Sustainable energy solutions for South African local government

A practical guide

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SAMSET
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Overview

Transport enables trade, commerce, employment, social interaction and indeed brings people together out of their immediate communities in a national and increasingly global life. Still mostly relying on fossil fuel and using roads shared by multiple competing modes including private vehicles designed for very high speeds and accelerations, transport is also characterised by many negative externalities. These include urban congestion, being a dominant source of local air pollutants, a major source of greenhouse gases and accounting, in South Africa, for 12 944 fatalities in accidents in 2015 and many more serious injuries annually of which pedestrians constitute over a third (RTMC, 2016).[1]

In countries like South Africa that are reliant on rapidly increasing quantities of crude oil to fuel its transport system, there are additional risks to energy security and a negative impact on the national balance of payments. Given the complexity of transport systems it is not possible to explore the details of all the social costs and risks that make current transport systems unsustainable and furthermore impractical to detail the many policy and engineering solutions being attempted to mitigate these costs. However it is possible to articulate some key sustainable transport concepts, present broad best practice in policy and planning and feedback key lessons from recent transport projects in South Africa, as much as they exist in the public domain.

Transport is becoming an increasing priority for local government in South Africa, particularly in the large metros. This was given considerable momentum by the hosting of the 2010 World Football Cup which saw investment at scale by national government in the transport infrastructure of hosting cities. Efforts have generally been focussed on bus rapid transit (BRT) systems although Gauteng has also seen the implementation of the Gautrain high speed rail system and there is now a considerable body of experience from which to draw lessons from both successes and failures. The large projects undertaken, have generally not been primarily motivated by aspirations for sustainability and rather respond to growing congestion and the persistent problem of access to transport in cities and towns subject to sprawl and the location of poor communities on the urban periphery. Cities stand to gain considerably however in many spheres, long term efficiency not the least, by orientating transport policy and its implementation toward goals of sustainability. Investment in public transport, particularly, can offer social, economic and sustainability benefits.

Key concepts and features of the transport system

Below are some key concepts that underlie sustainable transport policy and technology levers and give an overview of the transport system in South Africa in a sustainability context.

The impacts of transport on sustainability

As alluded to above, the transport system has many impacts which are borne both by individuals and society at large. The current transport system and the urban environment that it serves however arose in response to the needs and desires of people and persists as a result of strong drivers. The impacts and drivers of a petroleum fuelled car centred transport system are contrasted in Figure 1 below. A great many costs and benefits, some quite intangible, are at play.

In general, the persistence over time of a pattern of car ownership and sprawl as a society's income grows, would suggest that people have been willing to pay for the impacts of the transport system. Wealthier countries have also been able to partially mitigate some impacts such as accidents and local air pollutants through regulation and enforcement. Transport globally is however a significant contributor to greenhouse gas emissions that pose a high

1 Road Traffic Management Corporation (RTMC) (2016) Cost of Crashes in South Africa Research and Development Report.

risk of negative and potentially catastrophic climate change. This has proved difficult to mitigate with the growth of the world population and economy despite the emergence of low carbon technologies. The rapid growth of cities in developing countries has also seen serious congestion and marginalisation of the poor due to constrained mobility that threatens the transition of these societies to a more prosperous and equitable level. This has seen renewed pressure and new thinking directed at changing the transport system and the urban form which it serves.

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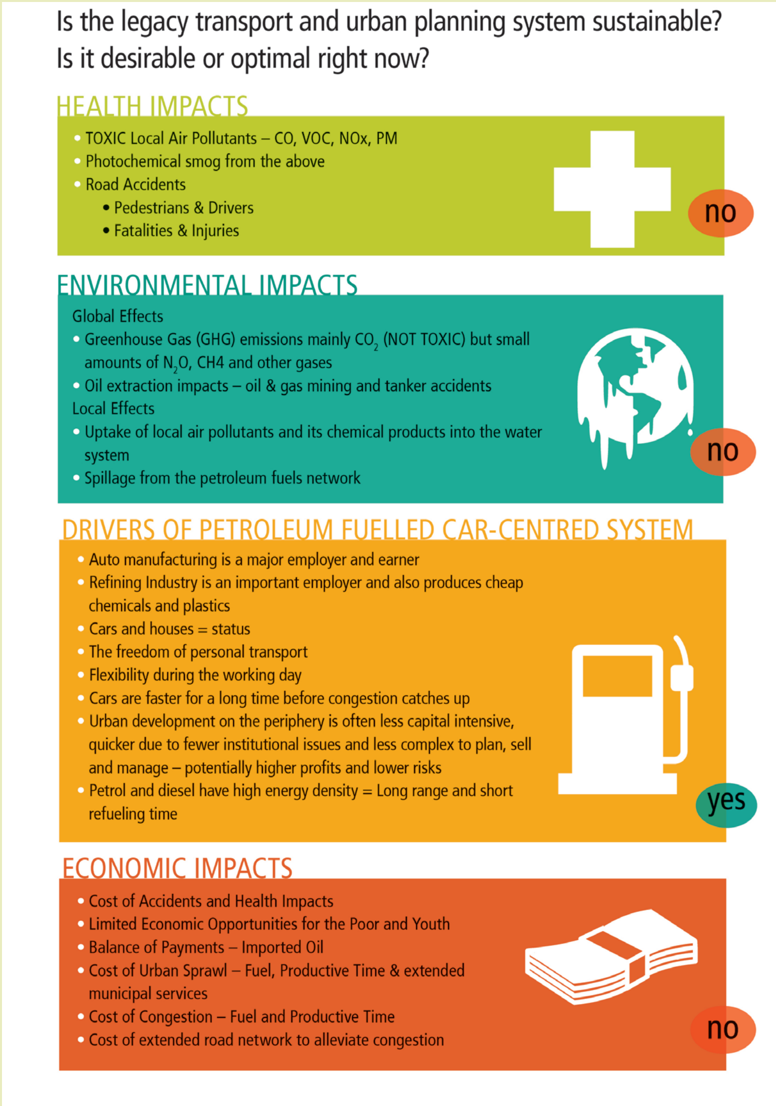
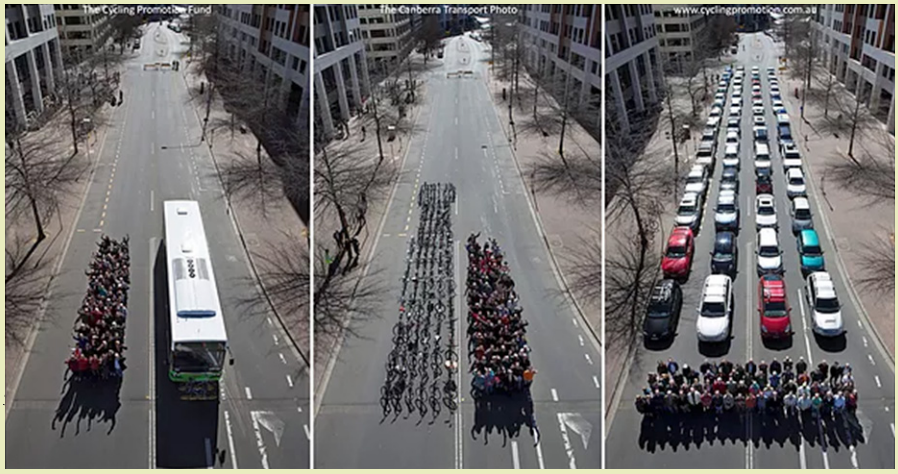
Figure 1: Contrasting the impacts and drivers of a petroleum fuelled car centred transport system



Mode choice and congestion

As shown in Figure 2 below, cars cause congestion in cities because they take up a lot of space. Motorcycles or bicycles take up less but there are safety risks unless there are dedicated lanes for the latter. Buses are safer and take up far less road space.

Figure 2: Passenger Modes and their Use of Road Space



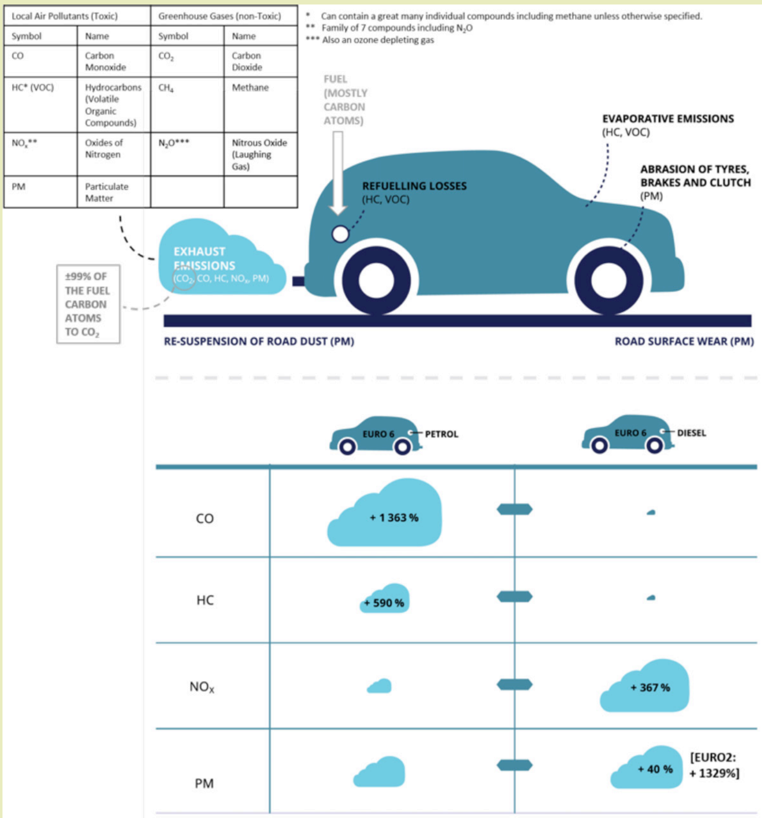
This set of photos demonstrates how the use of public transport, cyclists or private motorbikes over the use of private cars can reduce congestion in a city. Each option will transport the same amount of passengers!

Emissions from conventional Internal Combustion Engine (ICE) vehicles

The gaseous and particulate emissions from motor vehicles, particularly when petroleum fuelled, is a major source of impacts from transport. The main types of emissions and their relative scale in new technology petrol and diesel passenger cars is shown in Figure 3

Diesel light vehicles typically produce in the region of 10% less CO_2 than petrol fuelled equivalents however as shown below for some recent passenger car models from the South African market, vehicle size generally has a much greater impact on emissions. This is because larger vehicles will consume more energy when accelerating because of their higher mass and in certain cases are less aerodynamic and have more rolling resistance due to bigger tyres (SUVs).

Figure 3: Sources of Toxic and Greenhouse Gas emissions from Motor Vehicles and their relative scale in new technology Euro 6 petrol and diesel vehicles

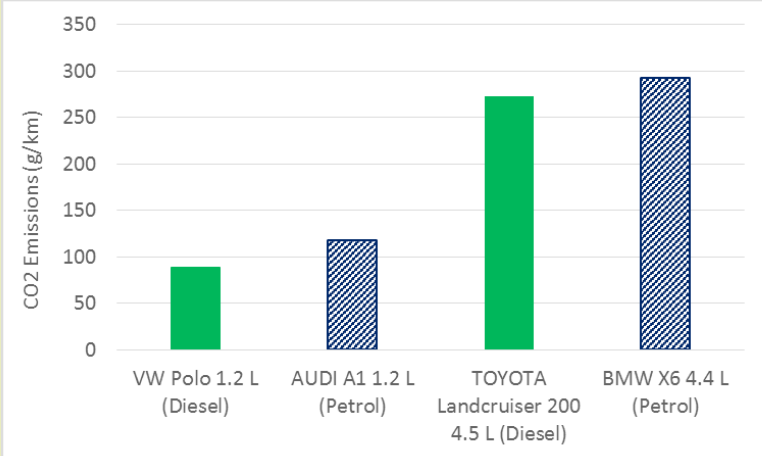


Local Air Pollutants (Toxic)		Greenhouse Gases (non-Toxic)	
Symbol	Name	Symbol	Name
CO	Carbon Monoxide	CO_2	Carbon Dioxide
HC* (VOC)	Hydrocarbons (Volatile Organic Compounds)	CH_4	Methane
NO_x**	Oxides of Nitrogen	N_2O***	Nitrous Oxide (Laughing Gas)
PM	Particulate Matter		

Source: Pastorello & Mellios (2016) Explaining road transport emissions –A non-technical guide. Copenhagen: European Environment Agency (EEA) adapted from the European Environment Agency.

The gaseous and particulate emissions from motor vehicles, particularly when petroleum fuelled, is a major source of impacts from transport.

Figure 4: relative impact of engine type and vehicle size (engine capacity in litres used as proxy) on CO_2 emissions as illustrated by selected recent light vehicle models



Source: data from manufacturer's published specifications

Useful transport indicators

In order to usefully quantify the demand for transport it is common to define it in terms of the following indicators:

- Trips – a single journey for one or more defined purposes e.g. work trips
- Vehicle kilometres (vkm) – The total distance travelled by a vehicle or fleet of vehicles in a specific time period. Longer trips will clearly require more vehicle km.
- Passenger kilometres (pkm) – the distance travelled by a single commuter for one or more trips e.g. A minibus with 10 passengers travels 1 km = 10 pkm. A car with one passenger travels 10 km = 10 pkm. Clearly then if there are more passengers in a vehicle there are more pkm for the vkm travelled.
- Tonne kilometres (tkm) – The distance travelled by a tonne of goods for one or more trips e.g. A truck with a 10 tonne payload travels 1 km = 10 tkm. A pickup/bakkie with a 1 tonne payload travels 10 km = 10 tkm

These indicators can be extended to energy and emissions as follows:

- Fuel Consumption (litres/100 km) – Most of us are familiar with this indicator usually expressed as litres of fuel consumed per 100 km travelled (litres/100 km) or its inverse Fuel Economy which is kilometres travelled per litre of fuel consumed (km/litres).
- Specific Fuel Consumption (litres/pkm or litres/tkm)– If the occupancy or payload of the vehicle is divided into fuel consumption it is possible to calculate the volume of fuel required to deliver a passenger km or tonne km
- Energy Intensity (MJ[2]/pkm of MJ/tkm) – Liquid fuels have quite consistent energy content, termed the Lower Heating Value (LHV) or Net Calorific Value, which for petrol is about 33 MJ/litre and for diesel about 36.5 MJ/litre. By multiplying this by Specific Fuel Consumption it is possible to convert to Energy Intensity. The fuel economy of an electric car is frequently expressed as kWh/km but this is easily converted to MJ/pkm by the factor 3.6 MJ/kWh.
- CO_2 Intensity (g CO_2/pkm or g CO_2/tkm) – As shown in Figure 3 above, liquid fuels are mostly carbon atoms and most of this becomes CO_2 in the combustion process. Given the narrow range of specifications of petrol and

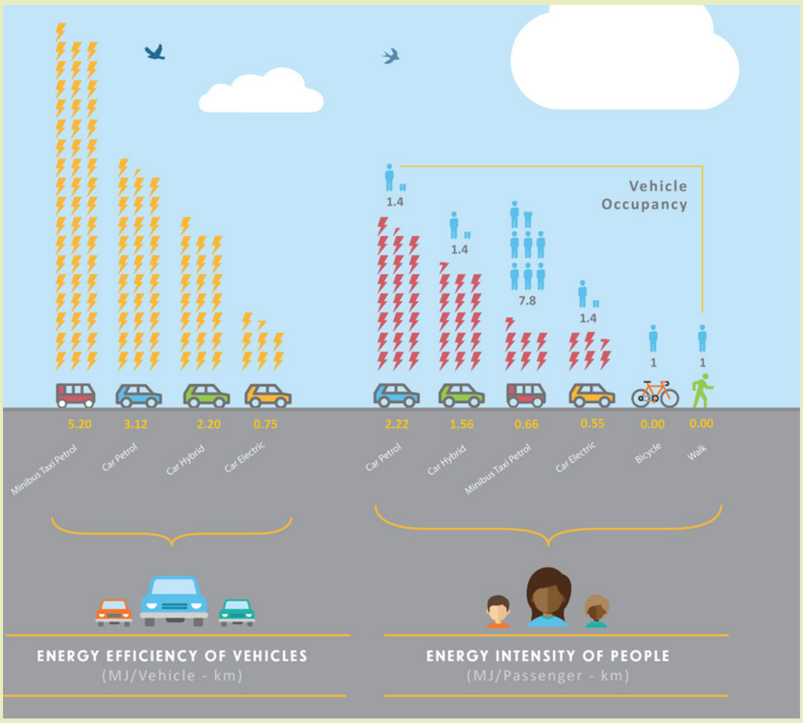
2 MJ is the symbol for Megajoule which is equivalent to 1 million Joules of energy

diesel, carbon content is quite consistent. Thus it is possible to readily estimate the amount of CO_2 in grams generated per pkm delivered by multiplying our energy intensity by emissions factors. These are around 75 g CO_2/MJ for diesel and 72 g CO_2/MJ for petrol. An electric car would not produce CO_2 emissions from the car at all.

- Wells to Wheels CO_2 intensity (g CO_2/pkm or g CO_2/tkm) – The emissions attributable to a trip are not just produced by the vehicle however. There can be considerable emissions produced in the supply chain of the fuel (including electricity) at mines, oil refineries and power stations. This is particularly important when assessing the impacts of electric vehicles fuelled by coal-fired power as discussed below in more detail.
- Lifecycle CO_2 intensity (g CO_2/pkm or g CO_2/tkm) – There are also emissions associated with the manufacture of the vehicle and the extraction and refining of its constituent materials like steel for the chassis and lithium for batteries. Including these emissions with the vehicle and fuel supply chain emissions would yield the full lifecycle emissions intensity. This becomes complicated to assess given the global nature of automotive parts production however and requires difficult to access data, complex analysis and specific expertise.

While fuel consumption will be higher for bigger and heavier vehicles, a number of factors drive a lower energy intensity for larger public transport and freight vehicles including reduced relative losses from drag, the fact that larger engines are generally more thermally efficient and that the cargo area/volume as a percentage of total increases with vehicle size. It follows from this that if it possible to double the load of goods or people on a vehicle with a marginal increase in fuel consumption large gains in efficiency when meeting transport demand can be made. A large city bus will for instance use around 2.5 times as much fuel per km as a minibus taxi but can carry more than 4 times as many people. This principle is illustrated for a number of examples below in Figure 5.

Figure 5: Energy efficiency of Vehicle Types and the Impact of Occupancy on Energy Intensity - Data typical of City of Cape Town



Source: Kane L (2016) What do we mean by low carbon transport? Undertstanding how people move in Cape Town. Cape Town : Open Streets Briefing Paper

In the discussion above that LARGE and FULL vehicles will use the least energy and produce the LEAST emissions when transporting goods and people.

BUT it is evident that LARGE and EMPTY vehicles will use the most energy and produce the MOST emissions when transporting goods and people.

Matching the vehicle to the application or the operational circumstances is therefore extremely important. In certain circumstances this may be a minibus taxi rather than a large bus.

Transport, the economy and the environment

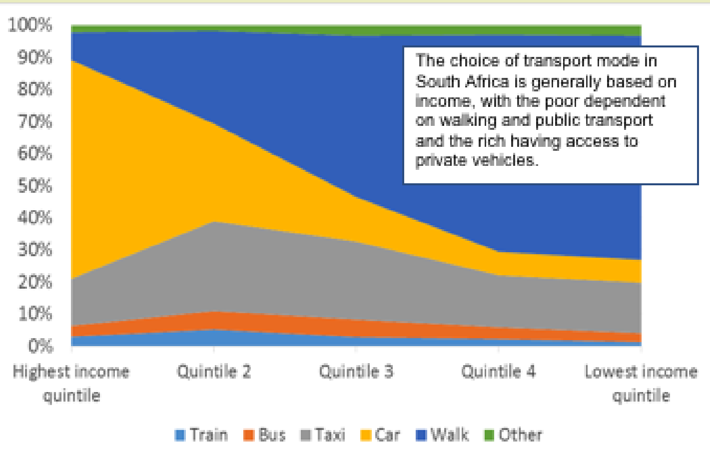
While reducing trips clearly saves energy, it is important not to lose sight of the direct relationship between trips and the economy. As well as being required for the exchange of goods, trips enable the personal interactions that open up new opportunities for people and organisations for future employment and trade. Different economic directions may be more or less transport intensive, but broadly transport demand will grow in lockstep with the economy over and above the population growth. There is thus a trade-off between economic growth and the constraints that arise on continued growth through congestion and the need for more transport infrastructure that may not have been priced into the cost of the goods being traded. The following important principles arise from this:

- Trips are economically beneficial but policy should aim to make these as short and efficient as possible.
- It stands to reason then that the design and co-location of commercial and industrial developments and the residential developments that feed them with labour need to facilitate trips that are as short and efficient as possible. See Transit Orientated Development (TOD) and Integrated Land Use Planning below.
- If such urban design facilitates a high proportion of non-motorised trips (walking and cycling) then substantial cost and emissions savings are possible.
- If mass transit is operated efficiently at high capacity in urban areas it can similarly have both substantial economic and sustainability benefits.
- On the other hand, public transport that poorly matches the urban environment it serves and has low average occupancy will have both economic and sustainability dis-benefits. This trade-off makes the operation of transport services extremely challenging because availability is a major component of the quality of service from the commuter's perspective but unused capacity is very costly for the operator. This speaks to the importance of investment in the people and systems that support operations.
- Mechanisms need to be put in place to price the future cost of transport infrastructure into public and private goods and services. Land Value Capture below briefly expands on this in practice.

Urban transport in South Africa – the passenger picture in brief

The broad transport situation in South Africa is well understood thanks to travel surveys undertaken at national and city level.[3, 4] As can be seen in Figure 6 below there is a marked contrast in mode choice between income groups, a very high share of walking trips for low-income commuters and a very high share of private car use for the highest income quintile.

Figure 6: Share of modes in daily trips by income group (calculated using national household travel survey 2013 per person data for random travel day).



3 Stats SA. National Household Travel Survey Statistical Release P0320. s.l. : Statistics South Africa, 2013.

4 Nel City of Cape Town: Secondary data analysis of the Household Travel Survey (2012) for the Low Carbon Central City Transport Strategy. s.l. : Report Commissioned by Open Streets http://openstreets.org.za/ (2016).

In a large metropolitan city like Cape Town, the modal split is around 50% private to 50% public transport going into the CBD (Nell, 2016). Surveys show that driver only car trips are over fourfold higher than passenger car trips (4) indicating that private commuting is generally by single occupancy vehicles which leads to increased congestion and inefficient fuel consumption with associated high levels of carbon emissions. The transport sector is currently responsible for about 25% of carbon emissions in South African cities with the share of car ownership having grown from 23% to 33% between 2003 and 2013. (SEA, 2015). [5]

Information on people's travel time budgets are gathered by the National Household Travel survey and this is useful in assessing the efficiency of the transport system and if congestion is affecting this. Evidence suggests that on average around the world and across cultures there is a preference for a daily time budget of around 1.1 hours, a number sometime referred to as the 'Marchetti' constant [6]. Surveys suggest average time budgets in South Africa are significantly longer than this and this tells a story of economic 'drag' due to transport difficulties and growing congestion as shown below.

Table 1: Indicative Change in commuter travel times by income group between 2002 and 2013 for Cape Town

	2002	**2013**	
Income level	**Total Personal Time Budget (hr/day)**	**Work Trips (hr/day)**	**Education Trips (hr/day)**
Low	1.6	1.8	1.0
Middle	1.1	1.9	1.0
High	0.9	1.7	1.1

Source 2002: Adapted from Behrens (2002) Findings of an activity-based household travel survey in Cape Town, with particular reference to walking as a travel mode. 21st Annual South African Transport Conference South Africa 15 – 19 July 2002.

Source 2013: Cape Town Household Travel Survey Data (separate study to NHTS) in Kane (2016) What do we mean by low carbon transport? Understanding how people move in Cape Town, Open Streets Briefing paper, September 2016.

Table 2: Daily Work Travel Times for South Africa by income group indicated by the National Household Travel Survey (NHTS) 2013

Income Group	**Excl. Walking Only Trips (hrs)**	**Including walking Only Trips (hrs)**
All	1.6	1.3
Highest quintile	1.4	1.3
Quintile 4	1.6	1.4
Quintile 3	1.7	1.3
Quintile 2	1.7	1.2
Lowest quintile	1.6	1.2

Source: Calculated from the published data files for NHTS 2013 available from Datafirst, University of Cape Town

5 SEA (2015) State of Energy in South African Cities, Sustainable Energy Africa, Cape Town.

6 Schafer & Victor (2000) The future mobility of the world population. Transportation Research Part A, 34, 171-205.

The data suggests the following:

- In Cape Town, whereas 10 years ago the car mode was a lot faster than public transport, evidence suggests this gap has closed significantly due to congestion.
- National figures for travel time are also very high relative to global norms although the car mode (high income) still has an advantage (dominates highest income quintile).

Informal or semi-regulated minibuses remain the dominant form of public transport in South Africa with an increased modal share indicated between 2003 and 2013, having apparently attracted learners and workers from walking, despite increased public investment in formal public transport. Available public transport services differ across cities. In most cities there are bus and minibus taxi systems, with rail found in the main metropolitan cities, but not in the smaller cities (Stats SA, 2013).[7] City bus and train systems provide the most efficient forms of transport in terms of energy per commuter kilometre; however, even though these are by and large the same price or cheaper than minibus taxis, they are sometimes underutilised. This is due to:

- Inconvenience. Bus and train systems do not service many informal settlements and efficient feeder systems to nodes in main routes are frequently not in place.
- Unreliable reputation although the perception of service of some BRT systems is good. The high end Gautrain has high levels of satisfaction but is expensive
- Perception that they are slower than taxis.
- Safety concerns, particularly on Metrorail trains.

There is a need not only for continued investment in large scale infrastructure to improve the formal public transport system but also investment in its operational systems in terms of security, fare systems and responsive operational management in order for it to improve its current share of commuters.

For many years scheduled bus services were operated by concessions to private operators such as Golden Arrow bus Service in Cape Town and Putco in Durban, administered by provincial government effectively operating on a substantial subsidy basis to cover areas and times of low demand. With exceptions, in general the quality of service has been low in terms of commuting speed, accessibility and reliability and on occasion subject to serious abuses of the subsidy. The Department of Transport and Metro Authorities took the opportunity of the 2010 World Soccer Cup to act strongly in favour of transport system reform. Large public transport projects initiated in South African cities in the last 10 years include the following:

- Gautrain high speed rail – Gauteng
- Rea Vaya BRT System – City of Johannesburg
- A Re Yeng BRT System – City of Tshwane
- MyCiti BRT System – City of Cape Town
- GoDurban Integrated Rapid Public Transport Network (IRPTN) – eThekwini
- GoGeorge Integrated Public Transport Network (IPTN) – George
- Libhongolethu Integrated Public Transport Network (IPTN) – Nelson Mandela Bay Municipality
- Yarona – Rustenburg's rapid transport service
- Ekurhuleni's Harambee Bus Rapid Transit (BRT) has undertaken initial testing and is set to launch in July 2017 [8]
- Polokwane's Municipality's Integrated Rapid Public Transport Service (IRPTS) is reported to be on schedule to go live in March 2018 [9]
- Buffalo City, Mangaung and Msunduzi completed public transport network development planning and service contract designs in 2013/14 [10] but the current status of these projects is unclear.

7 Stats SA (2013) National Household Travel Survey Statistical Release P0320.

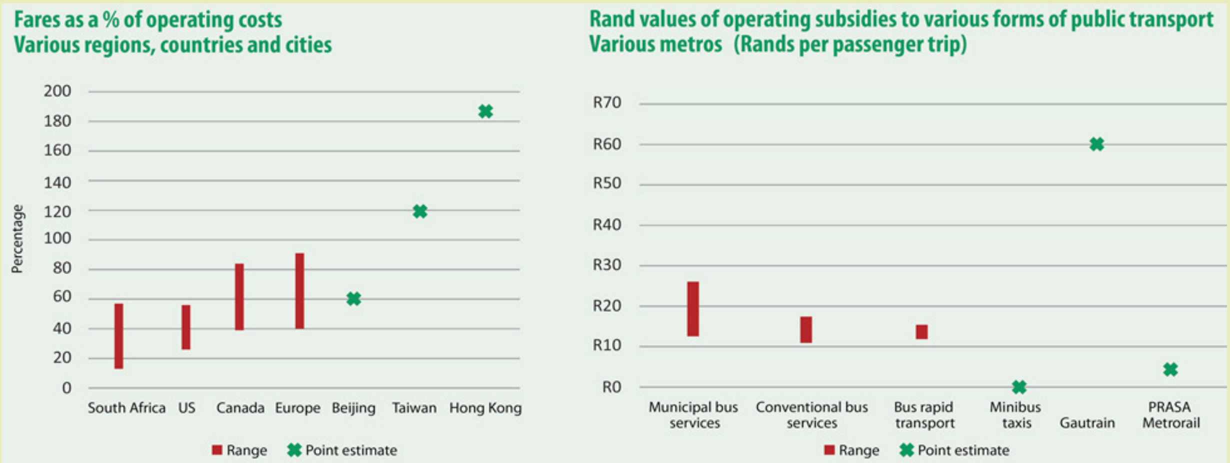
8 http://ewn.co.za/2017/02/08/watch-ekurhuleni-test-for-long-awaited-brt-system

9 http://www.observer.co.za/integrated-rapid-public-transport-service-on-track/

10 http://www.gov.za/about-government/government-programmes/bus-rapid-transit-system-brt

Despite vast capital expense, these projects have not however, in the view of some, delivered affordable and financially sustainable public transport. This is primarily, it is believed, because urban densities are generally low and where residential densities are high in former apartheid era townships, economic opportunities and infrastructure are limited and distances to potential work long, resulting in inefficient cities with long travel times. The costs of transport services and doing business are therefore high and this combined with the limited purchasing power of the lower income cohorts who are the primary public transport users, results in a smaller share of public transport costs being recovered than is generally the case in the rest of the world as shown in Figure 7 below.

Figure 7: Cost recovery Rate of Public Transport in South Africa compared to Selected Regions and Costs per Trip of Modes



Source: National Treasury (2014), Performance and Expenditure Review - Public Transport, Government Technical Advisory Centre, National Treasury, Pretoria.

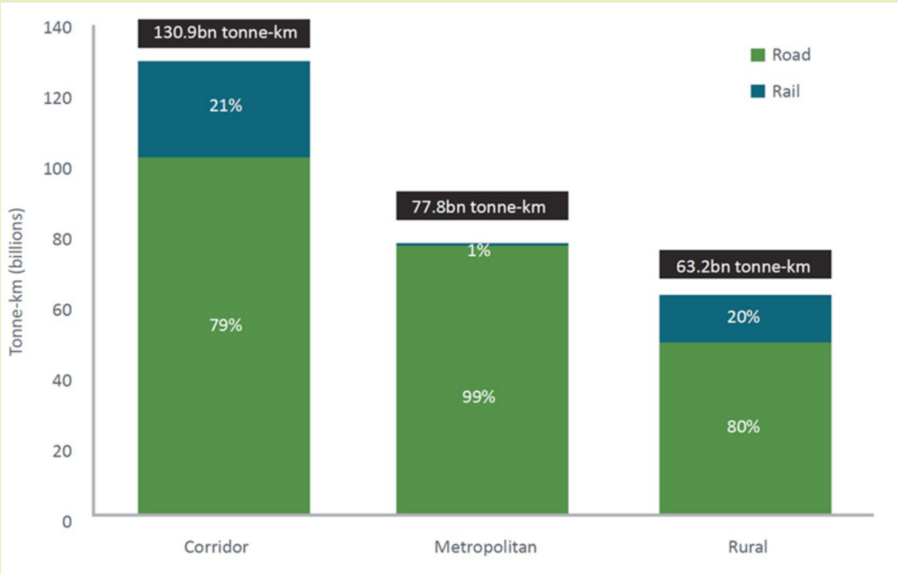
Also evident from Figure 7 is that while very large sums are spent on transport subsidies none of it, since the winding down of a difficult and sporadic taxi recapitalisation programme, is now spent on minibus taxis, the mode which conveys the vast majority of public transport passengers.

City bus and train systems provide the most efficient forms of transport in terms of energy per commuter kilometre; however, even though these are by and large the same price or cheaper than minibus taxis, they are sometimes underutilised.

Urban transport in South Africa – the freight picture in brief

South Africa's large cities are geographically dispersed across a large land area with its economic hub of Gauteng on an inland plateau, relatively far from the nearest port. It has been described as having a 'spatially challenged' economy (CSIR, 2013)[11] and the corridors between the major cities dominate the demand for general freight (excluding mining commodities) with most of that supplied by road transport as shown below.

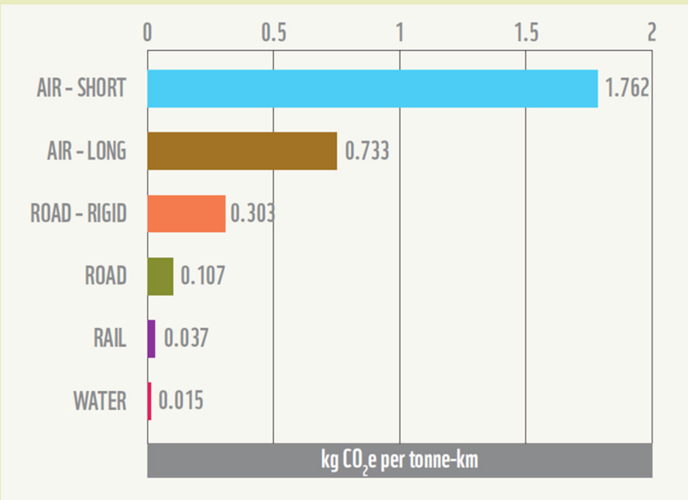
Figure 8: Distribution of General Freight Demand in the South African Economy in 2014



Source: Havenga, JH, et al. (2016) Logistics Barometer South Africa 2016, Stellenbosch University

Metropolitan freight actually contributes almost 50% of the total volume of freight demand in tonnes compared to 16% for corridor freight, but the shorter distance reduces its share of total freight tonne-km to around 15%. The energy and emissions intensity of freight transport varies markedly by mode as shown below with rail typically producing a third of the emissions of long haul road transport and a tenth of smaller rigid trucks.

Figure 9: Typical CO_2 equivalent Emissions Intensities of Freight Modes



Source: WWF (2013), Low Carbon Frameworks: Transport - Understanding Freight Emissions, World Wildlife Fund

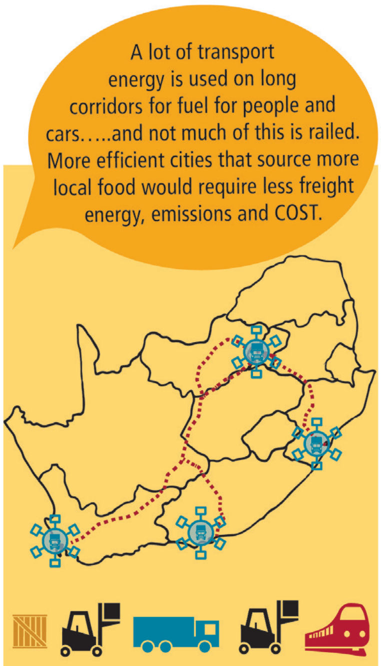
11 CSIR (2013) 10th Annual State of Logistics Survey for South Africa 2013 – Bold Steps Forward, Council for Scientific and Industrial Research (CSIR).

When corridor freight is regarded at a commodity level it is easier to see opportunities for making logistics more sustainable. As shown below on some corridors the most freight, energy and emissions intensive commodities emissions are processed food and petroleum fuels. This presents opportunities for reducing emissions by localising food or tolling certain commodities that make the whole intercity journey by truck.

Figure 10: opportunities for intermodal freight transport for key commodities and the freight impacts of moving petroleum fuels on major corridors in South Africa (2009 Data)

FREIGHT COMMODITY SHARE

Commodity	Corridor	Share of road tmk	Share of rail tmk
Processed Foods	CapCor	23%	0%
	NatCor	20%	2%
	Other Cor	20%	1%
Beverages	CapCor	9%	6%
	NatCor	7%	1%
	Other Cor	7%	2%
Other Chemicals	CapCor	6%	2%
	NatCor	6%	2%
	Other Cor	6%	1%
Wood & Wood Products	CapCor	4%	0%
	NatCor	4%	7%
	Other Cor	4%	23%
Paper & Paper Products	CapCor	2%	2%
	NatCor	4%	3%
Fuel & Petroleum Products	CapCor	4%	1%
	NatCor	20%	6%
	Other Cor	6%	12%



NatCor: Transport Corridor between Durban and Gauteng
CapCor: Transport Corridor between Gauteng and Cape Town
tkm: tonne.km being the product of the mass of freight and the distance travelled

Commodities like the top 5 shown that are readily packaged on pallets and in containers are logical candidates for INTERMODAL FREIGHT. In this type of logistics trucks do the distribution at either end of the journey and trains do the long haul. Specially designed containers and trailers make the mode changes fast. For 2009 it was estimated that just over a quarter of freight on corridors was intermodal friendly and nearly half of that could be realized on the CapCor and NatCor corridors alone.

Source: Adapted from Centre for Supply Chain Management, Department of Logistics, University of Stellenbosch and the WWF

van Eeden & Havenga (2010) Identification of Key Target Markets for Intermodal Freight Transport Solutions in South Africa. Journal of Transport and Supply Chain Management.

The use of intermodal freight transport solutions does not have to damage the trucking industry because the number of trucking trips actually increases but they are far shorter. In fact the trucking companies would do as much or more logistics but their costs in terms of overtime, fuel costs, maintenance and insurance decrease. Consequently a joint venture between road hauliers and the rail utility could benefit all parties[12].

12 Centre for Supply Chain Management, Department of Logistics, University of Stellenbosch and the WWF

Corridor Freight and Intemodal Transport Solutions

- A lot of freight tonne.km is metropolitan as expected but nearly double this is on the corridors between metropoles: It's not in the city but it's of the city.
- It can see that rail is much less emissions intensive and fuel consumption and costs are lower but that it has a minority share of corridor freight. Rail lost market share because of speed and convenience but with new methods rail can be used in an efficient, cleaner and cheaper logistics process with intermodal transport.
- *"The process of intermodal transport consists of short-distance road feeder services to an intermodal terminal in a logistics hub where freight is consolidated into main-line block trains running the length of the corridor to a destination terminal. From the destination terminal, it is transported to distribution centres or end destinations via road transport"*, Centre for Supply Chain Management, Department of Logistics, Stellenbosch University.[1]

1 Havenga, Simpson, Fourie & de Bod (2011) Sustainable Freight Transport in South Africa: Domestic Intermodal Solutions. Journal of Transport and Supply Chain Management.

Electromobility in South Africa and potential impacts on sustainability in the short and long term

Electromobility refers to a broad category of vehicles which are generally characterised by having electric motors drive the wheels some or all the time instead of mechanical drive from an internal combustion engine. These include the following:

- Battery Electric Vehicles (BEV): Where externally charged batteries are the energy source
- Hybrid Vehicles: These have come to refer broadly to a hybrid of a battery electric vehicle and a combustion engine and fall into two main categories:
- Non Plug-in Hybrids: Also termed 'conventional' hybrids these vehicles are never connected to an external electricity source. The battery is kept charged by recovering braking energy and the combustion engine if necessary.
- Plug-in Hybrids: Plug-in hybrids can be fueled with both petroleum fuel and electricity from a filling pump or charger. The driver now has much more control over the share of electricity and petroleum fuel they use and can respond to the limits on availability of either. Some types of plug-in hybrids are called Extended Range Electric Vehicles (EREVs).
- Fuel-Cell Vehicles (FCV): Fuel Cells produce electricity from on-board hydrogen fuel. The electricity produced by the fuel cell can either supply the wheel motors directly or charge a battery, effectively acting as a range extender.

Battery electric vehicles, in general, have higher capital costs than conventional petroleum fuelled vehicles although prices are dropping with battery costs having fallen by a factor of 4 since 2008 (IEA, 2016)[13]. Electricity is furthermore significantly cheaper than diesel in most countries, including South Africa and maintenance costs are claimed to be around 30-50%[14] cheaper for battery electric vehicles. This may in certain circumstances offset a price premium over the lifetime of a high mileage vehicle like a public bus. Caution should however be exercised around the full costs of charging infrastructure, particularly if a project aim is to power vehicles with 'green' energy as discussed below.

While battery electric vehicles produce zero emissions from the vehicle itself, there may be considerable emissions associated with the fuel supply chain. In South Africa most electricity is produced from coal and therefore the emissions from coal power stations needs to be taken into account when comparing the current emissions of an electric car operating in South Africa to those of a petroleum fuelled vehicle. In addition, the supply chain of South African petroleum fuels is also higher emitting than globally typical particularly in terms of CO_2 because of a large Coal-To-Liquids (CTL) refinery [15].

To assess the current environmental benefits of electromobility the emissions need to be estimated for the supply and production of the fuel and electricity as well as those from the vehicle itself (wells-to-wheels basis). The results of such an assessment for selected passenger car models is shown below in Figure 11 and Figure 12[16]. The discretionary choice of whether to drive a big car or a small car makes a big difference to energy economy as demonstrated above and small conventional cars currently give rise to lower GHG emissions than battery electric vehicles in the South African context if CTL emissions are not considered. In this case non-Plug in hybrids seem to give rise to the least GHG emissions. If CTL is included at its national production share, battery electric vehicles significantly outperform gasoline fuelled conventional vehicles on a GHG emissions basis but small diesel fuelled IC engine cars are comparable because the CTL refinery produces proportionally less diesel.

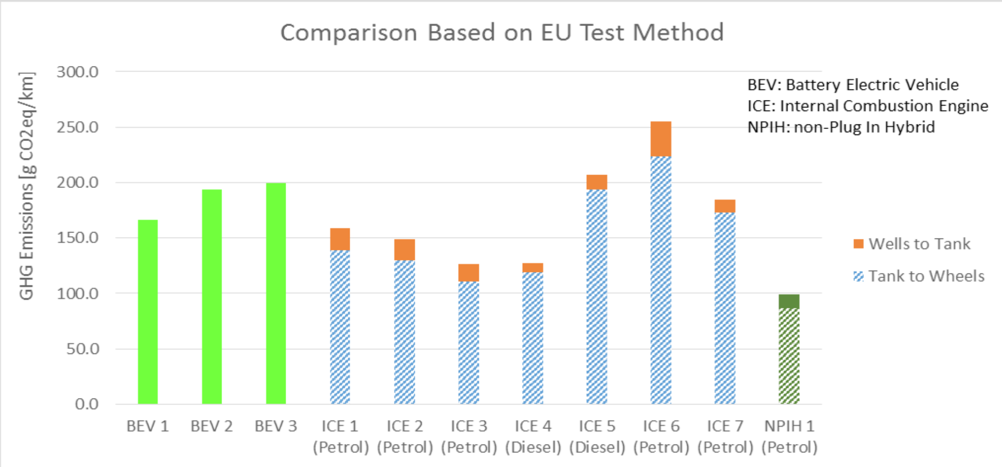
13IEA (2016) Global EV Outlook 2016 – Beyond one Million Electric Cars. International Energy Agency, Paris.

14Fuso Trucks: http://media.daimler.com/marsMediaSite/en/instance/ko/World-premiere-the-new-all-electric-Fuso-eCanter.xhtml?oid=13669591; BYD Buses: http://www.tct.gov.za/docs/categories/1562/Alternative%20transport%20solutions.pdf

15The CTL production process produces liquid fuels from coal by first gasifying the coal and then liquefying the gaseous products by catalysis in a relatively energy and greenhouse gas intensive series of processes.

16SEA (2016) Well-to-Wheels Greenhouse Gas Emissions and Energy Comparison between Battery Electric Vehicles, non-Plug in Hybrids and Conventional Passenger Cars for South Africa. http://www.cityenergy.org.za/uploads/resource_401.pdf; Excel Calculator: http://www.cityenergy.org.za/getfile.php?id=400&category=7

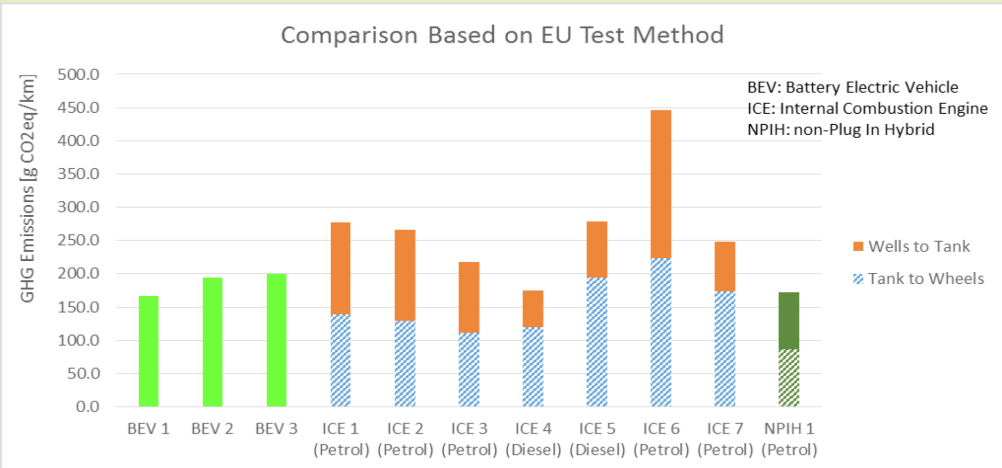
Figure 11: Wells-to-Wheels GHG Emissions for selected model passenger cars when CTL production is excluded from refinery supply system



Source: SEA (2016). Well-to-wheels greenhouse gas emissions

BEV: Battery Electric Vehicle, ICE: Internal Combustion Engine, NPIF: non-plug in hybrid. The models have been selected to cover a range of manufacturers and illustrate a range of emissions. For ICE vehicles the higher emitting models are heavier vehicles with bigger engines.

Figure 12: Wells-to-Wheels GHG Emissions for selected model passenger cars when CTL production is included in the Refinery Supply System

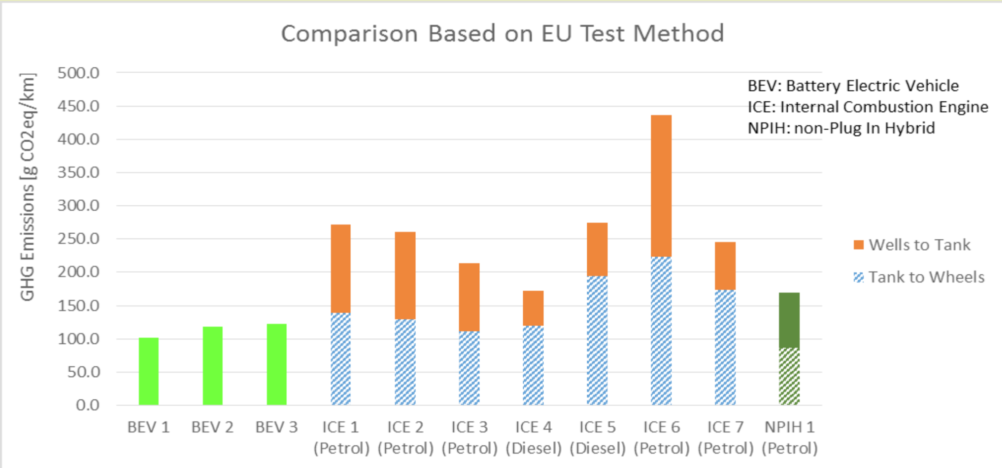


Source: SEA (2016). Well-to-wheels greenhouse gas emissions

BEV: Battery Electric Vehicle, ICE: Internal Combustion Engine, NPIF: non-plug in hybrid. The models have been selected to cover a range of manufacturers and illustrate a range of emissions. For ICE vehicles the higher emitting models are heavier vehicles with bigger engines.

Assuming, however, that 25% of battery charging is shifted from using the national grid to off-grid solar embedded generation at home and the workplace and that nuclear and renewable generation rises to a 25% share of grid electricity, then GHG emissions from the operation of battery electric cars would drop to around half of even small conventional cars and non-plug in hybrids as shown below.

Figure 13: Simulated Wells-to-Wheels GHG Emissions for Selected Model Passenger Cars when CTL production is included in the Refinery Supply System and 25% of BEV Charging is Embedded PV and Grid Electricity is 25% Nuclear/RE



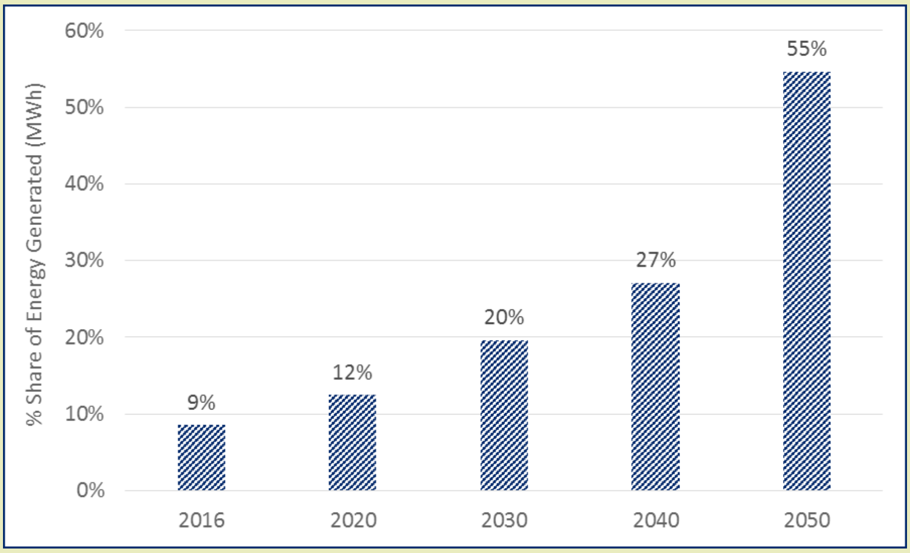
Source: SEA (2016).

In general, South Africa's coal intensive electricity supply means that the operational wells-to wheels GHG emissions from battery electric passenger cars are comparable to compact conventional passenger cars operating on crude oil distilled liquid fuels despite the far superior energy efficiency of the electric vehicles. This gives non-plug in hybrids a GHG emissions advantage in areas solely supplied by conventional refineries. There is however significant synthetic CTL fuel production in South Africa and if this is taken into account at its national share of production, then battery electric cars start to offer significant GHG emissions advantages over compact gasoline fuelled cars. Diesel fuelled cars are still comparable[17] because the CTL production is more gasoline heavy. Clearly then, in areas that are exclusively or mostly CTL supplied (such as areas of Gauteng), electric cars are significantly lower emitting on a relative basis with the caveat that if fuel demand were to drop in those areas because of electric cars, the CTL fuel would simply be distributed elsewhere given the nature of the supply system in the country.

If 25% of Battery electric vehicle charging is however shifted from the national grid to embedded solar supply at home and work and the grid electricity supply shifts to 25% nuclear and renewable sources, both attainable targets, then the operational GHG picture shifts unambiguously in favour of battery electric cars. The shift to carbon free energy sources supplying the electricity grid will however likely take quite some time as indicated by the latest Integrated Resource Plan Update Base Case results shown in Figure 14 below. Clearly then, in principle, South African policy supporting electric cars should incentivize small scale embedded charging as much as the cars themselves for the time being. The City of Cape Town is proposing rather 'wheeling' or 'offsetting' with solar energy to reduce the net emissions of their order of 11 electric buses from BYD, a chinese automobile manufacturer for the MyCiti service to come into operation at the end of 2017.

17 Diesel passenger cars still only account for around 10% of the car market if SUVs are included, with few compact models to choose from. In general, the fuel savings attained with diesel passenger cars have also not offset the capital and maintenance premium in South Africa.

Figure 14: Projected share of carbon-free electricity generated (Nuclear, CSP, Solar PV and Wind) in the IRP Update Base Case



Source: DoE (2016) Integrated Resource Plan Update Assumptions, Base Case Results and Observations, Department of Energy, Government Gazette, 25 November 2016, No. 40445

Hydrogen Fuel Cells

Research and development into the automotive applications of hydrogen fuel cells continues, including on heavy vehicles, as fuel cells have the potential to extend the range and terrain accessible by electric freight vehicles and commuter buses. A recently announced long-haul freight truck prototype, the Nikolai, a non-plug in fuel cell battery electric hybrid, claims an impressive just less than 2000km range[18]. Like battery electric vehicles, fuel cell vehicles have zero emissions from the tailpipe. While not as energy efficient as battery electric vehicles, fuel cell vehicles typically have an equivalent fuel economy 40-60% better[19] than conventional vehicles with less of an urban driving energy penalty as well as, in most cases, a greater driving range than battery electric vehicles.

While capital costs of emerging offers have come down, the advances have not been as great as for battery electric vehicles. The practical experience of the Stuttgart Public Bus Company Stuttgarter Strassenbahnen AG (SSB) offers useful perspective(Wiedermann & Raff, 2017)[20]. They ran two fuel-cell bus demonstrator projects ten years apart in 2003 and 2014, the latter involving 6 fuel cell-battery hybrid buses running as a fully integrated component of their service. The price premium of the buses relative to a conventional diesel bus came down from 5-fold in 2003 to two-fold in 2014 and energy efficiency improved from 22 kg H2/100 km in 2003 to10-14 kg H2/100 km in 2014 mostly due to regenerative braking technology.

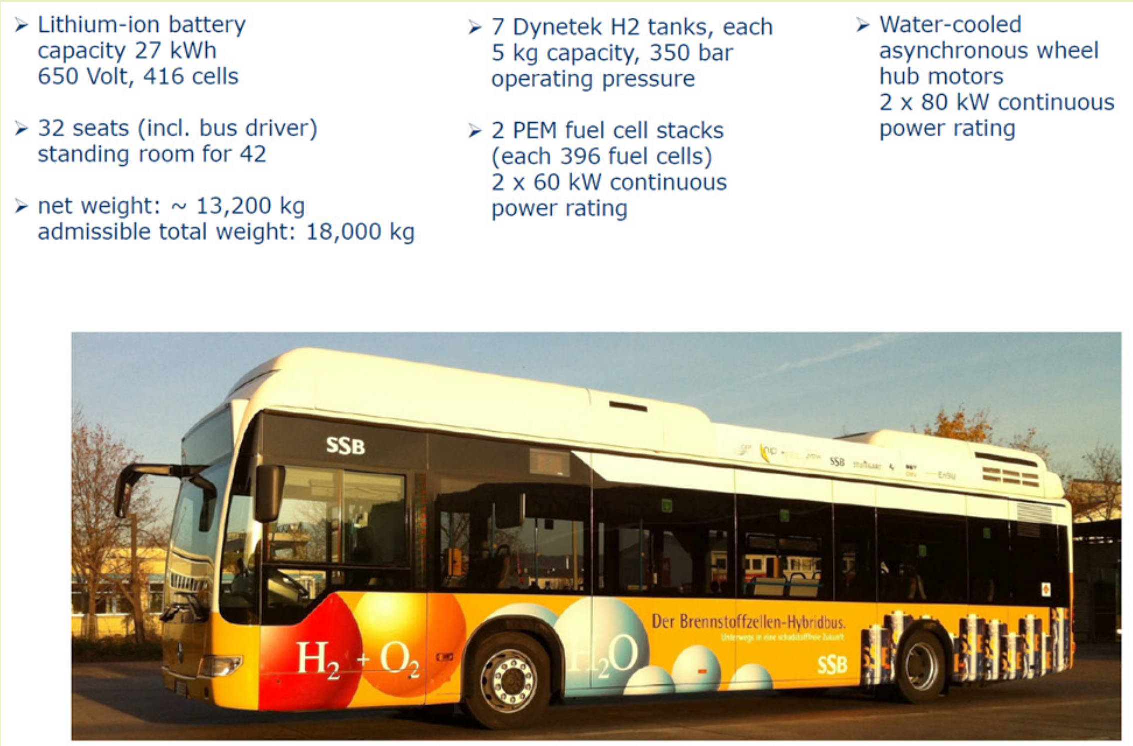
Hydrogen has very low volumetric energy density such that even when compressed to the very high pressure of 700 bar of modern hydrogen fuelling systems, it only has an energy content of around 9 MJ/litre compared to around 36 MJ/litre for diesel at atmospheric pressure. The challenge with hydrogen is therefore in the cost effective production, storage and distribution of the fuel. Global production of hydrogen is mostly by reforming of

18 https://nikolamotor.com/one

19 http://www.fueleconomy.gov/feg/fcv_sbs.shtml

20 Wiedemann & Raff (2017) Presentation at Fuel Cell Bus Workshop – Unleashing Industrial Opportunities for South Africa through a Zero Emission Choice. Department of Trade and Industry and GiZ workshop, Cape Town, 20th February 2017.

Figure 15: Hybrid Battery Electric Fuel-cell Hybrid Bus operated by SSB Stuttgart



Source: Wiedemann & Raff (2017) Presentation at Fuel Cell Bus Workshop – Unleashing Industrial Opportunities for South Africa through a Zero Emission Choice. Department of Trade and Industry and GiZ workshop, Cape Town, 20th February 2017.

fossil methane (Gupta, 2009)[21] and in 2003 SSB installed their own on-site Steam Methane Reforming (SMR) plant at considerable cost to the project but sold this plant and changed to sourcing hydrogen more cost effectively from a waste incineration plant for the 2014 project. SSB are very clear however that the 2014 project is still not financially viable without considerable external subsidy.

The leading concept for 'carbon-free' hydrogen production is water electrolysis supplied by solar PV electricity. This is potentially a useful way to store excess electricity produced by renewable plants at scale when demand is low. Aside from the efficiency penalty of converting electricity to hydrogen (around 25%) however, the costs of small on-site electrolysis has generally been high(Dodds &McDowall, 2012). [22] As such the costs in Germany of 'green' hydrogen from electrolysis is reported to be currently around Euro 9.50/kg compared to Euro 2.60/kg for hydrogen produced by SMR 21.

The Department of Science and Technology is supporting a concerted research initiative called Hydrogen South Africa (HYSA) which has three centres of excellence working to give the country a foothold in the industrialisation of the nascent global hydrogen economy.[23] They have developed production, fuel cell and storage technologies and potentially may make early public transport demonstrator projects viable in South African municipalities if their technical support can be combined with sufficient financial and institutional support.

21Gupta (2009) Hydrogen Fuel Production, Transport and Storage. Boca Raton: CRC Press Taylor and Francis Group.

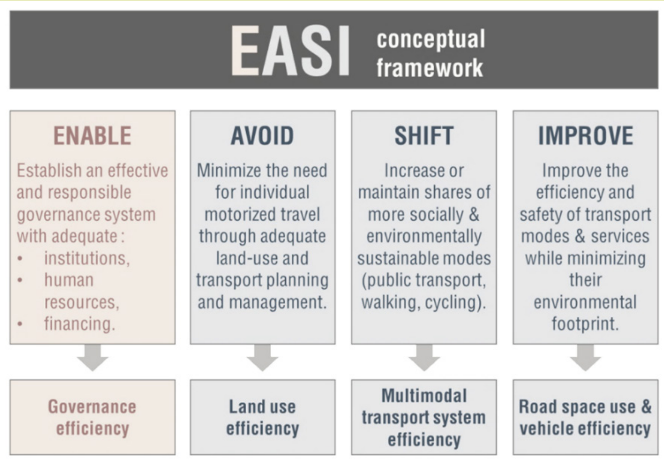
22 Dodds & McDowall (2012) A review of hydrogen production technologies for energy system models – UKSHEC Working Paper No. 6. London: UCL Energy Institute, University College London.

23 http://www.hysasystems.com/index.php/about-hysa

Concepts to policy frameworks

The concepts above have been structured into evolving policy frameworks designed to promote sustainable transport starting with Lee Schipper's World Bank Activity, mode Share, Intensity and Fuel mix (ASIF) framework (World Bank, 2016)[24] and the simplified Activity, Shift and Improve (ASI) (UNEP, 2011)[25] framework, both focussed on energy efficiency. A recently developed variation on these, EASI (World Bank, 2015)[26] has a strong additional institutional and governance component. EASI is outlined in Figure 16.

Figure 16: EASI– a robust conceptual framework to guide public action



Source: The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan.

The 4 pillars of EASI expand into policy recommendations which are presented below. Current transport policies and implementations in South Africa are briefly assessed against these recommendations:

Table 3: Policy Recommendations to support the 'Enable' Pillar of the EASI framework

E1	To define, adopt and implement, at central government level, a national urban transport strategy that ensures the sustained development and management of urban transport systems.
E2	To ensure that the main urban transport public responsibilities at urban/metropolitan level are assigned and carried out.
E3	To set up an entity in charge of urban transport planning and of guiding and coordinating public action aimed at the provision of a multimodal urban transport system.
E4	To provide all institutions and stakeholders in the urban transport sector with adequate human resources.
E5	To increase financial resources allocated to urban transport systems and to ensure the availability of long-term funding for urban transport.
E6	To create the preconditions for continued civil society participation in the development of urban transport systems.
E7	To enhance the involvement of the private sector in the provision of transport infrastructure and services.

Source: The World Bank (2015), "Policies for sustainable accessibility and mobility in urban areas of Africa", Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan

24 World Bank (1999) Transportation and CO_2 Emissions: Flexing the Link – A Path for the World Bank. Paris: The World Bank.

25 UNEP (2011) Towards a Green Economy – Transport – Investing in Energy and Resource Efficiency. United Nations Environment Programme.

26 The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan.

In South Africa a comprehensive national level transport strategy (E1) has been adopted in the form of the recently updated National Transport Master Plan (NATMAP) (DoT, 2016)[27]. Financial resources have been (E5) made available nationally to urban transport systems through programmes such as the Public Transport National Grant (PTNG) although the long term sustainability of current subsidy levels and established levels of compensation to minibus taxi operators, as formalisation expands, is in question (DoT, 2016). Large metropoles such as the City of Cape Town have however undertaken financial scenario analysis of their BRT expansion plans with the target of remaining within the target of 4% of property rates income in a future environment of reduced subsidy (City of Cape Town, 2015) [28].

Transport authorities (E3) have been set up by Cape Town (TCT) and eThekwini (ETA) but urban passenger rail is still centrally administered by PRASA and legacy subsidised bus contracts with private concessionaires are still administered by provincial governments. The steady expansion of Integrated Public Transport Network (IPTN) projects in the large metropoles and some secondary cities like George and Rustenberg over some 10 years has built a cohort of supporting professionals, private suppliers and to a lesser extent civil society bodies that to some degree address the remaining policy recommendations above in key regions. A good start has therefore been made on the 'enable' pillar with the potential to leverage the emerging institutional expertise to overcome the many challenges to expanding current systems, extending systems to new regions and improving the financial sustainability of all networks.

Table 4: Policy Recommendations to support the 'Avoid' Pillar of the EASI framework

A1	To plan for urban forms and land use that minimize the need for individual motorized travel and promote public transport and non-motorized transport modes.
A2	To deploy transport infrastructure and services in a manner that promotes sound urban forms and land use.
A3	To strengthen land use management.

Source: The World Bank (2015), "Policies for sustainable accessibility and mobility in urban areas of Africa", Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan

Generally low urban densities have been widely identified as a barrier to the financial sustainability of public transport in South Africa. Cape Town has identified Transit Orientated Design (TOD) in urban planning as a long term cornerstone of its plan to make its public transport network more financially sustainable. It is not clear however whether private developers and supporting professionals in the main as yet prioritise integration with a low carbon transport system. Furthermore, legislated public consultation processes can have the outcome of stalling mixed use developments at increased densities due to conflict with private interests. Broad policy is in place for this pillar in the large metros but implementation at scale will likely take some time. Secondary cities implementing public transport projects will be even more vulnerable to operational efficiency problems due to unsuitable urban form. Integrating land use efficiency through the urban planning and approval functions will therefore need to form a key component of long term planning for future projects.

27 DoT (2016) National Transport Master Plan, Synopsis Update, Draft Final Report, Pretoria: Department of Transport, Republic of South Africa.

28 City of Cape Town (2015) MyCiTi Business Plan 2015 Update Phase 1 and N2 Express, Transport for Cape Town (TCT), Cape Town.

Table 5: Policy Recommendations to support the 'Shift' Pillar of the EASI

S1	To adopt and systematically introduce, at all levels and scales, a multimodal approach to the development and management of urban transport systems.
S2	To develop and maintain for each urban area a pedestrian network that is continuous, safe and accessible for all throughout the day; and to develop and maintain bicycle paths with similar characteristics.
S3	To provide an integrated and hierarchical public transport system that is efficient, reliable and capable of serving the needs of constantly evolving populations and the urban economy.
S4	To plan and implement mass transit systems that operate on exclusive infrastructure and can form the backbone of the urban public transport system.
S5	To enhance the level of service provided by paratransit (minibus taxi) operators by way of full integration in the public transport system, which requires restructuring, modernizing and promoting them.

Source: The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan

The public transport projects of the last 10 years were initially very BRT focussed in what has been described as BRT "mania" or "fever" inspired by the remarkable achievements in South America particularly in the cities of Bogota and Curitiba. The political considerations of the times have made the rapid provision of modern formal motorised transport a priority and a multimodal approach, particularly inclusive of non-motorised modes, has perhaps suffered. An early recognition in eThekwini that the structure of the city precluded meeting major demand with full BRT and that an integrated multi-modal system centred around the existing rail network was more practical was, for example, subsumed by the Department of Transport's then focus on BRT as a condition for grant funding (Esteves & Bannister, 2015)[29].

The reframing of large scale national grant funded initiatives as Integrated Public Transport Network (IPTN) projects has however broadened the scope of planning and responses to challenges considerably. The City of Cape Town has indicated its intention of implementing the future phases of its public transport network expansion as a 'hybrid' system which, recognising the efficiency of the minibus taxi industry, aims to integrate an improved quality minibus service as feeders to trunks and core feeder routes with the possible further integration of the legacy provincially contracted private bus company (GABS) (Naidoo, 2016)[30]. The Go George IPTN directly purchased minibus taxis modified for full disabled access and fare system integration and have maximised flexibility in their fleet and scheduling to optimise financial sustainability.

Given the high walking mode share in low-income groups and the high rate of pedestrian fatalities, robust pedestrianisation initiatives are justified on safety and cost considerations alone but in general have yet to be prioritised outside of a broad commitment to TOD principles. Investment in cycling infrastructure is however more difficult to justify given the current low mode share but has niche applications. Aside from non-motorised transport then, the trend in policy implementation in current IPTNs has shifted broadly in line with the "shift" pillar recommendations above and future projects can draw directly from the planning and practice innovations currently unfolding.

29 Esteves & Bannister (2015) Implementing BRT in eThekwini. [Online] Available at: http://www.erln.co.za/images/jevents/5624aa29b92726.87366313.pdf

30 Naidoo (2016) Cape Town's Experience – Presentation to SABOA, Transport and Urban Development Authority, City of Cape Town.

Table 6: Policy Recommendations to support the 'Improve' Pillar of the EASI framework

I1	To improve planning, operation and maintenance of urban roads taking into account and balancing the needs of all transport modes and keeping the use of individual motorized vehicles under check.
I2	To define and implement realistic and gradually more demanding requirements in terms of fuel components, energy efficiency and gas emissions.
I3	To promote safe and environmentally responsible behavior by all urban transport stakeholders, by strengthening technical control of vehicles and by keeping the public informed of the negative externalities of individual motorized transport.

Source: The World Bank (2015) Policies for sustainable accessibility and mobility in urban areas of Africa, Africa Transport Policy Programme (SSATP), TRANSITEC Consulting Engineers Ltd (M. Stucki), in collaboration with ODA, CODATU and Urbaplan.

After the initial phases of IPTNs all implementing municipalities are acutely aware of the risk of reliance on subsidy and are focussing on operational efficiency of their bus fleets through mixing bus sizes, moderating expensive peak services and investing in control centres that monitor and respond flexibly to demand.

While the mass transit programmes discussed above do not, in general, have an implicit sustainability rationale, many of the larger metropoles have compiled greenhouse gas inventories and are in the process of setting mitigation targets. The impact of vehicle occupancy on energy efficiency is seen in Figure 5 above and it is likely that this will lead to policies targeting control of private motor vehicles and higher occupancies. These might include permission to use restricted lanes for cars carrying passengers or relaxation of restrictions to access parts of the central city for cars with passengers. Other than a small national level carbon tax on the purchase of passenger cars and light trucks there is, for the time being, little activity aligning with the 'improve' pillar of policy recommendations as regards private vehicles.

Electric vehicles are seeing rapid growth off a low base in Japan and Norway[31] and offer opportunities for energy efficiency but as is discussed in more detail below, South Africa's coal fired electricity largely erodes these gains unless solar charging is implemented.

31 https://electrek.co/2017/02/15/norway-electric-vehicle-market-share-record/

Implementation

A universe of implementation measures, appropriate to local government, that align with the EASI framework and thus promote sustainable transport are presented below in Table 7.

Table 7: Selected Sustainable Transport Implementation Measures for Local Government

Type of Measure	Description of Measure
Taxes	Congestion charges, vehicle registration fees, road tolls (e-tolls). Vehicle emission taxes at license renewal. Parking charges for high emission or low occupancy vehicles. Emission tolls on freight delivered by road corridors, in particular processed food.
Incentives	Reduction of parking costs and relaxation of access restrictions for low emission vehicles. Rebate of tolls for freight delivered by rail or multi-modal rail technologies. Waive vehicle licensing costs for low emission vehicles.
Subsidies	Access national Transport infrastructure and operations subsidies. General Revenue Funds (national, provincial and local levels for parking, road development, transport infrastructure and road transport operation).
Regulations	Regulatory restrictions to encourage modal shifts (road to rail). Restriction on use of private vehicles in certain areas and at certain times. Restriction on the use of higher emitting and low occupancy vehicles.
Planning	Urban planning and zoning restrictions e.g. enforce the urban edge and limit access to the CBD. Management of investment and usage of transport infrastructure. Development of NMT/bus/public-transport lanes/zones. Limitation of parking for private vehicles in congestion zones. Sector specific energy performance and GHG targets based on scenarios developed for a State of Energy.
Standards	Develop minimum policy level of service specifications for public transport services (e.g. operating times and frequency). Emissions standards for public transport fleets and municipal vehicle fleets .
Information Programmes	Information campaigns on externalities of car use and promotion of public transport alternatives. Marketing of public transport services. 'Green / Eco Driving' Campaigns.
Government Procurement of Public Goods or Services	Low emission vehicle procurement for IPTN systems. The Green Energy Efficiency Fund (GEEF) (facilitates the implementation of energy efficiency initiatives and renewable energy projects).
Direct Infrastructure Investment	Energy management and monitoring systems for fleets. Investment in alternative fuel infrastructure e.g. solar charging points for EVs. Investment in low emission vehicles for municipal fleets. Investment in mass public transport with dedicated infrastructure. Investment in transit (expansion of transport network) and non-motorised transport (Pedestrian walkways or cycle lanes).
Institutional Measures	Creation of a Transport Authority with a clear vision, mandate and resources. Integration of transport planning with environmental and urban planning. Integrate minibus taxi operators not yet incorporated as operators or shareholders of IPTNs to support the system on feeder routes. Collaborate with tertiary institutions on transport system engineering and management course content design. Offer bursaries and internships linked to human resource supply.
Research and Development	Continued investment in the development of energy and environment systems models and traffic flow models and their application to inform decisions on targets, policy evaluation and development impacts. Collection and dissemination of transparent, replicable, comparable and accurate public data on transport.

**See Section 8, Appendix – Overview of measures and responsibilities in GIZ's Urban Transport and Energy Efficiency Module 5h of the Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities for an extensive list of available measures.*

It is beyond the scope of this chapter to explore this entire universe of measures in detail. However, given the growing prevalence of single occupancy private vehicles in South African cities and their associated externalities, travel demand management strategies for this mode are discussed in more detail below.

Implementation Priorities in the Words of Practitioners

Some leading local practitioners in sustainable transport contributed their thoughts:

Lisa Kane, Independent Researcher, Consultant and Activist

- Think of road space as a precious resource – like water or energy – and allocate it efficiently. Single Occupancy Vehicles (SOV) are energy intensive and space intensive. Too many SOVs leads to congestion and delays for road-based public transport, walking and cycling (which are far more energy and space efficient). Public transport investment needs to be prioritised over road building for SOVs for congestion and energy reasons. Within 10 years there will need to be looking at restricting SOV use in most of our cities and large towns, as developed cities do, either by congestion pricing, higher parking fees or SOV-use restrictions. There also needs to be more 'squeezed' out of our roads by optimizing traffic signals better and investing more in junction design to improve bottlenecks.
- Make best use of vehicles already in use. At the moment cars are used very inefficiently and mainly by one person only. Car-pooling apps and autonomous vehicles look set to blur the line between private and public transport. This is a good thing for energy efficiency. Local government needs to remove barriers to, and invest in, technologies which improve the efficiency of existing vehicle use (e.g. car-pooling apps, public transport apps, walking apps).
- The barriers to technology uptake can be in surprising places. For example, the legality of car-pooling is not 100% clear at the moment and this has implications for car insurance. Public transport apps require access to data and forward thinking about open data policies in local government.
- Reduce the need to travel. Any large destination such as school, college, workplace, retail mall, hospital is also a large attractor and producer of movement. Many of these are managed by local or provincial government. Micro-changes at large destinations attracting many SOVs can have large impacts over time. Site-based travel planning could involve changes to timetables or work hours to enable sharing of vehicles or public transport, working with suppliers to reduce travel, educating students and staff about transport efficiency. There are many potential win-wins to looking closer at travel on a site-by-site basis: more work flexibility for staff with potential for better work outcomes, less time spent in traffic, reduced travel costs for individuals. The local authority itself is a good place to start with this.

Geoff Bickford, Programme Manager, South African Cities Network

- Action oriented integrated land use transport planning. Municipalities will need to ensure that actual land use and transport decision making is co-ordinated to give effect to good quality lifestyles based on public transport.
- Place a priority emphasis on walking, cycling and public transport over roads. Municipalities have ownership and control over the municipal road network and transport planning and design for this network. Despite the existing policy rhetoric municipalities have not managed to prioritise pedestrians and cyclists.
- Factor in the true cost of driving private vehicles. Currently the way transport is funded subsidises drivers. Municipalities will need to get drivers to pay the true cost (to society, the environment and the municipality) of driving, and capture these revenues to fund the improvement of sustainable transport options.

Promotion of travel demand management strategies to minimize passenger cars or single occupancy vehicles (SOV)

The upgrade of a public transport system to a more reliable, convenient and safe system can encourage people to change to public transport. Other strategies need to be put in place to encourage movement away from automobile dependence.

These strategies include:

- Implementation of high occupancy vehicle lanes, which mean that cars with three or more occupant can have access to a dedicated lane. This lane usually moves more quickly during the peak periods, with free flowing traffic rather than the bumper-to-bumper traffic that is common in the peak periods.
- Employer programmes which aim to encourage the use of alternative transport, such as public or non-motorised transport or car-pooling, to get to work. This could include preferential parking for those carpooling, subsidies for public transport tickets, guaranteed ride home and moving away from subsidized parking for single occupancy vehicles. Staggering of working hours within localities can also help reduce the expensive peak demand on public transport services and make them more financially viable.
- Park-and-Ride schemes allow people to park their cars at public transport interchanges and continue the journey on public transport. An important aspect here is the need for security at the site, in order to ensure the safety of the commuters as well as making sure that the cars are secure.
- The cost of traveling by private vehicle should also be looked at, including the need for accurate parking charges in the CBD. An international trend, which has been successful in a number of cities including London, Rome and Milan (see box), is the implementation of a congestion charge for access into certain areas of the CBD. The money taken from the charge covers the operational costs of the service as well as upgrading aspects of the public transport system.

The travel demand management strategies can only work if there are suitable alternatives put in place for the commuter.

'Area C' in Milan

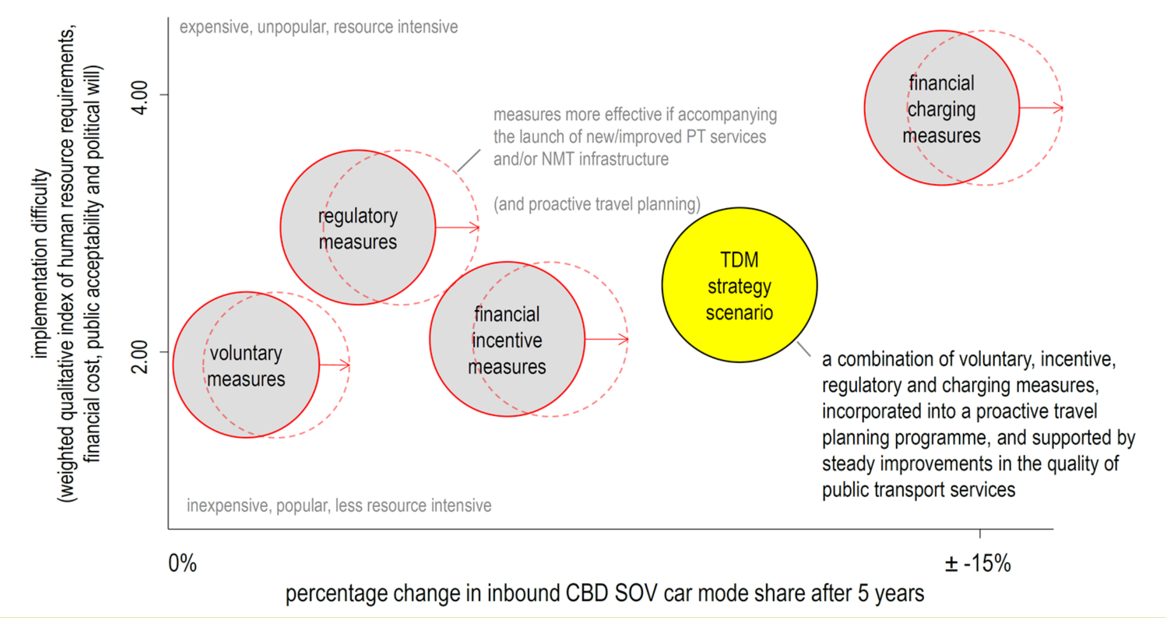
- 79% of citizens voted for a traffic restricted zone
- The central area of Milan (4.5% of area) was cordoned off by special gates in 2012. Cameras detect vehicle entrance with ANPR (Automatic
- Number Plate Recognition) technology.
- A daily entrance ticket costs €5 (congestion charge)
- Access for low emission and public transport vehicles is free.

Source: http://www.c40.org/case_studies/milansareacreducestrafficpollutionandtransformsthecitycenter

Travel Demand Measures (TDM) Measures to Reduce Single Occupancy Vehicles (SOV) – How much can they Achieve?

The potential range of effect of TDM in reducing SOV, as seen in various cities globally, was reviewed to assist with the design of a Travel Demand Management (TDM) strategy for Cape Town. The difficulty of implementation of types of measures was also assessed:

Figure 17: Hypothetical TDM strategy effectiveness in Cape Town based on effects in other cities (the yellow circle is a mix of the other measures)



Source: Behrens R, Adjei E, Covary N, Jobanputra R, Wasswa B, Zuidgeest M (2015). A Travel Behaviour Change Framework for the City of Cape Town, Proceedings of the 34th Southern African Transport Conference.

- Financial charging (see case of Milan above) seems most effective but could be difficult to administer and be unpopular (see high difficulty score above).
- In combination with other measures and with the correct packaging, sequencing, targeting and resourcing, a 10% reduction in the SOV mode share of traffic travelling in and out of the city centre could be achieved.

Provision of reliable, quality and financially sustainable public transport (Shift)

Public transport is an essential pillar of sustainable transport and that in order to compete with passenger cars it needs to be of sufficient reliability and quality. South Africa has seen concerted investment in public transport since the build up to the Soccer World Cup in 2010. Integrated Public transport systems mostly focussed on a high quality bus service have emerged and are emerging at different rates in the large metropoles but as the system grows so does the pressure on the state to subsidize this emerging system.

The most challenging areas from a financial sustainability perspective are former townships and low-income dormitory suburbs on the periphery. These areas are characterised by high densities that should help public transport economics but their isolation, low levels of local industrial and commercial development and high levels of informality place pressure on fares and create a highly peaked (and inefficient) demand profile.

Aside from a burgeoning global literature, the expansion of increasingly complex networks in the large South African metropoles has seen the growth of in-depth local expertise and a great many high quality local resources and analyses on the subject of public transport now exist published by transport authorities, consultants, academics and civil society. Key issues and details of some of the levers available to practitioners in carrying on this difficult but essential national enterprise will be highlighted.

BRT – what and why? (Shift)

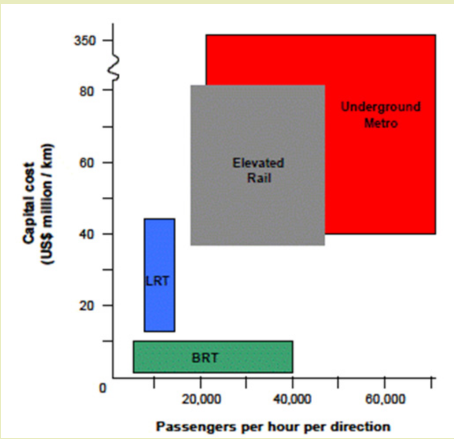
Public transport customers typically give the following reasons for switching to private vehicles:

1. Inconvenience in terms of location of stations and frequency of service;
2. Failure to service key origins and destinations;
3. Fear of crime at stations and within buses;
4. Lack of safety in terms of driver ability and the road-worthiness of buses;
5. Service is much slower than private vehicles, especially when buses make frequent stops;
6. Overloading of vehicles makes ride uncomfortable;
7. Public transport can be relatively expensive for some developing-nation households;
8. Poor-quality or non-existent infrastructure (e.g., lack of shelters, unclean vehicles, etc.)
9. Lack of an organised system structure and accompanying maps and information make the systems difficult to use; and
10. Low status of public transit services.

Source: Wright (2002 edition) Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities – Module 3b, Bus Rapid Transit, GiZ.

Bus Rapid Transit (BRT) has become synonymous with the South African public transport project since the build-up to the soccer world cup 2010. BRT is a bus-based mass transit system that has the potential to deliver high capacity public transport at a cost that is far more affordable for developing countries than rail options as shown in Figure 18 below.

Figure 18: The Financial Rationale for BRT – Mass Transit at Relatively Low Capital Cost



Source: Wright (2002 edition) Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities – Module 3b, Bus Rapid Transit, GiZ, http://www.sutp.org/files/contents/documents/resources/A_Sourcebook/SB3_Transit-Walking-and-Cycling/GIZ_SUTP_SB3b_Bus-Rapid-Transit_EN.pdf

It achieves this not only through engineering and systems features but also through a range of best practice approaches across operations that extends to safety, communications and public relations with an overarching focus on the customer. These detailed aspects of BRT are now well standardized around key aspects such as the following

- Efficient pre-paid, contactless and integrated fare collection
- Busway alignment
- Priority at intersections
- Dedicated right of way and corridor selection
- Quality of Service Planning and Operations
- Quality of Infrastructure
- Quality of Communications
- Accessibility and integration with other modes

These can be assessed and scored relative to documented best practice such as the BRT Standard [32]. As well as establishing a global standard for public transport that can compete with private transport, this enables transport authorities to implement pragmatic aspects of BRT as resources allow while still integrating these incremental improvements into a greater philosophy of service delivery. The BRT standard has 30 scoring criteria and 8 criteria for deductions of which the following are a few examples:

EXAMPLE 1: EXPRESS, LIMITED, AND LOCAL SERVICES

Mass-transit systems can significantly increase operating speeds and reduce passenger travel times by providing limited and express services. Instead of stopping at every station in the manner of local service, limited services skip lower-demand stations and stop only at major stations that have higher passenger demand. Express services usually collect passengers at one end of the corridor and drop them off at the other end.

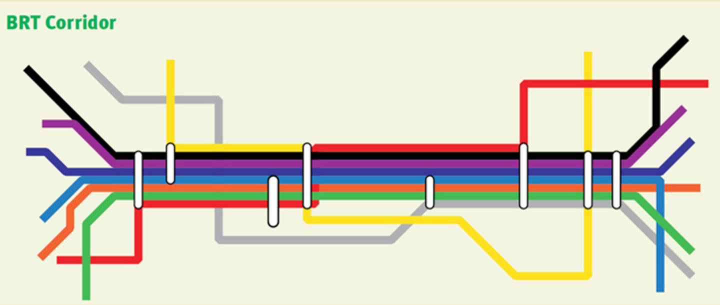
EXAMPLE 2: MULTIPLE ROUTES

Having multiple routes that operate on a single corridor helps to reduce door-to-door travel times by reducing transfers.

This can include:

- Routes that operate over multiple corridors, as exists with TransMilenio in Bogotá or Metrobús in Mexico City;
- Multiple routes operating in a single corridor that go to different destinations once they leave the corridor, as exists with the Guangzhou, Cali, and Johannesburg BRT systems.

Figure 19: Multiple Routes on a BRT Corridor



Source: The BRT Standard 2014 Edition

32 The BRT Standard 2014 Edition

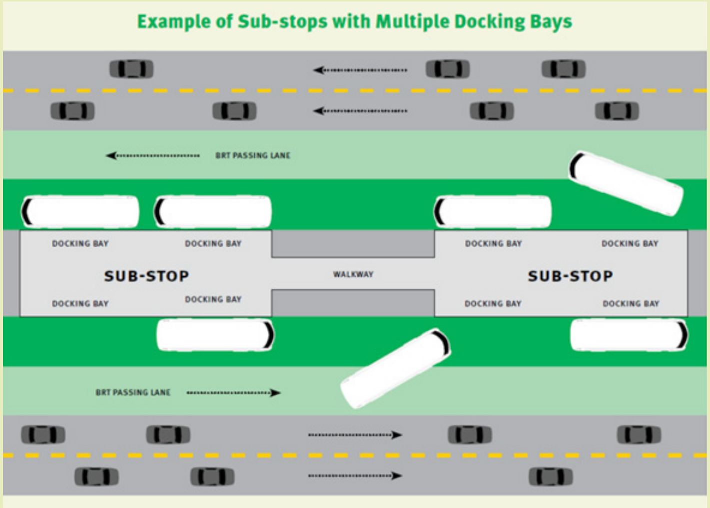
EXAMPLE 3: STATION CONFIGURATIONS – PASSING LANES; MULTIPLE DOCKING BAYS AND SUB-STOPS

Passing lanes at stations allow express service to overtake stopped buses from local services while multiple docking bays and sub-stops prevent congestion by allowing buses to pull up behind one another to disembark passengers as shown below

EXAMPLE 4: INTEGRATION OF BIKE LANES WITH BUSWAY

Integration with other modes, especially sustainable modes, is prioritised in best practice BRT design. Cycling access and dedicated cycling path provision along corridors gives commuters this sustainable option and allows access to the BRT service.

Figure 20: High scoring BRT station configuration with passing lanes and multiple docking bays and sub-stops



Source: The BRT Standard 2014 Edition

Figure 21: Cape Town's myCiti service is a hybrid system with some routes operating in mixed traffic but they score full BRT Standard points for this cycling path along the length of a transit corridor

Source: The BRT Standard 2014 Edition

"Latin America is today the epicentre of the Global BRT movement. A third of BRT route kilometres and nearly two thirds (63%) of ridership are in Latin America (Cervero, 2013)[1]

"If you have the correct town planners and engineers who understand the bigger picture and who can actually incorporate local conditions in the city's planning, they can ensure that the BRT system is sustainable. But if you have somebody who doesn't understand the background and just wants to replicate other places, you are not going to have a sustainable (economically) system", Prof. Wynand Steyn, Chairman of the 34th annual Southern African Transport Conference (SATC)[2]

It does not make sense for South Africa to only be a follower of Latin America in the implementation of BRT and public transport in general. Objectively, our combined challenges such as lower urban densities, security issues, huge income disparities, poor distribution of commercial activity along transport routes and less depth in operational experience and competitiveness are in general greater and projects will fail in the long term if there are no evidence of significant customisation and innovation. The development pathway will necessarily be longer and more arduous and plan for these setbacks should be expected.

1 Cervero (2013) Bus Rapid Transit (BRT): An Efficient and Competitive Mode of Public Transport, Institute of Urban and Regional Development, University California Berkeley, Working Paper 2013-01.

2 http://www.bloemfonteincourant.co.za/mangaung-has-fallen-behind-with-brt-system/

While BRT is much cheaper than rail because the capital equipment is less extensive, the multifaceted high standard of service benchmark described above means it is still very expensive in a South African context especially in relation to the dominant minibus based paratransit. The spatial characteristics of our cities make financially viable public transport challenging. Urban planning is therefore a key aspect of success as well as operational excellence. The entry of modern bus services into poor informal areas on the periphery, in particular, needs to be coupled with long terms plans for urban land renovation and management and fostering of local commercial enterprise.

TOD – Transit Orientated Development (Avoid, Shift, Enable)

The imperative to integrate public transport in the urban development process arose as a necessity in the face of the difficulties of developing viable and competitive public transport services. This gave rise to the notion of Transit Orientated Development (TOD) which has been described as follows:

TOD: "Compact, mixed-use, pedestrian-friendly development organized around a transit station. TOD embraces the idea that locating amenities, employment, retail shops, and housing around transit hubs promotes transit usage and non -motorized travel (Suzuki et al., 2015).

TOD is an approach to planning of which the guiding principles are as follows:

8 key Principles to Guide "Transit-oriented development"

The Institute for Transport and Development Policy's Principles of Urban Development for Transport in Urban Life:

1. [walk] Develop neighbourhoods that promote walking
2. [cycle] Prioritize non-motorized transport networks
3. [connect] Create dense networks of streets and paths
4. [transit] Locate development near high-quality public transport
5. [mix] Plan for mixed use
6. [densify] Optimize density and transit capacity
7. [compact] Create regions with short commutes
8. [shift] Increase mobility by regulating parking and road use

> "TOD implies high quality, thoughtful planning and design of land use and built forms to support, facilitate and prioritize not only the use of transit, but the most basic modes of transport, walking and cycling."[1]

1 Institute for Transport and Development Policy (ITDP), (2014) "TOD Standard v2.1"

Some key aspects of TOD and possible mechanisms for financing the required shift are explored below.

LAND USE PLANNING AND URBAN DENSITY (AVOID, SHIFT, ENABLE)

It stands to reason that the way in which a city is organised will have an effect on the efficiency with which it functions, particularly transport. The financial sustainability of high quality public transport in South Africa is extremely challenging and so it is important for transport authorities to leverage the advantages of planning interventions as much as possible even though these can take many years to bear fruit. This is a vast and specialised subject and will be limited to two related planning criteria that are supportive of public transport; mixed land use and urban density, briefly explaining these, how they could be assessed and their impacts.

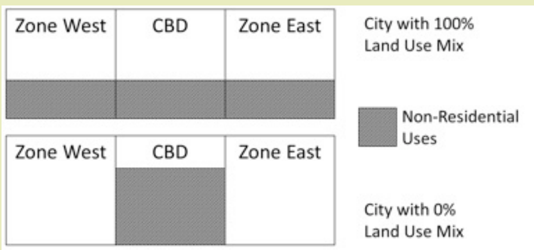
What is mixed land use?

A mixed or integrated land use environment is one where commercial/industrial, residential and educational land uses are proximate instead of concentrated remote from each other in large and unintegrated areas.

How can land use mix be measured?

A practical indicator for land use mix is the proportion of area taken up by non-residential uses in a zone or zones of interest relative to the situation in the CBD, as illustrated in Figure 22 below. Thus for a land use mix of 0%, all of the non-residential land uses are situated in the CBD, representing a monocentric city with segregated land uses. At a land use mix of 100%, each zone has a proportion of the non-residential land uses that is equal to the total proportion, including the CBD.

Figure 22: A method for measuring urban land use mix: as the average proportion of the area that is taken up by non-residential uses in zones of interest relative to that proportion in the CBD



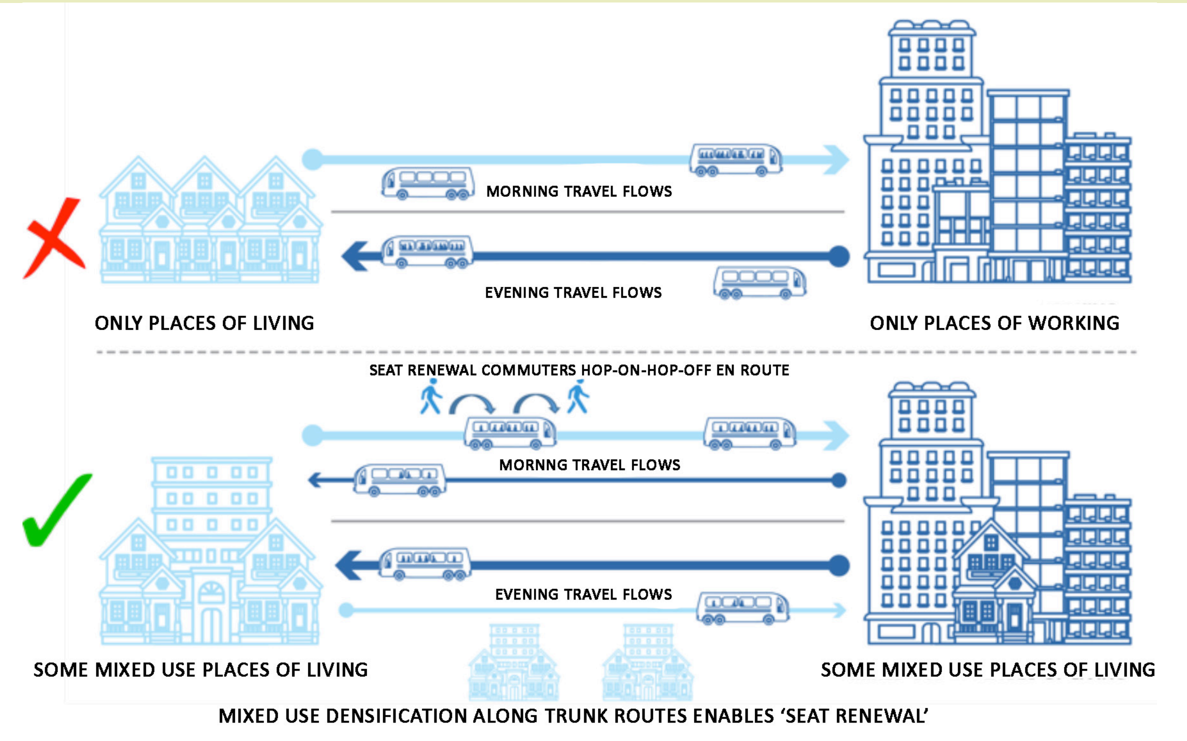
Source: adapted from Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

What are the benefits to public transport of mixed land use?

A residential area may be very dense and promise an economy of scale to a public transport system but will likely have very low levels of activity during core working hours. This gives rise to tidal flows of commuters leaving to and returning from work and education at peak hours. Not only does this require a system with a large capacity for the peak that is underutilised outside of peak but tends to create a situation where overfull buses or trains travel in one direction at peak but return empty to their origin as they circulate to meet overflow or off -peak demand. These empty trips have a financial performance of zero.

As shown below in Figure 23, in a mixed land use scenario however commuters will tend to travel in both directions, termed bi-directional flow, reducing both empty trips and congestion. This bi-directional flow will reduce car congestion as an additional benefit. If mixed use development was to extend along a transit corridor 'seat renewal' will occur whereby there is a regular exchange of passengers embarking and alighting at stations between terminals. This creates a higher turnover of fares and opens up space for better cost recovery by moving away from distance based to trip based fares with the added benefit that poor people remaining on the periphery are not penalised.

Figure 23: The benefits of mixed land use and densification: reduction of empty trips, bi-directional flow and seat renewal

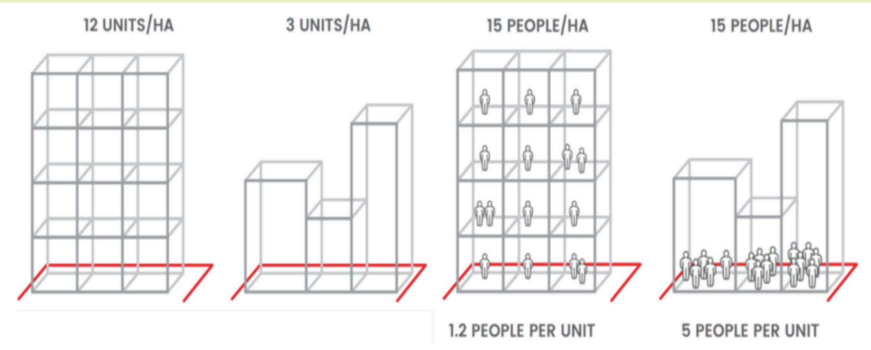


Source: Adapted from Bickford and Khoza (2016) Transit Oriented Density Framework – Towards a Deeper Understanding of Density, South African Cities Network (SACN), Johannesburg.

What is Urban Density?

Density, as commonly defined in urban planning terms, is the concentration of people, domiciles or activity within a given space. It may be relatively fixed such as the number of dwelling units per hectare (du/ha) or it may be in flux such as the number of people per hectare (pax/ha) within the CBD during certain times of day. Figure 24 below shows how the two commonly used planning definitions of units or dwelling units per hectare and people per hectare relate to each other for different spatial configurations.

Figure 24: Relationship between commonly used planning definitions of urban density



Source: SACN Bickford and Khoza (2016) Transit Oriented Density Framework - Towards a Deeper Understanding of Density, South African Cities Network (SACN), Johannesburg.

Both du/ha and pax/ha are useful from a public transport planning perspective as they will reflect in some measure the potential concentration of demand for a service. Such densities are expressed in gross base, gross or net terms, which according to the City of Cape Town's Densification Policy (CoCT, 2012)[33] are defined as follows:

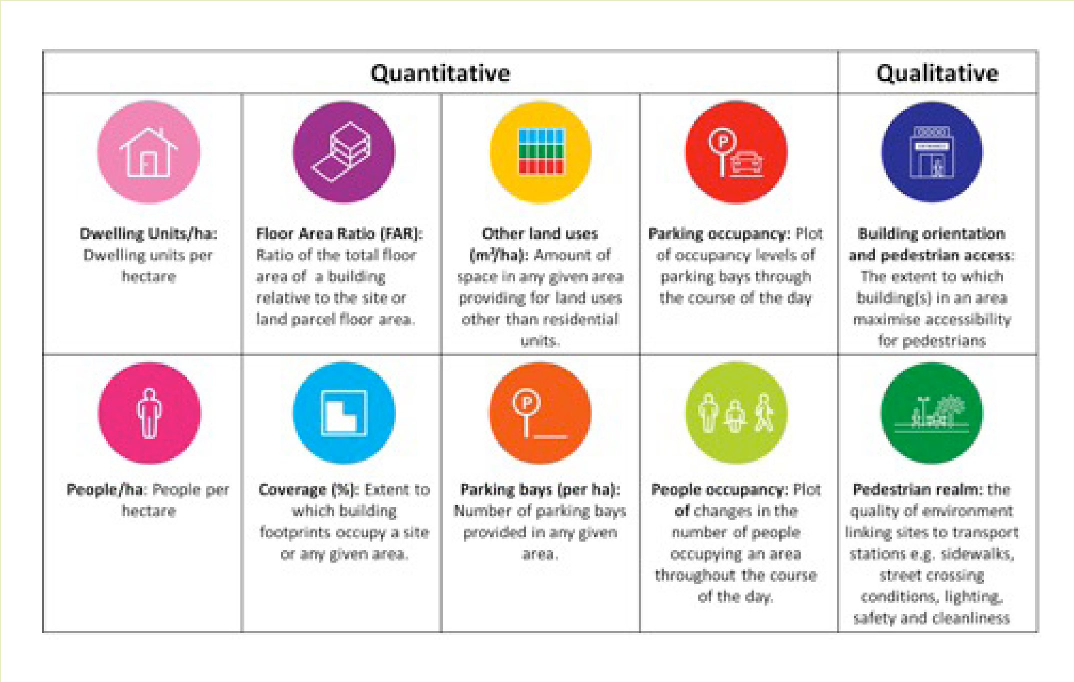
- **Gross urban density (du/ha):** The number of dwelling units per hectare of land calculated in a designated area on the basis of land used for residential purposes and other land uses, such as industry, commerce, education, transport and parks. Excluded are land-extensive uses, such as agricultural land and natural areas/ nature reserves/parks.
- **Net urban density (du/ha):** The number of dwelling units per hectare of land calculated on the basis of land used for residential purposes, including the garden and off-street parking, if any.
- **Gross base density (du/ha):** The average number of dwelling units per hectare across the city as a whole or a smaller unit, excluding land-extensive uses, such as agricultural and rural land and large natural areas/nature reserves.

The Cape Town Densification Policy, for example, targets a gross base density of 25 du/ha but a net density of 100-375 du/ha (equivalent to a gross density of about 50-180 du/ha) on activity routes. These are routes of significant scale where public transport corridors would typically be planned. However, from Figure 24 it can be seen that dwelling units per hectare will translate to variable concentrations of people and will furthermore not reflect the general suitability of the urban environment for public transport. Additional indicators can contribute then to a richer picture of density that supports mass transit.

The theory of Transit Orientated Development (TOD) has informed the emergence of a broader range of urban density related indicators. The South African Cities Network (SACN) has developed a Transit Orientated Density Assessment Framework of 10 indicators which are summarised in Figure 25 on the next page:

33 City of Cape Town (2012) Cape Town Densification Policy, February 2012

Figure 25: South African Cities Network (SACN) Transit Orientated Density Assessment Framework



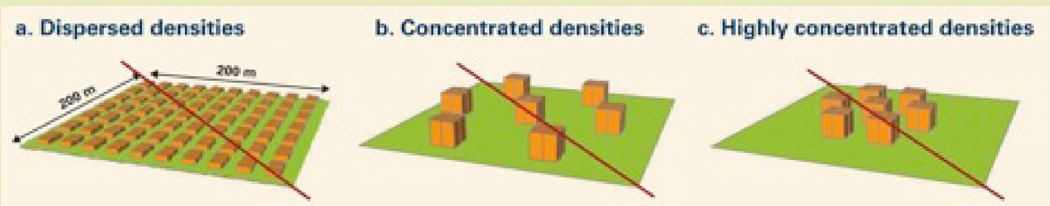
Source: Bickford and Khoza (2016) Transit Oriented Density Framework – Towards a Deeper Understanding of Density, South African Cities Network (SACN), Johannesburg.

SACN has developed this framework to give an overall assessment at different scales (site, zone, city) of the land use characteristics that support viable mass transit. Maintaining such sets of indicators offer the potential to now systematically assess the progress of the urban environment towards public transport friendliness and sustainability in general. Other research has focussed on density relative to the transit corridors themselves and this has given rise to the idea of "articulated density" or more simply "people near transit" discussed below.

What is Articulated Density (people near transit)?

Densities that are strategically distributed across parts of a metropolitan area are more important for enabling transit and land-use integration than average population densities. This is termed "articulated density" and is illustrated in principle below in Figure 26. All three layouts have the same average population density but the layout in panel c is better suited to mass transit than that in panel a because more people will be near the mass transit line and not need to make long feeder trips.

Figure 26: Three configurations of the same average density relative to an illustrative mass transit line (red diagonal)



Source: Suzuki, Cervero & Iuchi (2013) Transforming Cities with Transit, Washington DC: World Bank.

Los Angeles which has a relatively high, evenly distributed average population density is often cited as an example of unsupportive or dysfunctional density, which aggravates congestion and poorly supports competing mass transit (Cooke, 2016).[34] Curitiba by contrast has relatively low average population density but has achieved high articulated density through long term integrated planning which contributes to the success of its high capacity and unsubsidised BRT system (Suzuki et al. 2013).[35]

How can articulated density be measured?

The Institute for Transportation and Development Policy (ITDP)[36] has proposed an indicator called *"People Near Rapid Transit"* (PNT) as the proposed indicator for Sustainable Development Goal Target 11.2[37]. PNT measures the number of residents in a city who live within a short walking distance (1 km) of high-quality rapid transit. This is generally equivalent to a 10- to 15-minute walk, depending on factors specific to the local environment like topography and pedestrianisation. The intention is to estimate accessibility and rapid transit coverage in large cities and provide a high-level proxy for the integration of land use and transport. The basic features of the methodology is as follows:

- The indicator is expressed as a percentage of people in the area being evaluated that live near (< 1km) mass transit.
- Mass transit is limited to high capacity modes: Light rail, BRT or metro line.
- Criteria around station spacing, route capacity and fare collection are set.
- Census data at neighbourhood and preferably block level is preferred but spatial imagery- based approximations may suffice where data is limited.

The ITDP evaluated their PNT indicator on a number of OECD and non-OECD cities including Johannesburg which is compared to Rio de Janeiro in Figure 27 below. The challenges of integrating public transport with the existing urban form in South Africa are clearly evident and speak to the use of this indicator in our cities. If the Rea Vaya system is extended to dense areas in the west however, PNT will improve markedly.

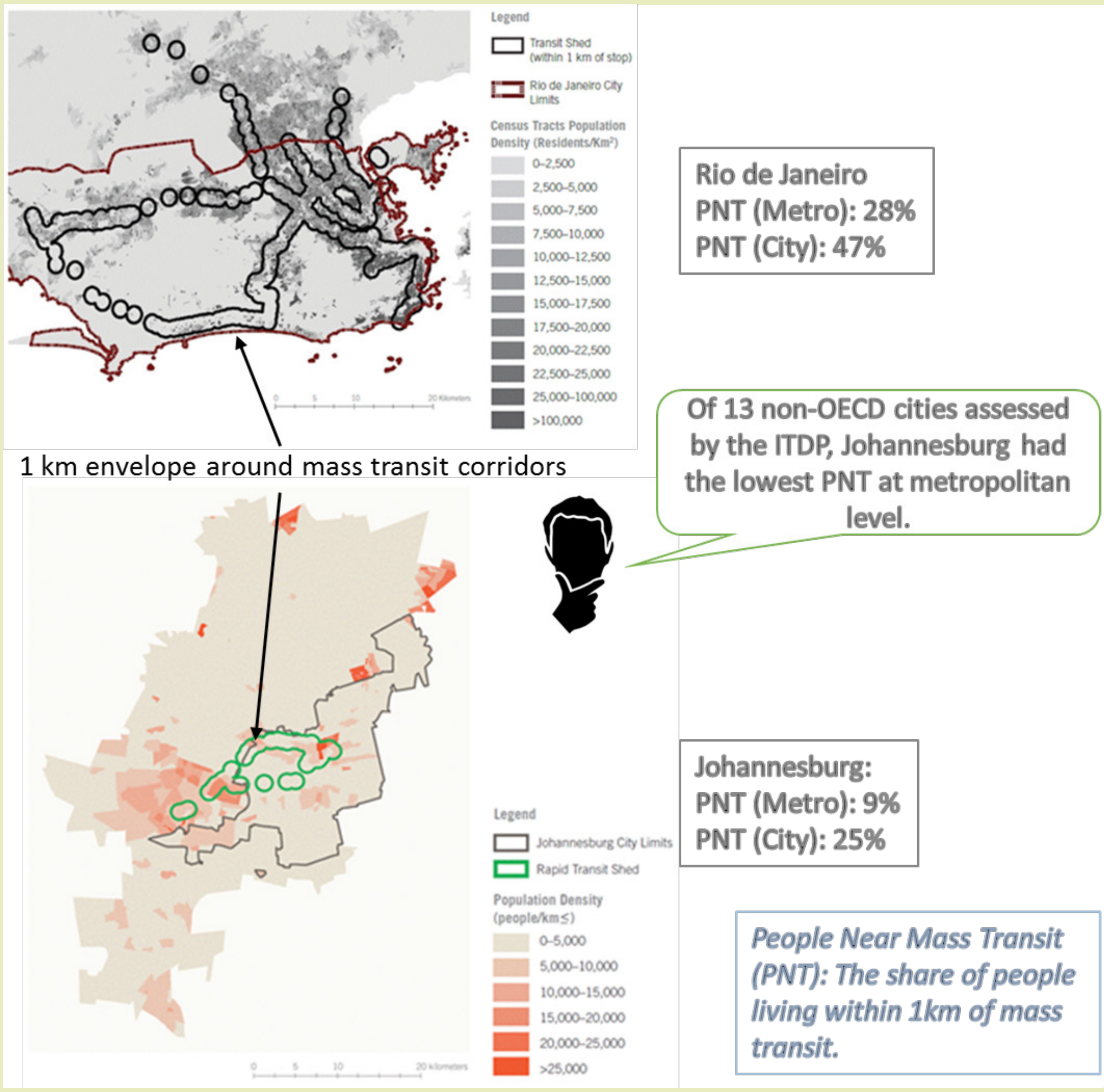
34 Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

35 Suzuki, Cervero & Iuchi (2013) Transforming Cities with Transit. Washington DC: World Bank.

36 Marks, Mason & Oliveira (2016) People Near Transit: Improving Accessibility and Rapid Transit Coverage in Large Cities. Institute for Transportation and Development Policy (ITDP), October 2016.

37 SDG Target 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

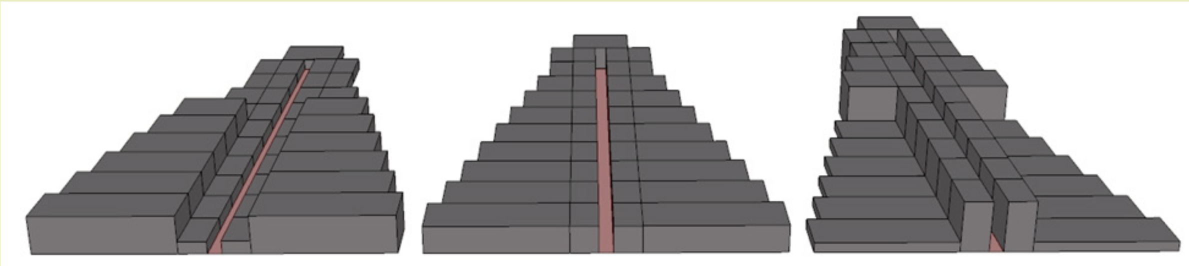
Figure 27: Comparison of the "People Near Rapid Transit" (PNT) indicator assessment of articulated density for Rio de Janeiro and Johannesburg



Source: Marks, Mason, Oliveira (2016) People Near Transit: Improving Accessibility and Rapid Transit Coverage in Large Cities, Institute for Transportation and Development Policy (ITDP), October 2016.

The PNT concept has been independently used at the University of Cape Town to model the potential impacts of improved articulated density (and land mix) on a representative South African transport corridor with feeder routes (Cooke, 2016). The simplified corridor is shown below in Figure 28. Each block segment is a component of the passenger catchment area of the transit corridor called a Traffic Analysis Zone (TAZ). The arrangement is triangular with the CBD at the point of the triangle and the catchment widening with distance from the CDB. The smaller TAZs adjacent to the central trunk are called TOD zones and the people in that zone can access the trunk directly without a feeder trip. In likewise fashion to PNT, if articulated density is 20% then 20% of the people in the catchment area will be in the TOD zones and similarly if articulated density is 80% then 80% of the people in the catchment will be in the TOD zones.

Figure 28: Quantification of articulated density on three illustrative trunk corridors with the same gross population density: 20% (left); 43% (centre) and 80% (right) The height of the block segments represents localised population density



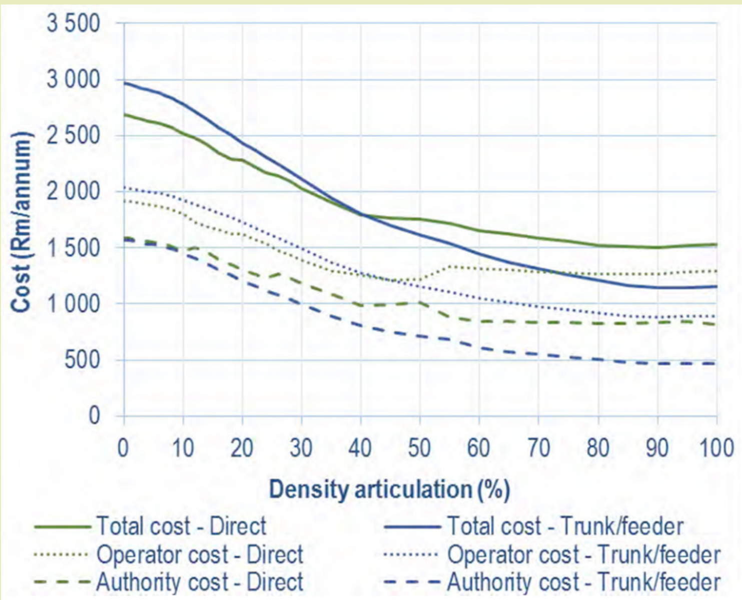
Source: Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

What are the potential impacts of articulated density?

The potential impacts of articulated density will be explored using selected results of Cooke's recent modelling study, given its local focus. The current South African situation was deemed to have, in general, poor articulated density of around 20% as illustrated in Figure 28 on the far left above. When density articulation was varied while keeping gross population density at 50 pax/hectare, significant cost reductions were evident for both the simulated operator and authority for the two classic system arrangements:

- Trunk-Feeder: Feeder lines feed terminal stations at intervals on the main trunk
- Corridor service: Each feeder line does direct to CBD terminal stations at the end of the trunk.

Figure 29: Cost components when varying density articulation on a 20km corridor

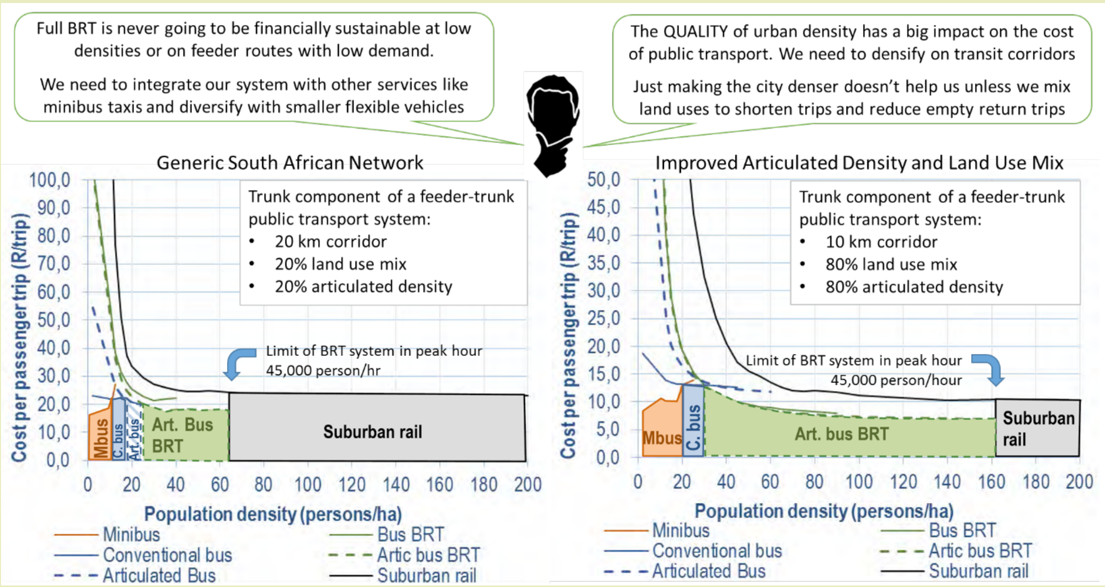


Source: Cooke (2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

What are the impacts of density and articulated density in combination with land use mix?

Articulated Density and land use mix are potentially complementary in practice because various uses benefit from proximity to a transit corridor and such developments might be more attractive to both developers and tenants. Cooke (2016) combined the impact of articulated density with land use mix which was quantified as shown in Figure 22. The effect of varying gross density on the cost of various modes, was tested for the classically South African situation and contrasted with a more ideal situation of 80% articulated density, 80% land use mix and a shorter corridor of 10km instead of 20km. The results below show a marked impact on costs and the gross density at which different modes become viable.

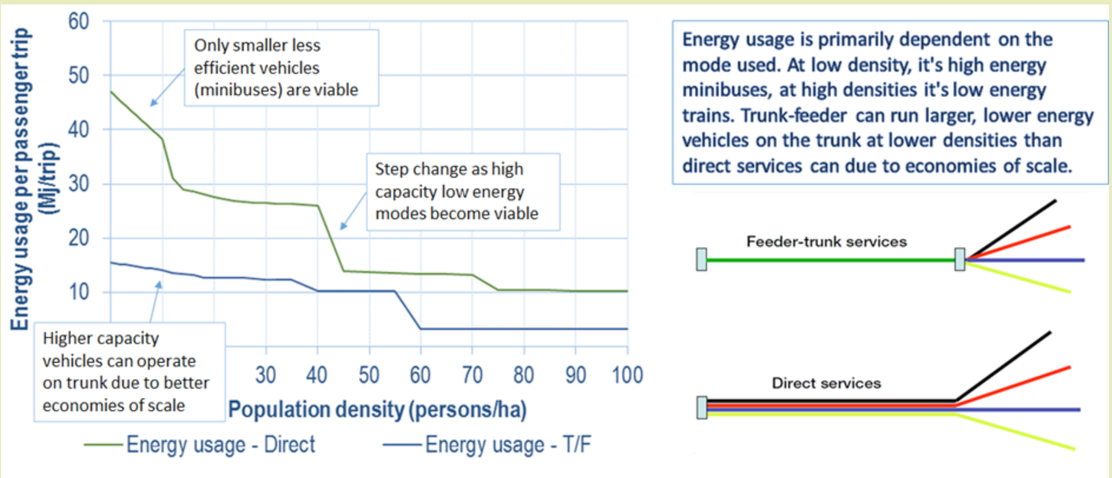
Figure 30 - Simulated Effect of increasing population density on the total cost of different modes for a generic South African Public Transport Network contrasted with a Network having more Supportive Land Uses



Source: Adapted from Cooke 2016) Investigating the relationships between land use characteristics, public transport network features and financial viability at a corridor scale, MSc Dissertation, Department of Civil Engineering, University of Cape Town.

The energy intensity of operation was also assessed for the two different system configurations in response to population density as shown below in Figure 31.

Figure 31 - Simulated Effect of increasing population density on the energy intensity of public transport supply for Trunk-feeder and Direct System Configurations



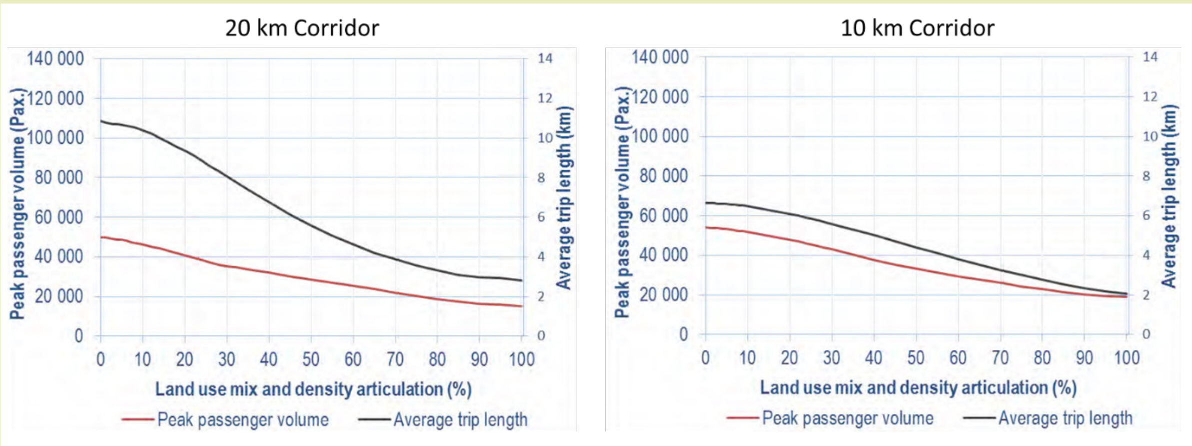
Source: Cooke (2016) and Wright (2002)

What can be learnt from these cost simulations of articulated density and land use mix change?

The purpose of this type of modelling exercise is not to replicate reality precisely but several powerful indicative insights arise out of the work as follows:

- The cost of the modes that require large vehicles and extensive infrastructure like articulated bus BRT and Light Rail are very high at low gross densities as expected, because low demand doesn't offset their capital and operating costs.
- At low gross densities minibuses and conventional buses are more cost effective. This effect is even more pronounced for feeder routes to the trunk (not shown – see Cooke 2016) where minibuses are still more cost effective even at quite high gross densities
- In a situation of unsupportive land use conditions however, increasing gross density beyond a certain point does not strongly reduce the cost of a public transport system even on the trunk because the peak demand increases, making the system more inefficient.
- A high peak demand makes the system inefficient because the system has to be scaled for the peak but is underutilised off-peak.
- A more supportive land use environment, aside from significantly reducing the costs of the high capacity modes, also improves the response of the costs of these modes to increasing gross density. This is because peak passenger volumes and average trip length are reduced as shown below.

Figure 32: Effect of increasing complementary land use mix and density articulation on peak passenger volume and average trip length for a constant gross density of 50 pax/hectare



- From the above comparison between a 10 km and 20 km corridor it can be seen how longer corridors create a large catchment area with long feeders leading to high average trip length which amplifies the problems of low land use mix.
- A direct system configuration is likely to be cheaper at low densities because of lower infrastructure requirements although this difference reverses as densities increase. The direct configuration is however likely to be significantly less energy efficient in the low density scenario. Generally, there seems to be a long term cost and sustainability advantage to planning for trunk-feeder systems.

LAND VALUE CAPTURE (ENABLE)

The structure and historical legacy of South African cities is characterised by sprawl, concentrations of poverty on the periphery and service backlogs. This places enormous strain on their financial sustainability. The historical model of state subsidy and partial recovery of this from fares is therefore less and less viable. It is thus critical to integrate municipal finance aspects into sustainable development planning, particularly for capital intensive public transport infrastructure and to innovate where possible. A group of instruments and policies called "Land Value Capture" (LVC) (also called Land Based Financing) are described as follows:

> *"(Land) Value capture is a term used to describe the process of extracting (in different ways) the additional value that accrues to a property following different types of public investment (e.g. The Gautrain). The value extracted is therefore the value over and above the value the property would have had without the public investment. The additional value created by the investment is often termed the "value increment". Since the additional value was created because of the state's actions rather than the owner's, it is arguably justifiable for the state to lay claim to this additional value through various mechanisms for some public purpose." (McGaffin et al. 2016)*[38]

Land value capture has been used only on occasion by city governments in South Africa although interest is growing and some of its tools like raising finance through bonds or special rates assessments are established practice.

Land value capture increments are generally classed in two categories:

Use-related (also called development or project based) value capture mechanisms: These mechanisms accrue value to a public good directly from the increased value of properties that arises from regulatory changes or infrastructure investment by selling or leasing land or selling or trading development rights.

Income-related (also called tax or fee-based based) value capture mechanisms: These mechanisms accrue value to a public good more indirectly by extracting surplus from property owners, through a tax or fee instrument such as a property tax, betterment charges or special rates assessment.

The process of land Value Capture is shown schematically below in Figure 33, linking these the two categories above to typical mechanisms that have been used to date and emphasising the oversight and technical inputs that are required for success. The mechanisms themselves are briefly described in Table 8 and Table 9 on the following pages.

Table 8: Use-related (also called Development or Project based) value capture mechanisms

Density Bonuses[1]	A zoning-based incentive aimed at encouraging developers to provide certain public amenities or to meet certain public objectives in exchange for allowing greater floor area and/or building height. The idea is that the additional revenue that the developer could generate from the sale of additional units would compensate for the inclusion of affordable housing or unprofitable public amenities.
Air-Rights[1]	The granting of air rights above public infrastructure to the private sector could be aimed at encouraging the provision of public amenities, affordable housing, encouraging greater densities and increasing the City's tax base.
Tax Abatement	This is a reduction or exemption from taxes for a specific period of time in a designated area, usually to stimulate investment in locations with lower demand. An example of this in South Africa is the Urban Development Zone.
Lease or Disposal of State-owned Land	Instead of maximising the market value of the land sale or lease, the state may choose to prioritise other policy objectives, such as affordable housing in well located areas. However, such leasing or disposal could also represent an income-generating opportunity.
Land-adjustment[2]	Landowners pool their land together for reconfiguration and redevelopment, and contribute a portion of their land to raise funds to partially cover the public infrastructure development costs. Transit- Oriented Development land readjustments have been widely used in countries such as Japan to secure land, share infrastructure costs with the private sector, and to achieve a desired urban form.

1: Where a density bonus applies to building height its sometimes also referred to as an 'air right'. Leveraging 'air rights' have been successful in Brazil where rights to multi-storey development were curtailed in many cities, increasing their value and then traded or sold

2: Also sometimes called land re-adjustment

Source: adapted from McGaffin et al. (2016)

38 McGaffin et al. (2016) Value Capture in South Africa – A way to overcome urban management challenges and unlock development opportunities? UCT-Nedbank Urban Real Estate Research Unit, Department of Construction Economics and Management, University of Cape Town.

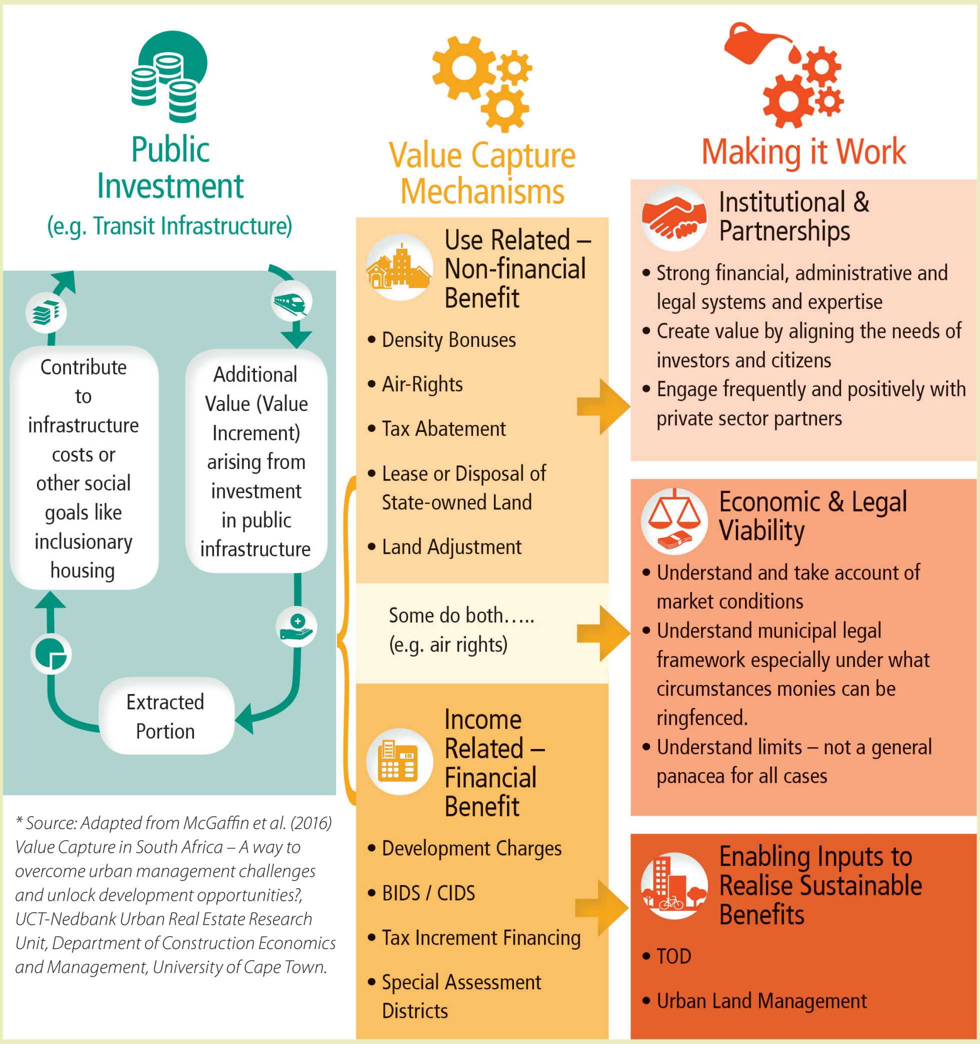
Table 9: Income-related (also called tax or fee-based based) value capture mechanisms

Development Charges	A well-known levy imposed on developers to pay for infrastructure requirements resulting from additional and expanded land uses
Business or City Improvement Districts (BIDS/CIDS)	These are delineated zones where an additional charge is levied on properties to finance top-up services to supplement the standard services provided by the state, often focused on security and cleansing. They often perform additional roles, such as area marketing, which together with the increased security and cleanliness, have demonstrably resulted in increased property values. Essentially then these are 'betterment charges'.
Tax Increment Financing (TIF)[1]	TIF schemes enable municipalities to borrow against the future anticipated incremental tax revenue (property rates in South Africa) that would be generated within a specific geographic area as a result of the construction of large-scale infrastructure.
Special Assessment Districts (SAD)[1]	These are similar to TIFs except that the income that is used to repay public funds or borrowings is in the form of a levy that has been agreed to upfront with the affected property owners within the SAD. This reduces the financial risk for the municipality, which instead is spread amongst the property owners.

1: TIF schemes usually involve the raising of a bond on the back of the expected increment income that would accrue as a result of the infrastructure investment. If the interest on the bond is to be covered by the existing or increased property rates of the owners benefitting from construction, the only way to ring-fence this income under South African law would be through structuring it as a special rates assessment.

Source: Adapted from McGaffin, R, et al. (2016)

Figure 33: One route for meeting the challenge of financing sustainable transport in South Africa's tightening fiscal environment – Land Value Capture



It has been argued that use-based LVC has certain advantages over income-based LVC as follows (Suzuki et al. 2005) [39].

Use-based LVC Advantages

- The financing of capital-intensive transit infrastructure and transit-oriented development related investments without creating what is effectively a disincentive[40] to developers to invest through taxes and fees which can also give rise to public opposition.
- The potential to generate expanding revenues in the longer term, relative to the immediate land value increment, arising from higher transit ridership, retail shops, leisure facilities, parking, and residential buildings in the precinct of station areas.
- A collaborative relationship is necessarily forged between government, transit authorities, developers, businesses, and residents in and around stations rather than just unilateral action by government or transit authorities.

Against this need to be considered the following cautions.

Use-based LVC Cautions

- Use-based LVC requires complex property development processes involving a number of regulatory, legal and commercial processes. A land price needs to be decided on or projected up-front based on market trends, and the distribution of profit or of potential profit needs to be decided though negotiations, based on the contribution of each stakeholder. This requires municipalities, in general, to be quite highly capacitated with professional and business skills.
- A healthy property market with rising prices creates a conducive environment for use-based LVC but a lack of caution and analysis can expose governments and transit authorities to high risk particularly if excessive speculation is distorting prices and perceptions of value.
- Use-based LVC requires favourable 'macro' conditions, a strategic vision, a supportive regulatory and institutional framework, and considerable expertise. These conditions don't necessarily co-exist as a matter of course, especially in the developing economies who need innovative financing the most.
- Income-based LVC (taxes and fees) has the advantage of sustainability as its not dependent on a finite land resource or the cyclical appetite for projects of the market. There is no reason not to combine the use of use-based and income-based LVC judiciously and appropriately. The adoption and implementation of LVC should therefore depend on the conditions and needs of each city.

In addition to these general cautions South Africa has its own challenges

South African Challenges

- Available land in cities is predominantly privately owned and state land is difficult to obtain due to lack of clarity in terms of nominal ownership by a department or state entity or their jurisdiction over a transaction. Furthermore because expropriation is such a sensitive political issue in South Africa and the region, perceptions of state coercion in the use of land can quickly create negative sentiment.
- The greater share of market demand prefers a product that does not necessarily achieve the land use mix and density needed for transit orientated development. Stakeholders who buy-in to mixed and densified development therefore need to change customer preference.

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39 Suzuki, Murakami, Hong, Tamayose (2015) Financing Transit-Oriented Development with Land Values – Adapting Land Value Capture in Developing Countries. The World Bank Group.

40 Also termed 'regressive taxation' or 'fiscal or market distortion'.

- The greater share of market demand in population terms sits in the low to lower middle income segments where subsidisation levels, household affordability and access to finance inhibit an initially more expensive but more sustainable residential product in the medium term.
- Current poor economic growth limits demand for job creating land uses.
- There has as yet, in practice, been limited appetite in leadership to limit the award of land use rights to direct the market into desired locations and away from the sprawl city. In part this relates to the extreme pressure on local government to facilitate economic growth of any kind. It is unlikely, for instance, that 'air rights' could be leveraged because in general they would be granted virtually unconditionally. As noted by Zack and Silverman, "Within local government the old fashioned planning functions of zoning, regulation and enforcement have been down-graded, become outmoded and are considered less important than either strategic planning or service delivery"(Zack & Silverman, 2007) [41].

Historically poor areas stand to gain the most from mixed use developments integrated with transport but urban management challenges that discourage investment remain challenging and administratively demanding. The availability of capacity can limit the scope of projects. As has been noted, "Integrated development can only follow capacity, not vice-versa" (Demacon 2010), [42] that being said, township renewal programmes have been extensively pursued, particularly large retail developments chasing rising incomes in these areas, but including projects with a larger social vision for instance the development of Khayalitsha CBD (Clacherty 2010) [43].

These challenges are however, in the main, not out of the ordinary for a developing country and no reason not to move forward boldly. Indeed, the country has seen a great deal of experimentation, a measure of success and much learning put into the public domain in the last 20 years. Innovative land value capture will to some degree need to become a driver of the changing urban landscape to achieve sustainability and quality of life in our growing cities and towns.

Effect of global legislation through technology import (Improve)

The effect of global legislation on the emissions and fuel economy of vehicles is an important consideration in assessing the cost benefit of proposed vehicle procurement interventions to promote transport sector sustainability. Global legislation has been a driver of technology change, commercialisation and mass production of vehicle environmental solutions since the early 90s and this technology change tends to disseminate into subsidiary markets like South Africa. However, it is important to understand under what circumstances this will occur effectively. The technology that has been developed in response to legislation limiting emissions of local air pollutants (CO, NOx, VOC and PM) has mostly relied on treating the exhaust gases chemically or capturing the pollutants in devices located in the exhaust. Engine innovations have also been required to enable this or enhance this particularly in the control of fuel and air in the engine. As shown below for the case of local air pollutants that directly affect the health of mostly urban dwellers, the introduction of exhaust gas after-treatment using catalytic converters and particulate traps has apparently been highly effective.

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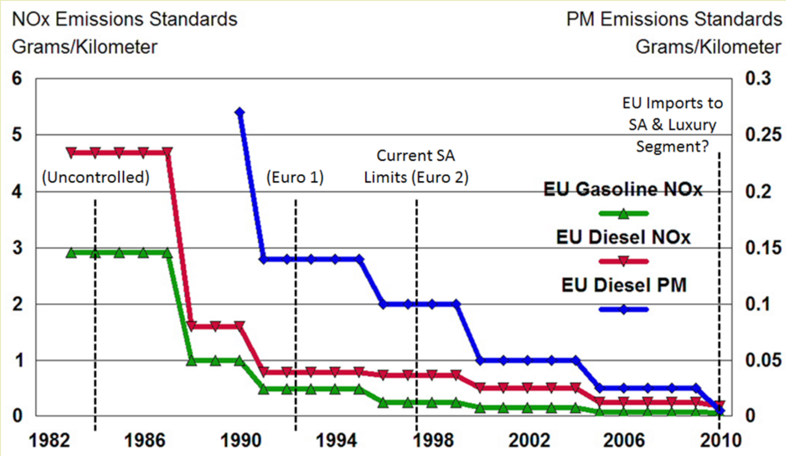
41 Zack & Silverman (2007) Using Regulation as a tool for better urban management, National Treasury, DBSA, South African Cities network and Department of Provincial and Local Government.

42 Demacon (2010) Impact of township shopping centres market research findings and recommendations, Demacon Market Studies.

43 Clacherty (2010) Operations and Management of Township Nodal Developments: Khayelitsha Business District Case Study, Training for Township Renewal Initiative, South African Cities Network and National Treasury.

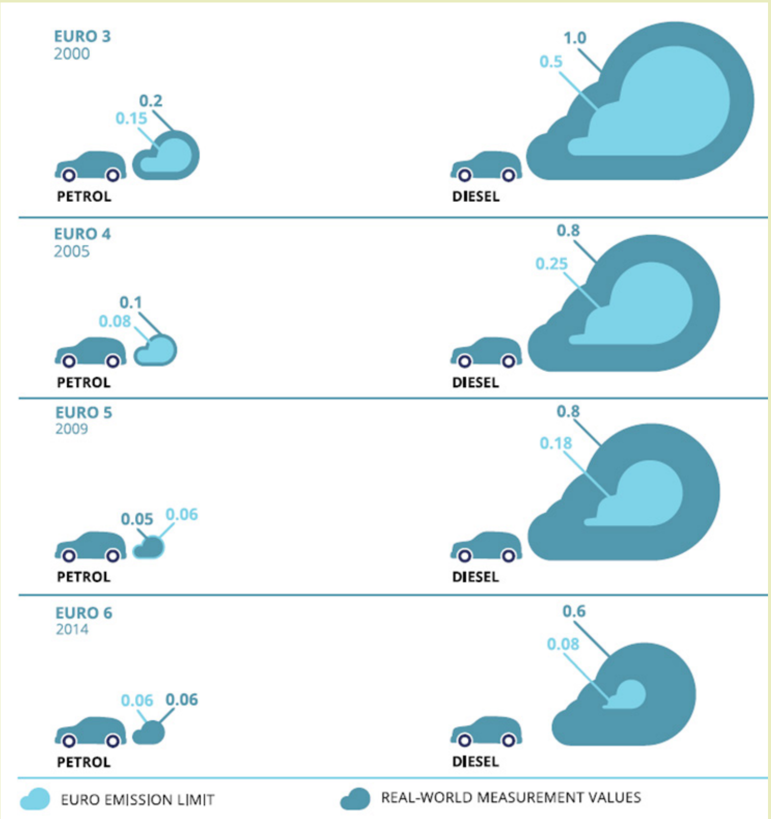
Figure 34: Evolution of European Emissions Legislation for Oxides of Nitrogen (NOx) and Particulate Matter (PM) for Diesel and Petrol Passenger Cars



Source: Walsh (2013) The Future of Vehicle Emissions Regulation in the EU and Internationally, Slide Presentation, European Commission Environment Green Week Conference, Brussels 4-7 June 2013.

The conformance to the emissions limits above is however measured by a standardised test method that has been shown to significantly under-report emissions, especially for diesel passenger cars as shown below.

Figure 35: Comparison of Real-world conformance to NOx Emission Standards by Fuel Type and Legislation Level for the EU



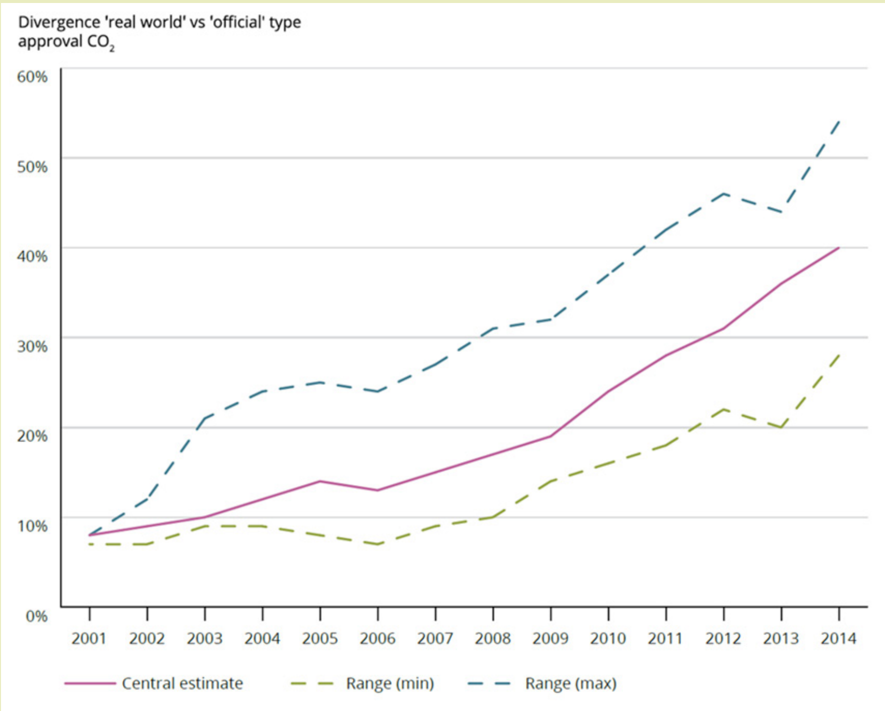
Source: Pastorello & Mellios (2016) Explaining road transport emissions - A non-technical guide. Copenhagen : European Environment Agency (EEA).

These devices also degrade with time and can be significantly affected by octane enhancing additives in the fuel or the fuel sulphur level (often used as a proxy for fuel cleanliness). With an older fleet for which there is no regular in-service testing there is therefore no guarantee of the actual emissions level. It can be assumed though that, in general, in a subsidiary market like South Africa, where there is a moderate emissions standard for new vehicles with many higher standard vehicles imported, that on average emissions are much lower than an untreated exhaust on a per car basis.

The European Union legislated against passenger car CO_2 emissions in 2009 with Regulation EC No 443/2009 which stipulates a 120 g/km CO_2 fleet average emissions level for each manufacturer [44]. The limit drops to 95 g/km CO_2 fleet average emissions per manufacturer from 2020. Vehicles under 50 g/km earned super credits for manufacturers for a limited window till 2016 which effectively incentivised electromobility technologies.

As with local air pollutants the standard EU test method under reports real world fuel consumption and CO_2 emissions but this gap has been widening over time as shown below.

Figure 36: Divergence of real-world CO_2 emissions from manufacturers' type approval CO_2 emissions



Source: Pastorello & Mellios (2016) Explaining road transport emissions - A non-technical guide. Copenhagen : European Environment Agency (EEA).

The reduction of emissions of both local air pollutants and greenhouse gases from our vehicle fleet in response to importing new technology is therefore quite uncertain and will be less than the stringency of the legislation suggests. It is therefore important for cities to track real world emission levels as follows based on the "to measure is to know" principle:

- Using ambient air quality stations in the metropoles, keeping levels of service adequate and making data easily and freely available.
- Regularly estimate the vehicle fleet energy intensity using data from the registration database and fuel sales to assess whether this is being mitigated in response to technology change.

44 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32009R0443

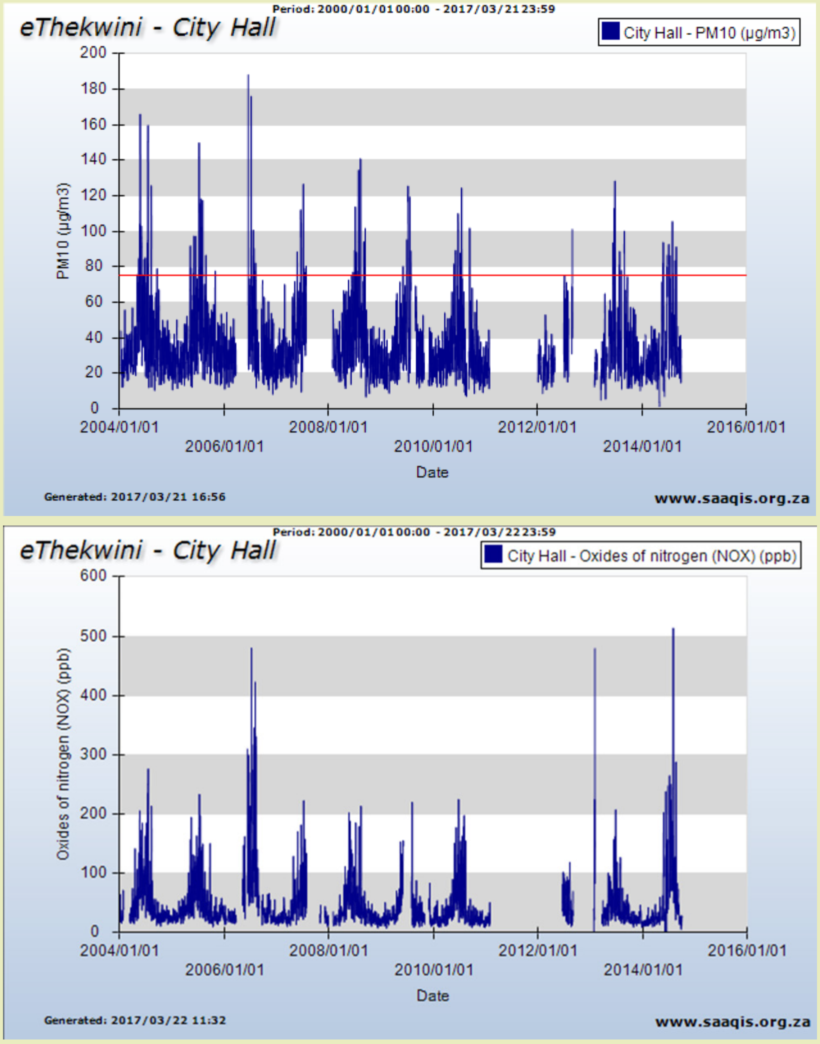
Ambient Air Quality Monitoring in South Africa – Where is our Air Quality going?

Air quality as reflected by the concentration of a number of pollutants is measured at a number of monitoring stations in the major metropolitan areas including Johannesburg, Tshwane, eThekwini, Ekurhuleni and Buffalo City.

The data can be viewed online at www.saaqis.org.za. Graphs like that below can be generated by monitoring station and pollutant.

The seasonal variability of pollutants due to weather make the data quite noisy but more problematically, underfunding means most data series have long gaps due to instrument problems that can't immediately be addressed.

Figure 37: Daily Average Concentrations of PM10 and NOx for City Hall



Source: www.saaqis.org.za

The daily averages above also do not show the number of hourly exceedances of health standards so a lot of analysis is required to assess with precision whether our air quality has got worse or stayed the same.

From the data for various cities it can however be seen that other than a reduction in SO_2 from reduced fuel sulphur content, environmental regulations are not driving substantial reductions in the other harmful pollutants probably largely because industry and the car population is growing, even if the cars are getting cleaner. Furthermore, the real world emissions of cars seem to be higher than that promised by the standards, as seen above.

Data quality needs to improve if the constitutional right to clean air is to be fulfilled: Measurement is essential for knowledge.

Interventions in Freight Transport

New truck technologies (Improve)

Auto manufacturers are in the early stages of rolling out a number of fully battery electric truck models for local delivery applications which offer zero-emissions at city level and in the longer term, reduced emissions at national level as the electricity supply becomes lower emitting. The Mercedes-Benz Urban eTruck is based on a heavy-duty, three-axle short-radius Mercedes-Benz distribution truck. This vehicle is specified for a 25 tonne Gross Vehicle Mass and a 200 km range making it a candidate for daily city deliveries of bulkier freight like building materials. From the same Daimler stable, the smaller 6 tonne fully electric Mitsubishi Fuso e-Canter is slated for a small series production run in 2017. [45]

Figure 38: Mercedes-Benz Urban eTruck – fully electric urban freight delivery for bulkier commodities

Source: Copyright - Daimler https://www.daimler.com/products/trucks/mercedes-benz/urban-etruck.html

The emergence of battery electric technologies across the full weight capacity range required for urban deliveries opens the possibility, in the near future, of creating traffic restricted zones that only allow zero emission vehicles without exemptions for delivery vehicles.

The potential of hydrogen fuel cells as range extenders for heavy-duty electric trucks has been discussed above. These could potentially operate on the long corridors supplying goods to and exporting goods from South African cities. This is a longer term low emission solution, given the difficulties and costs in creating a hydrogen fuelling infrastructure. The promotion of inter-modal freight discussed below offers a more immediate prospect for reducing emissions from the energy intensive arterials to our cities.

Promoting intermodal freight transport solutions in South Africa at a city level (Shift)

There is potential for multi-stakeholder financial benefits offered by the development of intermodal freight transport systems for suitable classes of commodities and there have been various local projects to develop the required engineering. It may require ongoing collaboration between multiple stakeholders, including municipalities, to see

45 http://media.daimler.com/

significant impact. There are a number of measures cities can consider to promote intermodal freight transport along corridors as follows (Havenga et al.2011):[46]

- Inclusion of GPC Scope 3 Freight Transport emissions in the city's Greenhouse Gas (GHG) Inventory according to the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (WRI, 2014) [47]. According to the GPC standard, inclusion of Scope 3 road transport emissions is discretionary. This will include an estimate of GHG emissions arising from 50% of the distance covered by freight transport trips originating and ending within the city boundary along corridors. The data required to make this estimate can be obtained from sources such as the Centre for Supply Chain Management, Department of Logistics, University of Stellenbosch.
- Acting to initiate engagement between the stakeholders needed to develop local intermodal freight transport solutions as follows:
    - The Rail Transport Authority (Transnet) and any relevant private rail freighters
    - Road hauliers of intermodal friendly commodities
    - Producers and packagers of intermodal friendly commodities
    - Interested container, trailer and rolling stock engineers and suppliers
    - Third parties who stand to gain from reduced impacts, risks and costs such as insurers, authorities responsible for national highway maintenance and National Treasury
    - Relevant national ministries such as the Department of Transport
- The setting of GHG mitigation targets for corridor freight in conjunction with stakeholders based on the inventory.
- Allow access to traffic restricted areas only for local goods and for intermodal friendly classes of goods that have been transported intermodally.
- Exemption from inner city tolls (where these are in force e.g. Gauteng) for vehicles towing specialised intermodal freight trailers.

46 Havenga, Simpson, Fourie & de Bod (2011) Sustainable Freight Transport in South Africa: Domestic Intermodal Solutions. Journal of Transport and Supply Chain Management.

47 WRI (2014) Global Protocol for Community-Scale Greenhouse Gas Emission Inventories An Accounting and Reporting Standard for Cities. World Resources Institute (WRI), C40 Cities, ICLEI.

Case Study 1: Go George Integrated Public Transport Network – A Case of innovative technical solutions and a rocky implementation road

Go George *is the first high quality public transport project to be implemented outside of the big metros in the municipality of George in the Southern Cape. Go George began with a municipal mobility strategy in 2003 and negotiations with the minibus taxi industry began in 2007 with Phase 1 only rolling out in December 2014 after challenging and protracted negotiations. The following are the main features:*

- *George had limited resources and the project has been a three way collaboration between the provincial government's department of public works, The national Department of Transport who grant funded the project and George municipality.*
- *Minibus taxi operators could choose whether to 'buy-in', in other words become shareholders in the new system using part of their compensation or 'buy-out' and take compensation for the loss of their business entirely in cash. It is useful to compare the final settlement with projects in other cities* [48]*:*
  - *The average lump sum paid out to affected minibus taxi operators in George was R260 000*
  - *This is just over half of the R500 000 paid out by MyCiti in Cape Town excluding a scrapping allowance for relinquished vehicles. Operators could use this compensation to buy shareholding in the new operating company.*
  - *Rea Vaya in Johannesburg agreed to pay month instalments of R5 500 to shareholders for a maximum of 4 years until replaced by dividends generated by the Vehicle Operating Contractor (VOC) of which the former minibus owners are now shareholders. In the Rea Vaya arrangements operators could only 'buy-in'. In practice the City of Johannesburg is financing the VOC through operational payments to continue these instalments and if this should continue over the 12 year contacting period the payout will be R792,000 in real terms.*
  - *The currently non-operational Libhongolethu IPTN in Nelson Mandela Bay has enjoyed the least implementation success extending to a relatively onerous settlement for the city that was paying out R6 500 per month to former operators on BRT pilot routes who relinquished their vehicles, with a later settlement guaranteeing a "profit" of R8 000 per month for the entire 12 year contracting period to minibus taxi operators operating outside of the pilot routes. This equates to a total of R1,152 million in real terms.*
  - *In the now famous cases of Bogotá in Columbia and Curitiba in Brazil, existing paratransit operators that became shareholders were guaranteed a return that would replace and possibly exceed their former livelihood but did not receive additional cash payments. In Bogotá there was a competitive bidding process in which former operators received preference. In Curitiba it was mandatory for operators to consolidate into smaller consolidated formal operating companies that received concessions.*
- *In spite of the long and complex negotiations, the* Go George *service was violently disrupted, allegedly by disgruntled minibus taxi operators in August 2015 and four buses were burnt and 9 arrests made. The stated grievances cited a loss of livelihood due to the service.* Go George *has since resumed normal operations but future roll-out in areas serviced by minibus taxi operators who have bought out or were outside the process*

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48 Von der Heyden, Hastings & Leitner (2014) Models and Implications for Industry Compensation in the Restructuring of Public Transport In South Africa. Proceedings of the 33rd Southern African Transport Conference (SATC 2014), (Pp. 385-398). Pretoria, South Africa.

may be difficult. It is not clear if the relatively lower compensation compared to other projects contributed to grievances and there is at least reason to question the virtues of a "buy-out" option given that a livelihood is lost as a consequence.

- *Of six planned phases, three are implemented with the* 4^{th} *phase intended to be rolled out at the end of 2016*
- *Three sizes of bus are used, depending on demand, to optimise operational efficiency. The service is extended to areas that were too space restrictive even for midi-buses and therefore a minibus variant was developed with local suppliers that had the necessary fare collection and display equipment but also enabled 'universal access' for disabled commuters in compliance with the Department of Transport's grant stipulations.*
- *Currently the service sells about 11 000 tickets daily and is reportedly popular although it still requires substantial levels of subsidy.*
- *Tickets are pre-bought but tickets can still be bought on the bus with the correct change.*
- Go George *appears to have been a success on many levels despite problems and forms an extremely useful learning platform for IPTN rollouts in other secondary cities*

Figure 39: Converted Minibus Taxi developed by DBSA for Go George Integrated Public Transport Network

Source: GoGeorge http://www.gogeorge.org.za/wp-content/uploads/2016/02/Minibus-with-wheelchair-lift-1.jpg

Case study 2: The Mother of BRT in Africa – MyCiti Bus Rapid Transit System and the City's Transport and Urban Development Authority (TDA)

In common with other recent city driven public transport improvement initiatives, Cape Town's started with a bus service with a BRT vision established for the 2010 Soccer World Cup. This was called myCiti and has grown significantly since that time.

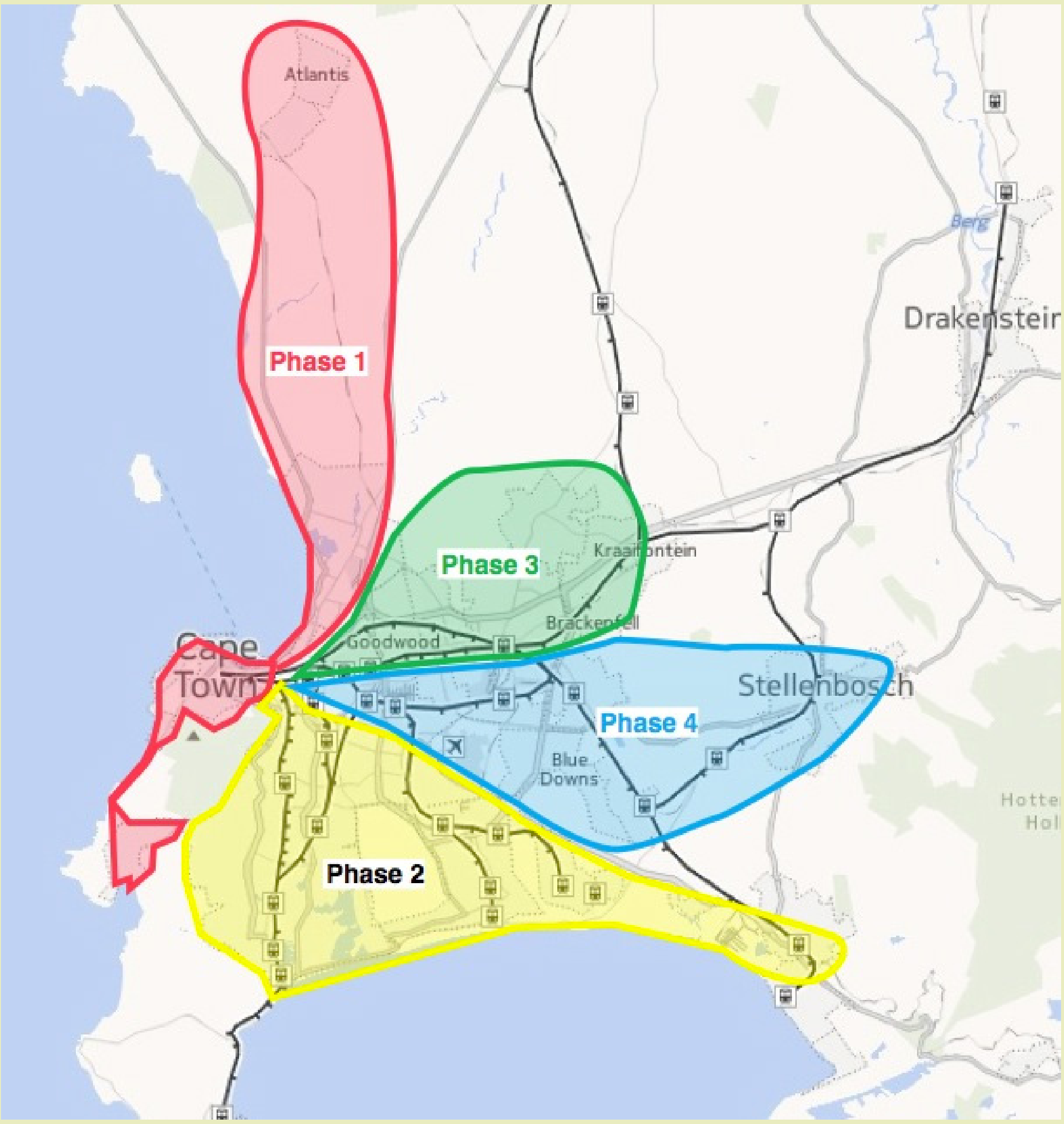
Figure 40: myCiti Bus and Route Schematic Map

MyCiti in a nutshell

- The biggest of the new IRT/BRT/IPTN systems – at around 67,000 passengers per weekday
- Operates 18m and 12m vehicles on trunks and 9m buses on feeders
- 558 drivers on 255 peak time buses
- The 377 vehicles are operated by private operators
- 3 X 12 year operating contracts
- 1 X 3 year operating contracts
- Two of these operating companies owned and run by previous informal minibus taxi operators
- Automated fare system using bank cards with back office function in the banks
- 44 routes with BRT style 42 stations (pre-swiping of cards) and over 700 open stops (cards swiped on bus).

The myCiti system is planned in 4 Phases as shown below. Phase 1 and the N2 Express routes connecting the Airport, Mitchell's Plein and Khayalitsha are operational, work has begun on Phase 2A, the Lansdowne-Wetton Corridor

Figure 41: Planned Phases of the MyCiti System



Source: futurecapetown http://futurecapetown.com/wp-content/uploads/2012/10/Screen-Shot-2012-10-16-at-12.01.29-AM.jpg

Establishing a dedicated transport authority is recognised as a cornerstone of establishing and operating a modern mass transit system. A Transport Authority called Transport for Cape Town (TCT) was established by Cape Town Constitution Bylaw, No. 7208 in 2013 to administer an Integrated Public Transport Network. This entity recently subsumed urban planning to become the Transport and Urban Development Authority (TDA). The long term outcome of this arrangement as it evolves in response to political and developer interests is worth watching by other cities and other transport authorities.

The planning process of TDA has been well documented in the public domain [49, 50]. At a high level, the following are some key pillars of this planning:

- *Planning driven by data gathering, indicator development and modelling*
- *Profiling of transport user groups and requirements*
- *Development of a Transport Development Index (TDI) [51] to benchmark the state of transport in the city (partly based on the Arthur D Little Mobility Index) [52]*
- *Detailed Temporal traffic demand modelling (using EMME/3) of travel analysis zones across the city linked to estimates of system cost. This allows the operational and cost impacts of interventions like peak moderation and bus headway (time between buses) adjustments to be estimated as well as the impacts of land use change patterns.*
- *Real time monitoring of the fleet (Control Centre contract has been problematic and only now reinstated with the control centre set to be operational in mid-2017 [53])*

NMT and pedestrian accidents

Enabling Non-Motorised Transport (NMT) is a cornerstone of both BRT and TOD. This is something of a developed country perspective as South Africa has a very high NMT (but low bicycle) share. This is not however by choice of the commuters themselves. While it is desirable to promote NMT with high income commuters, objectively, the safety of existing walkers (and cyclists) is of more immediate concern. The rate of pedestrian accidents in South Africa is high, likely because the high walking mode share (Figure 6) is combined with a legacy of car dominated cities with relatively poor pedestrianisation. Pedestrian accidents have historically been reported to be particularly high in Cape Town [(54)] possibly, in part, because of the bisecting of dense neighbourhoods by the N2 highway which is difficult to mitigate now.

In general the NMT network is extensive, with around 435 km of walkways and cycleway reported to have been constructed between 2006 and 2013 [55]. TDA undertook 6 NMT projects in the 2014/15 year covering about 27 km in total. Accidents are also part of their TDI index but it is not clear if pedestrian accidents are carved out of this or if there has been any analysis of opportunities to reduce pedestrian accidents. This issue is however highlighted in the public comments to the Integrated Transport Plan. TDA are developing an NMT Bylaw with the goal of "regulating the provision, operations, maintenance and enforcement required for NMT to be integrated into the overall public transport system" [51].

Cycling accidents have however been reviewed as part of the recently published Draft Cycling Strategy for the City of Cape Town[56] which has as its vision:

> *"Cape Town is the premier Cycling City in South Africa where cycling is an accepted, accessible and popular mode of transport for all – residents and visitors alike."*

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49 City of Cape Town (2015a) Comprehensive Integrated Transport Plan 2013 – 2018, 2015 Review. Transport and Urban Development Authority (TDA).

50 City of Cape Town (2015b) MyCiTi Business Plan 2015 Update – Phase 1 and N2 Express. Transport and Urban Development Authority (TDA).

51 http://www.tct.gov.za/en/uap/tdi/

52 Van Audenhove, Korniichuk, Dauby & Pourbaix (2014) The Future of Urban Mobility 2.0 Imperatives to shape extended mobility ecosystems of tomorrow. Arthur D. Little and UITP.

53 http://www.tct.gov.za/en/news/general/myciti-control-centre-to-track-all-myciti-buses-within-next-few-weeks/page-1/

54 Liebenberg & Garrod (2005) Alleviation of the Pedestrian Safety Crisis in the City of Cape Town. Proceedings of the 24th Southern African Transport Conference (SATC 2005).

55 City of Cape Town (2013) 2013 – 2018 Comprehensive Integrated Transport Plan. Transport and Urban Development Authority (TDA).

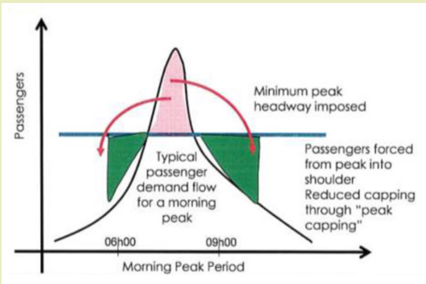
56 City of Cape Town (2017) Draft Cycling Strategy for the City of Cape Town. Transport and Urban Development Authority (TDA).

The strategy has the following long term desired outcomes:

- *An increased mode share of cycling from 1% to 8% by 2030 (trips of 10-15km are targeted);*
- *Cycling has significantly contributed to a substantial reduction in congestion and GHG emissions in the City by 2030;*
- *More people across all sectors of the population have access to affordable bicycles and are cycling;*
- *There has been a substantial shift to utility cycling;*
- *Cycling is substantially safer and secure;*
- *Cycling infrastructure and systems serve the needs of cyclists; and*
- *Cycling is an accepted means of travel.*

Cost Recovery and Financial Sustainability

Figure 42: Illustration of 'Peak Capping' by imposition of minimum headway and capacity constraint



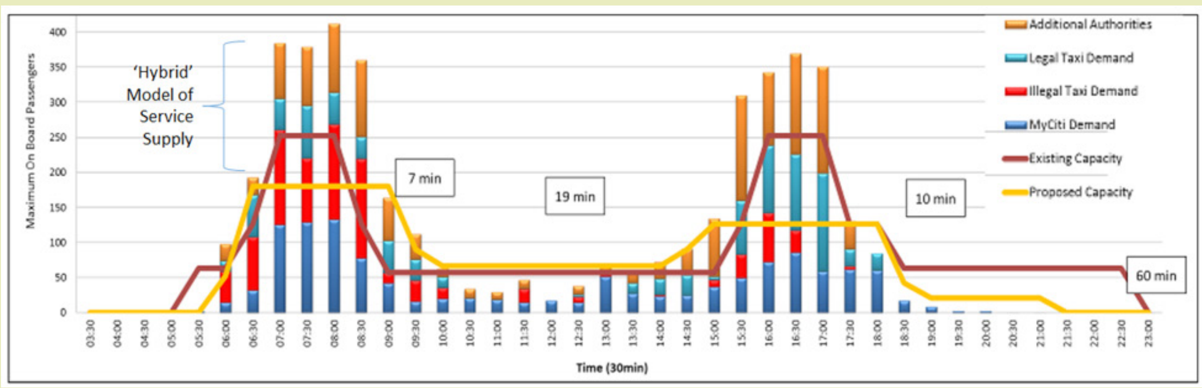
Source: Bosch D, Grey P, Bulman A, van Ryneveld P, "Business Development: Models and optimisation, Slide Presentation UATP Workshop (2015) Best Practice in Public Transport Africa for Africa.

The initial service level of a bus service is based on prospective passenger demand and myCiti policy has been to adjust this after 6-8 months in the form of peak moderation and reduction of late night services. Moderation and optimisation of the system has enabled myCiti to achieve an increase in cost recovery from 25% at the start of operations to 37% in September 2014 and another high watermark of 50% in October 2016.

Essentially peak moderation is a trade-off between the quality of service in terms of meeting unmanaged passenger demand and the operating cost of the system by limiting services at the morning and evening peaks usually by increasing headways (the times between buses). The concept is shown below in Figure 42.

This is illustrated for an actual route analysis for a full day below contrasting the current capacity of the myCiti system with a proposed flattened capacity with increased headways that will capture the shoulders of the peak. The other bus authority (Golden Arrow Bus Service) and legal minibus taxis cater for the unmet peak not willing to shift in a 'hybrid' bus system that for the time being is more financially sustainable.

Figure 43: Example Route with Proposed Moderation of myCiti capacity at Peak in a more financially sustainable 'hybrid' bus system



Source: City of Cape Town (2015b) MyCiTi Business Plan 2015 Update – Phase 1 and N2 Express, Transport and Urban Development Authority (TDA).

While initial moderation efforts have been successful, net revenue growth has been small mainly due, it seems, to the difficulties with attracting taxi passengers and challenges related to the enforcement against illegal taxis which retain a high share of peak demand as shown above. A key aspect of business planning has therefore been the efforts toward continued integration with other modes, discussed briefly below.

Moving Towards a Hybrid System – Potential Integration with Minibus Taxis, Golden Arrow Bus Service (GABS) and Metrorail

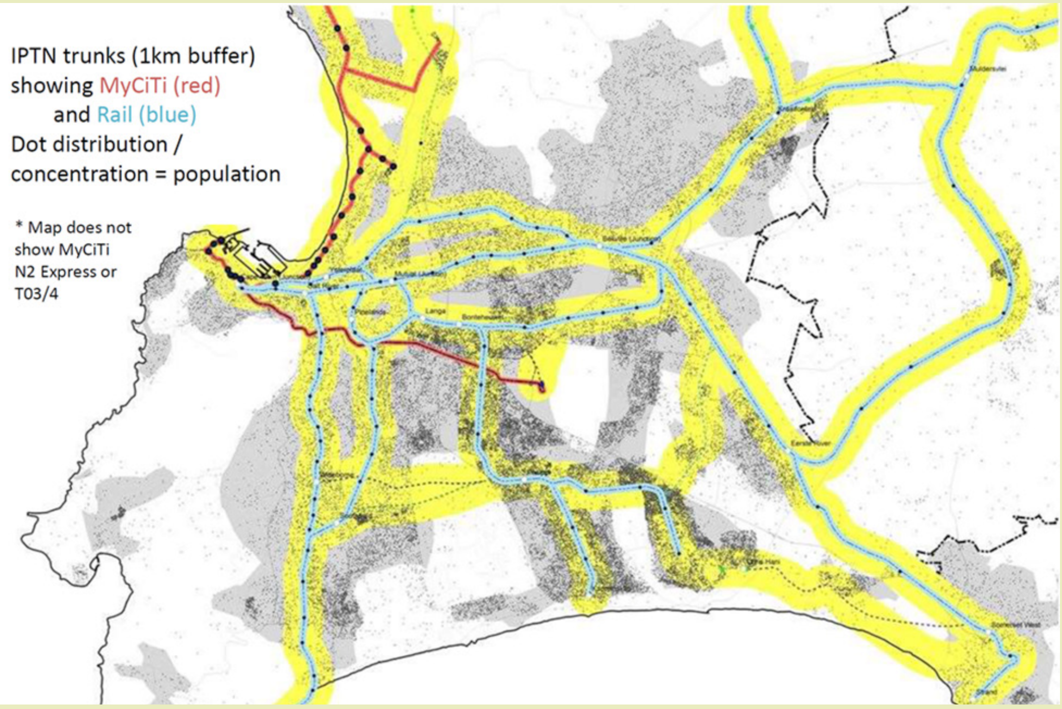
While still TCT, the mandate of TDA was the planning and administration of an Integrated Public Transport Network (IPTN). It is now clear that a BRT solution for meeting the full demand on every corridor is not financially viable. Therefore integration with other services in a hybrid system particularly on feeder routes and off-peak times is being pursued as this offers the potential to reach the goals of an efficient and reliable public transport service without excessive new capital costs. There are three main opportunities:

- *The Golden Arrow Bus Service (GABS)*
- *The minibus taxi paratransit service*
- *The Metrorail service*

Golden Arrow bus service is a larger conventional bus service with wide coverage, high capacity (around 250,000 passenger trips/day) and a long history. Its operations are subsidised through a Public Transport Operating Grants of around R870 million administered through the Provincial Government which could help make a unified entity more financially sustainable.

Around 12,000 minibus taxis, both legal and illegal, operate in the city. The industry is plagued with sometimes violent competition for routes but its high mode share and efficiency means that continued integration into the formal system is a difficult but essential task.

Figure 44: Cape Town's Rail Network (blue) relative to population density



Source: Bosch, Grey, Bulman & van Ryneveld (2015) Business Development: Models and optimisation, Slide Presentation UATP Workshop, Best Practice in Public Transport Africa for Africa

The national state owned enterprise the Passenger Rail Agency of South Africa (PRASA) operates an extensive suburban network of 610 km (Figure 44) through its Metrorail commuter services division.

The potential for a highly effective integrated transport system is clear but the legacy of jurisdictional arrangements are now somewhat at odds and furthermore tied in with national politics. Recent years has seen a great deal of negative publicity regarding the quality of service of Metrorail in Cape Town regarding reliability and safety, with vandalism of infrastructure arising from both protest and criminality reportedly common. In the midst of this commuter rail crisis, discussions with the City of Cape Town have been ongoing around the first steps of improvement and integration including fare system integration and signalling upgrades.

Case Study 3: Bogotà's Trans-Milenio – the BRT Catalyst

Figure 45: Dedicated Busway with passing lane – TransMilenio Bogotà

Source: TransMilenio SA

Bogotà is one of the most densely populated cities in the world. In the 1990s, many of the main road ways were heavily congested and the traffic speed during rush hour was only 10km/hour. The use of private cars was a major cause of congestion. Although ± 71% of motorized person trips were made by bus, 95% of road space was used by private cars, which transported only 19% of the population.

By the end of the decade, a new mass transit system, named TransMilenio was designed and partially implemented to solve these large inefficiencies of mass transit in Bogotà. Along with the mass transit system in Curitibà, TransMilenio has earned a reputation as one of the most successful and cost effective mass transit systems ever implemented[57] and furthermore this was achieved in a hitherto chaotic developing country city dominated by paratransit. It has since been the site of many study tours by policy makers and transport professionals, including from South Africa.

TransMilenio is a flexible bus system that uses exclusive bus-ways to feed people into and out of the central business district (CBD). The stations are located in the middle of the road to facilitate the transfer between buses in both directions. The bus stops are 57 stations, located every 700 meters and are equipped with pay booths, registering machines, surveillance cameras and infrastructure such as bridges, pedestrian

57 Pienaar, Krynauw, Perold (2005) Public Transport: Lessons to be Learnet from Curitiba and Bogota, Proceedings of the 24th Southern African Transport Conference (SATC 2005)..

crossings and traffic lights designed to ease the entrance of passengers into the system.

At the end of the corridors, three principal access stations were built as the meeting point for feeder buses and buses from traditional systems that work in the neighbouring municipalities.

TransMilenio quickly grew to a capacity of 800,000 commuter trips per day and is impressive in terms of the scale of logistics alone. A survey conducted 2 years after TransMilenio was introduced revealed:

- *32% decrease in travel time for users.*
- *80% decrease in traffic accidents.*
- *30% decrease in the number of fatalities caused by traffic accidents.*
- *30% decrease in noise pollution.*
- *37% increase in time spent by mothers and fathers with their children.*
- *There have been a number of criticisms based on the way the system works.*
- *Buses and stations are often packed to or beyond safe operating capacity, even during non-rush hour periods.*
- *The use of diesel buses instead of clean burning natural gas or electric-powered light rail is best defined as an economic decision made to benefit the private contractor and not the best interest of the city.*
- *Because TransMilenio is based on diesel rather than electric energy, its costs increase with increasing oil prices and this causes the fares to be increased to meet this cost.*
- *Many users complain about pick-pocketing inside the bus, a problem which is made worse by overcrowding.*

In addition to exclusive bus-ways, the City of Bogotà has 230km of bike lanes, with plans to increase this to 350km, as well as expanding sidewalks and adding a 17km pedestrian zone. Among the travel demand management (TDM) measures instituted are forbidding private cars to operate in Bogotà CBD during the morning and evening peak. Parking fees were increased by 100% and fuel taxes were increased by 20%. Bollards were built to prevent people from parking illegally on the sidewalk. A key promotion measure is "car free day" held once a year on a week day and car-free Sundays on particular roads.

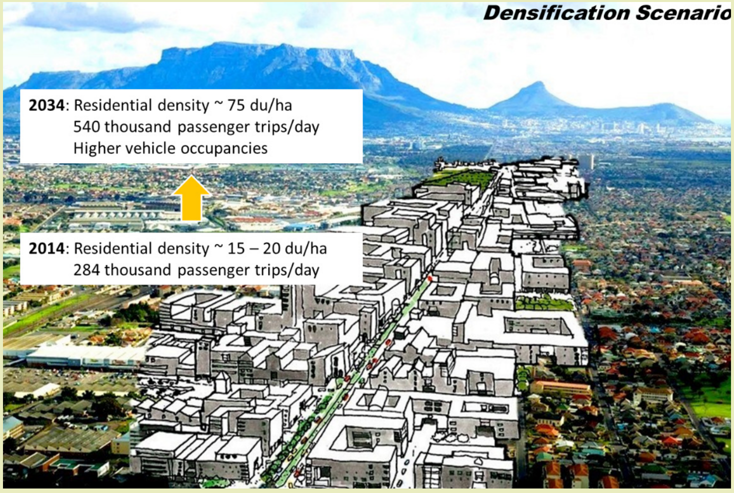
Case study 4: Urban densification and transport energy and emissions – Voortrekker Road

This case study explores some of the results of a technical support study [58] for the City of Cape Town undertaken in 2014 and funded by the SAMSET project (http://samsetproject.net/). The Voortrekker Road Corridor is one of the key routes in Cape Town's transport network, and at the time the City was prioritising the densification of the corridor to promote a more efficient transport system amongst other goals. This study assessed the energy, carbon emissions (CO_2) and energy cost implications of such densification compared with a 'business as usual' approach of more sprawling, low density urban expansion. The densification assessment assumes just over a doubling of the population along the corridor in 20 years (by 2034) raising urban densities from the current 15 to 20 dwelling units per hectare to the level of 75 dwelling units per hectare to a depth of 500m along 40% of the 17 km length of the road (Figure 46). This was contrasted with an alternative scenario of accommodating this population increase in more outlying areas such as Fisantekraal or the proposed WesCape development (Figure 47).

A model of energy consumption by mode was developed for this purpose, combining current traffic observations by mode and expert opinion in the City of Cape Town to estimate the future transport system characteristics for the densification and the sprawling scenarios.

58 Sustainable Energy Africa (2014) Voortrekker Road corridor densification in Cape Town: Energy and Carbon emissions analysis. Report prepared for the City of Cape Town, http://www.cityenergy.org.za/uploads/resource_313.pdf

Figure 46: Voortrekker Rd Densification Scenario: Urban densities rise from the current 15-20 dwelling units/hectare to a level that makes public transport sustainable (75 dwelling units/hectare)



Source: City of Cape Town Website - Spatial Planning and Urban Design Department

Figure 47: Low Density Alternative Scenario: Voortrekker Rd does not densify and the additional population is accommodated on the urban periphery requiring more trips (Less local employment) at double the distance

The results of the modelling show that very significant energy and cost savings accrue for the densification scenario by 2034 as shown in Figure 48 and Figure 49 on the nextpage.

The social cost of fuel savings arising from this reduction in energy demand are substantial reaching nearly R1 billion per year by 2034 in real terms assuming a base year cost of around R14/litre for petrol and diesel, escalating by a conservative 2% per annum in real terms.

These results only consider behaviour changes, which are difficult to model, quite superficially and likely underestimate their potential. For example, the higher concentration of people may result in greater economic activity in the immediate area, and appropriate mixed zoning may lead to more amenities and services in the locality, both leading to reduced travel needs. On the other hand implementation involves many challenges as follows in the information box on the next page:

Figure 48: Modelled Impact of Voortrekker Rd on Transport Energy Demand (CO_2 reduction is proportional)

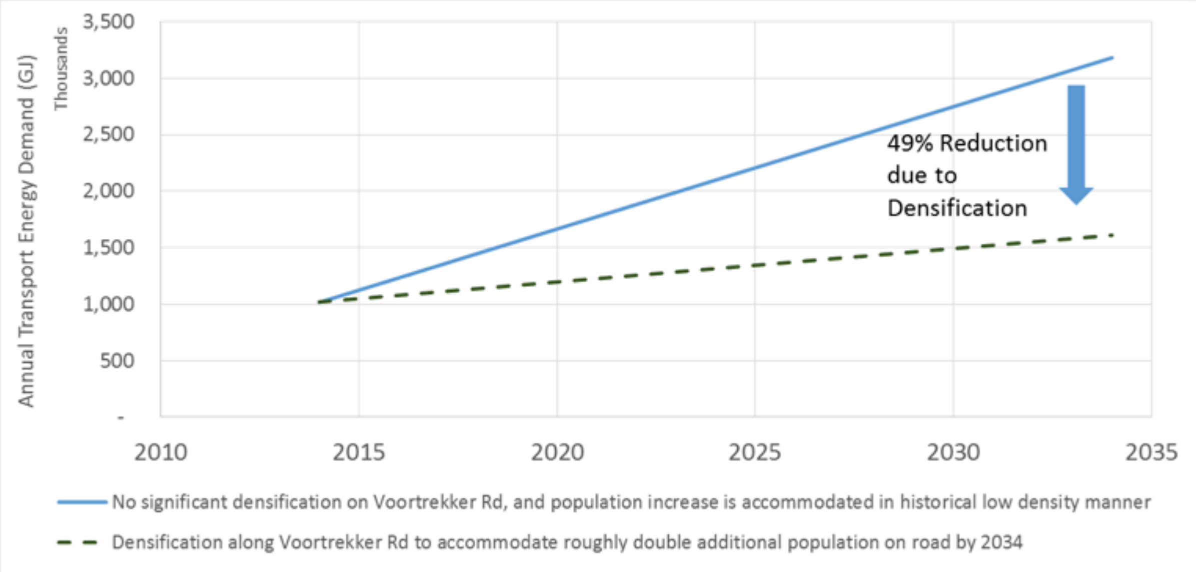
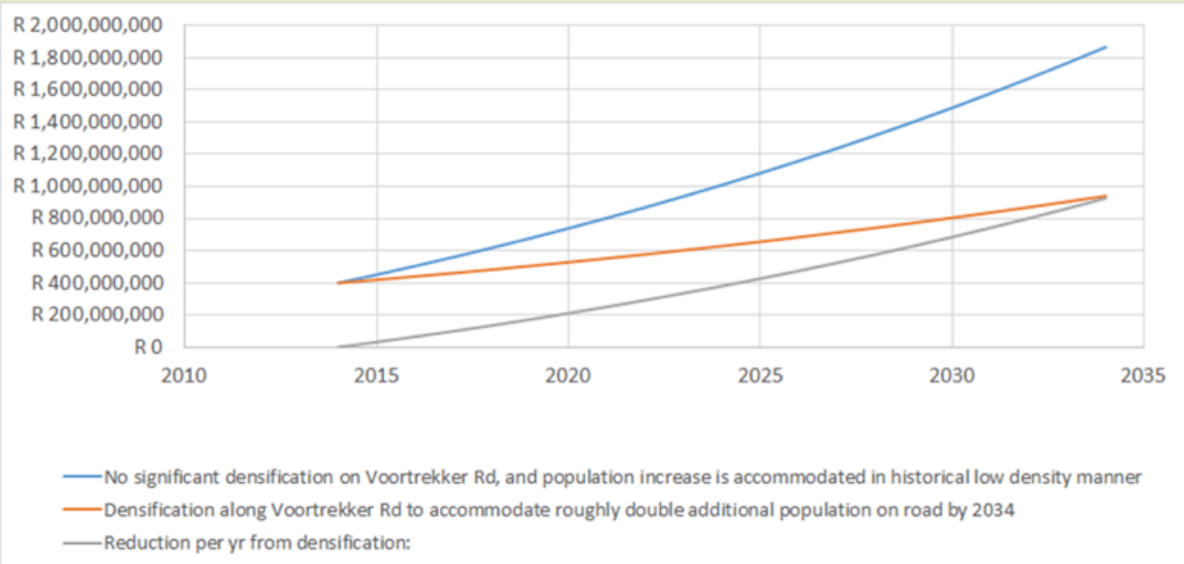


Figure 49: Modelled Energy Cost Savings (Real - assuming 2% escalation) of Densification of Voortrekker Rd



Challenges to Densification

The benefits of densification in South African cities are clear. Indeed, a lot of key social and economic interventions such as public transport and municipal / utility services can't be implemented and extended sustainably and affordably without it. Thus densification has been a policy goal for some time but has proved very challenging. While the type of modelling above is all very well, a number of critical barriers exist:

- The availability of land within inner cities is problematic. State land can have 'proxy' owners such as departments or state owned entities that defend their territorial rights. There is no legal framework to prioritise the housing crisis and compel state entities to make underutilised state land available to the market or to local government for rezoning and development,

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- The availability of land within inner cities is problematic. State land can have 'proxy' owners such as departments or state owned entities that defend their territorial rights. There is no legal framework to prioritise the housing crisis and compel state entities to make underutilised state land available to the market or to local government for rezoning and development,
- Similarly there is no policy or regulatory framework at national, provincial or local government level that compels private sector contributions towards accommodating poorer households on private land in more socially and environmentally sustainable locations.
- Developers respond to market opportunity. The typical household that would be the target of densified urban developments AT SCALE frequently fall in a gap above the income threshold for a state subsidy but below the level considered viable for home loans by the banks. At national government level the need for reform of the social housing subsidy framework is well understood but implementation appears to have stalled.
- Most housing demand sits in the poorest segment of the community that is dependent on state subsidy which is awarded within the framework of a state housing policy that doesn't necessarily consider urban form, the burden of long commutes, integration with transport systems or sustainability and crowds out other responses to the problem.
- The problem with trying to drive residential densification with transit planning as a way to fulfil Transit Orientated Development (TOD) goals, is that they operate on very different lead times.

Until these challenges are addressed, densification may be limited to isolated 'gentrification' developments. Implementation of densification therefore involves the co-operation and buy-in of many partners: local government, provincial government (administer housing subsidies), national government, property developers, potential commercial tenants in mixed use developments, civil society in the housing sector and financial institutions.

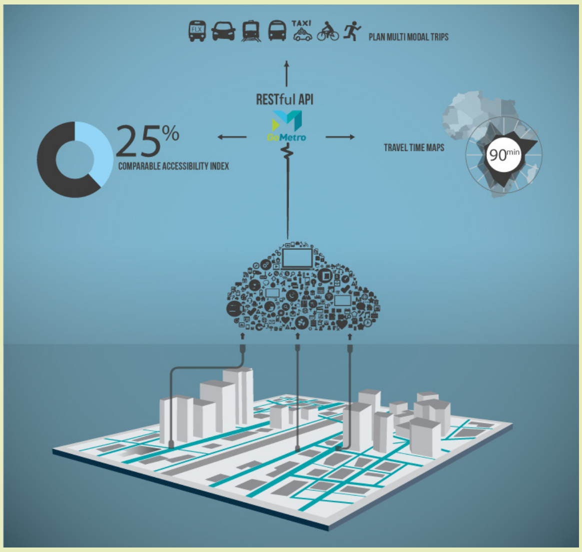
Case study 5: The SMART City – Mobile apps to close the gap between supply and demand

South Africa has seen the emergence of at least two technology companies supplying mobile platform smart travel apps; GoMetro (www.getgometro.com) and WhereIsMyTransport (https://whereismytransport.com/).

In both cases the main value proposition is the delivery of static schedule information as well as real time information on transport scheduling adjustments, timetable changes or delays to commuters for a range of modes including buses and trains and even paratransit. This opens up the potential to capture commuter movement data to sell back to suppliers and also to sell advertising. Both of these services to demand and supply sides working together make the system potentially far more efficient.

In the case of GoMetro the apps available to commuters have not only been developed for smart phone but also for cheap low-tech phones by using Unstructured Supplementary Service Data (USSD) technology (similar to Short Message Service) which exchanges text strings with low data requirements.

Figure 50: A Fast Moving Tech Landscape: SA Start-ups GoMetro and WhereIsMyTransport Offer Data Services to Commuters (mobile phones), Suppliers and now Analytics for Developers



Source: GoMetro

Resources

GiZ's Sustainable Urban Transport Project (SUTP) – Sourcebook Modules

The SUTP Sourcebooks investigate the key areas important for a sustainable transport policy framework in developing cities. The sourcebooks are periodically updated.

http://www.sutp.org/en/resources/publications-by-topic/sutp-sourcebook-modules.html