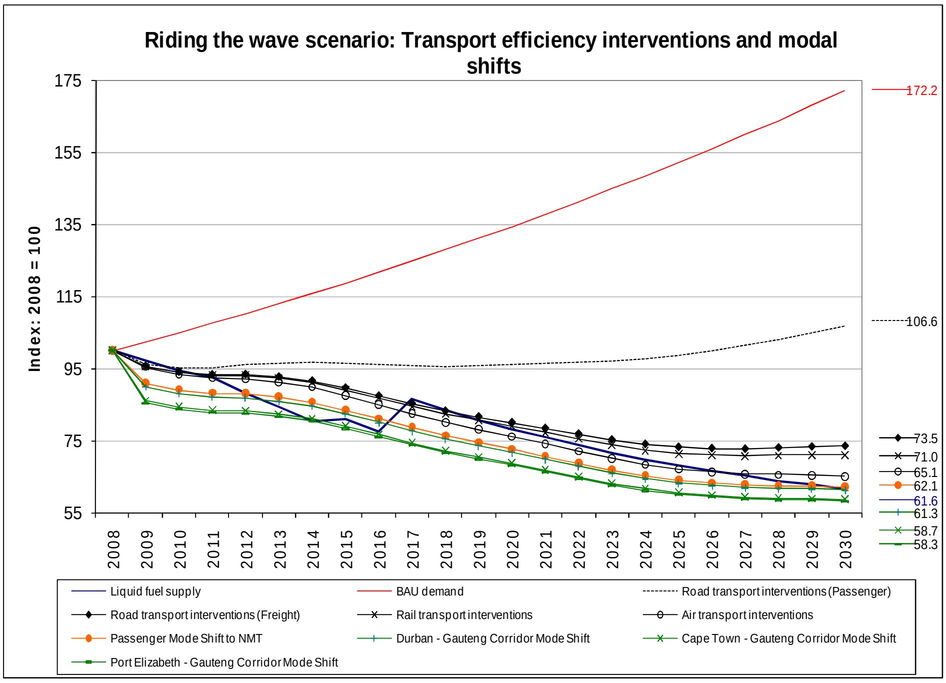
From 2023 the advantages of functional and functioning national, regional and local transport systems are there for all to see: the transport spine and its ability to move goods and people timeously is clearly a precondition for trade and therefore economic activity. The transport system facilitates the social relations of production and consumption each and every day, and whatever the difficulties and challenges, facilitates the trading of goods and services and therefore the exchange of money. The fact that it is still possible to move goods (freight) around the country (primarily through electrified rail) has a positive economic knock-on effect. One of these effects is that there is sufficient food for the population. Where there are food shortages, brought on by droughts (as a result of climate change) some of the local organic farmers are able to fill the gap. The demand for biofuels increases less dramatically as a result of the incentivising of non-oil based transportation and farming. Many farmers still have an incentive to produce crops for food on their land. While it is not necessary for government to intervene in the pricing and availability of food supplies (e.g. in order to avoid conflict) it does subsidise key staples to ensure that the poor have access to food.

The stabilization of the economy and society generate a basic confidence in many individuals who continue going about their delay lives, which are being transformed through slower, localized growth, as well as new living patterns (i.e. in closer, denser, settlements). This results in the availability of basic food and fuel and also prevents runaway inflation. Unemployment is still a big social problem as many large businesses continue to retrench workers as they restructure to meet changed conditions. Nevertheless, new work opportunities – particularly in the field of community gardens (as also happened in Cuba after the 1991 collapse of the Soviet Union and the consequent marked decline in oil imports) and local public transportation and energy and waste recycling infrastructure – offer an alternative to those who would otherwise be unemployed.

4.4.2.5 Riding the wave – impact of transportation efficiency measures

In addition to fuel efficiency measures, the riding the wave scenario requires modal shifts; these are implemented as a last resort owing to the large infrastructure expenditure and behavioural changes required. Mode shifts will probably have the greatest impact on our current way of life. The embedded public transport shift is assumed to double in this projection, as well as in the next projection (scenario 3). The first new modal shift is a passenger shift towards non-motorised transport (NMT). It is expected that a maximum of 10% of car trips, 2% of taxi trips and 1% of bus trips are eligible to move towards NMT. The Durban – Gauteng corridor carries the highest tonnage of all corridors in South Africa; however, the Cape Town – Gauteng corridor accounts for the greatest amount of tonne-kilometres. Shifting road freight to rail on the Cape Town – Gauteng corridor will thus reap a greater benefit than the Durban – Gauteng corridor. Nonetheless, a freight modal shift from road to rail on at least one of these corridors is required for demand to approach supply levels.

Figure 4.4-6: Riding the wave scenario – efficiency measures for all modes



See also Appendix 8

4.4.3 Scenario 3 – "Taking the back roads"

4.4.3.1 Basic setting

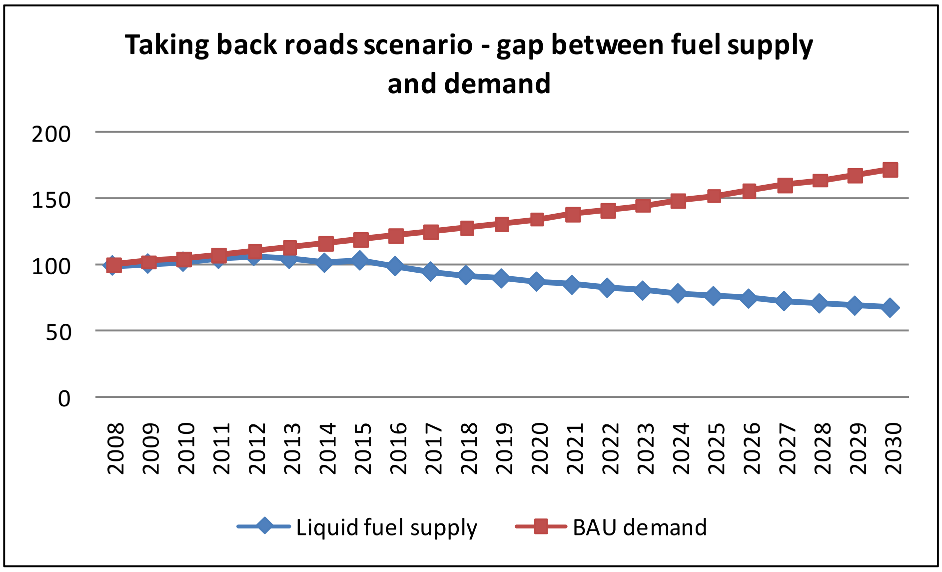
In this scenario, the impact of peak oil is relatively low. There is a later peak and a slower rate of production decline. However, it is difficult to mobilise finance and political will towards the development and implementation of alternatives. The liquid fuel supply assumptions are spelled out in the table below.

Table 4.4-3: Taking the back roads scenario assumptions – Late peak, slow oil depletion & constrained alternatives

Source of liquid fuel	Assumptions
Oil imports	• rise by 2% per annum (p.a.) to 2012 • decline by 2% p.a. from 2013 to 2015 • decline by 4% p.a. from 2016
CTL	• Sasol maintains existing production of 150,000 bpd at Secunda • Sasol adds 30,000 bpd to Secunda in 2015
GTL	• PetroSA maintains existing production till 2012, thereafter declining at 20% of 2012 production p.a. as feedstock depletes, so that production falls to zero by 2017
Biofuels	• rise to 2% of liquid fuels (13,000 bpd) by 2013 in line with the DME's Biofuels Industrial Strategy; thereafter constant

The quantitative projections resulting from these assumptions are shown in Appendix 9 and the figures below. As the graph shows, BAU demand and supply begin to part ways around 2012 and the gap becomes ever wider.

Figure 4.4-7: Taking the back roads scenario – fuel supply/demand gap



See also Appendix 9

4.4.3.2 The beginning of taking the back roads (2009 - 2014)

In this scenario, South African society continues its business-as-usual path and does not take the opportunity to do any proactive planning before the oil crisis becomes manifest. The peak is late and the rate of decline is slow and there is a muted response to the need to develop alternatives and take actions that will result in reduced consumption in order to reduce the high levels of oil dependence.

South Africa is still reeeling from the meltdown of the global financial system and the economy has been hard hit by the global recession. Export orders are cancelled and unemployment levels rise as businesses struggle to survive. It takes 7 years for the economy to pick up again and economic growth is sluggish.

Politically there has been no serious debate about the sustainability of our current growth model. Due to the "politics of discontent" no clear vision is developed that could act as a unifying force to glue various key leadership figures and actors from society together. The recession has strengthened the resolve of the labour movement as workers struggle to cope with the pressures on their incomes brought about by rising inflation, but weakened their bargaining power as jobs were lost.

While the recession affects many people no major changes are made to transport policy or to create energy saving measures and the poor economic conditions have hampered initiatives to develop alternatives. Insofar as potential transportation efficiency measures are concerned, there is no proactive policy to address these critical areas of regulation of vehicular design, traffic management, etc. Consequently there is no policy platform from which action can be initiated.

As it becomes clear that there are constraints to South Africa's supplies of imported oil, a poorly coordinated response begins to emerge and public pressure grows on the government to do something. The government's response is reactive and ministers find themselves on the defensive and are having to "make it up" as they go along. Government is focussed on a number of other issues and the nation's social energy is dispersed.

A new global climate change treaty has been agreed, to which the South African government is a signatory. It is very stringent and places responsiblities on governments world wide to significantly reduce the CO_2 emissions in their countries. This places an obligation to introduce measures which affect the transport sector. The treaty places heavy emphasis on a range of measures to reduce emissions.

4.4.3.3 The middle of taking the back roads (2015 - 2022)

It has now become clear that the world has passed the oil production peak and that there will be less and less oil available globally each year. Most people have an understanding that there is a problem but there is weak leadership from government and many people take things into their own hands and find ways of using less fuel. Prices of petrol and diesel rise continually, placing ever greater pressure on families and businesses. The Department of Transport initiates some of the measures to reduce fuel consumption (referred to in figure 4.4-8). These are not well communicated to the public even though there is a public campaign urging restraint on fuel usage. The effects on society are uneven as poorer people suffer more than wealthier individuals.

As the energy crisis deepens it becomes clear that new forms of transportation are required. Investment in public transport is desperately needed, but funds are limited and come at a high cost. Some railway lines are upgraded and more trains are commissioned. Freight continues to be moved predominantly on the roads because the railways do not yet represent a viable alternative. Moving freight by rail takes time and is often stolen because of the lack of security. Measures are taken by individual transport companies seeking to reduce their costs. Ways of streamlining trucks begin to catch on amongst transport companies and some impressive results become manifest. Significant fuel savings are achieved despite the absence of government leadership. Drivers start changing their driving habits and start to heed the advice of a number of key radio personalities by driving more slowly with less stopping and starting. This, too, begins to have a noticeable effect. Many people are conscious of their choices when purchasing new vehicles. Fuel-efficient cars sell relatively well. Hybrids have become the most popular cars and are now being offered by a number of manufacturers. Electric cars are also becoming more popular, particularly for short distances. Many people begin to buy them to avoid the high costs of fuel. However this begins to place a strain on the already overstretched electricity supply situation.

As the price of oil continues to rise, the theft of fuel increases and organised crime begins to control a growing black market in fuel. Because of its high value they intensify their efforts to control this market and present law enforcement authorities with a real challenge. This is a worldwide phenomenon and piracy is common.

Globally, new innovations in transport systems emerge having been slowed down due to the economic recession that began in 2008. It is difficult to adopt them because of the high costs involved. All transport modes are operating as efficiently as possible, to try and remain profitable.

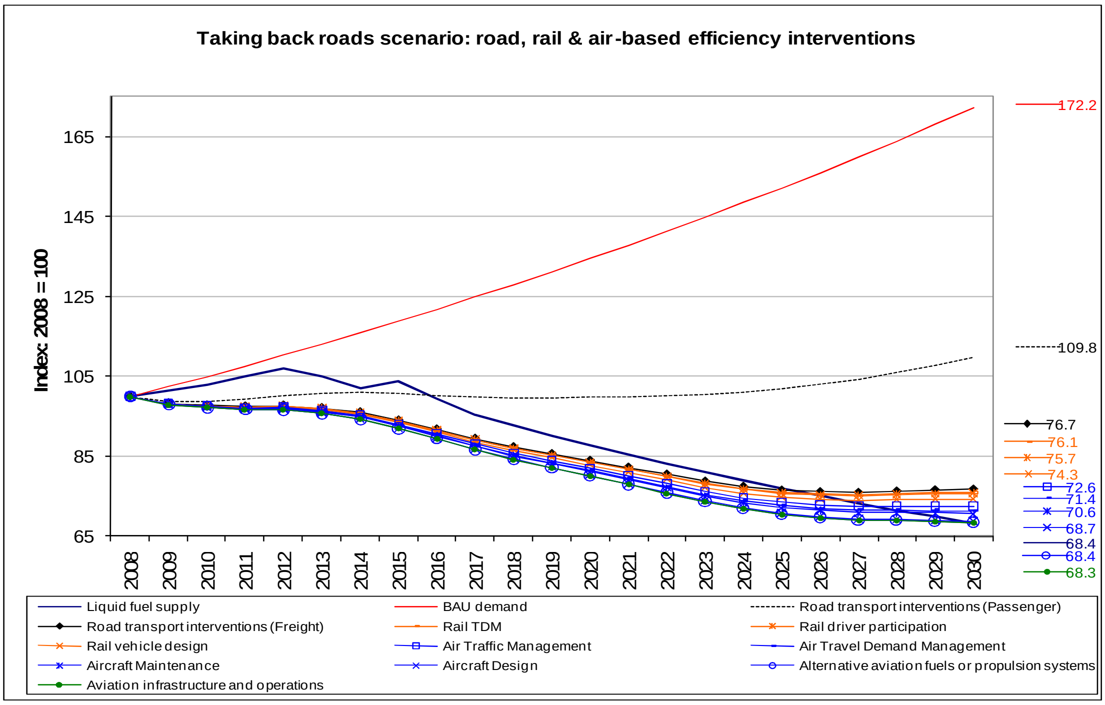
4.4.3.4 The end of taking the back roads (2023 - 2030)

The slow rate of oil production decline has been a lucky escape for South Africa. It has meant that the measures that have been taken to avert severe fuel shortages have been effective despite an initially muted government response. This has come about largely due to the efforts of business and civil society. Citizens and businesses took actions because they were affected and sought to improve their own situations. Many new businesses sprung up offering services that had an impact on the overall level of oil dependence. Consumer choices affected fuel consumption levels. Many families changed their lifestyles by moving closer to work opportunities while others brought their livelihoods home. Politics was for a time focused on energy but this has shifted now and other issues have taken centre stage. There is still a long way to go to ensure that South Africa is rid of its oil import dependence, but this has been significantly reduced and a path is being followed that will further reduce dependence.

4.4.3.5 Taking the back roads – impact of transportation efficiency measures

Although this scenario describes a situation in which there is a limited government response to the oil depletion challenge, for illustrative purposes the interventions that would be required for liquid fuel demand to match supply are calculated and shown in Figure 4.4-8: transport interventions on all modes (road, rail and air) are required. The rail interventions include: travel demand management (idle reduction and consist management), driver participation (engineer training) and vehicle design (aerodynamic fittings, regenerative braking and rolling resistance reduction). The air interventions are air traffic management, travel demand management, maintenance, vehicle design, alternative fuels or propulsion systems and infrastructure and operations changes. These have the following fuel saving effects:

Figure 4.4-8: Taking the back roads – shift to most efficient modes



See also Appendix 10

4.4.4 Scenario 4 – “Bumpy road”

4.4.4.1 Basic setting

The “Bumpy road” scenario assumes that the global oil production peak is reached in 2010, but that the peak in world oil exports is again reached earlier, in 2008. It is further assumed that South Africa’s imports peak when world oil exports peak. The post-peak decline is initially moderate (4% per annum) and after three years quickens to 8% p.a. This faster rate can be interpreted either as rapidly declining oil import availability, due to a higher underlying rate of depletion from oil field and/or the result of various negative feedback effects (as described in Section 2.3), or to the impact of high oil prices, or both.

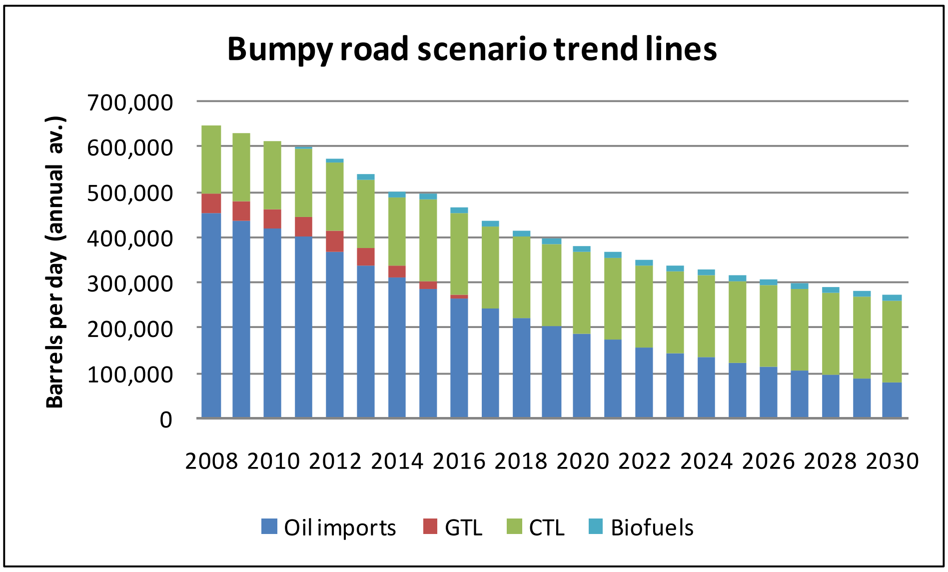
In terms of the domestic alternatives, this “bumpy road” Scenario can be viewed as either the result of inaction by relevant authorities in mobilising new investments, or the result of deteriorating financial and economic conditions which constrain new investments. Sasol continues with its extension to Secunda but does not construct the proposed Mafutha plant. PetroSA is unable to secure new feedstock for its Mossgas plant and existing reserves deplete rapidly from 2012. Imports which would require the construction of new pipelines or an LNG terminal are assumed to be infeasible due to adverse financial and economic conditions. Further expansion of biofuels beyond the DME’s target for 2013 is assumed to be constrained by climate changes (e.g. droughts) and related food security concerns.

Table 4.4-4: Bumpy road scenario assumptions – Early peak, rapid oil depletion & constrained alternatives

Source of liquid fuel	**Assumptions**
Oil imports	• decline by 4% p.a. from 2009 to 2011 • decline by 8% p.a. from 2012
CTL	• Sasol maintains existing production of 150,000 bpd at Secunda • Sasol adds 30,000 bpd to Secunda in 2015
GTL	• PetroSA maintains existing production till 2012, thereafter declining at 20% of 2012 production p.a. as feedstock depletes, so that production falls to zero by 2017
Biofuels	• rise to 2% of liquid fuels (13,000 bpd) by 2013 in line with the DME’s Biofuels Industrial Strategy; thereafter constant

The quantitative projections resulting from these assumptions are shown in Appendix 11 and the figures below. Supply falls monotonically to less than half of its current level in 2030.

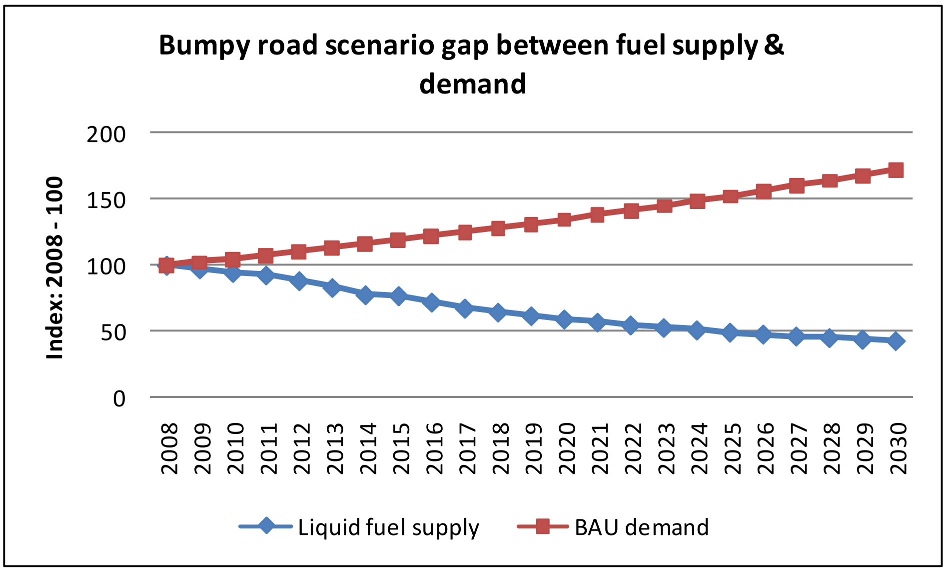
Figure 4.4-9: Bumpy road scenario – fuel supply trend



See also Appendix 11

The gap between BAU demand and supply grows continuously so that by 2030 supply (42.4 index value) is less than a quarter of projected BAU demand (172.2 index value).

Figure 4.4-10: Bumpy road scenario – fuel supply/demand gap



See also Appendix 11

4.4.4.2 The beginning of the bumpy road (2009 - 2014)[5]

The beginning phase of the bumpy road is marked by several key economic, transport, food, security and governance issues. The lack of reaction by the state, markets and society to fuel and transportation is symptomatic of a greater social malaise, namely a low level of awareness of the financial, energy and climate-change issues facing the world and the nation. There is an uncritical acceptance that economic growth is sustainable and is the route to resolving the plethora of social and other issues facing the nation. This last point reflects a distinct lack of leadership and vision about a sustainable future for South Africa. This lack of vision and forward planning in turn arises from the deterioration of social trust and standards of governance among the ruling political elite. Nevertheless, some of the worst effects of the global financial and economic downturns are mitigated somewhat by the ongoing state investment in infrastructure, consequent on South Africa hosting the 2010 FIFA Soccer World Cup. The result from a transportation perspective is that while there have been road transportation fuel efficiency measures implemented, the non-availability of sufficient alternative fuels and propulsion systems means that a growing gap starts appearing between fuel supply and demand, although the full significance of this gap becomes apparent only by 2012.

The global airline industry is in serious trouble as its operating costs rise dramatically. Many large airlines worldwide need to be saved from bankruptcy through state intervention; others go insolvent and are sold off to the highest bidders. Many privately owned airlines struggle to stay aloft as high fuel prices cripple their profitability. International tourism declines markedly after 2010, hitting South Africa's balance of payments hard. Domestically, road transportation companies are forced to increase their tariffs, and the cost of moving goods rises noticeably. With its dependency on road transportation for the movement of people, goods and services, South Africa is confronted with the limitations of its transportation infrastructure. As mentioned earlier, shifting road, rail and air freight to Maglev is a process with a long lead time, and this provides no immediate solution to the problems of transporting freight and thereby keeping one of the economy's life arteries flowing. There is increasing criticism of Transnet and the Department of Transport for not having invested more heavily in public transport over the past

[5] Periodisation of the bumpy road draws to a large extent on the fragmentation scenario explored by Hendler, Holiday, Ratcliffe and Wakeford (2007: 45-48)

10 years. The rail network has for many years been downgraded and has lacked ongoing maintenance and investment. Its commuter services are limited and do not offer a viable service to those who need it. The costs of upgrading and expanding public transport have risen dramatically. South African Airways incurs ever greater losses, much to the annoyance of both government and taxpayers. Airline tickets rise to their highest levels since the airline was founded. Many people's mobility is constrained by the high price of fuel. People plan their travel and holidays much closer to home while overseas travel becomes a privilege only affordable by the wealthy.

4.4.4.3 The middle of the bumpy road (2015 - 2022)

By 2015 the beneficial effects of the World Cup on the South African economy are fading. The official unemployment rate starts rising rapidly, breaching the 30% mark, while the broad rate reaches 50%.

International geopolitical developments reduce the supply of oil coming to South Africa, resulting in shortages, especially in smaller cities and the interior. Alternatives to liquid fuels are extremely limited and cannot be scaled up to meet the shortfall. There is no option but for consumers to downscale their consumption of petrol and diesel. Car pooling becomes commonplace. Many private car owners are forced to use public transport, which becomes heavily over-subscribed. Many commuters opt to work from home whenever possible, and businesses have to allow more flexible working hours. The national government is forced to take emergency measures to limit fuel consumption. National road speed limits are reduced and fuel rationing is introduced. The demand for motor cycles and smaller cars increases in relative terms, but overall the automotive industry is hard hit as consumers postpone new vehicle purchases indefinitely. Cycling becomes increasingly commonplace in urban areas. Members of the taxi industry stage protests at the high fuel prices, and incidents of violence increase. The costs of road maintenance soar, since asphalt is a by-product of oil refining and the costs of operating machinery have risen steeply. As a result, road infrastructure deteriorates. This negatively affects the distribution of many goods, including food.

Farmers are very hard hit by the rising prices and shortages of fuel. Farmers make representations to the government for subsidies on their fuel costs, as an increasing number face bankruptcy. Food prices continue to rise and help to keep the headline inflation rate in double figures. With the financial ruin of many farmers, food production decreases, creating shortages which drive prices even higher. This creates severe problems for the poor.

4.4.4.4 The end of the bumpy road (2023 - 2030)

From 2023 the problems of a dysfunctional transport system start to weigh heavily on all aspects of society: the fact that it is no longer possible to move goods (freight) around the country easily has had a severe economic knock-on effect. One of these effects is that there is a lack of food for the population. The problems in agriculture require that certain food categories have to be imported. Food producers in various parts of the country are severely hit as drought years become more frequent and high temperatures continue to prevail as a result of climate change. The demand for biofuels increases dramatically as a result of the oil price spike. Many farmers have great incentive to produce corn for ethanol, reducing the land available for food. Government is forced to intervene in the pricing and availability of food supplies in order to avoid conflict. Key staples have to be subsidised to ensure that the poor have access to food. Localised food shortages necessitate the development of system of emergency food distribution and production to supply hard hit communities. This places an additional cost burden on the state, in the context of a diminished fiscus due to declining taxes, an outcome of economic recession.

Many individuals panic and begin to hoard both fuel and food. This results in both food and fuel shortages which drives up prices further. Unemployment is still the biggest social problem as many large businesses continue to retrench workers as sales continue to fall. High food prices undermine the diets of many people living with HIV-Aids, and this contributes to a rise in the rate of HIV/Aids deaths, resulting in a growing number of HIV orphans. As a result of all these factors, violent crime increases as vulnerable people become desperate. In some areas large gangs openly loot houses and shops where security is weak. The army and security services are on continual high alert as poor people protest their circumstances and often take to looting of supermarkets and other food stores. This is widespread across the country, but especially common around urban informal settlements.

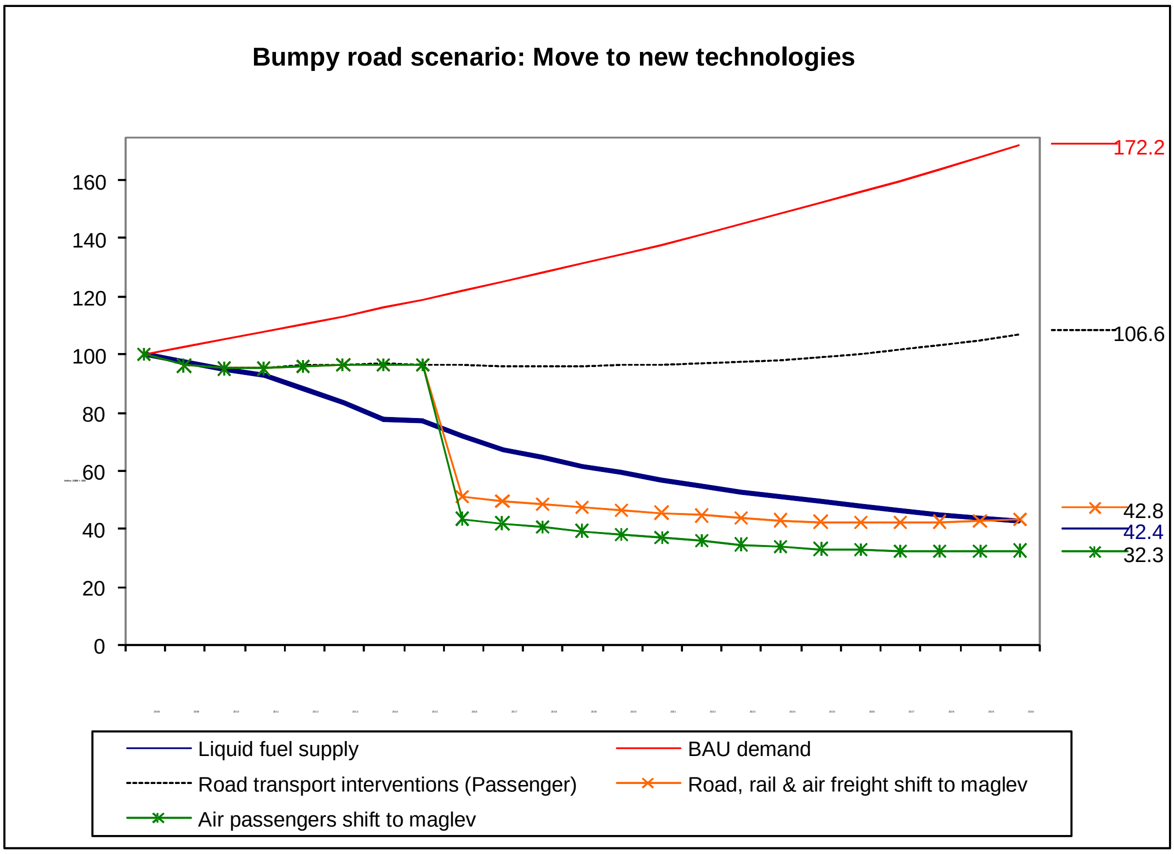
Increasing local conflict, high prices, unemployment, and low levels of mobility begin to break down the structures of governance. The administration in many smaller towns collapses, as they are unable to collect the revenues to sustain their operations as many people default on their rates and other services payments. Central government is no longer able to step in and cover these deficits as it too is under fiscal pressure. There are many reports of motorists being attacked as they travel through the countryside. Trucks are often stopped and looted of their contents as rural people attempt to cope with the collapse of their support systems. This disrupts the distribution of goods to rural areas as well as the distribution of food to urban areas. Groups in both rural and urban areas fill the gap created by the lack of governance and set up their own militias to protect these areas. The leadership is most often self-appointed and acts primarily in its own interest. The country is increasingly fragmented into small units controlled by uncoordinated militias.

Having left their response so late, government, the markets and society are faced with the direct risk of rapid economic dysfunctionality (as the transport system falters) and the likelihood that this will spark social unrest and instability. It becomes critical for the state to initiate the most effective response within the shortest time possible.

4.4.4.5 Bumpy road – Impact of transportation efficiency measures

The bumpy road scenario assumes that the response to peak oil by government leaders and authorities is muted. However, for illustrative purposes the interventions that would be required for liquid fuel demand to match supply are calculated and shown in Figure 4.4-8. The suite of efficiency measures and mode shifts considered in the previous scenario (Taking the back roads) is insufficient; this scenario would require new technology to bridge the gap between supply and demand. The proposed technology is maglev, which is about 95% more efficient in freight transportation than the other modes combined. If maglev systems are available, it is expected that domestic air travel along these routes will also shift to the maglev system. Of course, supplanting the entire freight industry is not realistic, but this emphasises the need for drastic measures to match fuel demand with supply in this scenario. It is assumed that maglev infrastructure can only be available from 2016 onwards, if investment starts in 2008. A greater shift towards alternative fuels and propulsion systems could alleviate the supply/demand gap but would not be able to close it.

Figure 4.4-11: Bumpy road scenario – move to new technologies



See also Appendix 12

4.5 Summary and conclusions

During the assessment of potential measures to improve energy efficiency in the transportation system, clear packages of measures emerged. If the "Well planned journey" scenario materialises in the future, South Africa can rely on the improvement of road based transport, while in the case of the "Bumpy road" scenario, new technology is required to bridge the gap between the demand for and supply of oil. Table 4.5-1 provides a summary of the findings.

Table 4.5-1: Peak oil projections and the required transport interventions

Peak oil projections	**TRANSPORT INTERVENTIONS**			
	Road based measures only	**Road, rail and air based measures**	**Mode specific measures and mode shifts**	**Move to new technologies**
Well planned journey	Entirely sufficient (Index: +10.9)	Not required	Not required	Not required
Taking the back roads	Insufficient (Index: -8.3)	Barely sufficient (Index: +0.1)	Not required	Not required
Riding the wave	Insufficient (Index: -11.9)	Insufficient (Index: -3.5)	Sufficient (Index: +3.3)	Not required
Bumpy road	Insufficient[6] (Index: -64.2)	Insufficient[6] (Index: -64.2)	Insufficient[6] (Index: -64.2)	Entirely sufficient (Index: +10.1)

In the most optimistic peak oil projection (Figure 7) the gap between oil demand (BAU) and the projected supply is 84.4 index points. As road based measures have the highest efficiency improvement potential, these were explored first. Implementing a group of passenger road based measures only will result in the remainder of a 22.2 index point gap. It is therefore

[6] In this projection only a person travel shift is possible.

required to implement freight road based measures as well. In 2030 implementing all passenger and freight road based measures that are feasible in South Africa, will result in a 10.9 index point surplus. A slight mode shift towards road based public transport is included in these measures.

If there is a more severe, although still relatively slow, reduction of the oil supply, road based measures alone will not be sufficient. The supply-demand gap is 103.8 index points. The gap, if all road based measures are implemented, still exists and is 8.3 index points wide. As a second step, adding feasible rail and air based measures was explored. Implementing all feasible road, rail and air measures appears to be just barely sufficient (index surplus of 0.1 points) to close the supply-demand gap in this case.

A third peak oil projection that was explored is a rapid decline in oil supply. The supply-demand gap in this projection is 110.6 index points. Implementing only road based measures leaves an 11.9 index point gap. Moreover, adding all rail and air based efficiency measures still leaves a 3.5 index point gap. It is clear that further, more drastic, measures are needed. The next step would be to promote a substantial mode shift. This shift will mainly materialise via long distance freight rail and a shift towards non-motorised transport in passenger transit. The result of a substantial move towards rail is an index surplus of 3.3 points.

In the most extreme peak oil projection, the “Bumpy road” scenario, the supply-demand gap is expected to be 129.8 index points. None of the measures based on existing transport systems is sufficient to close the gap. A greater passenger transport shift towards non-motorised transport and public transit is required. All aviation passenger and all freight based movements need to be carried out via very energy efficient systems, such as Maglev. Given that the development of these systems will require time, government needs to make sure it plans accordingly. If all freight and aviation passenger trips in South Africa are transferred to these efficient systems, an index surplus of 10.1 points is realised by 2030. It needs to be mentioned that this surplus is expected to be reduced over the years that will follow. Only changes in land-use and reduced economic activity are left to combat the potential future gap that is expected by 2035, if the conservative projections become reality.

Important conclusions:

- It is critical to start investing in measures now, as many of them have long lead times, where benefits are only realised after several years.
- It is possible to manage the process of making a transition to more sustainable transport systems. This will require authorities to begin to implement all interventions across all modes immediately.
- It should be kept in mind that although the scope of this study only extends to 2030, there is no definite reason why the trends will cease after this time (although the associated degree of uncertainty rises as one moves further into the future). With this in mind, it seems to be a much better investment to construct a maglev system now, as benefits will extend beyond the study period.
- There are very distinct differences in the responses to the various scenarios, providing quite a strong message as to the risk posed by oil depletion.

Appendices

Appendix 1: Passenger Road Transportation Efficiencies

Passenger Road Transport Expected Efficiency Gain						
Efficiency Improvement Measure	**2010**	**2015**	**2020**	**2025**	**2030**	**Total**
Hybrid-electric vehicles	0.01	0.04	0.10	0.16	0.17	17%
Biofuels	0.01	0.02	0.04	0.05	0.06	6%
LPG vehicles	0.01	0.02	0.03	0.04	0.05	5%
Electric or Hydrogen vehicles	0.00	0.03	0.05	0.09	0.15	15%
Road efficiency measures	0.01	0.05	0.12	0.18	0.20	20%
Maintenance	0.01	0.04	0.07	0.10	0.12	12%
Driver behaviour	0.00	0.01	0.03	0.07	0.15	15%
Smaller vehicles	0.01	0.02	0.03	0.03	0.04	4%
Company cars and travel allowances	0.01	0.03	0.05	0.07	0.08	8%
Integrated TDM	0.01	0.06	0.15	0.23	0.25	25%
Car pooling	0.00	0.02	0.04	0.06	0.07	7%
Driver assistance systems	0.00	0.03	0.07	0.11	0.12	12%
PT priority systems	0.07	0.09	0.10	0.10	0.10	10%

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 2: Freight Road Transportation Efficiencies

Freight Road Transport Expected Efficiency Gain						
Efficiency Improvement Measure	**2010**	**2015**	**2020**	**2025**	**2030**	**Total**
Hybrid-electric buses and trucks	0.00	0.01	0.03	0.07	0.20	20%
Aerodynamic fittings	0.01	0.03	0.05	0.08	0.10	10%
Lightweight materials	0.00	0.01	0.01	0.02	0.02	2%
Tyres	0.00	0.01	0.03	0.05	0.05	5%
Maintenance	0.01	0.04	0.07	0.09	0.12	12%
TDM	0.01	0.06	0.15	0.23	0.25	25%
Driver behaviour	0.01	0.05	0.12	0.18	0.20	20%
Road efficiency measures	0.00	0.01	0.03	0.05	0.05	5%
Fleet vehicle tracking systems	0.00	0.04	0.09	0.14	0.15	15%

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 3: Rail Transportation Efficiencies

Rail Transport Expected Efficiency Gain						
Efficiency Improvement Measure	**2010**	**2015**	**2020**	**2025**	**2030**	**Total**
Idle reduction	0.00	0.02	0.03	0.04	0.05	5%
Aerodynamic fittings	0.00	0.02	0.03	0.04	0.05	5%
Regenerative Braking	0.01	0.03	0.05	0.08	0.10	10%
Rolling resistance	0.01	0.03	0.05	0.08	0.10	10%
Consist management	0.00	0.02	0.03	0.04	0.05	5%
Engineer training (driver behaviour)	0.00	0.02	0.06	0.09	0.10	10%

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 4: Air Transportation Efficiencies

Air Transport Expected Efficiency Gain						
Efficiency Improvement Measure	**2010**	**2015**	**2020**	**2025**	**2030**	**Total**
Aircraft improvement	0.02	0.08	0.14	0.19	0.25	25%
Redesigning auxiliary loads	0.01	0.02	0.02	0.02	0.02	2%
maintenance	0.01	0.03	0.05	0.08	0.10	10%
TDM	0.02	0.06	0.11	0.15	0.20	20%
Infrastructure and operations	0.00	0.04	0.09	0.14	0.15	15%
Air Traffic Management	0.01	0.04	0.07	0.09	0.12	12%
Bio-fuels	0.01	0.02	0.04	0.05	0.06	6%

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 5: Well planned journey scenario data projections

Year	Oil imports	GTL	CTL	Biofuels	Total liquid fuels	Liquid fuel supply	BAU demand
	bbl/day	bbl/day	bbl/day	bbl/day	bbl/day	index	index
2008	455,000	45,000	150,000		650,000	100	100
2009	464,100	45,000	150,000		659,100	101.4	102.5
2010	473,382	45,000	150,000		668,382	102.8	105.1
2011	482,850	45,000	150,000	4,000	681,850	104.9	107.7
2012	492,507	45,000	150,000	8,000	695,507	107.0	110.4
2013	482,657	45,000	150,000	13,000	690,657	106.3	113.1
2014	473,003	45,000	150,000	13,000	681,003	104.8	116.0
2015	463,543	45,000	180,000	13,000	701,543	107.9	118.9
2016	445,002	45,000	180,000	13,000	683,002	105.1	121.8
2017	427,202	45,000	260,000	13,000	745,202	114.6	124.9
2018	410,113	45,000	260,000	13,000	728,113	112.0	128.0
2019	393,709	45,000	260,000	13,000	711,709	109.5	131.2
2020	377,961	45,000	260,000	13,000	695,961	107.1	134.5
2021	362,842	45,000	260,000	13,000	680,842	104.7	137.9
2022	348,328	45,000	260,000	13,000	666,328	102.5	141.3
2023	334,395	45,000	260,000	13,000	652,395	100.4	144.8
2024	321,019	45,000	260,000	13,000	639,019	98.3	148.5
2025	308,179	45,000	260,000	13,000	626,179	96.3	152.2
2026	295,852	45,000	260,000	13,000	613,852	94.4	156.0
2027	284,018	45,000	260,000	13,000	602,018	92.6	159.9
2028	272,657	45,000	260,000	13,000	590,657	90.9	163.9
2029	261,751	45,000	260,000	13,000	579,751	89.2	168.0
2030	251,281	45,000	260,000	13,000	569,281	87.6	172.2

SOURCE: Constructed by the author Wakeford (ASPO SA), specifically for this project

Appendix 6: Well planned journey – projected transportation efficiencies

Year	Liquid fuel supply	BAU demand	PASSENGER ROAD TRANSPORT EFFICIENCY IMPROVEMENT MEASURES						FREIGHT ROAD TRANSPORT EFFICIENCY IMPROVEMENT MEASURES					
Scenario	Optimistic	BAU	Local government interventions	ITS	Driver participation	Alternative fuels or propulsion systems	Vehicle size	Travel Demand Management	Freight local government interventions	Freight Travel Demand Management	Freight ITS	Freight operator participation	Freight vehicle design	Freight alternative fuels or propulsion systems
2008	100	100	100.0	100	100	100	100	100	100	100	100	100	100	100
2009	101.4	102.5	99.7	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6
2010	102.8	105.1	100.9	100.7	100.6	100.6	100.6	100.6	100.6	100.6	100.6	100.6	100.6	100.6
2011	104.9	107.7	102.6	102.3	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1
2012	107.0	110.4	104.7	104.3	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0	104.0
2013	106.3	113.1	106.7	106.2	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7	105.7
2014	104.8	116.0	108.7	107.9	107.4	107.4	107.4	107.4	107.4	107.4	107.4	107.4	107.4	107.4
2015	107.9	118.9	110.5	109.3	108.7	108.7	108.7	108.7	108.7	108.7	108.7	108.7	108.7	108.7
2016	105.1	121.8	112.3	110.7	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0
2017	114.6	124.9	114.0	112.1	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3	111.3
2018	112.0	128.0	115.9	113.6	112.6	112.6	112.6	112.6	112.6	112.6	112.6	112.6	112.6	112.6
2019	109.5	131.2	117.9	115.2	114.1	113.1	113.0	112.4	112.2	111.2	110.7	110.1	109.9	109.6
2020	107.1	134.5	119.9	116.8	115.7	113.5	113.4	112.2	111.7	109.8	108.7	107.5	107.1	106.7
2021	104.7	137.9	121.9	118.5	117.3	113.9	113.8	111.9	111.2	108.4	106.8	105.0	104.4	103.7
2022	102.5	141.3	124.0	120.2	118.8	114.4	114.1	111.7	110.7	107.0	104.8	102.5	101.6	100.7
2023	100.4	144.8	126.1	121.9	120.4	114.8	114.5	111.5	110.3	105.6	102.8	99.9	98.8	97.7
2024	98.3	148.5	128.4	123.8	122.2	115.2	114.9	111.2	109.8	104.2	100.9	97.4	96.1	94.7
2025	96.3	152.2	130.9	126.1	124.3	115.7	115.2	111.0	109.3	102.8	98.9	94.8	93.3	91.7
2026	94.4	156.0	133.7	128.6	126.6	116.1	115.6	110.8	108.8	101.4	97.0	92.3	90.6	88.7
2027	92.6	159.9	136.7	131.3	129.1	116.5	116.0	110.5	108.4	100.0	95.0	89.7	87.8	85.7
2028	90.9	163.9	139.9	134.3	131.8	117.0	116.3	110.3	107.9	98.6	93.0	87.2	85.0	82.7
2029	89.2	168.0	143.2	137.4	134.6	117.4	116.7	110.1	107.4	97.2	91.1	84.6	82.3	79.7
2030	87.6	172.2	146.6	140.7	137.5	117.8	117.1	109.8	106.9	95.8	89.1	82.1	79.5	76.7

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 7: Riding the wave data projections

Year	Oil imports	GTL	CTL	Biofuels	Total liquid fuels	Liquid fuel supply	BAU demand
	bbl/day	bbl/day	bbl/day	bbl/day	bbl/day	index	index
2008	455,000	45,000	150,000		650,000	100	100
2009	436,800	45,000	150,000		631,800	97.2	102.5
2010	419,328	45,000	150,000		614,328	94.5	105.1
2011	402,555	45,000	150,000	4,000	601,555	92.5	107.7
2012	370,350	45,000	150,000	8,000	573,350	88.2	110.4
2013	340,722	45,000	150,000	13,000	548,722	84.4	113.1
2014	313,465	45,000	150,000	13,000	521,465	80.2	116.0
2015	288,387	45,000	180,000	13,000	526,387	81.0	118.9
2016	265,316	45,000	180,000	13,000	503,316	77.4	121.8
2017	244,091	45,000	260,000	13,000	562,091	86.5	124.9
2018	224,564	45,000	260,000	13,000	542,564	83.5	128.0
2019	206,599	45,000	260,000	13,000	524,599	80.7	131.2
2020	190,071	45,000	260,000	13,000	508,071	78.2	134.5
2021	174,865	45,000	260,000	13,000	492,865	75.8	137.9
2022	160,876	45,000	260,000	13,000	478,876	73.7	141.3
2023	148,006	45,000	260,000	13,000	466,006	71.7	144.8
2024	136,165	45,000	260,000	13,000	454,165	69.9	148.5
2025	125,272	45,000	260,000	13,000	443,272	68.2	152.2
2026	115,250	45,000	260,000	13,000	433,250	66.7	156.0
2027	106,030	45,000	260,000	13,000	424,030	65.2	159.9
2028	97,548	45,000	260,000	13,000	415,548	63.9	163.9
2029	89,744	45,000	260,000	13,000	407,744	62.7	168.0
2030	82,565	45,000	260,000	13,000	400,565	61.6	172.2

SOURCE: Constructed by the author Wakeford (ASPO SA), specifically for this project

Appendix 8: Riding the wave – projected transportation efficiencies

Year	Liquid fuel supply	BAU demand	Road transport interventions (Passenger)	Road transport interventions (Freight)	Rail transport interventions	Air transport interventions	Passenger Mode Shift to NMT	Durban - Gauteng Corridor Mode Shift	Cape Town - Gauteng Corridor Mode Shift	Port Elizabeth - Gauteng Corridor Mode Shift
Scenario	Rapid	BAU								
2008	100	100	100	100	100	100	100	100	100	100
2009	97.2	102.5	96.1	95.7	95.6	95.4	91.0	89.8	86.1	85.4
2010	94.5	105.1	95.2	94.1	93.9	93.5	89.2	88.0	84.4	83.7
2011	92.5	107.7	95.1	93.3	93.1	92.5	88.2	87.0	83.5	82.8
2012	88.2	110.4	96.0	93.4	93.1	92.3	88.0	86.8	83.3	82.6
2013	84.4	113.1	96.3	92.7	92.3	91.3	87.0	85.9	82.4	81.7
2014	80.2	116.0	96.5	91.6	91.1	89.9	85.7	84.6	81.1	80.5
2015	81.0	118.9	96.3	89.6	89.0	87.5	83.5	82.4	79.0	78.4
2016	77.4	121.8	95.9	87.4	86.8	85.0	81.1	80.0	76.7	76.1
2017	86.5	124.9	95.7	85.2	84.4	82.4	78.6	77.6	74.4	73.8
2018	83.5	128.0	95.6	83.2	82.3	80.1	76.4	75.4	72.3	71.7
2019	80.7	131.2	95.8	81.6	80.6	78.1	74.5	73.5	70.5	69.9
2020	78.2	134.5	96.1	80.0	78.9	76.1	72.6	71.6	68.7	68.2
2021	75.8	137.9	96.4	78.4	77.2	74.1	70.7	69.8	66.9	66.4
2022	73.7	141.3	96.7	76.9	75.5	72.1	68.8	67.9	65.1	64.6
2023	71.7	144.8	97.0	75.2	73.7	70.1	66.8	65.9	63.2	62.7
2024	69.9	148.5	97.7	74.0	72.3	68.4	65.2	64.4	61.7	61.2
2025	68.2	152.2	98.6	73.2	71.4	67.1	64.0	63.2	60.6	60.1
2026	66.7	156.0	99.8	72.8	70.9	66.3	63.2	62.4	59.9	59.4
2027	65.2	159.9	101.2	72.7	70.6	65.7	62.7	61.9	59.3	58.9
2028	63.9	163.9	102.9	73.0	70.8	65.6	62.5	61.7	59.2	58.7
2029	62.7	168.0	104.7	73.3	71.0	65.4	62.3	61.5	59.0	58.5
2030	61.6	172.2	106.6	73.5	71.0	65.1	62.1	61.3	58.7	58.3

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 9 Taking the back roads scenario data projections

Year	Oil imports	GTL	CTL	Biofuels	Total	Liquid fuel supply	BAU demand
	bbl/day	bbl/day	bbl/day	bbl/day	bbl/day	index	index
2008	455,000	45,000	150,000		650,000	100	100
2009	464,100	45,000	150,000		659,100	101.4	102.5
2010	473,382	45,000	150,000		668,382	102.8	105.1
2011	482,850	45,000	150,000	4,000	681,850	104.9	107.7
2012	492,507	45,000	150,000	8,000	695,507	107.0	110.4
2013	482,657	36,000	150,000	13,000	681,657	104.9	113.1
2014	473,003	27,000	150,000	13,000	663,003	102.0	116.0
2015	463,543	18,000	180,000	13,000	674,543	103.8	118.9
2016	445,002	9,000	180,000	13,000	647,002	99.5	121.8
2017	427,202		180,000	13,000	620,202	95.4	124.9
2018	410,113		180,000	13,000	603,113	92.8	128.0
2019	393,709		180,000	13,000	586,709	90.3	131.2
2020	377,961		180,000	13,000	570,961	87.8	134.5
2021	362,842		180,000	13,000	555,842	85.5	137.9
2022	348,328		180,000	13,000	541,328	83.3	141.3
2023	334,395		180,000	13,000	527,395	81.1	144.8
2024	321,019		180,000	13,000	514,019	79.1	148.5
2025	308,179		180,000	13,000	501,179	77.1	152.2
2026	295,852		180,000	13,000	488,852	75.2	156.0
2027	284,018		180,000	13,000	477,018	73.4	159.9
2028	272,657		180,000	13,000	465,657	71.6	163.9
2029	261,751		180,000	13,000	454,751	70.0	168.0
2030	251,281		180,000	13,000	444,281	68.4	172.2

SOURCE: Constructed by the author Wakeford (ASPO SA), specifically for this project

Appendix 10: Taking the back roads – projected transportation efficiencies

					Rail interventions			Air interventions					
Year	Liquid fuel supply	BAU demand	Road transport interventions (Passenger)	Road transport interventions (Freight)	Rail TDM	Rail driver participation	Rail vehicle design	Air Traffic Management	Air Travel Demand Management	Aircraft Maintenance	**Aircraft Design**	Alternative aviation fuels or propulsion systems	Aviation infrastructure and operations
Scenario	Slow	BAU											
2008	100	100	100	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2009	101.4	102.5	98.8	98.3	98.3	98.3	98.3	98.2	98.2	98.2	98.1	98.1	98.1
2010	102.8	105.1	98.9	97.8	97.8	97.8	97.7	97.6	97.5	97.4	97.3	97.3	97.3
2011	104.9	107.7	99.4	97.5	97.5	97.5	97.3	97.2	97.1	97.0	96.8	96.7	96.7
2012	107.0	110.4	100.3	97.8	97.7	97.7	97.5	97.3	97.1	97.0	96.7	96.7	96.7
2013	104.9	113.1	100.8	97.2	97.1	97.0	96.8	96.6	96.4	96.2	95.8	95.8	95.8
2014	102.0	116.0	101.0	96.1	96.0	95.9	95.6	95.3	95.1	94.9	94.5	94.4	94.3
2015	103.8	118.9	100.7	94.0	93.9	93.8	93.5	93.1	92.8	92.6	92.1	92.0	92.0
2016	99.5	121.8	100.3	91.8	91.6	91.5	91.1	90.7	90.3	90.1	89.5	89.4	89.4
2017	95.4	124.9	99.9	89.4	89.3	89.1	88.7	88.2	87.8	87.5	86.8	86.7	86.7
2018	92.8	128.0	99.7	87.3	87.1	87.0	86.4	85.9	85.4	85.1	84.4	84.2	84.2
2019	90.3	131.2	99.8	85.6	85.4	85.2	84.6	84.0	83.5	83.1	82.3	82.1	82.1
2020	87.8	134.5	99.9	83.9	83.6	83.5	82.8	82.1	81.5	81.2	80.2	80.1	80.0
2021	85.5	137.9	100.1	82.2	81.9	81.7	80.9	80.2	79.6	79.1	78.1	78.0	77.9
2022	83.3	141.3	100.3	80.5	80.2	79.9	79.1	78.2	77.6	77.1	76.0	75.8	75.8
2023	81.1	144.8	100.5	78.7	78.3	78.1	77.2	76.3	75.5	75.0	73.8	73.6	73.5
2024	79.1	148.5	101.0	77.4	77.0	76.7	75.7	74.7	73.9	73.4	72.1	71.9	71.8
2025	77.1	152.2	101.9	76.5	76.0	75.7	74.7	73.6	72.7	72.1	70.7	70.5	70.4
2026	75.2	156.0	103.1	76.1	75.6	75.3	74.2	72.9	72.0	71.4	69.9	69.7	69.6
2027	73.4	159.9	104.4	75.9	75.4	75.0	73.9	72.5	71.5	70.9	69.3	69.1	68.9
2028	71.6	163.9	106.1	76.2	75.7	75.3	74.0	72.6	71.5	70.8	69.1	68.9	68.8
2029	70.0	168.0	107.9	76.5	75.9	75.5	74.2	72.6	71.5	70.7	68.9	68.7	68.6
2030	68.4	172.2	109.8	76.7	76.1	75.7	74.3	72.6	71.4	70.6	68.7	68.4	68.3

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

Appendix 11 Bumpy road scenario data projections

Year	Oil imports	GTL	CTL	Biofuels	Total	Liquid fuel supply	BAU demand
	bbl/day	bbl/day	bbl/day	bbl/day	bbl/day	index	index
2008	455,000	45,000	150,000		650,000	100	100
2009	436,800	45,000	150,000		631,800	97.2	102.5
2010	419,328	45,000	150,000		614,328	94.5	105.1
2011	402,555	45,000	150,000	4,000	601,555	92.5	107.7
2012	370,350	45,000	150,000	8,000	573,350	88.2	110.4
2013	340,722	36,000	150,000	13,000	539,722	83.0	113.1
2014	313,465	27,000	150,000	13,000	503,465	77.5	116.0
2015	288,387	18,000	180,000	13,000	499,387	76.8	118.9
2016	265,316	9,000	180,000	13,000	467,316	71.9	121.8
2017	244,091		180,000	13,000	437,091	67.2	124.9
2018	224,564		180,000	13,000	417,564	64.2	128.0
2019	206,599		180,000	13,000	399,599	61.5	131.2
2020	190,071		180,000	13,000	383,071	58.9	134.5
2021	174,865		180,000	13,000	367,865	56.6	137.9
2022	160,876		180,000	13,000	353,876	54.4	141.3
2023	148,006		180,000	13,000	341,006	52.5	144.8
2024	136,165		180,000	13,000	329,165	50.6	148.5
2025	125,272		180,000	13,000	318,272	49.0	152.2
2026	115,250		180,000	13,000	308,250	47.4	156.0
2027	106,030		180,000	13,000	299,030	46.0	159.9
2028	97,548		180,000	13,000	290,548	44.7	163.9
2029	89,744		180,000	13,000	282,744	43.5	168.0
2030	82,565		180,000	13,000	275,565	42.4	172.2

SOURCE: Constructed by the author Wakeford (ASPO SA), specifically for this project

Appendix 12: Bumpy road – projected transportation efficiencies

Year	Liquid fuel supply	BAU demand	Road transport interventions (Passenger)	Road, rail & air freight shift to maglev	Air passengers shift to maglev
Scenario	Rapid	BAU			
2008	100	100	100	100	100
2009	97.2	102.5	96.1	96.1	96.1
2010	94.5	105.1	95.2	95.2	95.2
2011	92.5	107.7	95.1	95.1	95.1
2012	88.2	110.4	96.0	96.0	96.0
2013	83.0	113.1	96.3	96.3	96.3
2014	77.5	116.0	96.5	96.5	96.5
2015	76.8	118.9	96.3	96.3	96.3
2016	71.9	121.8	95.9	50.7	43.4
2017	67.2	124.9	95.7	49.3	41.8
2018	64.2	128.0	95.6	48.1	40.4
2019	61.5	131.2	95.8	47.1	39.2
2020	58.9	134.5	96.1	46.2	38.0
2021	56.6	137.9	96.4	45.2	36.9
2022	54.4	141.3	96.7	44.3	35.7
2023	52.5	144.8	97.0	43.3	34.5
2024	50.6	148.5	97.7	42.6	33.6
2025	49.0	152.2	98.6	42.1	32.9
2026	47.4	156.0	99.8	42.0	32.5
2027	46.0	159.9	101.2	41.9	32.2
2028	44.7	163.9	102.9	42.1	32.2
2029	43.5	168.0	104.7	42.4	32.3
2030	42.4	172.2	106.6	42.8	32.3

SOURCE: Constructed by the authors Lane and Vanderschuren, specifically for this project

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5. Energy conclusions and recommendations for the NATMAP

A report submitted to the National Department of Transport by

The Association for the Study of Peak Oil (SA)

in association with

Marianne Vanderschuren

and

Tanya Lane

November 2008

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Executive Summary

Strategic Implications of Peak Oil

- Peak oil is inevitable and the South African national transportation system is vulnerable to liquid fuel price spikes and liquid fuel depletion.
- A business-as-usual trajectory for transport in South Africa will not be feasible after global oil production peaks.
- The longer there is to prepare for the decline in fuel supplies the more orderly and manageable the transition to alternative fuels and transportation modes/systems is likely to be.
- Initially the authorities need to focus on creating fuel efficient usage and later on mode shifts and new transportation infrastructure.
- Long-term transport planning needs to be aligned with land use and spatial planning in terms of a reconstructed space economy.

Sustainable Transport System

- The transportation system reproduces a larger macro-economic reality and social environment which in turn are embedded in a set of natural systems that provide eco-services and energy in order for society to function.
- Therefore the question of a sustainable transport system raises the more fundamental question of a sustainable economy and society.
- At the present historical juncture the global economy faces a fundamental challenge to restructure or be rendered unsustainable.
- A sustainable transport system is one that helps to reproduce the conditions for a sustainable economy and society by:
    - Drawing progressively off renewable energy resources (as far as possible)
    - Managing existing energy usage efficiently
    - Not excessively polluting the environment with waste
    - Valorising its assets and minimizing its liabilities
    - Empowering individual users as well as broader communities through the relevance and practicality of its services.
- Accordingly, the national transport system cannot become sustainable within an unsustainable economy and society but should support and follow the guidelines that are emerging as a road map to a sustainable economic and social future.

- This means that the development of a sustainable transport system is an iterative process, resulting in flexible and changing patterns of movement and movement routes, in response to broader macro-economic and sustainability policies.

Energy and Transportation Scenarios to 2030

- There is a substantial degree of uncertainty about the timing of the global oil peak and the rate at which production will thereafter decline; these variables are beyond the control of anyone in South Africa.
- The second major axis of uncertainty, namely the speed and comprehensiveness with which government authorities (and to an extent private businesses and individuals) prepare and respond appropriately, is however under South Africans' control. Prudent risk management implies that transport planning authorities should anticipate the risk of an early peak and rapid decline in global oil production (and thus South Africa's oil imports) by implementing a broad suite of policy interventions beginning as soon as possible.
- Key interventions to minimize the chance of disruptions to the transport system and therefore to the functioning of the South African economy include:
    - road, rail and air-based transport efficiency measures;
    - shifts from private to public transportation and (in the case of long haul freight) from road to rail transportation.

- However, should oil deplete at a rate faster than projected in this assignment, then the above measures may not be adequate to balance the demand for and supply of liquid fuels for the transportation system, in which case large-scale investment in new transport technologies would be required.
- Furthermore, beyond 2030 – the time limit for projections of oil and liquid fuel depletion in this assignment – it is likely that the liquid fuel supply/demand gap will continue to grow.
- This suggests that what will be required to close the gap are changes in life style and significant reduction of origin-destination distances over which goods have to be transported and people to travel, to reproduce economic functioning and social life.
- The re-planning of the South African space economy, in line with a sustainable macro-economic strategy, will become critical for the implementation of a sustainable transportation system.

Principles for Transport Planning

- Aim at long-term sustainability
- Understand interconnections between the economy, energy, land use, the environment and transportation systems
- Initiate action to mitigate the impact of peak oil now
  - Start with short-term fuel efficiency measures
  - Emphasize modes of transport where mechanical energy is used most efficiently
  - Advocate non-motorised transport within urban areas (short distance)
  - Move to mass transit
  - Shift long-distance freight off roads and on to rail
  - Review measures every five years, based on monitoring and evaluation of impact
- Create an energy consciousness amongst the population
- Develop Vision and Leadership

Comments on DoT and DME Strategies

- Most conclusions of this assignment align with those of the DoT and DME.
- However, the assignment differs from the DoT and DME strategies in that it questions the long-term sustainability of the current South African economic growth and spatial planning model, in the light of the depletion of oil and other resources.

Recommendations

- Short-term (1 to 3 years)
  - Create an energy awareness programme
  - Promote non-motorised transportation
  - Promote fuel efficiency measures
  - Plan for new long-term transportation infrastructure
- Medium-term (3 to 7 years)
  - Continue further public education and awareness programme
  - Finalise long-distance infrastructure investment and planning
  - Implement transport mode shifts
  - Review earlier short-term measures
- Long-term (7 to 10 years)
  - Implement long-distance infrastructure

- Expand the quantity of goods and number of people affected by transport mode shifts
- Review earlier medium-term measures

Strategic Platform for Action

- In order to cover the downside risk of the previous recommendations the following strategic action platform needs to be put in place:
  - Concerted focus on winning over stakeholders and building consensus for an energy awareness programme;
  - A proper Vision and planning to ensure a successful driver education programme (to achieve substantial efficient fuel usage);
  - Thorough planning and implementation for funding, capacitation and incentivisation of municipalities to ensure the effective implementation of non-motorised transport;
  - Concerted focus on designing appropriate incentives for private operators to get involved in freight transport (both as users and operators); and
  - Championing the necessity of a sustainable space-economy that is facilitated by an aligned and embedded transportation system.

Monitoring and Evaluation

- Indicators of sustainable transportation should be formulated within the following key performance areas (KPAs):
  - Triple bottom line balance sheet of the overall transportation system (showing financial, social, and environmental assets and liabilities);
  - Triple bottom line income/expenditure statement of the overall transportation system (showing income from the state, private sector and passengers versus operating expenditures);
  - Perceived value by the transport system's market and stakeholders.
- The 5 yearly reviews should take place against key performance indicators (KPIs) that have been formulated within the foregoing KPAs.

5.1 Introduction

This report is the last of four reports for the National Department of Transport on the implications of peak oil for the National Transportation Master Plan (NATMAP).

The first report (i.e. Section 2) of this assignment examined the status quo with regard to transport and its energy usage in South Africa, and concluded that in the context of the peaking and decline of global oil production, the South African transport system is very vulnerable, because of its high level of dependency on petroleum-based liquid fuels as an energy source and the fact that about 70% of current liquid fuel consumption is met by imported oil.

The second report (i.e. Section 3) analysed the strengths and weaknesses, opportunities and threats of various energy sources and propulsion systems. This report concluded that the most effective strategy would be to focus on efficiency and conservation of oil-based and electrical energy within the existing transportation system, at least in the short- to medium-term. Significant energy conservation could be achieved through a shift from private passenger transport to mass public transport (road and rail), as well as from shifting freight from road to rail on major corridors. The report also noted that in the longer term local transportation systems would have to align with local economic processes, which means that urban spaces will have to be shaped in ways that are appropriate to the needs of the citizenry and also sustainable over the long run. In the medium term land use and spatial planning will have to change to mould local transportation systems to compact, minimum origin-destination social movement patterns – if this does not happen formally it will happen informally, but with greater social and technical costs.

The first two reports (referred to above) demonstrate that the depletion of liquid fuel supplies, with concomitant price rises, means that South Africa is going to have to change the ways in which it transports passengers and goods, based on alternative fuels and propulsion systems, that will be sustainable in the long run.

Any attempt at defining the necessary interventions needs to take account of the extent of two critical uncertainties, namely when the global production and supply of oil will peak and how rapid the post peak depletion will be.

To take account of the extent of these uncertainties the third report (i.e. Section 4) rehearsed the future through *scenario thinking* (GBN, 2007: 4). Trends identified in the first two reports were used in conjunction with scenario planning as a tool for initiating new thinking about managing energy sources more strategically, and identifying appropriate alternative fuels, propulsion systems and transportation modes, in the face of inherent and increasing uncertainty – shaped by a wide range of geopolitical, environmental, economic and social forces. If certain scenarios materialize in the future each will require a specific and clear package of measures to address the shortfall between the available liquid fuel supply and a business-as-usual fuel demand trajectory. In the most optimistic scenario considered by this assignment ("Well planned journey") South Africa can rely on the improvement of fuel efficiency in road-based transport, while in the most pessimistic scenario ("Bumpy road") a radically new transportation technology will have to be rapidly implemented in the future to bridge the gap between the demand for and the supply of oil-based liquid fuels for transportation. Two intermediate scenarios ("Taking the back roads" and "Riding the wave") that were also considered by this assignment as more realistic rehearsals for the future, require not only road-based measures of fuel efficiency but also rail and air-based fuel efficiency measures as well as transport mode specific efficiency measures and transport modal shifts. The report also points to the fact that after 2030 the oil depletion and oil price spiking trends will continue and therefore that investment in radically new transportation technologies (like Maglev) might be considered now as these benefits will extend beyond the study period. Likewise, the report also pointed to the potential for fuel savings through re-planning the space economy to reduce travel distances.

5.1.1 Subject of this report

The subject of this report is the synthesis of the previous three reports into a set of realistic conclusions and recommendations that can form the basis of a national transportation strategy that takes account of the imminent decline in global oil production. While the timing of the peak in oil production is uncertain, there is little question that the more time there is to prepare for the peak, by reducing South Africa's dependence on imported oil, the better. This report recognises the uncertainties inherent in attempting to predict with a high degree of accuracy the timing of the oil production peak. It is because of the uncertainties that a risk assessment approach has been taken in order to examine the levels of potential risk associated with the proposed recommendations. In particular, this report will examine the risks of not implementing suggested measures to mitigate oil depletion. The risk assessment will also enable policy makers to have a more realistic overview of their options and the likely consequences of the actions they can take. The recommendations cover a range of actions that include transport efficiency improvement measures, and alternative fuels, propulsion systems and transportation modes, that could be implemented within the context of different scenarios for the timing of peak oil and subsequent rates of oil depletion, over the next 22 years (i.e., to 2030).

5.1.2 Background to investigation

The investigation, of which this report forms a part, arose from a proposal that was submitted to the National Department of Transport at the invitation of the Deputy-Director General, Mr Situma, who is managing the process of developing the NATMAP. The intention behind this study is to complement the work which has already been commissioned by the Department to develop the NATMAP. To this end ASPO-SA assembled a team of people whose combined expertise covers the critical issues that need to be examined, so that the NATMAP will consider the impact of global oil depletion on both the South African transport system and space economy.

The objectives of this investigation are, therefore, that:

- it should produce a standalone strategic set of documents;
- these documents should be used as reference works by the consultants employed to develop the NATMAP;
- these documents should be used as reference works by the National Department of Transport;
- pending departmental decision, these documents should be made available as public discussion documents;
- these documents will contribute to drawing out the strategic implications of oil depletion for the transportation sector and its development over the coming decades until 2030; and
- these documents will contribute to setting out a number of routes to a likely end state within the time frame of the NATMAP.

These documents will contribute to explicating the implications of these routes in terms of energy alternatives, energy savings and likely investment.

5.1.3 Objective of strategic documents

The key objectives of these strategic documents, of which this specific report is the fourth, are:

- to highlight the key strategic implications for the transportation sector of global oil depletion;
- to identify key principles which should be factored into transportation planning with a long-term time horizon in the light of the depletion of key energy and other resources;
- to identify a number of plausible scenarios which arise as a consequence of global oil depletion;

- to assess the risks associated with these scenarios to transport planning in the light of the inevitability of oil depletion during the time frame of the NATMAP;
- to identify high-level alternative strategies to the current business-as-usual and demand-led approach for different modes of transport in the light of oil depletion.

5.1.4 Limitations of scope of investigation

The scope of the investigation has been limited to an agreed table of contents for all four documents, between the Department of Transport, the main contractor and the ASPO-SA consulting team.

5.1.5 Plan of Development

Before explicating the specific recommendations for interventions aimed at ensuring an adequate supply of energy for South Africa's transport system, it is necessary to summarise the implications of peak oil to ensure that there is a set of guiding principles as a context within which to formulate the proposed interventions. Accordingly Section 5.2 identifies the implications of peak oil for a strategy aimed at enhancing the South African transportation system's efficient usage of fuel and developing alternatives to oil-based transport. Section 5.3 defines the meaning of "sustainability" and "sustainable transport" in order to lay the basis for a set of guidelines for a sustainable transportation system. Section 5.4 takes the specific conclusions for the two most realistic scenarios (referred to above) as the basis for an analysis of how to achieve parity between the supply of and demand for liquid fuel by the transportation system. Section 5.5 explicates the guidelines for transport planning. Section 5.6 summarises some key conclusions from relevant policy documents of the Department of Transport (DoT) and the Department of Minerals and Energy (DME), and notes the convergence and divergence of conclusions of this assignment with those of the DoT and DME. Section 5.7 lists the principal recommended interventions that the DoT could make to mitigate the likely impact of global oil depletion. Section 5.9 subjects these proposed interventions to an analysis of the risks to their successful implementation. The mitigation measures arising out of this risk analysis serve as a platform for strategic action that would be required to counter the downsides of the proposed interventions. Finally, Section 5.10 identifies key performance areas that could form the basis for future monitoring and evaluation of the effectiveness of the interventions.

5.2 Strategic implications of peak oil

The key strategic implications of peak oil are as follows:

- **Peak oil is inevitable; only the timing is uncertain.**

  The above follows from the following facts. Oil must be discovered before it can be produced. Oil must be extracted, refined and transported before it can be used. On the human time scale, oil is a finite, non-renewable resource. The more oil we use now the less we have for the future. Exponential growth goes hand in hand with depletion of non-renewable resources. Exponential growth in human populations and consumption of physical resources, including non-renewables like oil, is not sustainable indefinitely on a finite planet. The life-cycle curve of oil production is roughly a bell curve (the so-called Hubbert curve) – this is empirically verifiable (e.g. US-48, North Sea, etc.). Global production of oil will at some point reach a peak and then begin to decline.

- **The longer there is to prepare for the decline of oil supplies the better, as the more ordered and manageable the process of transitioning to alternatives is likely to be.**

  Petroleum products have the highest energy density of any known easily portable energy carrier. Replacing the current oil-based infrastructure requires time, financial and human resources and energy. The longer we take to change our consumption patterns the more constrained our options will be for doing this in an orderly manner.

- **The impact of peak oil on the global economy is likely to be severe because of the high dependence on oil for so many facets of the global economy.**

  Oil provides approximately 35 per cent of the world's primary energy supply and up to 95 per cent of all transport fuels. It also provides the feedstock for petrochemical products and is a critical ingredient in the system of industrial agriculture. It is uncertain precisely when the oil production peak will occur, what the post-peak rate of depletion will be, whether sufficient substitutes for oil will be developed, produced and installed in time to avert damaging shortages, and what scope there will be for conservation and efficiency to offset the decline. It is also uncertain precisely how people, countries, and markets will react when the decline sets in. Nevertheless, based on available evidence, it appears to be likely that: oil production will not increase substantially beyond its current level; between 2008 and 2015, oil output will begin an inexorable decline; there is a significant risk of a rapid decline (cliff) in global production at some point; and, without proactive mitigation well before the peak, shortages will occur causing the price to spike.

- **A business-as-usual trajectory for transport in South Africa will not be feasible after global oil production peaks.**

  Constrained supplies of imported oil will affect the South African transport system in all scenarios developed in this report; it is only the size of the demand/supply gap that varies over the period under consideration. Energy supply constraints and rising fuel prices will become the dominant factors driving transport options, on both the supply and demand sides. A transport strategy should therefore seek above all to reduce dependence on imported oil.

- **The most cost effective and easy to implement measures involve creating energy efficiencies and other transport management measures. In the longer term, mode shifts, new propulsion systems and new infrastructure will need to be implemented.**

  On the demand side, there is an extensive range of measures that the transport authorities could implement in order to reduce liquid fuel consumption. Some of these, such as fuel rationing, car free days and reduced road speed limits, were introduced in response to the oil shocks of the 1970s and are therefore tried and tested. Many of the traffic management systems and measures to influence driver behaviour have proved to be successful in limiting excessive fuel consumption and vehicle emissions in other countries. There is also considerable scope for reducing oil consumption through improved vehicle design.

  Of particular importance to reducing liquid fuel consumption in the medium term will be transport mode shifts: firstly a shift from private passenger to public and non-motorised transport; and secondly from road freight to rail freight. In respect of the latter, maglev systems show great promise in terms of energy efficiency, although infrastructure costs are likely to be high.

- **South Africa should develop alternatives to oil-based liquid fuel transport to lessen the oil dependency of the transport system in the medium to long term.**[1]

  South Africa is already a leader in coal to liquid (CTL) and gas to liquid (GTL) fuels, and this advantage should be built upon, as long as it is done in a manner that does not significantly

[1] Of importance in this regard is to specify the timing of alternatives, some of which involve infrastructural development. In this assignment "short term" refers to about 1 to 2 years, and is the period in which one cannot expand capital stock. Therefore, capital investments to produce more fuel domestically should be regarded as medium to long term projects.

increase the country's carbon emissions (e.g. any new CTL plant should incorporate carbon sequestration technology). South Africa should also develop electricity from renewable sources to power transportation not only on the road network but also for the rail network.

- **For the long term, transport planning should ideally happen in conjunction with sustainable land use and spatial planning, both aiming to reduce transport distances and oil dependency.**

  Sustainable land use and spatial planning should be defined in terms of global sustainability criteria that encompass the natural and social environments as well as the macro-economic and financial environments. While the relationship of transportation to these broader environments falls beyond the scope of this assignment, they are nevertheless the rationale for and the context within which management of sustainable energy resource usage should be considered, including the energy required to power the national, regional and local transportation systems. Broader government policies in respect of environmental conservation, macro-economic stability and growth, financial intermediation and stability as well as social inequities and poverty, create the framework within which the transportation system functions and set the supra-transportation goals toward whose realisation transportation policies are meant to contribute.

5.3 Definition of sustainability and sustainable transport

The larger systemic context of transportation is that it is embedded in a set of natural systems that provide key eco-services in order for it to function. It is imperative that the relationship between transportation (as well as between all other socio-economic sectors) and natural systems is sustainable.

'Sustainable' means "that which can be maintained over time." Heinberg (2007) suggests as a yardstick the durability of previous civilizations, which lasted up to several hundreds or even thousands of years. The World Commission on Environment and Development (1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Thus both intra- and inter-generational equity should be a driving values behind a vision of a sustainable future. In terms of these values, poverty and a high degree of inequality are incompatible with sustainable development. Sustainable development is usually understood to include economic, social and environmental dimensions.

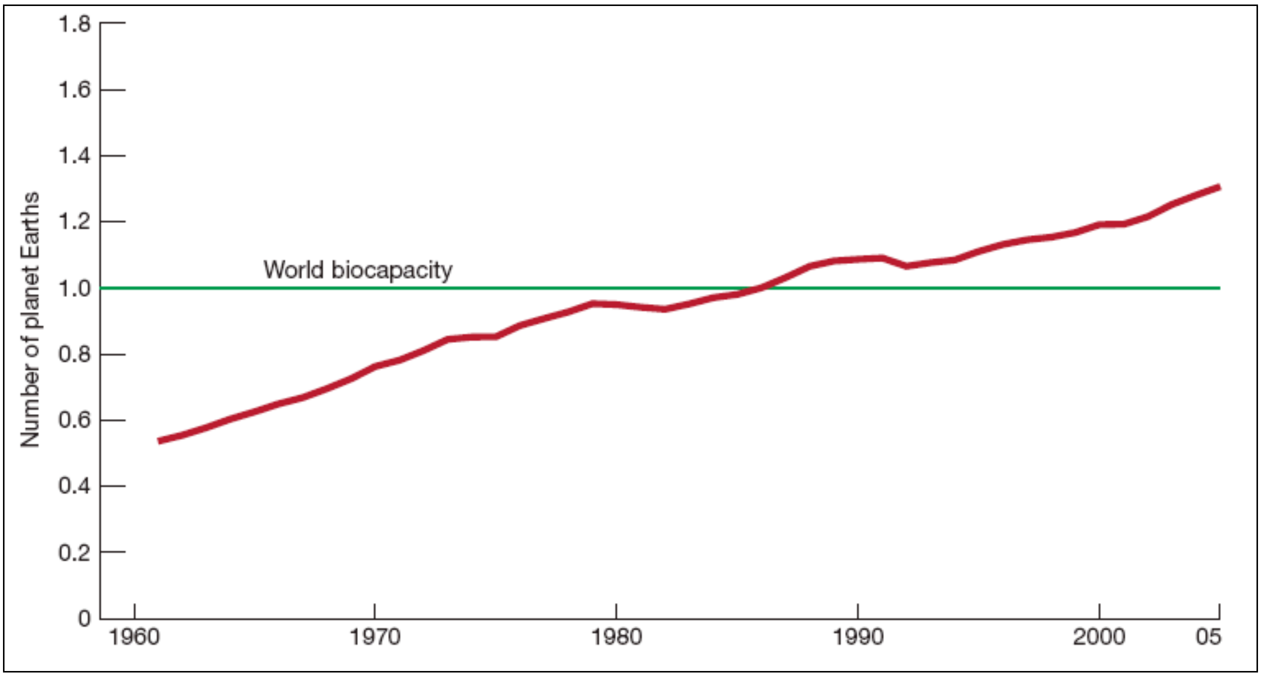
Environmental economist Herman Daly has suggested three conditions for sustainability, focusing on the resource base (Meadows, Meadows and Randers, 2004):

- the rate of use of renewable resources must be less than or equal to their rate of regeneration;
- the rate of use of non-renewable resources must be less than or equal to the rate at which they can be replaced by sustainable renewable resources; and
- the rate of pollution emissions must be less than or equal to the rate at which they can be absorbed and processed by the environment.

The above applies equally to the rate of usage of energy resources required to power the South African national, regional and local transportation systems. Currently, these transportation systems function at different levels to convey passengers (i.e. workers, employees) as well as goods (freight) to primary, intermediate and final consumers in the South African economy. The economy is based on an exponential growth model driven by debt financing. Debt financed economic growth models (with their consequent market and debt bubbles, the unwinding of which has led to the current profound credit crisis in the Western global financial system) have in recent years been interrogated for sustainability. Daly (1996), for example, emphasizes the difference between growth, defined as an increase in size or quantity (e.g. of populations or resource throughput) and development, defined as qualitative improvement. Growth will ultimately run up against finite limits, since we only have one Earth. Wackernagel and Rees (1996) introduced the notion of humanity's Ecological Footprint, the total land and water area needed to support the global population. Currently our collective footprint is calculated as nearly 30 per cent greater than the capacity of the biosphere to support us (WWF, 2008). In its most recent report the World Wildlife Fund (WWF, 2008) notes:

> "We have only one planet. Its capacity to support a thriving diversity of species, humans included, is large but fundamentally limited. When human demand on this capacity exceeds what is available – when we surpass ecological limits – we erode the health of the Earth's living systems. Ultimately, this loss threatens human well-being."

Figure 5.3-1: The Earth's biocapacity, 1961-2005



Source: WWF, 2008

As can be seen humanity's demand on the planet's living resources, its Ecological Footprint, now exceeds the planet's regenerative capacity by about 30 per cent (Figure 5.3-1 above). In other words, we now need an additional third of a planet in order to sustain human life at current consumption levels; clearly an impossibility. Globally, we are in the zone where the long-term sustainability of the human race and many other animal and plant species is in question. It has only taken some 45 years to move from having half of the planet to spare (i.e. more than adequate capacity) to where we are now. These changes are happening very rapidly. This global overshoot is growing and, as a consequence, ecosystems are being degraded and waste is accumulating in the air, land and water. The resulting deforestation, water shortages, declining biodiversity and climate change are putting the well-being and development of all nations, including South Africa's, at increasing risk.

Clearly, there is a tension – if not a contradiction – between the current economic growth models and sustainable planetary life; there are structural limits to a type of economic growth that involves ever-increasing consumption of resources. Economic growth in turn is facilitated by – or perhaps driven by – a debt-based global financial system, which is arguably itself unsustainable. One view is that "built on an ideology of free market capitalism and unlimited economic growth" the financial world has deviated "too far from [economic] reality", leading to adjustments and the "crisis and panic" that currently characterize global financial markets.[2] Fractional reserve banking systems in which money is created through the issue of debt, on which interest has to be paid, require continuous economic growth in order for new wealth to be generated to pay of the interest. Thus environmental and resource constraints on economic growth imply that debt-based monetary systems are unsustainable in the long-run.

If economic growth is undermined after peak oil – most countries that have recorded absolute decreases in liquid fuel consumption for sustained periods have been in recession (negative growth) – it is quite possible that within 10 to 15 years the goal of economic growth will have been replaced with broader and more specific sustainable development goals, in terms of various quality of life and environmental indicators. The type of development that is pursued is important for transport because it will determine the patterns of conurbation and within the spatial dimensions of living and working places, the type of transportation plans that are implemented in South Africa.

5.3.1 Sustainability of the transportation system

Transportation must be considered in the light of the above and needs to stand in a sustainable relationship with the natural systems within which it is embedded, in respect of its rate of usage of both renewable and non-renewable resources, as well as its rate of waste output. There are concrete implications arising from this point for:

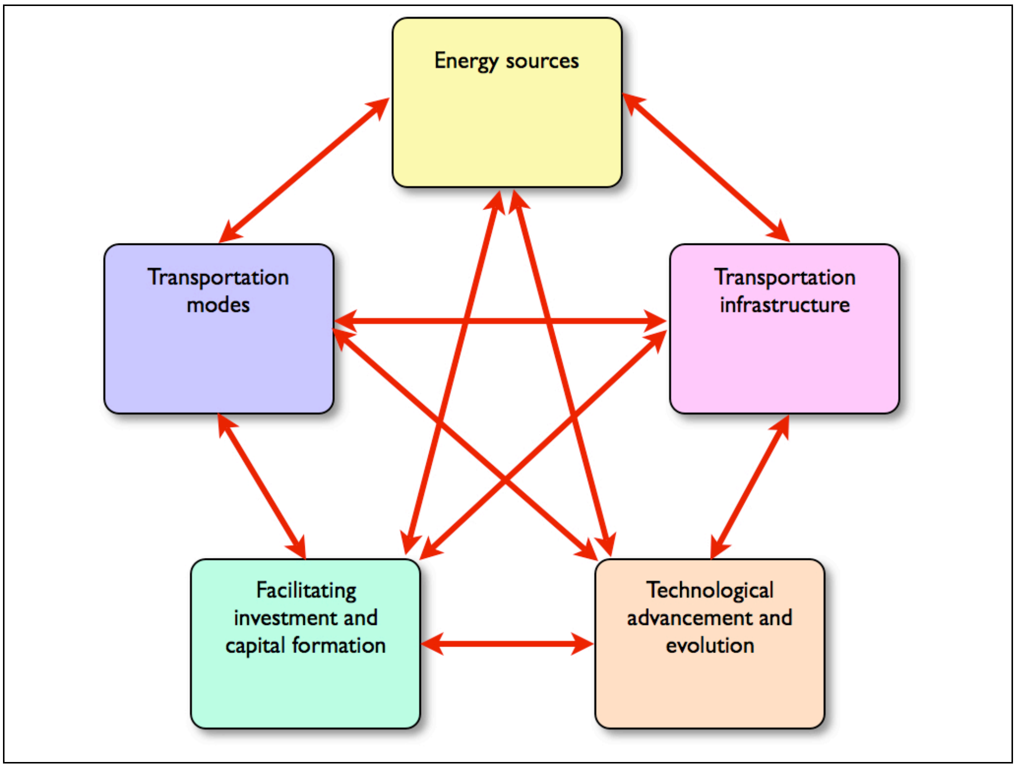
- the source of energy supplied to and consumed by transportation modes and systems;
- the management of transport energy demand;
- the use of most energy efficient and environmentally friendly systems;
- the disposal and recycling of the waste generated by the national transport systems (once past their lifespan, cars and other means of transport pose a significant waste disposal challenge).

[2] "A long Term Solution to Our Financial Crisis: The Other Forms of Capital", Nate Hagens, an explanation of themes by Robert Costanza, director of the Gund Institute b for Ecological Economics at the University of Vermont Cf. "Unravelling Financial Frakenstein", by Joseph Edozien, Chairman of the South African New Economics Network (SANE), www.sane.co.za; chairman@sane.co.za

The economic and social dimensions of sustainable transportation also embrace socio-economic empowerment, while recognizing the need for institutional facilitation and resource efficiency. In this view sustainable transport:

- balances the technical aspects of transport provision with the critical need for appropriate, decent and affordable transport within broader communities and metropolitan areas;[3]
- balances the technical aspects of transport provision with the requisite institutional frameworks for public transport delivery;
- is delivered in a co-evolutionary process between empowered participants engaging with government, understanding and utilizing appropriate technologies and moving away from the conventional modes of delivery;
- recognises that current energy sources that power the transport system are finite and need to be replaced with renewable sources over time.

Figure 5.3-2: Interrelationships and co-evolution between transport, energy and technology



Source: Compiled by the author Simon Ratcliffe specifically for this assignment

3 E.g: Does the high-tech Gautrain project adequately address the need, each and every day, of hundreds of thousands of workers, for decent, efficient, secure and affordable transport between their living places and the factory gates?

5.4 Energy and transportation scenarios to 2030

The impact that peak oil will have on economic growth is uncertain. Over the past half century economic growth has been strongly correlated with rising oil consumption, and most global economic recessions have followed supply and/or price shocks.[4] However, it does not necessarily imply that growth is not possible if liquid fuel consumption is decreasing. While some activities will be contracting, others could be expanding (including the investments in alternative energy and transport infrastructure). Patterns of fuel consumption will depend on the two key uncertainties or variables addressed in the scenarios explored in the third report (Hendler *et al*, 2008c) - i.e. the rate of oil decline (and thus the rate of increase in the oil price) and how well authorities and individuals respond. That report demonstrated that the chance of sustaining economic growth (improving living standards) would be maximised if the appropriate energy sources and transport system efficiencies were exploited at an early stage. By contrast, if policy actions were delayed or non-existent, the likely result would be protracted economic recession and social dislocation.

The business-as-usual fuel consumption curve (see the appendices to the third report) represents a projection of demand if there were no constraints on global fuel supplies or economic growth, and provides a benchmark against which to compare projections of liquid fuel supplies under various assumptions. Table 5.4-1 provides a summary of the four scenarios explored and the transport interventions that would be required to 'close the gap' between BAU demand and available supply of liquid fuels. The scenarios showed that if the indicated transport measures are introduced timeously, mobility through the transportation system (and the economic activity it supports) could be sustained, at least until 2030.

Table 5.4-1: Peak oil scenarios and the required transport interventions

PEAK OIL SCENARIOS	**TRANSPORT INTERVENTIONS**			
	Road based measures only	**Road, rail and air based measures**	**Mode specific measures and mode shifts**	**Move to new technologies**
Well planned journey	Entirely sufficient	Not required	Not required	Not required
Taking the back roads	Insufficient	Barely sufficient	Not required	Not required
Riding the wave	Insufficient	Insufficient	Sufficient	Not required
Bumpy road	Insufficient[5]	Insufficient	Insufficient	Entirely sufficient

Source: Hendler, *et al* (2008c: 16)

[4] See Wakeford (2007).
5 In this projection only a person travel shift is possible.

In the "Well planned journey" scenario, global oil production peaks late and the rate of decline is relatively slow. Domestic energy alternatives are scaled up, within certain constraints. The resulting gap between BAU oil demand and projected liquid fuel supply can be met with a combination of passenger and freight road efficiency measures as well as a slight mode shift towards road based public transport.

In the "Taking the back roads" scenario, world oil production peaks relatively late and declines relatively slowly, as in the previous scenario. However, domestic liquid fuel supplies are constrained by lack of action by the relevant public and/or private authorities, and/or by economic conditions. In this case, (passenger and freight) road based transport efficiency measures alone will not be sufficient to close the supply-demand gap; all feasible road, rail and air transport efficiency measures would be barely sufficient to close the supply-demand gap.

In the "Riding the wave" scenario, oil supplies peak earlier and decline more rapidly. However, domestic liquid fuel substitutes are scaled up over time, to partially offset declining oil imports. Nonetheless, the supply-demand gap requires the implementation of all road, rail and air based efficiency measures as well as a substantial mode shift. This shift would mainly materialise via long distance freight rail and a shift towards non-motorised transport in passenger transit.

Finally, in the "Bumpy road" scenario, oil depletion again sets in early with a rapid rate of decline. However, domestic energy alternatives are not scaled up owing to inaction and economic constraints. In this scenario, none of the measures based on existing transport systems is sufficient to close the demand-supply gap. A greater passenger transport shift towards non-motorised transport and public transit is required. All aviation passenger and all freight based movements need to be carried out via very energy efficient systems, such as Maglev (magnetic levitation) trains. Given that the development of these systems would involve substantial lead times, transport authorities should plan accordingly. In this scenario, it is likely that at some point changes in land-use will also be required to avoid damaging effects on economic activity.

To reiterate, there is a substantial degree of uncertainty about the timing of the global oil peak and the rate at which production will thereafter decline; these variables are beyond the control of anyone in South Africa. The other axis of uncertainty, namely the speed and comprehensiveness with which government authorities (and to an extent private businesses and individuals) prepare and respond appropriately, is however under South Africans' control. Prudent risk management implies that transport planning authorities should anticipate the risk of an early peak and rapid decline in global oil production (and thus South Africa's oil imports) by implementing a broad suite of policy interventions beginning as soon as possible. This would also be very beneficial to the environment and climate by reducing the emission of transport pollutants, including carbon dioxide.

The guiding principles for transport planning (section 5.5) and the recommendations (section 5.7) that are proposed below are informed by the foregoing scenarios, which provide a number of lenses through which to view the future. The "Well-planned journey" and "Riding the wave" scenarios provide idealized pictures of what is possible with widespread, cross-sectoral buy-in with actions initated almost immediately. At present, relatively few policy makers across most government departments and members of the business community are sufficiently aware of the peak oil issue and its implications. However, there is already within certain government departments like the Department of Transport and the Department of Minerals and Energy, a comparatively advanced awareness of the energy depletion and climate change issues facing the society as a whole and the transportation system in particular. These departments are in a prime position to provide pro-active leadership for the country's efforts to mitigate the impact of global oil depletion.

5.5 Guiding principles for transport planning

- **The overarching principle for transport planning should be that it aims for long-term sustainability based on a realistic appreciation of future world and domestic trends.**

  In particular, global oil depletion – together with climate change – implies that a business-as-usual trajectory is unsustainable. It cannot be assumed that past trends in economic growth, urbanisation and population growth will continue indefinitely.

- **The sooner a peak oil mitigation strategy is developed for transportation in South Africa the more effective it will be.**

  Timing is critical to the success of any measures taken. The energy inefficiencies in the current system are the cushion, the room that we have to manoeuvre in the short-term, and the factors that provide space for planning in order to keep the economy on an even keel. It is important to use this time judiciously. The timing of the peak is one of the key uncertainties so it is vital to use the time before the peak to do as much preparation as possible. It is critical to start investing in measures now, as many of them have long lead times, where benefits are only realised after several years. Renewable energy has a vital role in South Africa's long-term transportation solutions: the government and private sector need to rapidly plan and develop the renewable energy infrastructure, which will take time to be scaled up.

- **Government and the private sector must create an energy consciousness as part of their larger efforts to change the current mindset that accepts energy wastage.**

  There needs to be a multi-faceted communication strategy that starts with key senior level officials within government that is geared towards informing people of the issues and showing them how to make energy savings that will benefit themselves, as well as the country.

- **Leadership must have a vision regarding the energy issues and the strategic transportation response.**

  The most effective leadership is by example. Senior Ministers need to show what they have done and make sure that their actions and practices match the message they are putting out.

- **Start by implementing energy efficiency measures in the short-term, making provision for the longer-term measures with long lead times.**

Public awareness regarding fuel-efficient driver behaviour, vehicle maintenance and the advantages of the use of public and non-motorised transport should be developed. Government should investigate potential incentives for behavioural change. Furthermore, optimization of traffic controllers has substantial fuel efficiency benefits. Investments in the human resources required to generate this efficiency benefit should be made immediately.

- **Review the measures taken to mitigate energy scarcity at least every 5 years.**

There are levels of uncertainty around energy security and the timing of the peak in global oil production, as well as the uncertainties around the impact that these will have on the South African economy. In addition, new technological developments are taking place which may have significant impact on mitigation efforts. Develop new vulnerability indicators to enable timely interventions.

- **Understand the interconnections between the economy, energy, land-use, the environment and our transport systems.**

It should be borne in mind that although the scope of this study extends only to 2030, there is no definite reason why the identified trends will cease after this time (although the associated degree of uncertainty rises as one moves further into the future). South Africa's energy consumption is currently intimately tied to its economic growth model, which needs to be interrogated and restructured for sustainability. Restructured economic activity, under the impact of global oil depletion, will most likely take the form of more localized production and consumption, i.e. products and services will be consumed within a limited radius of where they were produced because the cost of a globalised trading process will increase substantially. Within the space economy, urban land-use planning will be a vital tool for reducing journey distances and creating space for non-motorised transport, which must be integrated into long-term mitigation planning and strategic thinking.

- **Emphasize modes of transport where the passenger weight versus tare vehicle mass ratio is highest, and where the mechanical energy efficiency is greatest.**

Much of the inefficiency and wastage of liquid fuel and energy in the current transport system is because most of the fuel consumed goes towards moving the weight of the vehicle rather than the weight of the passenger. For some types of motorised vehicles this ratio can be as low as 1:9, indicating that 1 litre of fuel is being used to move the passenger while 9 litres are being used to move the vehicle (see Section 2.3.4 of the second report). Electric engines are in general much more energy efficient than internal combustion engines.

- **Advocate non-motorised transport where possible and give the legal rights of cyclists and pedestrians precedence over the rights of motorcars on the roads.**

  One of the reasons that the Netherlands has such an integrated and vibrant non-motorised transport sector is because cyclists have protective legal rights, giving them precedence over users of motor-cars. The Dutch are the most avid users of bicycles in Europe. In the Netherlands colliding with a bike will be the fault of the motorist, no matter what. Pedestrians and cyclists are considered to be in a weaker position with respect to potential injury than someone driving a car so the entire liability for damages will be placed on the motorists and not the pedestrian or cyclist. This, together with the provision of appropriate infrastructure, is the reason for the high usage of non-motorised transport in the Netherlands. It has had the effect of reducing traffic congestion in urban areas, reducing oil dependency and providing a valuable source of aerobic exercise with its resultant health benefits.

- **Move towards mass transit.**

  As indicated, public transport is more energy efficient than private motorized modes. Government should advertise and possibly subsidise public transit systems and find ways to improve them, so that they become more appealing to the section of the society that has access to private cars.

- **Move long-distance freight off the roads and onto rail.**

  While the mode shift principle in freight transport is sound, there are a number of severe challenges that need to be overcome in order for this to be a viable option. For decades the rail network has fallen into disrepair and efficiency levels have fallen resulting in a lack of confidence in rail as a commercial option for the movement of freight. In order to overcome this negative sentiment towards the railways, it might be prudent to find mechanisms that give freight operators an interest in rail operations by providing commercial incentives.

5.6 Comments on DoT and DME strategies

5.6.1 Introduction

With regard to the strategies of the Departments of Transport and Minerals and Energy as they currently stand, comments will be made as they are pertinent to the brief and remit of this study.

5.6.2 Strategies of the Department of Minerals and Energy

The Department of Minerals and Energy has developed its Energy Security Master Plan which has two components, Electricity and Liquid Fuels. Both are pertinent to the scope of work undertaken by this study. The Energy Security Master Plan recognizes the centrality that energy plays in the economy by stating the following:

> "Energy security means ensuring that diverse energy resources, in sustainable quantities and at affordable prices, are available to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management requirements and interactions among economic sectors." (DME, 2007)

The Master Plan makes provision for the development of supply chain solutions to South Africa's liquid fuels supply challenges, for the management of liquid fuels demand, as well as emergency response tactics. Its longer-term approach aims to integrate supply, demand, macroeconomics, geopolitics and climate change. It also seeks to allow for the making of well informed choices with respect to energy supply, energy carriers, demand sector strategies, as well as energy transformation approaches, and is cognisant of the need to minimize the negative impacts on the environment and the economy.

The Master Plan intends to achieve the following outcomes:

1. In the short term, secure adequate supplies of affordable energy for continued economic growth and development;
2. In the medium term, enable policy- and decision- makers to make informed decisions on these complex inter-dependent energy outcomes, and
3. In the long term, ensure that the strategic planning and subsequent growth and development are sustainable (DME, 2007).

In terms of its planning approach the department has chosen to go down a central energy planning route rather than a market signalling one, in order to achieve the maximum participation of a number of stakeholders in the design of demand and supply sectors. The department lists a number of strategic options, which include the following that are relevant to this study:

1. In respect of the manufacturing of petroleum products, it has recommended that the local production of finished petroleum products be promoted, and specifically, that at least 30% of finished products be manufactured from indigenous raw materials;

2. It recognised that climate change needs to be considered as an important component of integrated energy planning and should, therefore, be incorporated in the energy modelling process. The incorporation will require data collection and climate change monitoring;

3. It saw a need for the alignment of fuels specification and other standards (including housing and building standards) to at least those countries that trade with South Africa. To ensure security of supply, it would therefore be recommended that global fuels specifications be adopted. Such an approach would aim to ensure that South Africa does not become a "dumping ground" for low grade fuels;

4. South Africa sources, through private players, more than 80% of its crude oil supply from Iran and Saudi Arabia, potentially putting the country in a precarious position, should some form of Middle Eastern conflict erupt. It recommended that 30% of all crude consumed in South Africa be procured through PetroSA and that South Africa, through its national oil company, acquires its own crude vessel;

5. In the bid to support promotion of local production of liquid fuels, it is recommended that a policy of limited imports be re-endorsed;

6. A major part of energy security is managing the energy demanded by all sectors in the economy. It is therefore recommended that as part of the energy security strategy, energy efficiency be strongly promoted in all energy consuming sectors of the economy. The energy demand management approach aims to include appropriate selection of energy carriers for different applications. At the centre of demand management however are appropriate demand sectors' strategies, starting from the industrial strategy through to appropriate transport strategies. Indications are that oil will run out sooner rather than later and a transport strategy that is over 90% dependent on oil is guaranteed to land South Africa in serious trouble in a few years time. No form of planning will find South Africa oil, when it has all been mined or acquired by those with more might or insight;

7. Problems in the petroleum sector have indicated the need for some level of coordinated planning of infrastructure investments, as it is done in some economies, irrespective of whether it is the state or the private sector making such investments. It recommended that an "independent energy planning coordinator" be considered.

The conclusions of this assignment are broadly in line with the thinking in the DME as articulated in their strategy documents. The recommendations of this assignment are specific actions that embody these conclusions and can contribute to achieving an integrated and coordinated response. The DME clearly advocates the promotion of energy efficiency across all sectors as a means toward the achievement of energy security. It has also clearly identified the risks associated with the reliance on oil procured mainly from the Gulf States. In fact, the DME has recently acted to mitigate this risk by establishing a relationship with Venezuela, a major oil exporting nation. Where the DME and this assignment differ is on the question of the long-term structural impediments to growth and therefore on the need for transforming South Africa's macro-economic strategy and space economy regulations to reduce the impact of oil depletion, financial bubbles and climate change on vast numbers of the population[6]: while the DME is silent on this issue this report notes a questionable compatibility between the current growth model and the limits of energy supply and environmental degradation; it also refers to widely held views that contrary to accepted wisdom growth may be reproducing the conditions of poverty and marginalization rather than being a precondition for addressing them.[7]

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[6] Oil depletion and the puncturing of financial credit bubbles tend to push an economy towards smaller growth rates and ultimately towards recession if the causative factors are severe enough; this is usually accompanied by inflation, leading to the phenomenon of stagflation (economic stagnation and general price inflation), but a severe recession could also be accompanied by price deflation as the economy recedes rapidly and demand falls faster than supply. In either case there are job losses and the less skilled and (usually) poorer segment of the workforce are the first to be retrenched. The communities from which these people come are also the least resourced to absorb the shocks of natural disasters (like Hurricane Katrina) which are thought to be stimulated by climate change.

[7] Cf. Swilling (2008: 1) who argues that "neo-liberal philosophies have allowed market forces to ransack global resources for the benefit of the billion or so people who make up the global middle and upper class that enjoys an ecological footprint that is far greater than their fair share of global resources". Critiquing classical Keynesianism, contemporary neo-liberalism, and (authoritarian) developmental statism, he also notes that 20% of the global population who live in the richest countries account for 86% of total private consumption expenditure, whereas the poorest 20% account for only 1,3% (according to the United Nations Development Programme - UNDP).

5.6.3 Current strategies of the Department of Transport

The Department of Transport has developed a number of transportation strategies over the last ten or so years. These include "The Public Transport Strategy", "Moving South Africa", and the "Rural Transport Strategy for South Africa".

5.6.3.1 The Public Transport Strategy (PTS)

The Department of Transport has recently developed its Public Transport Strategy (DOT, 2007) that has two key thrusts, Accelerated Modal Upgrading and Integrated Public Transport Networks. While this strategy is focused primarily on passenger transport, its central thrust is closely aligned with some of the findings of this study. It also recognizes the need for planning to mitigate the inevitability of peak oil. It states:

> "The expected peaking of global oil production within the next decade will mark the end of the cheap fossil fuel era. This, together with the increasing pressures for drastic cuts in climate change emissions – means that the mass motorisation of the South African population will not be possible, and neither is it desirable, nor equitable."

The PTS has a vision for the enhancement of public transport and has a timeframe for its implementation to 2020 and regards integrated rapid public transportation networks as the mobility wave of the future and as the only viable option that can ensure sustainable, equitable and uncongested mobility in liveable cities and districts. Its long-term vision is to develop a system that places over 85% of a metropolitan city's population within 1km of an Integrated Rapid Transport Network track. It also aims to achieve a mode shift of 20% of car work trips to public transport networks. It notes that in 2003 there were 1.85m workers in metropolitan cities who used a car to commute to work and assumes a doubling of this to 3.7m by 2020, which would mean attracting 750 000 (20%) of these workers to public transport networks.

The PTS further envisions a radically transformed public transport system that is driven by service delivery, is user-friendly, and of high quality in order to attract people away from their use of cars. It envisions services that are cheap, frequent, punctual and staffed by highly productive personnel and responsive to customer needs. The means through which reduced travel times will be achieved will be through a system of dedicated median bus routes and enclosed stations with pre-board fare payment for road trunk corridors and dedicated infrastructure and priority slots for passenger rail corridors. By 2020 the DOT aims to place all residents of the large cities within 1 km of the network and have incentives in place to get car users to switch to public transportation. The PTS also envisages the growth of non-motorised transport networks to enable walking and cycling and that link with the Public Transport Networks. It aims to have 100km of high quality walkways and cycleways in each of the 18 identified cities and districts by 2014. In 6 rural areas, by 2014 there will also be large scale walking and cycling infrastructure and services in smaller urban and rural districts.

This strategy is in line with the conclusions drawn in this study. Nonetheless, the project team is concerned about the implementation of these plans as that is the part that has been lacking in the past. The team looks forward to witness delivery.

5.6.3.2 Moving South Africa

The Moving South Africa (MSA) Strategy recognises that productive infrastructure, including transport assets, is one of several key preconditions for national economic growth. It understands that by investing in assets like bridges, roads, ports, or even telephone lines, a nation can structure development by reducing transport and communications costs, thereby facilitating further trade and creation of wealth. Indeed, transport is generally seen as an engine of growth and a guarantor of national integration, both internally and with the external global economy.

In addition to meeting the needs of customers and the nation, MSA emphasised the need for the transport system to do so sustainably and in a manner which allows levels of service to be continuously upgraded. Its concern for sustainability arises from the need to meet customer goals and national objectives over time, because it argues that, if the system cannot support itself, customers will inevitably be dissatisfied. It argues that there are many reasons why sustainability matters. First, and foremost, it is important for meeting customer needs for cost, levels of service, capacity, and modal choice. Second, sustainability is a necessary condition for upgrading, though it is not sufficient unto itself. Third, transport is a long-term industry – especially reinvestment in infrastructure – which requires advance planning and funding availability. And fourth, loss of one industry could destabilise other parts of the system, creating undesirable effects on customers, system costs, and service levels (DOT, 1999).

In the research, MSA found many gaps which threaten the sustainability of transport. These include:

- the R3.3 billion annual road underfunding;
- the capital reinvestment below required levels for almost all modes;
- a national vehicle fleet which, on average, is operating at above 80% of its useful economic life;
- externality costs not currently borne by operators who incur them; and
- systemic cross-subsidisation within some entities that perpetuates poor operating practices in otherwise money-losing operations.

Among the causes of the sustainability problem it saw the following:

- insufficient financing;
- escalating externality costs;
- low levels of capacity to address the problems;
- weak or absent mechanisms to enable the transport system to anticipate changes in demand, or to respond to changes in national goals and customer needs.

MSA clearly saw sustainability purely in economic terms, rather than more holistically and recognizing its resource, environmental and social dimensions, which is the focus of this assignment.

The MSA clearly recognized the need to have an integrated and strategic vision and argued,

> "The combinations of distance and dispersion of settlements and economic activity present a major challenge to transport when the resources of both government and transport customers are limited. It is for this reason that the strategic framework we present here addresses not just the issues inside of transport, but also the spatial relationship between the transport system and its customers." (DOT, 1999).

For both urban and freight customers, the strategy was to consolidate core transport assets into high volume corridor networks and dense development nodes. These corridors and nodes would concentrate demand for services into a focused area that would enable the low cost, high quality and affordable backbone of the total transport system. This is the *Strategic Network*. The dense demand and the simpler corridor network would lead to higher vehicle utilisation, larger volumes per vehicle and a resulting lower cost per passenger and per unit of freight. Some of the conclusions of this assignment support the approach that seeks to consolidate corridors for transportation purposes.

In support of this strategic network, feeding into it, distributing from it, and serving the needs of customers for transport between points outside of the core it saw a *Supporting Network* which must itself be sustainable as part of the total system, but because of lower demand density patterns. It saw its operations as characterised by lower levels of fixed cost and higher levels of variable cost.

Sustainability would be improved through the optimal deployment of modes in these networks and the corridors of which they are made up. The emerging deployment of transport modes would occur according to where each mode was able to provide the most economic level of utilisation given the density and patterns of demand in a corridor. (DOT,1997).

The limitation of the MSA study was in not seeing the broader energy and environmental constraints to the system as a whole. However, it did establish a number of useful principles and saw a number of the important interconnections within the transport system. It also saw the need for the establishment of strong institutions to serve as the locus for taking decisions on fixing the scope of the system and defining the role of modes. As mentioned earlier, mode switching has not yet been implemented.

5.6.3.3 The Rural Transport Strategy for South Africa

The Rural Transport Strategy (RTS) has arisen from the recognition that while 50% of South Africa's population live in rural areas, 72% of the country's poor are in these areas and need some form of special treatment within the context of an overall transport strategy for the country. It developed two areas of strategic thrust, to promote coordinated rural nodal and linkage development, and to develop demand-responsive, balanced and sustainable rural transport systems (DOT, 2007:2).

It also recognized the need for integrated sustainable rural development that combined rural transport, and rural spatial planning and rural local economic development, as well as an expanded public works programme. It sees rural transport development as focused on delivering rural transport infrastructure and services and provides guidelines linking rural road and transport planning processes with the emphasis on special rural transport initiatives such as intermediate means of transport, animal drawn carts and other low technology solutions. It also promoted non-motorised transport, as well as pedestrian walkways and bridges.

It highlighted the inter-relatedness with other sector departments in pursuance of social cohesion and sustainable livelihoods and proposed the establishment of transport forums and guidelines on possible institutional arrangements. The intergovernmental relations structures were seen as pivotal in strengthening coordination and alignment of programmes (DOT, 2007:2).

5.7 Recommendations

5.7.1 Introduction

The analysis undertaken during the course of this assignment indicates that there are high levels of inefficiency within the transportation system. This applies to passenger and freight road transport, as well as rail and air transport. The inefficiencies include the following:

- poor traffic control measures;
- a high proportion of road traffic used by private vehicles;
- a high proportion of freight that uses the roads;
- low vehicle occupancies in private transport;
- high levels of wastage through high levels of private transport;
- low levels of passenger weight relative to gross vehicle mass;
- low investment in public transport;
- inefficient ratios of passenger/freight weight versus tare vehicle mass that has to be moved; and
- a lack of appropriate non-motorised transport infrastructure.

5.7.2 Short term recommendations (1 to 3 years)

5.7.2.1 Create an energy awareness programme

Develop a strong energy consciousness through a comprehensive and concerted awareness creation programme. This programme needs to involve all key energy consuming sectors and those severely affected by the oil peak. It would therefore need to include the following sectors:

- Transport
- Agriculture
- Motor car manufacturing
- Mining
- Tourism

The Department of Minerals and Energy jointly with the Department of Transport should identify champions within the above sectors and in association with them should formulate a communication strategy vis-à-vis the key sectoral players.

In addition, the Department of Transport should facilitate the development of a driver educational programme that places strong emphasis on efficient liquid fuel consumption through:

- appropriate driver behaviour;
- improved vehicle maintenance;
- the buying and using smaller vehicles; and
- telecommuting where possible.

Finally, local governments should be encouraged to invest in human resources that can optimize traffic controllers, in turn reducing congestion, pollution and fuel consumption.

This programme needs to involve key leadership figures who need to model the changes being asked of others. Leadership by example is vital because it demonstrates to the public the integrity and willingness to practice what is being preached by their departments.

5.7.2.2 Promote non-motorised transport

A programme that advocates and facilitates non-motorised transport needs to be implemented as soon as possible. In fact, this is already being promoted by as part of the Public Transport Strategy. Local authorities will play a key role in implementing this programme and as a first step will have to formulate and finalise NMT plans.

5.7.2.3 Promote fuel efficiency measures

Fuel efficiency measures need to be implemented, beginning as soon as possible. These will in turn begin to create and reinforce the raising of awareness. Fuel efficiency measures need to include road transport (both passenger and freight), rail and air. Fuel efficiency measures are easy to implement and can begin immediately. Within the commercial sector, education can be targeted within industries. While fuel prices and economics will play a crucial part in focusing the attention of business owners and managers, who in all likelihood will be seeking their own efficiency related measures, a government led campaign can complement such initiatives.

Road passenger related efficiency measures

- Reduced road speed limits

  These would be implemented through governmental regulations and enforced by local traffic departments.

- Car pooling

  In the metropolitan areas car pooling should be incentivized by the local authorities through a rebate on entry costs into demarcated, high traffic volume, inner cities. This can be implemented electronically through technology that counts the number of occupants in a vehicle – the City of London currently uses similar technology to register the free access of electric and hybrid cars to the inner city area.[8]

- Company cars and travel allowances

[8] Sourced from the author, Simon Ratcliffe during a recent stay in the City of London, UK.

Tax incentives for company cars and travel allowances should be scrapped.

- Hybrid-electric vehicles

  Subsidies for research and development (from the Department of Transport) as well as incentives for users (see example from the City of London referred to in footnote) could be implemented (through local governments).

- Public transport priority systems

<u>Other travel mode efficiency measures</u>

It is likely that some, but not all, of these measures would be implemented by private operators as a response to rising fuel prices. The Department of Transport could prompt both private and state operators towards fulfilling these measures through a series of regulations (penalties) and incentives (e.g. additional tax rebates for costs incurred in aerodynamic fittings and fitting vehicle tracking systems), while local governments could reward freight pooling within their areas of jurisdiction through a combination of penalties and incentives.

- Road freight related efficiency measures

  Aerodynamic fittings
  Fleet vehicle tracking systems
  Freight pooling within the same geographical areas

- Rail related measures

  Aerodynamic fittings
  Engineer training
  Idle reduction

- Air transport related efficiency measures

  Air traffic management
  Maintenance
  Air travel demand management

5.7.2.4 Plan for new transport infrastructure for the long-term

Planning of the long-term and infrastructural elements of the strategy needs to begin now because of the long lead-times in design, capital raising and the planning process that includes the necessary approvals. Planning also needs to take place in the following areas:

- Spatial planning, particularly in conjunction with local authorities.
- Cross sectoral planning particularly between the Department of Transport and the Department of Minerals and Energy. Other departments that need to be involved in planning include the Department of Agriculture, Department of Public Works, Department of Science and Technology and the Department of Land Affairs so that initiative taken have a coordinated effect.

A permanent cross-sectoral planning body needs to be established to ensure that planning efforts are acted upon.

A concerted programme of road repair needs to be implemented as soon as possible. Once the oil peak is reached and global supplies of oil become scarce, the repair of tarred roads will become more expensive and difficult due to the shortages and higher prices of the basic raw material (bitumen), which is derived from oil. A research programme into alternative materials should be established and supported.

A review of the context of global oil supply and the mitigation measures should be taken after five years.

5.7.3 Medium term policy recommendations (3 to 7 years)

During this period the effects of the previous efforts should be having effect and reducing the quantity of liquid fuels consumed in South Africa. The educational programme should have borne fruit and people all over the country in all sectors and from all backgrounds should understand the importance of energy saving and should have implemented measures that apply to them. It is during this period that it is likely that the peak in global oil production will have been passed and countries will be desperately seeking to reduce their oil consumption and bringing it into line with supply and what is nationally affordable. During this period the following measures will need to be taken:

- Further public education and awareness raising programmes should be undertaken. But by now they need to be taken to a different level and it is likely that the effects of the global oil crisis will start being felt in South Africa, particularly through the price of liquid fuels. By taking timely steps to reduce the inefficiencies in the system, consumption will have dropped without severely affecting the economy.

- Long-distance infrastructural investment and planning would need to be in the final stages of planning or already in the process of implementation. The principle underlying new infrastructural development is that it needs to take place along corridors and routes where the impact will be greatest. This implies that the first new freight infrastructure projects need to take place on the Johannesburg–eThekwini corridor and the Gauteng-Cape Town corridor.

- By now early planning should have had the effect of lowering national liquid fuel consumption. As the energy crunch becomes manifest additional efforts will need to be taken to reduce oil dependency further. The efficiency measures referred to earlier will have to be developed, extended and consolidated as ongoing transportation practices.

5.7.3.1 Transport mode shifts

The first report in this assignment indicates that the modes that need to be emphasized are public transport over private transport, rail in preference to road, buses in preference to cars, larger buses in preference to mini-buses,[9] motorcycles in preference to cars and bicycles in preference to motorcycles. With regard to freight, the emphasis needs to be on large trucks over small and rail over road. These preferences need to form the bedrock of all choices, policies, regulations, campaigns and educational programmes. However, this point needs to be tempered by the requirement that appropriate vehicle size will also be determined by matching the specific demand. A downside of larger road vehicles is that they might cost more in terms of road maintenance.

Modal shifts are viewed as medium term interventions, because it is assumed that rail as the preferred (and more efficient) mode for freight on the Johannesburg-Durban and Johannesburg-Cape Town corridor is not only currently underutilized (and therefore requires new capital equipment purchased) but also requires new infrastructure to be built; and that this will also apply to corridor mode shifts elsewhere as well as to the introduction of large buses in preference to cars and mini-buses.

- Integrated travel demand management

  Integrated travel demand management should include the introduction of policies that incentivize ride sharing and telecommuting, as well as the technologies required to reduce the amount of physical travel between two points to a minimum. The Department of Transport should play the lead role in identifying and funding the application of these technologies,

[9] Section 2.3.4 of Hendler, *et al* (2008a: 80) indicates that larger buses are more fuel efficient.

which will have to be applied by the traffic departments of the larger metropolitan and other municipalities. It will probably be feasible to implement these measures over the medium term.

5.7.4 Long term integrated policy recommendations (7 to 10 years, and beyond)

Measures for the long-term need to ensure that the economy – and the transportation system that supports it – is able to function on less oil year after year. This implies that the preparation and planning for this period needs to take place in the short to medium-term timeframes and needs to be in place and functional in the longer-term timeframe. There will thus need to be an increasing reliance on renewable energy sources and a new infrastructure will need to deliver this energy as well as new or greatly expanded and upgraded versions of existing modes. There will need to be high proportions of passengers making use of public transport and much of the freight currently being transported by road will now need to be using the rail network. New energy efficient infrastructure, such as maglev rail, will now need to be completed and making a real difference. The non-motorised transport facilities now need to be fully functional.

By this time too, new spatial planning practices (such as the compact city approach) and all new settlement activity needs to be structured in a manner that reduces journey times and distances and ensures that most facilities are within walking distances.

To ensure that these developments have been implemented in the long-term the Department of Transport as well as local governments need to set up a monitoring and evaluation system in the short-term, and to regularly monitor progress towards the achievement of set targets.[10]

5.7.5 Conclusion on transport recommendations

The above recommendations for interventions in the national transport system can be categorized into the following sets:

- Transport vision and leadership recommendations.
- Project implementation recommendations (stakeholder energy awareness, driver education, new transport infrastructure, transport mode shifts and integrated travel demand management).
- Project facilitation recommendations (NMT programme).
- Transport regulation recommendations (various road, rail and air fuel efficiency measures).

[10] Section 5.9 of this report explicates criteria on the basis of which key performance areas in respect of the national transportation system could be identified for monitoring and evaluation

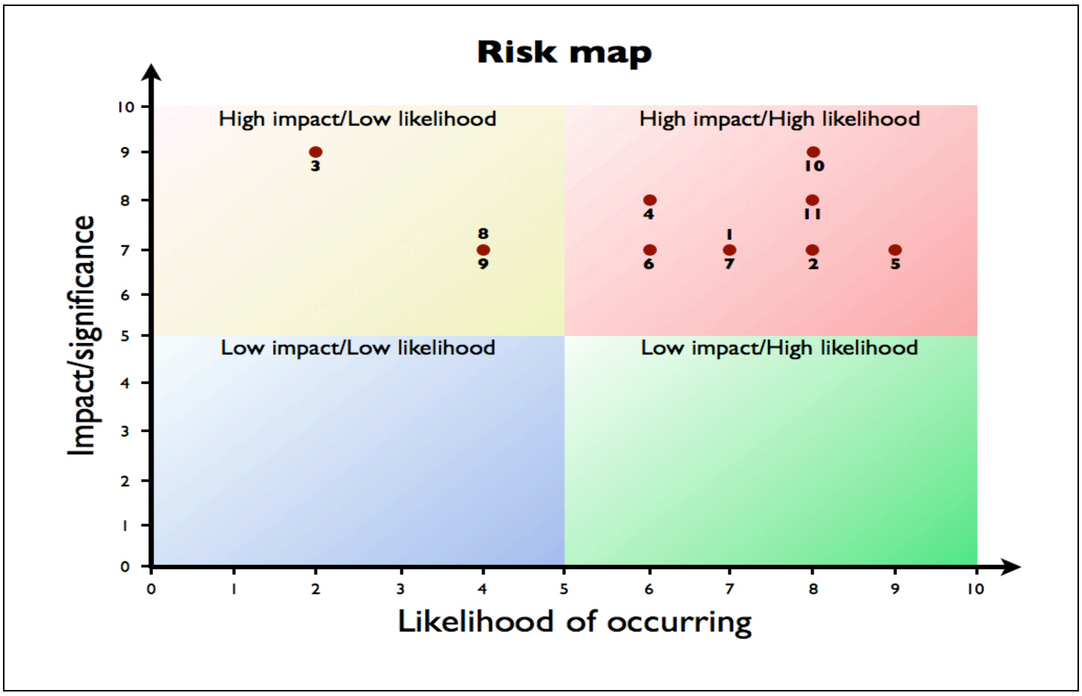
- Transport planning recommendations (spatial planning, in conjunction with local authorities; infrastructure planning for mode shifts).

These sets of recommendations are not simply implementable but could face as yet unidentified risks that would undermine the objectives that each recommendation is meant to achieve. The downside risks to the full set of recommendations are identified in the following section, and are followed by risk mitigation measures.

5.8 Strategic platform for action

Advisers to policy makers, who advocate certain interventions, should pass a "display test" which entails disclosing the downside of proposals and recommendations.[11] By disclosing the risks and analyzing how to manage these risks, policy advisers can add considerable value by incorporating into their recommendations measures necessary to counter the downside risks referred to. It is vitally important from a methodological perspective to conduct a risk analysis in order to provide the Department of Transport with a realistic set of recommendations that indicate the risks of the actions proposed. Accordingly, the above set of recommendations has been risk analysed (see the separate risk analysis table in the appendix, which also includes user guidance notes). The risk analysis enables a way of prioritizing the sets of recommendations for implementation and for acting upon. Figure 5.8-1 summarises the full set of risks referred to in the appendix:

Figure 5.8-1: Risk map of recommendations for the DoT



Source: Constructed by the authors Hendler and Ratcliffe specifically for this project

[11] Cf. Meth (2008)

Key to Risk Map

Risk number	Recommendation issue	Risk name
1	Transport vision and leadership	Leadership failure
2	Stakeholder energy awareness	Communication failure
3	Driver education programme	Project facilitation failure
4	Driver education programme	Project implementation failure
5	Non-motorised transport	Project facilitation and implementation failure
6	Transport mode shifts	Stakeholder resistance
7	Transport mode shifts	Lack of funds
8	Electrified rail	Regulation inhibitions
9	Fuel efficiencies	Regulatory failure
10	Spatial planning	Incoherent planning
11	Rail freighting	Project facilitation failure

The risk map is a useful tool for identifying and assessing risks according to both the impact as well as the likelihood of the risk. The risks that are highly likely to take place and which will have a severe impact, are located in the top right hand quadrant. These are the risks that the Department of Transport needs to pay priority attention to, as their occurrence could be fatal for the implementation of the recommendations in this report, which are necessary for a sustainable national transportation system.

The risks which are contained within the top left quadrant are high impact risks which however are less to occur – however, in the event of their occurrence they would have a severe impact on the recommended interventions. The Department of Transport therefore needs to monitor these risks and actively manage them. In the current risk analysis no risks appeared in the bottom quadrants, which would require active monitoring to determine whether the impact and/or likelihood of the particular risk was increasing.

As is clear from the Risk Map most of the risks fall into the High impact/High Likelihood quadrant:

- Intervention measure: transport vision and leadership; risk: leadership failure
- Intervention measure: stakeholder energy awareness; risk: communication failure
- Intervention measure: driver education programme; risk: project implementation failure
- Intervention measure: non-motorised transportation; risk: project facilitation and implementation failure
- Intervention measure: transport mode shifts; risk: stakeholder resistance

- Intervention measure: transport mode shifts; risk: lack of funds
- Intervention measure: spatial planning; risk: incoherent planning
- Intervention measure: rail freighting; risk: project facilitation failure

Three of the risks identified fall into the high impact/low likelihood quadrant:

- Intervention measure: driver education programme; risk: project facilitation failure
- Intervention measure: electrified rail; risk: regulatory inhibitions
- Intervention measure: fuel efficiencies; risk: regulatory failure

The appendix contains a detailed risk mitigation exercise for the risks referred to above. The following table provides a summary of the risk mitigation actions appropriate for each recommended intervention measure that falls within the high impact/high likelihood risk quadrant.[12]

[12] It is assumed that the DoT will at this stage simply monitor the risks in the high impact/low likelihood quadrant.

Table 5.8-1: Recommendations and risk mitigation summary

Recommended measures	Identified risk	Risk mitigation measures (i.e. to manage downside risks)
Create a transport vision and leadership and an energy awareness programme with sectoral champions	Failure of leadership Failure of communication Project facilitation failure	There needs to be strategic organizational positioning of the DoT in terms of its vision and position in the space economy, a capacity building exercise and a communication strategy to the relevant sectors. The specific secretariat function for the communication with sectoral champions is managed and executed by an outsourced service provider The DoT takes corrective action to ensure that the driver education strategy is thoroughly deliberated and then systematically scoped, put out to tender, adjudicated and appointments made for implementation.
Driver education programme	Project implementation failure	Transfer the risk to outside service providers to provide the education, and link proof of course attendance (e.g. certification) to the issuing of (new and renewed) drivers licenses
Promotion of non-motorised transport	Project facilitation failure Project implementation failure	Action will have to be focused on the municipalities which are the main locus of this risk, particularly their engineering, infrastructure design and planning departments. The National DoT could play a facilitating role in respect of funding for plans and capital costs, while provincial DoTs could play an enabling role to prompt NMT at the municipal level
Transport mode shifts	Stakeholder resistance Lack of funds	If the DoT succeeds in creating an energy awareness programme with sectoral champions, it should be able to manage stakeholder expectations and also channel these into contributing to the overall sustainable transportation system. In particular, the DoT incentivizes (e.g. through ownership opportunities, in terms of BoT, and other contractual forms of public private partnerships) the return of privately road-hauled freight to the rail network The DoT monitors the gap between the availability of and demand for funds for transportation and plays the role of champion to secure these funds
Spatial planning	Incoherent planning	Spatial planning falls outside the ambit of the DoT's brief; nevertheless, spatial planning is crucial for providing a contextual geographical framework for the national transport systems spines and arteries, and a sustainable transportation system is one which serves a sustainable space economy. The DoT continues to raise and contribute to this debate through existing (or new) integrated state structures that are tasked with finding sustainable solutions to the South African space economy. In this way the DoT also ensures that the transportation system reproduces the broader, emerging, sustainable space economy

Source: Appendix

Therefore, in order to successfully implement the recommended measures the DoT needs to attend to the following strategic issues which will provide it with a platform from which to launch and sustain the stated interventions:

1. Building of awareness of energy efficiency by winning over key stakeholders and managing the implementation of a successful driver education programme.

2. Facilitating funding, capacity and incentivisation to enable: (1) municipalities to implement NMT; and, (2) private operators to get involved in transport mode shifts (both as users and operators).

3. Championing the necessity for integrated planning of the space economy and ensuring that the transportation system is planned in such a way that it reproduces – rather than undermines – a sustainable space economy.

5.9 Monitoring and evaluation: key performance areas

Economic, environmental and social Indicators of sustainable, affordable transportation are necessary to measure the performance of transport delivery agents against set objectives. To enable the definition of performance indicators it is useful to view transport as an asset that needs to be valorised, in both its perceived and its economic value; likewise, it is also useful to measure the extent of informed participation by the users of transport in its provision. Defining the indicators for measuring these variables is a process for which there should be a clear starting point. Four conditions of economic and social sustainability of transport are presented, which should form the point of departure for defining performance indicators:

- The long-term economic value of the transportation asset should be more than the total financial, environmental and social liabilities secured by the asset.
- The ongoing economic, environmental and social costs of physically maintaining the transportation asset (both modal and infrastructural) and the necessary services that support its function must be affordable to the primary stakeholders, namely the state, the private sector and the passengers or users.
- The location, design and security of the transportation asset should reflect perceived value by its market.

This means that regardless of the broader macro-economic context of transportation it needs to be constantly valorised as a national (and/or private) asset, and it needs to serve the goals of economic development that provides access to economic activity and life opportunities for the South African urban and rural poor. The way in which these population categories, and indeed the entire society, will be enabled to have Sustainable Livelihoods[13]

[13] It is suggested that the Sustainable Livelihood approach (Scoones, 1998) is useful as an umbrella to categorise criteria and attributes, because it acknowledges that, particularly in poor communities, people gain their livelihoods through multiple activities rather than one formal job. In contrast to the previous environment and development thinking aimed at sustainable development, Sustainable Livelihoods is a people-centred paradigm, which emphasizes people's inherent capacities and knowledge and is focused on community level actions (Chambers, 1986; UNDP and Wanmali, 1999). According to Chambers and Conway (1992) (cited in Scoones, 1998):
"A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, and maintain or enhance its capabilities and assets, while not undermining the natural resource base."

is likely to undergo profound change as South Africa's growth strategy comes under increasing pressure from the triple forces of fossil energy depletion, financial instability and global warming. A changed space economy is likely to have a profound impact on transportation arteries and modes, with the primary aim of reducing origin-destination distances for workers, employers and suppliers of goods and services.

In South Africa the Sustainable Livelihood approach has been adapted to include time resources by Barbour and Kane (2003), and has been implemented in assessment tool in South African and Lesotho by Vanderchuren (Vanderschuren et al, 2006; Sah et al, 2008). The resources applied in Southern Africa are:

- Natural resources, such as fuel consumption and land-use quality;
- Human resources, such as access to basic services;
- Social resources, such as neighbourhood communication and emergency transport;
- Financial resources, which includes all the cost related to a project;
- Economic resources, such as job creation and entrepreneurship;
- Infrastructure and services; and
- Time, which includes free time available and independency of children to walk to school without adult supervision.

5.10 Conclusion

The analysis undertaken in the previous sections of this study indicate that within the timeframe of the NATMAP global oil production will peak and decline. This will have a profound effect on the world economy as crude oil prices rise and scarcity sets in. The effects can be dampened by timely planning and actions that will enable our transportation system to continue to function and underpin the economy through the movement of people and goods.

It is clear from our analysis that the inefficiencies in the current transportation system can act as a buffer from the immediate effects of peak oil in that they allow relatively easy fuel savings in the short term. They also provide the window of opportunity to implement more sustainable transport systems that will provide longer-term transport security.

It is recommended that the Department of Transport begin to take actions geared to the long-term transformation of the transport system as soon as possible. The energy constrained period that will be entered in the near future will require that our transport strategy favours public over private transport, light over heavy vehicles, non-motorised transport and a spatial planning regime that enables people to conduct all of their essential tasks within short distances of their homes.

In the long run economic and spatial pattern restructuring could be necessary to enable the continued functioning of the economy in a socially equitable and environmentally/energy sustainable fashion.

The recommendations of this study have been risk analysed, and risk mitigation actions are proposed as measures to avoid most of the downside risks for implementing the recommendations.

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Appendices

Risk management: using the risk map worksheet

1 Introduction: getting started

1.1 Key points about risk management

Risk management is:

(a) integral to managing the performance of the strategic project - not a "special technique" but part of the suite of skills that are needed to manage a well run project. Risk management is part of the skill range that focuses on delivering results ("outcomes") rather than simply managing inputs.

(b) thinking through the consequences of an action or inaction in terms of achieving the goals of the business - or more simply what might prevent us achieving our goals and what are we going to do about it?

(c) how a series of actions or inactions - either imposed on the project or generated from within - may damage the organisation and/or project as a whole. Taking a whole organisation view helps assess whether structural changes are needed to the organisation to mitigate risk.

(d) make choices around the risks worth taking - what are we best at managing? Are others better at managing some things that we currently manage? Could we manage things better?

1.2 Approaching risk management for the first time

Get started! To be effective in risk management you don't need the services of a risk specialist. As noted above, "thinking risk" is part of a suite of skills integral to managing performance.

Risk management is not the responsibility of one person. Overall responsibility for risk rests with the organisational leadership, but day to day responsibility is often delegated to the Chief Executive and other members of the management team. It is usual that the organisational leadership are (a) engaged in identifying and assessing risks facing the organisation and its projects (b) identifying or considering the appropriateness of responses to individual risks (c) considering the overall risk map and (d) monitoring performance and risk responses.

2 Risk map input sheet

2.1 Risk identification

2.1.1 Risk number

Sequential number as shown or manual input, used for reference only.

2.1.2 Date risk identified

In date format xx/xx/xxxx and is used as a reference only.

2.1.3 Level of risk

Numerical value (whole number) in range 1 to 5. The level of risk describes the importance of the risk in context of the organisation.

Level 1 risks are the significant risks that affect the organisation and/or project as a whole.

Level 5 risks are those risks that affect say a project, a specific aspect of a project or a particular team or department.

The levels are defined by the user, and by default risks are assumed to be level 1 risks. Most users will in the first instance consider those risks that affect the organisation and/or project as a whole.

2.1.4 Internal or external risk

Enter I or E in upper case only.

I = internal risk - those risks that are generated or largely generated/ influenced by events from within the organisation and/or project.

Example: enter I for "risk of loss of key personnel".

E = external risk - those risks that largely originate from outside of the organisation. Normal convention is that these risks are big risks that affect either the organisation and/or project as a whole or general socio-political climate in South Africa.

Example: enter E for "inflation risk" that would have the impact of increasing costs (and the opportunity to rental income), and reducing overall surplus, leading to delays in repaying loan finance.

There are some risks that lie on the boundary between being internal and external. General convention defines internal risks to include relations with customers, suppliers and other stakeholders and where there is an opportunity for the organisation and/or project to be pro-active in managing a risk.

2.1.5 Risk category

Use the following pick list to enter the full code as noted below. This describes the general headings of risk that are normally applied to risks maps in the transportation sector. Following the identification (in the third report) of key areas of uncertainty that could impact on fuel and transportation, grouping these risks together allows organisations to group and consider their main exposure to risk. This may result in organisations taking a whole risk category approach to managing risk rather than concentrating on individual action plans.

Code - "**Social**" - Social conflict and stakeholder activism (including consumer reisstance) that undermines the strategic project plans and interventions.
Code - "**Technological**" - Lack of technology and know-how required to enable the implementation of the strategic project plans and interventions.
Code - "**Economic/Financial**" - Lack of economic activity and/or required funding to implement strategic project plans and interventions.
Code - "**Environmental**" - Environmental degradation, infrastructure/resource breakdown/depletion and legal impediments that individually or collectively undermine the strategic project plans and interventions.
Code - "**Political**" - Political resistance to strategic project plans and interventions .
Code - "**Operational**" - Lack of internal systems and capacity to implement strategic project plans and interventions .
Code - "**Organisational**" - Lack of clear leadership vision and coherent strategy that is effectively communicated, and which undermines the implementation of strategic project plans and interventions.

2.1.6 Risk name

Input limited to 100 characters of free form text (including spaces).

This is a short name to identify the risk - short hand for use when describing the risk. This is also used as a label on the risk map.

Example: Risk: Increases in inflation, increasing costs and impacting on the viability of the financial plan. Risk name: inflation

2.1.7. Definition of risk

Describes the nature of the risk, and it is conventional to focus on what happens when the risk materialises (an adjective or verb) rather than stating the risk (a noun). Defining the risk in these terms helps understand what would happen to the business when the risk materialises.

Wherever possible make a reasonable quantification to the range of the risk. This is a matter of judgement, based on experience, knowledge of the sector and the economic and political environment. For some categories of risk, published material may be available to help quantify the upper or lower end of the scale. In some cases specific professional advice may be required.

It is advisable that the upper scale is set on the basis of a reasonable upper scale rather than the "worst than can possibly happen" scenario.

Example: Risk name : inflation (noun) - increase in inflation by up to 5%pts above inflation rate in plan [comment: in this case the risk is that inflation increases, and the reasonable estimate of the likely upper limit is 5%pts above the plan rate]

2.1.8 Impact of the risk on the organisation/project plan

Free form text with no upper limit to the length of the text.

Describes the impact of the risk on the organisation's and/or project's own business plan. This should consider both the general impact on the business and/or project plan and the specific impact on key performance areas/ indicators of the organistion and/or project. Where appropriate, it is useful to describe the risk in terms of changing nature of the risk with time - either because the risk changes or because of the "compounding effect" of a event should it endure for a number of years.

Example: Risk name: inflation - impact of increasing rate of inflation is that costs increase, but this is partly offset by the development of oil-independent fuel in transportation technology. The increase could be short term (less than one year) - in which case the impact is Rx in that year, in the case of a medium term increase (3 years) overall fuel surplus would decrease by y and have a severe impact on ability to balance supply of and demand for fuel.

2.2 Risk assessment

2.2.1 Life of risk

Numerical value (whole number) in range 1 to 3 where

1 = short term - one that the organisation and/or project is currently facing but is likely to expire within one year.
2 = medium term - one that will last up to three years.
3 = longer term - one lasting over three years.

This is useful when combined with the internal/ external risk measure. The risk map may reveal that the organisation has a majority of its risks in the "short term" and "internal" risk category - if this is the case the overall risk management strategy may concentrate activity on solving these more immediate problems. This may also indicate a shortfall in capacity to ensure more risk - simply because the organisation is overstretched. Alternatively, the organisation and/or project may have majority of risks in the longer term, external risk category - in which case activity would be focussed on limiting overall medium term exposure to risks that are faced by the sector and South African political economy in general.

2.2.2 Likelihood of risk happening

Numerical value (whole number) in range 1 to 10 where 1 is a remote possibility and 10 is an (almost) absolute certainty that the risk will materialise. The likelihood is largely judgemental, taking into account the period over which the risk map is being prepared. Risk maps can be prepared over any period that the organisation selects:-

(a) Risk maps for particular projects will have a lifespan of the project

(b) A business (or project) plan typically has a life of between three and five years, and the key is to consider the likelihood of a risk arising that will stop the SHI achieving its strategic objectives as set out.

Generally speaking, the longer the plan the more likely it is that a risk will materialise. For example - over a thirty year period it is increasingly more certain that there will be a period of high inflation. For certain types of risk this can be argued the other way - short term internal risks may be more likely in the short term than over the longer term.

For certain types of risk, it is possible to obtain statistical data to support the decision. However risk management is not a precise science and in practice is best approached as the judgement based on the knowledge and experience of those preparing the risk map.

2.2.3 Impact of risk

Numerical value (whole number) in range 1 to 10 where 1 is very minimal impact on the organisation's overall strategic plan and 10 where the impact of a risk would be severe - possibly a "fatal" event. Again, the rating is based on judgement and experience of those preparing the project and/or strategic plan.

One way of approaching the judgement is to consider how the organisation might recover/ address the risk if the risk did in fact materialise.

2.2.4 Risk score

No input permitted - this is the simple multiplication of the likelihood of the risk occurring x the impact of the risk on the organisation and/or project. The higher the combined score, the higher overall risk rating on the organisation and/or project.

The risks with the highest overall ratings will be the priority risks to be addressed. Risks have been categorised into the following bands:-

Band 1 - critical risks [shaded red] - those where there is a risk score in excess of 61. These are the most organisation/project critical risks to be attended to, and will be generally those risks that the organisation should prioritise both management time and other resources to respond to. These are also the risks that the organisational leadership will also continue to monitor.

Band 2 - high risks [shaded orange] - where the combined risk score is more than 31 but less than 61. Organisational leadership would address these as a priority but would receive less attention than the critical risks. The Board would be involved in scrutinising the management of these risks, but are less likely to be involved in developing action plans to respond to the risk.

Band 3 - medium risks [shaded yellow] - where the combined risk score is more than 16 but less than 31. These are risks which are significant and require management action, but are generally delegated to managers to respond to.

Band 4 - low risk [no shading] - low level risks that are periodically reviewed.

2.3 Risk response

2.3.1 Risk response category

Select one of four options (see below).

It is generally accepted that there are four alternative responses to a risk - to either accept, eliminate, modify or transfer the risk. When considering a risk it might seem that all four response categories might seem appropriate. If this is the case then it is possible that the there are a number of different risks falling within the risk as defined.

The choice of the response to a risk depends on whether the risk may also presents an opportunity to the organisation. For example, developing a new transportation project may well present a number of risks but at the same time present the opportunity of (a) meeting the strategic objective of the government to takle poverty and (b) prompting the introduction of an appropriate spatial planning policy. The organisation (i.e. DoT) may well choose to accept the risk.

The four alternative responses are interpreted as follows:-

Code-"**Accept**" the organisation chooses to accept the risk, either because it presents an opportunity to the organisation and government, is integral to the service provided or that there is no alternative but to accept the risk.

Code-"**Eliminate** " the organisation chooses to end the impact of the risk on the project, because it does not present any benefit to the organisation and/or project from continuing to live with the risk or that the impact of the risk on the organisation and/or project is too great. "Elimination" quite often means discontinuing/ terminating a service or a project.

Code-"**Transfer** " the organisation chooses to wholly or partially transfer the impact of the risk on the project. Transfer is quite often a cost effective option, largely because the organisation to whom the risk is transferred has scale and expertise in that service. Typical transfer of risk activity includes insurance, outsourcing of services and entering into partnership with others to provide key services.

Code-"**Modify** " the organisation chooses to make alterations to reduce the potential impact of the risk on the project. The majority of risk responses will fall into this category. It may be convenient to think of four different types of modification responses (a) corrective - a response that corrects a risk that has already started to be realised (b) preventative - action taken to prevent the most damaging aspects of the risk arising (c) detection - systems that will highlight when something has gone wrong.

2.3.2 Risk response: how is the risk managed, what action is being taken?

This is a *brief* description of the action being/ to be taken to manage the risk identified. In the same way that project plan objectives would be set, actions to respond to risk, should wherever possible be SMART - Specific, Measurable, Achievable, Realistic and Time bound. In general terms, it is easier to set SMARTer targets for internal risks - ones where the organisation has greater freedom to respond.

The risk response in this column should support the choice made in the "risk response category".

2.3.3 Controls: what information gives an early warning of the risk?

Theoretical risk management would describe "controls" as being a subsidiary set of actions to only those risks that can be modified. In practice, controls can be interpreted as early warning information of a risk that is materialising, enabling managers to take the "modification" steps required or to start contingency plans (if any) to deal with other categories of risk.

Example: Risk: increase in interest rates leading to increase in costs, reduction in surplus and reduced capacity to repay loans as they fall due. Information: Early anticipation of a sharp increase in interest rates could lead to discussion with lenders over the impact of such increases on the financial plan and capacity to repay loans.

2.3.4 Accountability: who is managing the risk?

It is normal to identify the person who is accountable for managing the response to the risk.

3 Interpreting the risk map

The risk map is a graphical presentation of the risks identified on the risk input sheet. The graph maps for each risk the impact (on the vertical - y axis) against the likelihood of occurrence (on the horizontal - x axis).

The risks are mapped as points on the risk map - each risk is shown in a coloured quadrant:-

Red quadrant (top right) : - high likelihood of occurring and when they occur they have a very significant to fatal impact on the organisation and/or project. These are the risks that are prioritised, actively managed and subject to review by the organisational leadership.

Tan quadrant (top left): - low likelihood of occuring, but if and when they do they will have a significant and damaging impact on the organisation and/or project. Activley managed, with a tendency to transfer the risk to third parties. A good example if this category are perils that are covered by insurance - designed to deal with infrequent "disaster" situations.

Mauve quadrant (bottom right) - high probablity of occuring, and probably have some experience of happening in the past. If or when they do materialise they are relatively manageable and have a limited impact on the organisation and/or project. This is managed, and quite often the response is to try and modify the cause of the risk. An example is a persistent failure in a IT system or process where redesign of the process or the IT equipment would deal with this persistent threat to the organisation and/or project.

Blue quadrant (bottom left):- low probablility of occurring and low impact on the organisation and/or project when the risk does in fact materialise. The appropriate response is quite often to monitor the progress of the risk to ensure that the risk isn't deteriorating. An example may be a low level problem on vacancy rate in a scheme. Regular monitoring of performance indicators would highlight whether the risk was increasing.

The value of this presentation is that if either there is a majority of risks in the top right hand (red) box, then the organisation and/or projects are challenged on a number of fronts, and overall are assessed as risky. This needs to be interpreted with care, as there is often bias in preparing a risk map - there is a natural human tendency to identify the things that might go wrong and over emphasise both the impact and likleihood of occurence. The whole process of addressing risk may also contribute to there being an over emphasis on the negative.

Over time, there should be a more even spread of risks across the risk map - as the systems of response to risk management improves then the tendency to over emphasise risk may reduce. This also presents an opportunity that gets to the heart of the purpose of risk management - improved systems of risk management enable organisations to increase the capacity to take on more risk - and risk that matters to delivering the vision of the organisation - more and better transport services.

The risk map is based on the risk score (using the same multiplication of likelihood x impact). The conclusions on which risks would be classified as critical, high, medium and low are slightly different.

Both the risk score and the risk map are important - the risk map highlights those risks with relatively low score (say 9), but this is merely a function of them being relatively infrequent, but disastrous when they happen. This is highlighted in the tan coloured box on the risk map and may result in some of the risk being transferred to third parties. The basic risk score is useful as a management tool to aid the monitoring progress on managing the response to the risk.

Risk mapping workbook

NATIONAL TRANSPORTATION SYSTEM		Date of preparation	05-Nov-08

Identify the risk								Assess the risk						Risk response		
Risk number	**Date risk identified**	**Level of risk**	**Internal or external risk**	**Risk category**	**Risk name**	**Definition of the risk**	**Impact of the risk on the organisation's strategic plan**	**Life of risk (years)**	**Likelihood of risk happening**	**Impact of risk on organisation/s trategic plan**	**Risk score**	**Risk group**	**Risk response category**	**Risk response: How is the risk managed? What action is being taken?**	**Controls: What information gives an early warning of the risk?**	**Accountability: Who is managing the risk?**
1	11/05/2008	1	I	Organisational	**(** *Transport Vision and Leadership* **)** **Leadership failure**	The DoT leadership is unable to develop a vision of an energy efficiciency future	The lack of leadership vision means that the organisation is not united around reducing oil dependency and conserving as much fuel as possible, resulting in *ad hoc* interventions, an incoherent approach and confused and often contradictory messages going out to potential sectoral champions. Communication with sectoral champions is generally unsuccessful - there are very few instances where joint structures and programmes are initiated and fewer still where they are implemented. This risk materialises now and persists for a while but eventually a belated visison is developed through force of circumstances and events	2	7	7	49	High	Accept	Organisational leadership of the DoT initiates a strategic planning process which focuses on: (1) Vision, Mission and Values; (2) Strategic position of the DoT as an organisation with a specific governance business ; (3) Coaching and personal development of all top management layers	**(1)** There is no clear, publicly communicated DoT Vision regarding oil depletion and the dependence of the transportation system on oil-based fuels; **(2)** There is no clear, publicly communicated strategy by the DoT to realise its Vision; **(3)** There is no ongoing consensus-building process with critical transportation stakeholders (e.g. taxi industry) regarding the implications of oil	The leadership of the DoT - the Minister of Transport
2	11/05/2008	4	I	Operational	(*Stakeholder Energy Awareness*) **Communication failure**	The DoT lacks the communication systems and know-how to effect an awareness programme with sectoral champions	Communication with sectoral champions is haphazard, intermittent at best. As a result the DoT's and the Minister's thinking is not getting communicated to the sectoral champiuons; neither is their thinking being understood by the Minister and the DoT. Meetings and correspondence do not happen consistently, and/or are not followed up timeously. Important action items get carried over instead of being expeditiously completed. This risk reflects bureaucratic inertia and persists over time	3	8	7	56	High	Transfer	The specific secretariat function for the communication with sectoral champions is managed and executed by an outsourced service provider	**(1)** Goal of identifying and communicatings with x number of sectoral champions is not met; **(2)** Follow up on action items does not happen timeously; **(3)** strategic communication objectives are not completed timeously; **(4)** joint programmes with sectoral champiuons are not put in place	The leadership of the DoT - the Director-General
3	11/05/2008	1	I	Operational	(*Driver Education Programme*) **Project facilitation failure**	The DoT lacks the project conceptualisation and facilitation competencies to enable a compulsory driver education programme	The DoT personnel are unable to expeditiously formulate and put out to tender the Terms of Reference for the work involved in developing a compulsory driver education programme focused on fuel saving and energy efficiency in the light of oil depletion, to adjudicate and appoint a service provider to implement and manage the contract. As government departments generally initiate and manage outsourced tenders, this risk is not expected to persist beyond a year, during which a change of administrations is disruptive of usual departmental work	1	2	9	18	Medium	Modify	The DoT takes corrective action to ensure that the driver education strategy is thoroughly diliberated and then systematically scoped, put out to tender, adjudicated and apointments made for implementation.	**(1)** very few if any drivers are being trained	Executive management in the DoT - appropriate Chief Director
4	11/05/2008	1	E	Operational	(*Driver Education Programme*) **Project implementation failure**	Many municipalities lack the systems and capacity to ensure the implementation of the compulsory driver education programme	The municipalities are unable to facilitate the implementation of these courses. Very few drvers therefore understand the full implications of peak oil for transport fuel consumption; most drivers continue behaving as usual, and do not practice fuel efficiency and fuel savings behaviour. As fuel depletion and fuel prices rise, drivers are forced to modify their behaviour, but this happens less effectively than if they understood precisely where they could save on liquid fuel usage; this risk is not expected to persist for beyond three years.	2	6	8	48	High	Transfer	The DoT transfers the risk by contracting outside service providers to provide the compulsory education, against specified criteria, and to issue certification as proof that can be presented to the local authorities on application for drivers licenses and licence renewal	Blockages to the issuing of new and the renewal of existing licenses as a backlog of untrained drivers builds up	Exevcutive management in the DoT - appropriate Chief Director
5	11/05/2008	3	E	Operational	(*Non-motorised transportation*) **Project facilitation & implementation failure**	Many municipalities lack the systems and capacity to implement a NMT system, i.e. involving pedestrian-friendly walk ways and cyclist-friendly cycle paths	The municipalities are unable to facilitate the implementation of NMT. As more and more ordinary citizens strat using bi-cycles and also walking in response to oil depletion and rising oil and fuel prices, the existing walk ways and pavements become congested; there are frequently accidents, with particulalrly high fatalities on major road arteries where the volume of pedestrian traffic has increased. Due to the low level of awareness of the significance of NMT, the proliferation now of NMT as a popular mode of transport, and general incapacity at municipal level, this risk is expected to persist. The impact of this risk on the overall transport strategy will increase over time, as more and more people take to the streets in response to oil depletion and oil and fuel price increases	3	9	7	63	Critical	Modify	Action to correct the incapacity at the municipal level will be required. This will be particulalrly focused on the engineering departments where infrastructure design and planning takes place and where plans will have to be put in place, and implemented, for secure walk ways and cycle lanes. DoT could facilitate funding incentives from the Treasury for municipalities to undertake and implement such plans, which would cover capital costs. Provincial transport departments could play an enabling and guiding role to prompt the emergence of these NMT	**(1)** This risk has already started to manifest itself, as witnessed by the numerous crosses that appear alongside major road arteries where pedestrians have been killed; **(2)** Ongoing roadside and road congestion by pedestrians and cyclists, as well as increasing casualties, will be an indication of the risk proliferating	The leadership of the DoT - the Minister of Transport
6	11/05/2008	2	I	Social	(*Transport modes shifts*) **Stakeholder resistance**	Stakeholders - like the taxi industry, the motor manufacturers - resist the implementation of modal shifts from private to public, and from private cars to buses and trains	The risk manifests as violent action against commuters making modal shifts to their means of transportation (i.e. the taxi industry as stakeholder) and extensive lobbying against the changing of transport modes (i.e. the motor manufacturers as stakeholder), resulting in a halt or a delay in the implementation of the required modal changes	3	6	7	42	High	Accept	Organisational leadership of the DoT initiates an awareness campaign with sectoral champions in order to communicate its Vision, Mission and Objectives, and to incorporate sectoral stakeholders	**(1)** Violence against commuters; **(2)** Blocked legislation and regulations in terms of legislation	The leadership of the DoT - the Minister of Transport

7	11/05/2008	2	E	Economic/Financial	(*Transport modes shifts*) **Lack of funds**	There is insufficient funding in the context of gathering world economic recession, to enable the shift in transport modes from liquid fuel propelled private cars to electrically funded rail transportation	The required rail upgrade cannot - and does not - happen	2	7	7	49	High	Modify	The DoT acts first to detect and confirm the lack of funds, and then to to prevent the risk from materialising by actively procuring whatever funds it is able to now. If funds remain scarce the DoT will attempt to get a larger budget allocation from the fiscus on the basis of transport being a national	**(1)** Stalled rail upgrade	The leadership of the DoT - the Minister of Transport
8	11/05/2008	2	E	Environmental	(*Electrified rail*) **Regulatory inhibitions**	Regulations aimed at curbing green house gases limit the extent of South Africa's coal burning electrical power stations, in turn impacting on the supply of electricity for electrified rail	The required move to rail freight and passenger transport is greatly limited	3	4	7	28	Medium	Modify	To prevent this risk from materialising requires that a significant quantum of national electricity requirements need to be generated through renewable sources. There is a co-ordinated government policy response and intervention, requiring as many residential and non-residential structures and technologies (including motor vehicles) to be electrically powered; within this context the DoT regulates each service station/garage to have renewable electrical energy supply charge up points, and all traffic signs and lights are shifted off the coal-burining sourced grid and on to solar	(1) South Africa gets penalised severely by international carbon related agreements and is prompted to limit its coal burning power stations	The Presidency, The leadership of the DoT - the Minister and the Director-General of Transport
9	11/05/2008	1	I	Operational	(*Fuel efficiencies*) **Regulatory failure**	Regulations and incentives aimed at prompting transport (road, rail and air) fuel efficiency measures are not packaged and made mandatory	Liquid fuel continues to be used inefficiently, effectively wasted, on South Africa's roads, and undermines the overall strategy by removing the "cushion" effect, i.e. the country's ability to absorb the first shocks of peak oil which leads to rapid depletion of fuel and price spikes. The risk has a relatively short life due to the fact that the onset of peak oil forces morte efficient and sparing usage of liquid fuels	2	4	7	28	Medium	Modify	The DoT organisational leadership prioritises the regulation of measures and incentives that are trageted at road, rail and air transport and have as their objective the more efficient and sparinhg usage of liquid fuel; this action is taken to prevent this risk from	**(1)** Shortages of liquid fuels; **(2)** Sudden spikes in the price of liquid fuels	The leadership of the DoT - the Minister and the Director-General of Transport
10	11/05/2008	1	E	Organisational	(*Spatial planning*) **Incoherent planning**	Origin and destination of travel becomes further and further separated in space, increasing travel time, fuel quantities and cost required at a time when fuel will be in short supply and very costly	Continuing non-enforcement of integrated planning means that urban sprawl continues, with ever widening distances between living (travel originations) and workplaces (travel destinations), placing massive pressures particularly on working and lower middle class communities as oil depletes and fuel prices spike - for them the transport system becomes dysfunctional. This risk is current and is likely to persist especially after 2030 when the maximum savings of liquid fuel will have been effected and there could be a need to travel less if new technologies and propulsion systems based on renewable energy have not taken over the transportation system.	3	8	9	72	Critical	Transfer	To change the spatial planning approach involves rethinking the urban space growth economy and as such is a cabinet policy decision. Therefore, the DoT effectively transfers this risk by escalating a response to this risk to the highest exzecutive authority	**(1)** Persistent (over medium to long-term) high prices of transportation in relation to unaffordability by the majority	The Presidency, The leadership of the DoT - the Minister and the Director-General of Transport
11	11/05/2008	3	E	Operational	(*Rail freighting*) **Project facilitation failure**	The DoT lacks appropriate incentives to make rail freighting sufficiently attractive to commercial freight operators to entice them to switch from road	This to some extent neutralises return to rail freight and exacerbates the problem of road freighting. It continues to creating both a fuel and an environmental problem through the emitted CO_2	3	8	8	64	Critical	Transfer	Create ownership opportunities for freight operators within an expanded rail network	Low volumes of freight traffic using the rail network	The Minister of Transport and the Director-General of the Department of Transport