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Energy and transport issues for Gauteng, South Africa

C J Cooper
Institute for Energy Studies, University of Johannesburg

Abstract
Rapid urbanisation brings unwelcome negative impacts, and places excessive pressure on infrastructure development and maintenance. In particular, transport networks become congested with negative impacts on energy logistics. The liquid fuel situation of South Africa and Gauteng is briefly examined. The paper considers the impact of constrained oil supply, and supply infrastructure, on transport. The author further suggests that the authorities in Gauteng should critically examine an ultra light rail option in order to reduce reliance on imported oil, while helping reduce road congestion. A more energy efficient transport network for the province, able to meet the transport needs of passengers and business, will help decrease environmentally damaging emissions.

Keywords: Gauteng, oil, cities, energy, transport

Introduction

The world has undergone rapid economic growth since 1985 when the price of crude oil dropped to nearly $10 per barrel. This growth has come with an increased demand on virtually all commodities, and while the signs of this were apparent in the early 1990s, the data has only really showed the extent of this increased economic growth during the last six years. Much of the global growth has taken place off a low base in countries such as China and India.

The demand for commodities has not been limited to metals, but includes energy and, in particular, oil. The price of oil has increased significantly since 2000. Much of this can be attributed to the increasing demand, coupled with limited increases in supply capacities. The ability of oil producers to significantly increase production is also questionable (Simmonds, 2005). It would seem that the analyses of Hubbert (1956), Deffeyes (2001, 2005), Campbell (1997) and others concerning "Peak Oil" may indeed be coming true. Political tensions in the Middle East have not helped ease speculative pressure on the price of oil.

South Africa is in many ways fortunate in having very large coal reserves. These have sheltered us to some extent from the high oil price. Unfortunately, this period of low energy prices is rapidly coming to an end, as surplus capacity is whittled away in the electricity sector and new capacity will need to be erected very urgently to meet the growing demand. This new capacity will have to be purchased with current Rands, which will mean a far higher capital cost applied to the price of electricity.

An issue which has been apparent in the local economy over the past four or five years has been the rapidly increasing demand on oil products, and more specifically, on diesel. Much of this demand has been caused by the move towards diesel-fuelled private motor vehicles, which are more efficient than petrol engined vehicles. However, some must also be a result of the increasing economic activity, utilizing large diesel powered vehicles to move goods. Road transport is being used at the expense of rail, especially for the major route between the port of Durban and the Gauteng economic heartland of South Africa.

The country, and especially Gauteng, is now at a point where some critical decisions regarding spatial, energy and transport planning is required. A review of options, preferably using a holistic approach to ensure sustainable development is suggested. This paper attempts to evaluate some of the overarching issues and to suggest solutions in areas where urgent decisions are required.

The South African oil situation

About 60% of South Africa's liquid fuel requirements are imported as crude oil for local refining. The remainder is produced from coal by Sasol and from natural gas by PetroSA, while a small amount of locally produced crude oil supplements these two indigenous synfuel streams.

An analysis of the South African energy balance for 2003, produced by the International Energy Agency (IEA, 2005:II175), indicates that about 97% of transport energy in the country is provided by petroleum products. This is a situation which will need to be addressed from a strategic point of view as a matter of urgency, especially if the price of

crude remains as high as it is (currently over $70/bbl), and if supply becomes more pressured as reserves reduce. The latter issue will be addressed later in a section on peak oil.

In terms of the historical petrol/diesel demand balance, South African refineries were petrol short and therefore produced excess diesel. There has been a change in the demand mix over the last decade. Data from Sapia show that national petrol demand increased by 9.97% between 1995 and 2005, while diesel demand increased by 49.39% over the same period. Further, for 2005, a diesel short situation of 91 Ml existed between refinery diesel capacity and demand (SAPIA, 2005). The continuing move to diesel-fuelled private vehicles and the imminent taxi recapitalisation plan (to replace petrol minibus taxis with diesel vehicles), will result in the product mix moving to an even greater diesel short situation. (It is noted that the entire taxi recapitalisation programme has yet to be finalised. The focus seems to be moving to safety and a mix of different engined vehicles.) Having insufficient refining capacity to meet demand is not in itself a problem, as the product can be sourced from international refineries. The challenge is in having sufficient infrastructure to move the product. This was highlighted by McClelland as reported by Bell (2006). (This will be exacerbated in Gauteng for reasons discussed in the following section.)

Gauteng oil demand and supply

In terms of diesel and petrol demand in Gauteng, data from the oil industry (for the period 1995 - 2005) indicates an increase in demand for diesel of 88.69%, and an increase in the demand for petrol of 13.92%. The comparison with growth in national demand for the same products indicates that diesel growth in Gauteng is exceptionally high. This should be a cause for concern amongst industry players and government. Table 1 indicates sales of these liquid fuels for the years 1995 to 2005. This increase, while welcome as an indicator of vigorous economic growth, should be particularly worrying to politicians, planners and other interested parties. The longer-term implications for continued and sustainable development are profound.

In terms of supply, Gauteng receives liquid fuels primarily from the Sasol plants and from Natref. The former is the oil-from-coal facility, while the latter is a crude refinery obtaining feedstock by pipeline from the coast. Sasol at Secunda (the main Sasol facility) was originally designed to produce more petrol than diesel in order to meet the country's (then) higher demand for petrol. A products pipeline from coastal refineries in Durban, operated by Petronet, is used to supplement product shortages. In addition to this line, there is a crude oil line feeding Natref and an older liquids line which is now converted to supplying natural gas to KwaZulu-Natal. Confidential sources indicate that as many as 200 road tankers *per day* are currently being used to truck liquids (primarily diesel) into the Gauteng area. The damage to road infrastructure not designed to handle this volume of traffic must be exorbitant. A detailed study of inland demand, refining and pipeline capacities and solutions is urgently required, but is outside the scope of this paper.

There is thus already a shortage of product in Gauteng (and presumably the rest of the inland market), a situation that can only deteriorate further as demand increases. To reinforce this, Bell (2006) noted that SAPIA has indicated that the inland short-fall for 2006 could reach 1.27 billion litres. Confidential information indicates that this could indeed be valid. Petronet, the pipeline subsidiary of Transnet, has indicated that the product line is at operational capacity and that a new line from the coast to Gauteng is being planned (Transnet, 2006a).

It seems that the focus is upon ensuring that supply capacities are expanded and strengthened. However, it appears that the demand side has been completely ignored, and this is perhaps where the greatest effort should be made. The following two sections highlight issues that should indeed encourage an urgent and critical examination of demand side options.

Oil and the environment

The energy/environmental interface has become an area of increasing importance to researchers, scientists, politicians, business leaders and the public. Challenges such as particulate, sulphur and nitrogen oxide emissions are impacting on the energy supply industry and on consumers. The increasing levels of energy related greenhouse gases have been the subject of many international conferences and workshops.

Table 1: Gauteng liquid fuel dales (Ml) and growth rates

	Diesel		*Petrol*	
	Volume	*Growth*	*Volume*	*Growth*
1995	1057.77		3641.25	
1996	1124.75	6.33	3812.66	4.71
1997	1174.37	4.41	3863.77	1.34
1998	1163.93	-0.89	3910.45	1.21
1999	1163.73	-0.02	3926.48	0.41
2000	1223.47	5.13	3792.36	-3.42
2001	1387.29	13.39	3810.60	0.48
2002	1451.46	4.63	3818.52	0.21
2003	1583.06	9.07	3923.94	2.76
2004	1735.94	9.66	4096.76	4.40
2005	1995.92	14.98	4148.25	1.26

It is clear that liquid fuels produce combustion products that contribute to rising atmospheric carbon levels. Vehicles with engines idling during peak hour traffic simply add to emissions. Every litre of petrol burnt adds 2.30 kg of CO_2, every litre of diesel adds 2.63 kg CO_2, to the atmosphere (BP, 2006). If an effort was made to reduce the 2005 consumption volumes of both petrol and diesel by 10%, this would result in a reduction in greenhouse gases by 1.48Mt pa for Gauteng alone. Simply reducing congestion would probably give these results due to more efficient engine operating parameters. Moving passengers and goods to electrically powered rail could be as effective. Analysis of electric vs. oil-fuelled transport shows electricity to be less polluting, and often more easily controlled. Obviously there will still be emissions, but this time at the power station.

One kWh of coal fired electricity will produce 0.98 kg CO_2 (Eskom, 2005). For petrol, one kWh produces 0.28 kg CO_2. Hence, petrol on this comparative energy basis is a far smaller emitter of carbon than coal fired electricity.

Compared to coal, gas fired electricity will have lower emissions, while nuclear electricity is effectively zero. Unfortunately, life is never simple and the efficiency of the use of each fuel needs to be considered. In terms of final efficiency, electricity is more efficient than liquid fuels. A petrol-fuelled vehicle is typically between 20 - 25% efficient if properly maintained. Electric motors are usually about 80% efficient, and regenerative braking is an option that can increase total system efficiencies. Using these efficiencies, the emissions per effective kWh are 1.23 kg CO_2 for coal fired electricity and between 1.12 and 1.4 kg CO_2 for petrol vehicles. Thus, overall, the emissions between coal fired electricity and petrol, taking final efficiency into account, are comparable but more detailed analysis of different vehicle options is needed.

Peak oil

There is a group of oil analysts who believe the ability to produce more oil has reached maximum and that additional supplies are unlikely to be found. Whether this is (or becomes) a reality, is in some ways immaterial. We know that fossil fuels are a finite resource when evaluated on the human time scale, and given our current rates of extraction and utilisation compared to natural regeneration. We further know that fossil fuels contribute to environmental challenges and there is an urgent need for us to reflect on how effectively we are using the fossil fuels our planet has been blessed with. Authors who have recently written about the concept of peak oil, and who have detailed their analyses, include Campbell (1997), Smil (2003), Korpela (2005) and Deffeyes (2001, 2005). Even oil companies are considering the possibility of an oil peak (see, for example, advertisements placed by ChevronTexaco in publications such as *Time*). Environmentally friendly alternatives will have to be developed to sustain our global economy which is, in many ways, built on a transport network powered by liquid fuels.

The investments in road transport infrastructure at the expense of rail are probably due to the initially lower capital requirements. However, a continuation of this is unsustainable because of reduced availability of land for road networks and the future availability of liquid fuels. An understanding of the long-term implications of constrained oil supplies indicates that a strategic decision to upgrade and expand rail infrastructures for freight and passenger transport is required.

If the peak oil theory is indeed correct, then our current transport infrastructure is unsustainable sooner rather than later. Can South Africa afford to plan transport systems on the premise that there is a never-ending supply of cheap oil? This is almost certainly a risk-filled option. If the theory is not correct, then the question of whether transport sustainability will be limited by environmental considerations becomes paramount.

Cities, energy and transport

Johannesburg (and its surrounds), Cape Town and Durban are rapidly developing into very large cities (even megacities). Because land is relatively cheap, population densities are low compared to megacities in the rest of the world. This places additional economic constraints onto suitable public transport systems.

Public transport (excluding mini-bus taxis) in South Africa is, to all practical purposes, non-existent, and what there is, relies on diesel. There is a small amount of commuter rail used in some areas of the country but this is an insignificant amount. The Department of Transport (DoT) released a survey on household travel patterns in 2003. Further analysis of the data presented in the report indicates that for South Africans who travelled during the survey period, 82.5% used either cars or mini-bus taxis. Only 12.3 % used buses and 5.2% trains (DoT, 2003). The implication of this is that a significant number of commuters rely on either private cars or on mini-bus taxis. Both are exclusively liquid fuelled modes of transport and are not the most energy efficient. The survey only considered transport of people but transport of goods also impacts on the infrastructure, on oil demand and on environmental emissions.

Transnet reports that freight traffic moved by Spoornet increased marginally to 182.1Mt for the year ending 31 March 2006 (Transnet, 2006b). More than half is the bulk transport of coal and iron ore. Unfortunately, the ton-km values were not given, as this would have proved a more useful measure of freight transport activity. According to

Joffe (2006), Spoornet handles only about 10% of South Africa's freight business. From an energy efficiency perspective this is an unsustainable situation. Rail is known to be more energy efficient than road over longer distances.

It is imperative that South Africa takes a long term view (both strategically and sustainably) about how to move goods and people. An attempt needs to be made to use the most efficient and environmentally friendly options available. Building the rapid rail link between Johannesburg and Pretoria, the Gautrain, is one option that is being turned into reality (Gautrain, 2006). However, the option does not adequately address the transport needs of the vast majority within the Gauteng region, nor does it adequately address a system to get commuters to stations. Most commuters live significant distances from the Gautrain route, and from the planned stations. It is clear from the congestion on our roads that an alternative needs to be sought over a far wider spatial area, and that this needs to be addressed as a matter of urgency.

On reviewing the Gauteng urban structure, it is noted that the population density is not as high as is found in many other megacities in the world. The population density of Johannesburg is 1962 inhabitants per km^2 (Metropolis, 2006) compared to cities such as New York, Tokyo, Paris and Hong Kong, which have densities exceeding 10 000 inhabitants per km^2 (City Glance, 2006). This makes the provision of public transport expensive and the transport planning authorities will need to be innovative in determining and selecting appropriate modes of public transport. South African cities have been designed more on the American model of suburban sprawl than on the multilevel, multi-apartment buildings model characteristic of European cities.

Pressure on petroleum suggests that an electrically powered transport network should be seriously considered. It is suggested that a consideration of ultra light rail may very well be an option for Gauteng. Such systems traditionally use small vehicles which weigh less than about 5t when loaded (Dearien, 2004). This reduces the investment required to build the infrastructure and reduces the energy requirements per unit because the vehicles are small and light.

There are a number of systems currently operational or under development that could be considered for use within the Johannesburg/Greater Gauteng area. It is suggested that a detailed review of these options be undertaken and that a full economic assessment be made of the different options. Schneider (2006) maintains a database of new and innovative transport systems that provide an excellent point of departure for any system assessment. Choosing an efficient system that will allow transport of passengers, as well as high monetary value, high time value and low volume freight, would be a bonus for megacities in an oil short world. An alternative network able to transport short-distance freight promises a more sustainable solution. Three proposals from Schneider's database that could be further examined for suitability for Gauteng are the Austrans, CyberTran and MegaRail concepts. The latter two have specifically been designed for both people and freight. The former concept is for people only but a brief evaluation of the concept indicates that the system should also be capable of moving freight. A brief description of the three concepts is perhaps appropriate.

Austrans (2006) is a light-weight driverless vehicle seating up to 9 passengers. It operates on narrow gauge steel rails on dedicated guideways, either at ground level, or elevated, or even underground. The special bogie design will allow a minimum turning radius of 8m, an advantage in many urban locations. No information on the use of this proposal for freight is available.

CyberTran (2006) is similar in concept to Austrans, but uses larger vehicles with a maximum capacity of 20 passengers. The system was specifically designed for both passenger and freight options. The rails are steel rod in prefabricated guideways, either at ground level or elevated. Large steel wheels are used and the vehicles, as with Austrans, are driverless.

MegaRail (2006) offers a number of different vehicle options including small vehicles for 4 - 6 passengers, medium sized vehicles seating 13 passengers, a system where a number of individual vehicles are joined for a larger capacity configuration and a freight unit. Information indicates that the system will use rubber wheels on steel rails, running on elevated guideways. Some options would be driverless, others use an operator.

Dearian (2004) indicates that for freight, a diesel truck would show a specific energy consumption of 0.266 kWh per ton-mile. An ultralight rail cargo vehicle has an estimated specific energy consumption of 0.08 kWh per ton-mile. A thorough and detailed analysis of specific energy consumptions for the different technologies needs to be made.

A secondary transport consideration, given urban developments at the expense of agricultural land, is the provision of food to the inhabitants. Gauteng is essentially now one massive urban sprawl with limited agricultural land and opportunities available within the megacity boundaries. This does not augur well for the future or the future of this city. If the oil price continues to increase (as is possible), then the transport costs for bringing food and goods into the area is going to become exorbitant. The possibility of a ghetto Johannesburg is not improbable unless some thought is given to ways of limiting the effect of high prices.

It seems that the energy component of urban planning has been largely ignored and this needs to

be addressed. The situation in Europe where relatively small cities and villages are interspersed with agricultural land makes economic and energy sense in that food does not need to be transported over significantly large distances to meet the basic nutritional needs of the people. The author recognises that this is an untested and possibly naïve statement, but it is meant to illustrate a better, more balanced approach to urban and agricultural development. The opportunities, and urgent need, for detailed studies in this area for Gauteng are significant.

Perhaps Gauteng planners and politicians need to reconsider the development of the cities. Possibly we need to review towns that are fairly close-by and could be upgraded into self-contained urban centres where transport, employment, residences and agriculture will co-exist as closely as possible. Reducing the amount of fossil fuel, or even centralized energy distribution for transport, can only be beneficial in helping reduce greenhouse gas emissions, whether at point of use or a central power station some distance away.

Conclusion

Supply constraints on oil, both from an infrastructure and a resource perspective, linked to environmental issues, will place increasing pressure on the transport systems of Gauteng province in South Africa. It is further clear that an efficient and effective electrically powered public transport system can contribute to a sustainable future for the megacity. It is suggested that further research be conducted to more rigorously analyse the sustainable viability of ultralight rail as a solution for Gauteng. At the same time, it must be recognised that innovative and holistic city planning solutions need to be evaluated and adopted to prevent a potential energetic death of the megacity.

Institutions and departments involved in town and spatial planning should be made aware of the critical need for including a comprehensive energy assessment of selected options flowing from their planning processes.

A move to electric powered public transport will impact on the electricity supply industry, an industry where capacities are currently under pressure. It is thus imperative that energy efficiency in general be addressed as a matter of national urgency. This aspect is not investigated in this paper.

References

Austrans, 2006: Austrans. Available online at: www.austrans.com. Accessed 21 August 2006.

Bell G, 2006: SA to remain a fuel importer. Business Report 25 July 2006. Available online at www.busrep.co.za. Accessed 7 August 2006.

BP, 2006: Carbon calculator – FAQs. Available online at: www.bp.com/sectiongenericarticle.do?categoryId=9008658&contentId=7016688. Accessed 17 August 2006.

Campbell CJ, 1997: The coming oil crisis. Multi-science Publishing Company. ISBN 0906522110.

City Glance, 2006: Population density worldwide. Available online at: www.cityglance.org/facts/population_density.shtml. Accessed on 24 August 2006.

CyberTran, 2006: CyberTran. Available online at: www.cybertran.com. Accessed 21 August 2006.

Dearien JA, 2004: Ultralight rail and energy use. In: *Encyclopaedia of Energy*, Elsevier, 2004 - Vol. 6 p255-266.

Deffeyes KS, 2001: Hubberts peak: the impending world oil shortage. Princeton University Press. ISBN 0691116253.

Deffeyes KS, 2005: Beyond oil: the view from Hubberts peak. Hill and Wang, New York. ISBN 0809029561.

Department of Transport, 2003: National Household Travel Survey 2003. ISBN 0-620-34979-4. Pretoria.

Eskom, 2005: Eskom Holdings Annual Report 2005. Eskom Johannesburg.

Gautrain, 2006: Gautrain rapid Rail Link. Available online at: http://corporate.gautrain.co.za/. Accessed 8 August 2006.

Hubbert MK, 1956: Nuclear energy and the fossil fuels. American Petroleum Institute Drilling and Production Practice, Proceedings of Spring meeting, San Antonio, 1956, pp 7-25.

International Energy Agency, 2005: Energy balances of non-OECD countries, 2002-2003. IEA, Paris.

Joffe H, 2006: Spoornet looks to regain freight share. *Business Day*, 18 August 2006, p 2.

Korpela SA, 2005: prediction of a world peak oil production. In: McKillop A and Newman S: The final energy crisis. Pluto Press, London. ISBN 0745320929.

MegaRail, 2006: MegaRail. Available online at: www.megarail.com. Accessed 21 August 2006.

Metropolis, 2006: Johannesburg, South Africa. Available online at: www.Metropolis.org/data/files/442_097_Johannesburg_Eng.pdf. Accessed 24 August 2006.

SAPIA, 2005: 2005 Annual Report - Facts and Figures. Available online at: www.sapia.org.za. Accessed 8 August 2006.

Schneider JB, 2006: Innovative transport technologies. Available online at: http://faculty.washington.edu/jbs/itrans. Accessed 8 August 2006.

Simmonds M, 2005: Twilight in the desert. John Wiley and Sons, New Jersey. ISBN 047173876X.

Smil V, 2003: Energy at the crossroads. MIT Press, Cambridge, Massachusetts. ISBN 0262194929.

Transnet, 2006a: Petronet annual report. Available online at: www.transnet.co.za/AR_2006/ops_petronet.html. Accessed 18 August 2006.

Transnet, 2006b: Spoornet annual report. Available online at: www.transnet.co.za/AR_2006/ops_spoornet.html. Accessed 18 August 2006.

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