Niche public transport operational and capital investment strategies to minimize fares in the light of increased energy costs

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ABSTRACT

Fuel costs are a significant component of a public transport fare. It is therefore of critical importance for measures aimed at containing household public transport expenditure to explore alternative ways of reducing fuel consumption or fuel substitution, where motorized travel is necessary. Alternatives include improved operational strategies, fleet acquisition strategies and alternative energy sources. The paper critically examines the extent to which improved public transport operational strategies as well as alternative energy sources can reduce the rate of increase of public transport fares.

1. INTRODUCTION

The largest proportion of households in South Africa relies on public transport for mobility. For many historical reasons, many of these households are characterised by relatively low incomes and as such considered captive to public transport. The 2005/2006 income and household expenditure survey (Statistics South Africa, 2008) shows that transport is the single household expenditure item that increased substantially relative to other items in the period 1995 to 2006. In this period expenditure on transport in the 20% lowest income quintile households rose from 4.0% to 10.6% (which is largely spent on public transport) and for the 20% highest income quintile households the expenditure increased from 18.3% to 28.3% (largely attributable to expenditure associated with private car ownership and use). In fact, on average, South African households spend 10 times more on transport than on education. The increased expenditure on transport in the low income quintile is indicative of the increased household burden of public transport costs. The South African transport policy, in the form of a White Paper, recommends a maximum of 10% of disposable household income to be spent on public transport (RSA, 1996). Besides being a burden on low income households, increased public transport costs also act as a potential deterrent for mode shift from private to public transport where such possibility exists.

The South African Department of Transport does not have a comprehensive strategy on how to contain the increasing costs of public transport or at least reduce the rate of increase in costs. Existing measures include: (i) subsidised public transport (currently mainly limited to train and selected bus services) and proposals to extend the subsidies to minibus taxi operators, (ii) introducing competition in the provision of subsidised public transport contracts to ensure that the public get better value for money (which is fraught with its own transitional problems), (iii) proposals to limit the subsidised one-way distance to 40km with the intention of discouraging long distance travel (somewhat contradicted by the continued peripheral location of low income housing), and (iv) coordinated transport and land use development through corridor development strategies (although corridors are usually defined in terms of vehicle mobility as opposed to person mobility). However, the absence of an explicit strategy to reduce household public transport cost burden remains a glittering gap.

Following from the premise that the costs of fuel are a significant proportion of the fare price, the study investigates operational and capital investment strategies that could contribute towards the reduction in the rate of fare increase, in the light of increased fuel prices. Indeed fuel prices are set to increase in the future given the expected decline in global oil supply reserves and the general dependency of South Africa on imported oil (Wakeford, 2008). Currently South Africa imports 63% of its liquid fuel and generates 30% from coal to liquid conversion process and another 7% from crude and gas to liquids conversion process (Wakeford, 2008). The paper attempts to re-look the formulation of public transport fares, to examine its composition and examine opportunities for reducing the rate of increase of fares. The focus is on road based public transport, especially minibus taxis as they are a dominant public transport mode (currently transporting about two thirds of public transport trips). A number of experiments are used to supplement desktop calculations and benchmarking exercises. The paper also reviews capital and operational costs associated with alternatively powered public transport vehicles and their implications on public transport fares.

2. PUBLIC TRANSPORT FARES

Table 1 provides a snapshot of public transport fares (one way cash fares), across different public transport modes and geographic locations in 2008 Rand value. From a passenger perspective minibus taxis are generally the most expensive mode of transport and trains are the cheapest. However, unlike buses and trains, minibus taxis do not receive an operating subsidy. It is apparent that the pricing of minibus taxis fares, while more expensive than buses, the difference is marginal and alludes to a price war. The high operational frequency of minibus taxis services is a competitive advantage, and it has over time seen the erosion of the bus travel market to minibus taxis (Lombard, et al, 2007). Nonetheless, one of the inherent advantages of bus services include the availability of different types of tickets (for example monthly tickets at reduced per km cost and potentially reduced fares).

Public transport fares can be classified as follows (Giannopoulos,1989):

- **Flat fare:** This is a single fare paid regardless of the distance travelled. This is the simplest form of fare and costs less to administer.
- **Distance based fares:** The fares vary with distance travelled, where normally, the longer the journey the higher the fare based on some rate. Often the rate tapers with distance travelled. Apart from being purely distance related, distance based fares can also be zonal or staged. Zonal fares are basically a flat fare applied for travel between specified geographic zones and allows for price discrimination on the basis of zonal attributes. With stage fares the route is segmented into a number of stages and the fare is then related to the number of stages travelled based. Relative to flat fares, however, distance based fares require more resources to administer.

The public transport fare payment methods also differ and include:

- **Cash fare:** The fare is paid for an individual trip.

Table 1: Public transport fares in different part of South Africa in 2008

Province	Trip from	Trip To	Distance	Taxi		Bus		Train	
				Cash fare (R)	Fare/km (R/km)	Cash fare (R)	Fare/km (R/km)	Cash fare (R)	Fare/km (R/km)
Gauteng	Soweto	Johannesburg CBD	18	8.00	0.44	6.00	0.33	4.50	0.25
	Mamelodi	Pretoria CBD	18	9.00	0.50	7.50	0.42	4.00	0.22
	Atteridgeville	Pretoria CBD	12	8.00	0.67	7.00	0.58	4.00	0.33
	Pretoria CBD	Johannesburg CBD	50	20.00	0.40	not available	N/A	8.00	0.16
	Alexandra	Johannesburg CBD	12	7.00	0.58	6.00	0.50	no train	N/A
	Orange Farm	Johannesburg CBD	40	12.00	0.30	not available	N/A	7.00	0.18
	Krugersdorp	Johannesburg CBD	30	9.00	0.30	no bus	N/A	7.00	0.23
Kwazulu Natal	KwaMashu	Durban CBD	15	7.00	0.47	5.50	0.37	8.00	0.53
	Westville	Durban CBD	15	6.00	0.40	5.50	0.37	no train	N/A
	Umlazi	Durban CBD	20	7.00	0.35	11.50	0.58	8.00	0.40
	Cato Ridge	Durban CBD	45	12.00	0.27	5.50	0.12	no train	N/A
Western Cape	Khayelitsha	Cape Town CBD	25	10.50	0.42	10.00	0.40	7.00	0.28
	Bellville	Cape Town CBD	18	8.00	0.44	not available	N/A	4.20	0.23
Eastern Cape	Motherwell	Port Elizabeth CBD	20	7.50	0.38	6.00	0.30	no train	N/A
	Mdantsane	East London CBD	20	7.00	0.35	no bus	N/A	5.00	0.25
Limpopo	Seshego	Polokwane CBD	10	6.00	0.60	6.50	0.65	no train	N/A
	Thohoyandou	Makhado/Louis Trichard	60	20.00	0.33	not available	N/A	no train	N/A
Northwest	Lichtenburg	Mafikeng CBD	60	20.00	0.33	no bus	N/A	no train	N/A
	Itsoseng	Mafikeng CDB	35	11.00	0.31	9.00	0.26	no train	N/A
Northern Cape	Galeshewe	Kimberly CBD	10	6.00	0.60	no bus	N/A	no train	N/A
	Prieska	Kimberly CBD	220	100.00	0.45	no bus	N/A	no train	N/A
Free State	Virginia	Bloemfontein CBD	130	70.00	0.54	90.00	0.69	30.00	0.23
	Botshabelo	Bloemfontein CBD	50	11.00	0.22	12.00	0.24	no train	N/A
Mpumalanga	Nelspruit	Barberton	35	70.00	2.00	not available	N/A	no train	N/A
	Bethal	Middleburg	80	15.00	0.19	no bus	N/A	no train	N/A

Source: Own enquiries

- **Season ticket:** This could be a weekly, monthly or annual ticket which usually offers discounts on individual trips and can result in large savings for the passenger.
- **Travel card:** a card allowing a specified number of public transport trips within a specified area over a fixed time period. It may apply to all public transport services or be limited to particular modes or operators.

In South Africa minibus taxis make use of a flat fare system and normally operate on the basis of a cash fare, most probably on the basis of administrative simplicity. Buses and trains on the other hand use a combination of the above fare types and payment methods.

The formulation of fare amounts differs from mode to mode. For taxis, and similar to unsubsidised buses, the process involves decisions by route associations, sometimes in consultation with commuters. For subsidised buses, individual operators make recommendations to the respective public authorities and once accepted the fare levels are implemented. Train fares are formulated by the South African Rail Commuter Corporation, an entity wholly owned by government. Generally, however, the process of fare setting is not entirely transparent and passengers are price takers. In a recent notice of changes in fare price one large bus operator said: "*The company will introduce an average fare increase of 4% with effect from 30 June 2008. This is not an annual increase, but purely influenced by unrelated fuel increases since the last quarter of 2007. The company has been absorbing these costs for three years now, offering much reprieve to our commuters…Our company has been heavily affected by this fuel price increase, given that we use 4 million litres of diesel per month*". Numerous organised commuter protests that took place across the country in the recent past are reflective of the general discontentment with the process of fare setting, besides the increased fares themselves.

Table 2 provides an estimate of what constitutes a minibus taxi fare from an operator perspective for a typical route operating between a city centre and a South African township. The essence of the estimation is the order of magnitude of individual fare model components rather than the accuracy of the figures, and assumes the following route parameters: route length of 30km, frequency of 8 return trips per day, and a demand of 4 500 passengers per month (average of 180 passengers per day). The fixed costs are associated with the purchase of a new vehicle, and the operating costs include fuel consumption, maintenance estimated from published rates (AA, 2008), licensing fees and driver salaries, and authors' own enquiries. A profit margin of 10% of total costs is assumed, leading to an average flat fare of over R9.30 per trip. Historically, costs associated with maintenance, depreciation, insurance and even vehicle repayments have generally been ignored and excluded from the costing of a service by minibus taxi operators. This alone could reduce the total monthly costs by about 20% and the fare by a similar amount. This pricing strategy has probably contributed to the observed increase in minibus taxi patronage at the expense of an absolute reduction in bus patronage across all the South African provinces (Lombard, et al., 2007). Further, infrastructure costs such as roadways and route facilities are assumed to be sunk costs. The net costs of operating a minibus taxi are also considerably sensitive to the number of passengers carried, and therefore drivers will typically endeavour to maximise patronage. Therefore any factor contributing to the lowering of the passenger demand per vehicle, for example increased number of operators per route, poses significant financial risk to the incumbent operators.

From the analysis of the order of magnitude of the individual contribution of the different costs to the total service costs, the cost of fuel is the highest at over 65% of the costs, followed by monthly vehicle repayment, vehicle depreciation and insurance. The contribution of the fuel cost to the total fare therefore implies that any strategy aimed at reducing the rate of increase of fare, need to focus on the reduction of the per km fuel consumption.

From the model presented in Table 2, a fuel consumption reduction of 10% results in an average fare reduction of about 7%. In the case presented, the fare would change to R8.70, and this could result in annual savings of about R300 per person (assuming travel for 250 days a year). A higher rate of fuel consumption saving would result in even higher cost savings. For a larger household, in which many people travel, the savings per household become comparatively significant.

Table 2: Estimates of a composition of a typical minibus taxi fare

Cost group	Costing parameter	Value	% Contribution to costs
Route operating parameters	Frequency (trips/day)	8	-
	Number of working days per month (days)	25	-
	Return distance (km)	60	-
	Number of passengers per month (passengers/month)	4 500	-
	Monthly distance travelled (km)	24 000	-
Fixed costs	Vehicle purchase cost (R)	250 000	-
	Vehicle repayment period (months)	60	-
	Interest rate %	18	-
	Monthly vehicle repayment	4 917	12.92%
	Straight line depreciation (years) with 20% salvage	20	-
	Depreciation	833	2.19%
Operating costs	Petrol price (R/litre)	8	-
	Petrol factor (litres/100km)	13	-
	Engine capacity (cc)	2501-3000	-
	Fuel	24 960	65.61%
	Service and repairs (R/km)	0.316	-
	Service and repairs	474	1.24%
	Insurance	2 000	5.26%
	Tyres (R/km)	0.272	-
	Monthly tyre costs	408	1.07%
	Vehicle licence fee	75	0.20%
	Public operating licence fee	4	0.01%
	Association membership	200	0.53%
	Driver's salary	3 000	7.89%
	UIF	20	0.05%
	Telephone	150	0.39%
	Traffic fines	1 000	2.63%
	Income tax	761	-
	Total monthly costs (R)	38 041	-
	Desired Profit margin@ 10% of costs		3 804
	Average fare (flat fare)		**9.30**

3. FUEL CONSUMPTION

For many years vehicle fuel consumption has been a subject of research for vehicle manufactures. This has seen significant improvements in vehicle fuel efficiency standards, for example, in Europe for the same engine size of passenger cars, the fuel consumption has on average dropped from 9.8 litres/100km in the 1970s to 7.4 litres/100km in the late 1990's (Braess and Seiffert, 2005). Various models of fuel consumption have been proposed and calibrated with varying parameters. However, the following factors generally feature in the fuel consumption functions as described and quantified in a Master thesis by Ding (2000):

- **Driving:** Aggressive driving in the form of rapid acceleration and braking consumes more fuel than cruise-type driving. In congested traffic flow conditions, aggressive driving is estimated to increase fuel consumption by up to 10%. Fuel consumption between drivers moving at the same cruise speed can differ due to the gear shift behaviour, where lower gear translates to higher fuel consumption. When idle the vehicle also consumes fuel, and even more fuel is required in order to move a vehicle from a complete stop that when it already has some momentum. Fuel consumption also increases with cold starts.
- **Road traffic conditions:** A 15% reduction in average speed in built-up areas can reduce fuel consumption by 20-25%.
- **Road conditions and alignment:** Driving on a gravel road increases fuel consumption (estimated at 35% more than on a smooth road). Fuel consumption increases on the uphill as well as with increased road windings.
- **Vehicles conditions and features:** A well maintained car is likely to have less fuel consumption than an non-maintained one, but the consumption will increase with vehicle age and use. Fuel consumption significantly increases with additional in-vehicle equipment such as air conditioning and automatic transmission. The lower the weight of the vehicle the lower the fuel consumption.
- **Weather conditions:** The wind conditions, temperature and humidity levels also affect fuel consumption.

For public transport vehicles, Vuchic (2007) concedes that, if all the abovementioned variables are similarly controlled, and apart from sound driving practices, very little can be done to significantly improve fuel consumption of a public transport vehicle with an internal combustion engine. Nevertheless, measures that increase the average operating speed of public transport vehicles such as provision of separate lanes, preferential treatment of public transport vehicles and less frequent stops result in the reduction of energy consumption for a given route and operating conditions (Vuchic, 2007). In views of this, limited experiments were performed to estimate the extent to which some of these measures could improve the fuel efficiency of public transport vehicles. The City of Tshwane was used as a case study and the experiments were limited to road based modes of transport.

3.1 Experimental setup to understand driver behaviour and influence of route conditions

Figures 1, 2 and 3 present the speed time profiles of bus, car and taxi, respectively, in the morning peak period in the City of Tshwane. The cumulative distance travelled is also plotted.

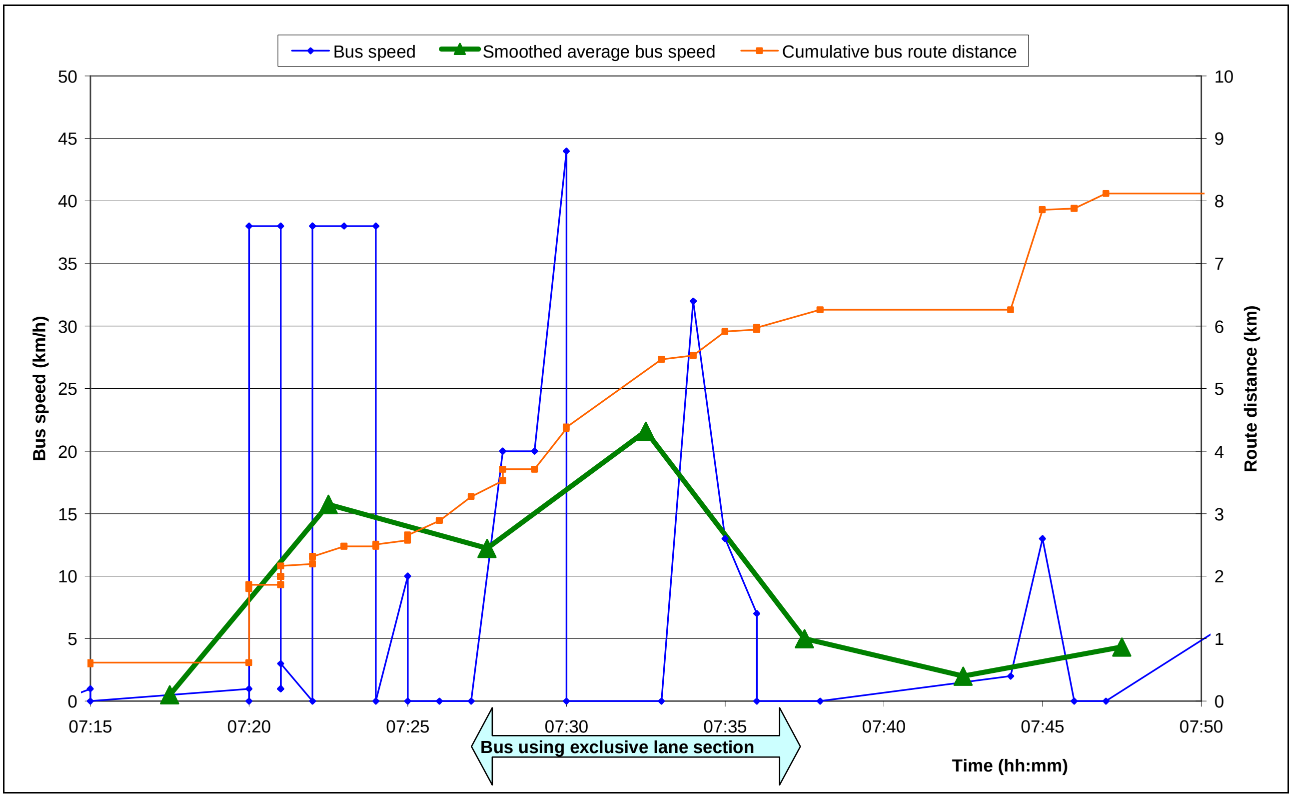

Figure 1: Speed-time-distance profile of a bus partially using an exclusive contra-flow lane

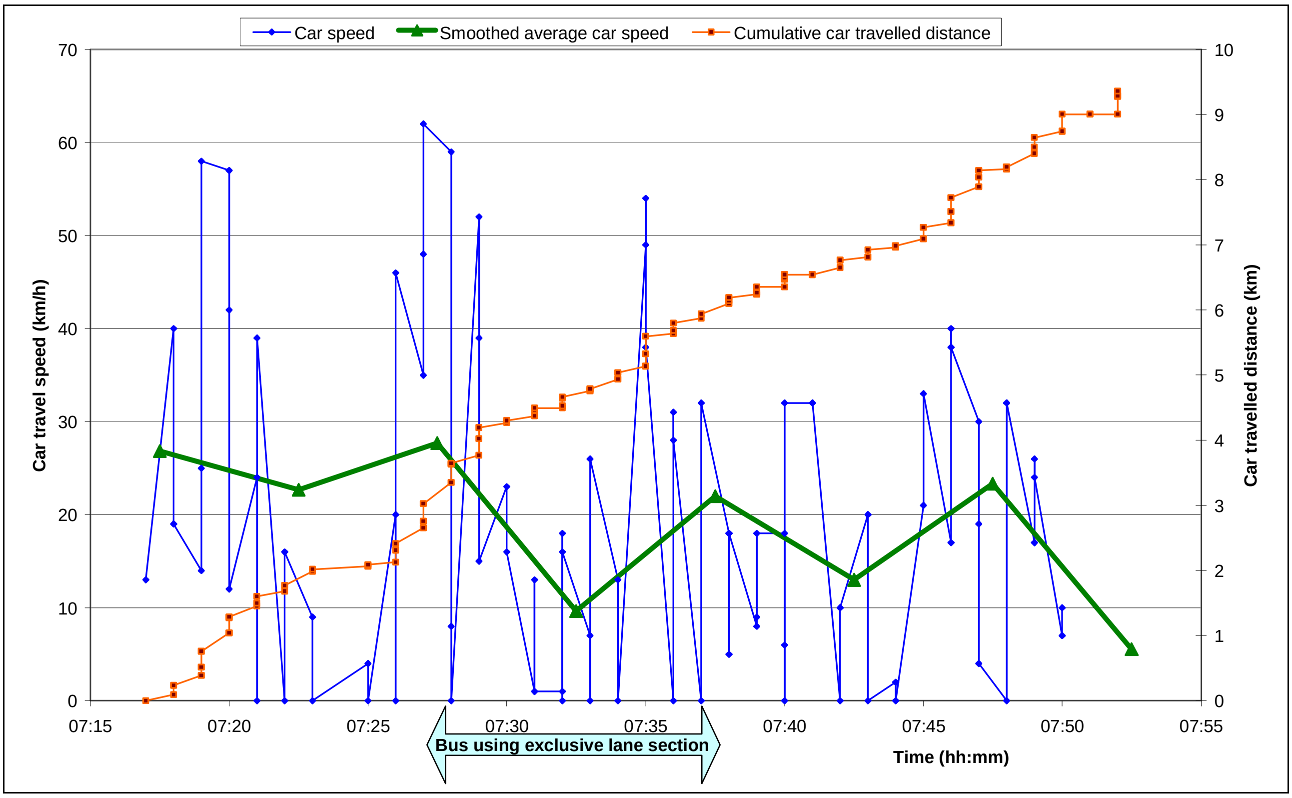

Figure 2: Speed-time-distance profile of a car in mixed traffic all the way parallel to the exclusive bus lane in Figure1

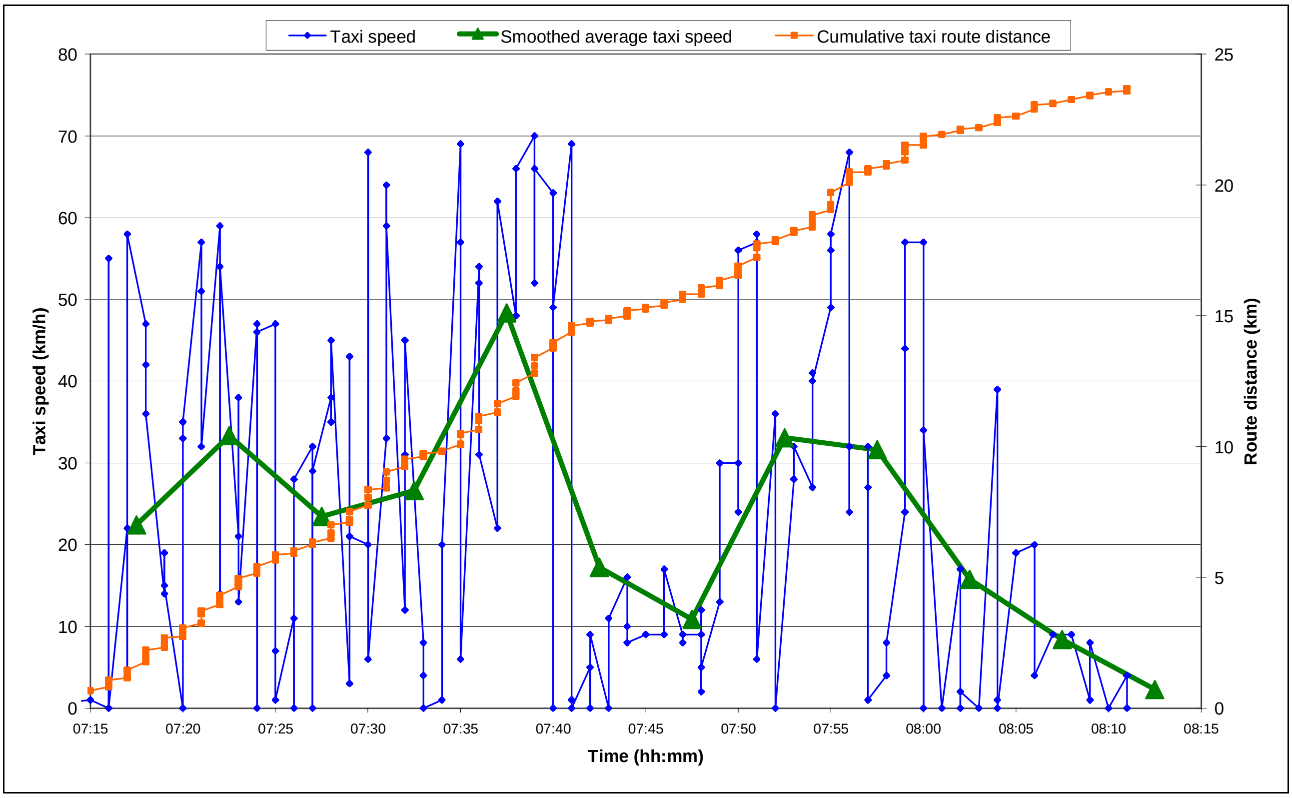

Figure 3: Speed-time-distance profile of a minibus taxi from Mamelodi to the inner city of the City of Tshwane

The speed and location measurements were captured from each vehicle by means of a GPS-logger. The logger, with an accuracy of about 5m, measured speed and geographic coordinates at frequency of up to 12 seconds depending on the signal strength. The measurements, however, are unlike those to calibrate driving cycles. Driving cycles are speed-time profiles, where speed is recorded every second, often used for laboratory estimation of vehicle emission factors and fuel consumption. Apart from usefulness to manufacturers, many countries around the world have developed standard driving cycles, especially in the urban areas, to characterise driver behaviour and to provide inputs into emission models. While South Africa does not have a published driving cycle, SABS (2004) and SABS (2006) provide for the recommended measurement of vehicle fuel consumption and emission testing. Driving cycles are different from driver to driver, and for the same driver from day to day and road type. Usually a synthesised driving cycle is used to represent the entire population. Therefore the profiles plotted in Figures 1 to 3 are only indicative of general driver behaviour and response to driving conditions and cannot be used to measure fuel consumption.

The bus in Figure 1 and the car in Figure 2 originated form the same point at the same time and on the same date, both destined to the inner city from a suburban location to the north of the City of Tshwane. Initially the average speed of the car is higher than the bus speed, attributable to the number of stops to pick up passengers along the route. However, between 7:27 and 7:37, when the bus uses an exclusive contra-flow lane its speed is significantly higher than that of the car which around the same time was moving through a heavily congested part of the road network. Figure 3 shows a taxi with an origin in Mamelodi, a township east of the city centre, destined to the city centre itself, operating in mixed traffic conditions. The average speed of the minibus taxi is generally higher than the bus speed in Figure 1 while operating in predominantly residential areas. However, between 7:37 and 7:52, the average speed drops significantly, attributable to relatively high levels of congestion along a stretch of road where the road network converges. The absence of an exclusive lane in this case resulted in double the travel time over the congested stretch of road than would have been the case if the prior average speed was maintained. It is also evident that once in the city centre, at about 07:47, the minibus taxi average speed also reduces.

3.2 Implication of the experimental findings on operations

The following conclusions can be drawn from the empirical measurements described above:

- Exclusive lanes and providing public transport priority notably improves the operating speed. Therefore, in addition to saving travel time, public transport priority measures also improve fuel consumption.
- Historically minibus taxis have not enjoyed public transport priority measure investments such as exclusive lanes. Such investments on minibus taxi routes will improve network fuel consumption.

The above savings would ordinarily be borne if the driving behaviour is cognisant of the need to drive economically. The effect of the number of stop and stop spacing was not investigated. Nonetheless, the existence of optimal stop spacing is conceptually possible for given operating conditions.

4. INVESTMENT IN ALTERNATIVELY POWERED PUBLIC TRANSPORT VEHICLES

Much of the investments into alternatively powered vehicles around the world seem to be primarily motivated by the aim to reduce vehicular emissions, and reduction of reliance on fossil fuels, more than the costs associated with such purchases. In contrast, investment costs in a developing country context are a major consideration in addition to the life cycle costs that include environmental impact. The question that arises relates to the implication of the adoption of these alternative technologies from the perspective of reducing the rate of increase of public transport operating costs given the expected rise petroleum fuel prices.

Table 3 attempts to piece together information obtainable on the costs (capital and operations) associated with the adoption of alternatively powered public transport vehicles. The focus is manly on the retrofitment of bus fleets, and the fuels under review are compressed natural gas, biodiesel, methanol, hydrogen, electric buses and hybrids (diesel and battery). The review, which is based on various sources, is high level in nature and not meant to be an accurate representation of the expected costs. For example, in some of the cases, the costs claimed from manufacturer warranties were not reported and therefore not reflected in the review. Lifecycle costing of alternatively powered public transport fleet, however, is subject of on-going research by the authors.

Apart from biodiesel fleets, it is clear that the capital costs associated with these alternatively powered fleets is significantly higher than the diesel and petrol alternatives. The operating costs are also higher, requiring specialist work force and operations. The higher costs can be offset by substantially increased patronage. In South Africa, however, the directional peak demand of transport is a direct disincentive, implying that a corridor strategy (whose performance is measured in terms of maximising persons per hour instead of vehicles per hour) would improve implementation feasibility. While more intensive research is required, at prevailing levels of public transport patronage, it would appear that biodiesel powered fleets would be relatively easier to adopt. The rate of increase of fares associated with such a strategy would over time be reduced if the price of petroleum diesel rises significantly and public transport patronage is concurrently increased. Notwithstanding the criticism of the use of biofuels on the grounds of threat to food security, it is worth investigating implication of limiting the use of such fuels to public transport.

Table 3: Indicative costs associated with alternatively powered public transport vehicles

Fleet type	Capital costs associated with the fleet	Operational costs associated with the fleet
Compressed Natural Gas	▪ For a fleet of 260 buses, purchase price equivalent to R3 190 000 per bus; Depot facility costs of R74 million including a fuelling station, and R20 million to bury pipes for high pressure gas [3]. ▪ Infrastructure costs equivalent to R101 880 per bus relative to a petroleum diesel bus [3].	▪ Measured 25% less fuel consumption per km compared to diesel [3]. ▪ Maintenance 5% higher than hybrid [3]. ▪ Equivalent of R2.70 per km operating costs [3].
Biodiesel -(20% blend with 80% petroleum diesel: B20)	▪ Same costs as a petroleum diesel bus [1]. ▪ Biodiesel production process costs make a litre of biodiesel more expensive than that of petroleum diesel [1].	▪ B20 buses exhibit the same fuel economy as petroleum diesel buses [1]. ▪ Engine and fuel system maintenance costs are identical with petroleum diesel buses [1]. ▪ Exhibits the similar road maintenance calls as petroleum diesel [1]. ▪ Compared to petroleum diesel it reduces particulate emissions, carbon monoxide, nitrogen oxides and unburned hydro carbons [8]. ▪ Reduction of 31% in particulate matter, 21% in carbon monoxide, 47% in hydrocarbons [1].
Methanol	▪ Total infrastructure costs 7 time more per bus than petroleum diesel bus infrastructure [1]. ▪ Methanol tanks are 6 times more expensive than those used in diesel fuels [1].	▪ Refuelling costs per bus twice those of petroleum diesel bus [1]. ▪ Require 2.5 more fuel resulting in larger tanks, with implications refuelling infrastructure and operational costs. ▪ Methanol can be used as a diesel substitute or blended [8]. ▪ It can be produced from natural gas, coal and biomass [1].
Hydrogen	▪ Equivalent of R12 million for a hydrogen station [1].	▪ Hydrogen becomes competitive to diesel and petrol when produced in large quantities, for example to supply thousands of buses [11].
Electricity – trolley buses	▪ R3 million per km for overhead contact wire system [10]. ▪ R5.2 million per substation unit [10].	▪ There more intensive the use and patronage for trolley bus the cheaper they are compared to diesel equivalent [10]. ▪ Electricity supply can be based on renewables. ▪ Trolley buses need more maintenance attention than equivalent diesel buses [10]. ▪ Trolley bus traction energy cheaper than diesel equivalent [10].
Hybrid	▪ Equivalent of R5 million per bus [3]. ▪ Battery conditioning stations (two per depot) at R700 000 [3].	▪ Fuel consumption 34% more than petroleum diesel bus [3].

5. SUMMARY

Energy costs are a significant component of the public transport operating costs and ultimately a large component of the fares paid by customers. In order to minimise the burden of increased cost of public transport as a result of increasing cost of fuel it is important that strategies to minimise fuel consumption and reliance on petroleum fuels be devised and adopted as part of transport policy. The paper investigated some niche opportunities for reducing the rate of increase of fares in the light of increasing petroleum based fuel prices. It was found that:

- Fuel costs are the biggest contributing factor influencing the costs of operating a minibus taxi service in a typical urban area.
- Public transport priority measures on public transport routes have notable impact on the speed of service and consequently fuel consumption.
- The use of alternatively powered public transport fleets to reduce dependence on petroleum based fuels attracts significant investment costs. While not quantified, these costs could be offset by increased public transport patronage and concurrently piggybacking on increased costs of petroleum based fuels.

In future, some of the shortcomings of the investigation would be significantly improved by carrying out a number of carefully controlled experiments under South African conditions. Such experiments should form an integral part of a transport policy monitoring programme.

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