The Future Role of Electric Bicycles in South Africa

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Abstract
Electric bicycles and Light Electric Vehicles (LEVs) have experienced a massive market growth over the last two years in Asia and Europe. “World demand for a lighter, environmentally friendly, high performance e-bike increases; in China alone, sales soared from under 100,000 units in 1998 to a staggering 4 million units in 2003[i]. It is not the rich first world that is leading the way in electric bicycles but the developing world, and this is for two main reasons – they are cheap to run and convenient to use.

Cost Effective Electric Bicycles (or ebikes) offer a very attractive solution to South Africa’s transport problems at the same time drastically reducing pollution levels. The cost and availability of transport is a basic factor in the quality of life and South Africa cannot afford to miss out on the electric bicycle revolution.

Over the last few years there have been four technologies that have progressed at an unprecedented pace in terms of cost and performance. These four enabling technologies are: Power electronic components, Permanent magnet Brushless motors, Microprocessor controllers, SLA, NiMH, Li-Ion and Li-P rechargeable batteries. These technologies now enable high performance and relatively cost effective electric bicycles to be built.

This paper will present the current costs of Electric bicycles, the capabilities of electric bicycles in terms of parameters such as range, speed and recharging time. The paper will also provide some financial models for financing electric bicycles in SA.

The paper will outline how electric bicycle use can substantially decrease traffic congestion, reduce pollution and reduce South Africa’s oil needs. If our transport regulators do not take into account this new technology, South Africa could lose an option to provide cheap and environmentally clean transport to its nation.

The Future Role of Electric Bicycles in South Africa

Electric bikes, or ebikes, have been around for the last 20 years but it is only in the last 5 years that they have really substantially increased sales. Ironically it is China that leads the way in electric bike usage, not the high tech West, and South Africa can learn valuable lessons on the benefits of this recently discovered transport and ensure that our national transport strategy takes ebikes into account.

***Ebike Technolog*y**

One of the enabling technologies of ebikes is the development of hub motors. These motors are unobtrusive, generate high torque at low speed, and are highly efficient which result in a solution which has no costly chains or gearing, traditionally the solution.

These motors can be brushless, meaning they only have bearing as a moving part and are thus extremely reliable. Inside the motor on the outer perimeter there are many "rare earth magnets" – magnets far more powerful than your normal magnet. Closer to the centre of the motor are the wire coils, also wired in three phases. As a pulse of electricity is sent to the motor from the controller the coils create a strong magnetic field, which repulses them from the magnets and causes the motor to advance (rotate) away from the magnets. The controller then sends another pulse of electricity and the next phase fires, rotating the motor even further.

Batteries are the weak link

Battery technology has improved and the simple Sealed lead Acid (SLA) battery has been improved since the advent of ebikes. When engineers first developed cheap and efficient hub motors they were surprised to see that it was the batteries that after a months use were failing and needing replacement. Now SLA batteries have been redesigned for ebike use and 200-400 complete recharges are the norm, giving a battery life of one to two years, all for the cost of one tankful of petrol.

New batteries such as Nickel Metal Hydride (NiMh) and Lithium Ion have been developed which have over 500 cycles and are far more robust and lighter than SLA technology, but it will be many years before they overtake the simple yet effective SLA battery.

Cost of Ebike Transport using different battery technology

Table 1: Cost comparison of different battery types

	Sealed Lead Acid	Nickel Metal Hydride	Lithium Ion	Lithium Polymer
Energy Density (W.hr/kg)	36	65	120	130
Typical weight of 430 Watt.hr battery-suitable for 50 km ebike range (kg)	11.9	6.6	3.6	3.3
Typical Cycle Life[1]	250	500	650	800
Charge Time[2]	4.5 hrs	3.5 hrs	3 hrs	3 hrs
Self-discharge/ month	5%	25%	5%	3%
Replacement cost of battery[3]	R 462	R 1,676	R 2,394	R 2,633
Approximate cost per 100km using ebike[4]	R 3.69	R 6.70	R 7.37	R 6.58
Electricity cost per 100km using ebike[5]	R 0.46	R 0.42	R 0.36	R 0.36
Total current cost per 100km for ebike	R 4.15	R 7.13	R 7.73	R 6.94
Potential total cost per 100km for ebike[6]	R 2.80	R 4.54	R 4.64	R 4.17
Notes				
1	Cycle life assumes 100% depth of discharge, and battery capacity is less than 80%			
2	Typical charge time, newer technologies halving this time			
3	Current SA retail prices inclusive of VAT. Prices will decrease with volumes			
4	Assumes battery is replaced with 80% capacity. In reality cost will be 20-30% lower as users will carry on using batteries at the expense of range			
5	Current Electricity cost 40 cents/kWhr; calc also takes into account charger losses			
6	Assumes battery price drops 25%, and that users use battery until 60% of original capacity			

The above table compares the current batteries available and shows the relative cost per 100 km travelled. What is particularly interesting is that even if electricity prices tripled, because of the relatively small cost of the electricity part, the cost of transport would barely increase. Compare this to car transport which would cost R60 per 100km at current prices for petrol[ii] (R 87 per 100 km if maintenance is included according to AA rates) and even motorbike transport which would cost over R18 per 100km (R25 per 100 km including maintenance) which would be comparable to the above scenario.

What is important to take note of, is that the cost to transport could be less than R3.00 per 100km travelled per person (if one takes the SLA example which is predominately used in China), far cheaper than any other form of transport available, even public transport.

Cost of EBike

Initially, ebike manufactures failed as they has supplied too small motors of less than 250 watts which consumers found to weak and to slow. Added to this, these motors were brushed motors which further reduces the efficiency of the motor by 20-25%. The trend is now to supply larger powered brushless motors of 500 Watt which can keep an ebike travelling at 32km/hr and easily up most hills.

Table 2: Comparing cost of ebikes

	Ebike[1]	Motorbike	Small Car	Taxi
Cost	R 3,500	R 9,000	R 75,000	
Monthly repayment	R 121.33	R 243.69	R 2,581.57	
Daily Payment[2]	R 5.60	R 11.26	R 119.24	
Average distance to work - (km)	15	15	15	
Overall running cost per 100km[3]	R 2.80	R 23.00	R 86.77	
Running Cost to work and back	R 0.84	R 6.90	R 26.03	
Total cost to travel to work and back	R 6.44	R 18.16	R 145.27	R 12.00
Effective cost of transport to work & back[4]	**R 3.64**	**R 12.53**	**R 82.12**	**R 12.00**
Interest Rate used	15.0%	14.5%	13.5%	
Capital repayment period	3	3	4	
Notes				
1	Retail price. Assumed with a South African market of 12,000 ebikes per year			
2	Assumes vehicle used 5 days a week for work.			
3	Assumes cost as using SLA ebike (see Table 1). For vehicles includes petrol and maintenance according to AA SA rates			
4	Basic assumption that vehicle can be sold for half the value of its initial purchase price.			

Above is a simplified comparison if one compares the cost to travel to work and back in the South African situation. It has made certain assumptions such as the average distance to work being 15 km and that the vehicle is used only to get to work and back, but it does bring to ones attention the basic actual cost to run different vehicles as a mode of transport to work. Ebikes in China are currently available for around R2000 but these tend to have no gears, and are the weaker 250 Watt brushed motors. It is highly likely that in the next couple of years 500 Watt brushless ebikes with 40 km range could retail for R2500.

Bicycles are an even cheaper form of transport, and have not been included in this table because of its clear advantages (though ebikes complement bicycle transport). Where ebikes has advantages over bicycles is their higher speed, ease of use (in wind and hilly conditions) and longer effective range – reasons which are particularly applicable to SA conditions

Environmental Saving

In Cape Town in 1997, 65% of the visible pollution was a result of vehicles[iii], and this figure was expected to rise to over 80% but 2005 (no further studies have been done). Furthermore, with the South African Taxi recapitilisation program converting the current taxi fleets to diesel, this could add to ongoing smog and pollution problem if these vehicles are not closely monitored. Already the Department of Environment Affairs and Department of Transport (in SA) are working on having mandatory emissions testing for vehicles during roadworthiness tests.

In South African cities, close to 15% of green house gases are as a result of motor vehicle emissions. Every litre of fuel consumed results in 2.5 kg of CO2, not to mention, not to mention other poisonous gases such as the NOX's and Carbon Monoxide.

Table 3: C02 emissions of different forms of transport

Emissions per 100km travelled	**kg C02**	
Small Motor Car	20	
Motor Bike	7.5	
Ebike	1.03	
Amount of C02 absorbed by tree pa - kg	22.7	
Notes		
For every litre of fuel consumed, 2.5 kg CO2 is emitted		
Assumed 8l/100km for car		
Assumed 3l/100km for motorbike		
Eskom (SA utility) produces 0.96 kg C02 per kWhr[iv]		
Assumed petrol price is R5.76 per litre (November 2005)		
Assumed need 430 Watt.hrs to travel 50 km on a bike		
Assumed charging efficiency of 80% (typical charging efficiency of SLA battery)		

As can be seen from Table 3, an ebike (using SA electricity which has amongst the highest CO2 produced per kW.hr) will produce approximately 20 times less C02 than a motor car and 7.5 times less C02 than a motorbike.

If SA had 50,000 ebike users travelling an average of 30 km each working day, this would result in 6,160 less tons of CO2 produced per month. 3.2 million trees would need to be planted to absorb all this C02.

Cars and motorbikes also emit noise and particulate pollution (causing smog and respiratory problems) into concentrated urban areas, and the run off from leaking oil and used oil cause countless problems to the environment. Motorised vehicles such as motorbikes and cars are most efficient the day they are brought and tend to get worse the older they are. According to the U.S. Environmental Protection Agency, 10 to 30 percent of the vehicles on the road create the majority of the pollution which is caused by age, poor maintenance etc.

In general, a tree absorbs 22 kg of carbon dioxide a year – so emissions on one 50 litre tankful means 6 trees need to be planted just to compensate for the extra Carbon Dioxide produced, clearly an impossible task to nullify just the greenhouse producing CO2.

Electric bikes are **the most energy efficient**[v] transport mechanisms in the world – greater even than cycling by human power and in today's world of increasing energy costs, the world's leaders need to start looking at energy efficiency.

Every part of an ebike should and can be recyclable, including the Lead Acid, NiMh and LiPolymer batteries (NiCd batteries should not be used as they are not recyclable and are extremely toxic to the environment. In most developed worlds they are not allowed to be sold). More over, because of the size (less than 30kg for the total bike), recycling becomes much easier. Compare this to a 1,200 kg car with plastics, metals and foams intertwined with oil which is more difficult to recycle and generally end their life in an unsightly dump. In an ebike, the most toxic part is the SLA battery which fortunately is recyclable. Lead acid batteries are a reasonable environmental success story of our time, with roughly 83% of all battery lead is recycled in SA. Compared to 42% of newspapers, 55% of aluminium soft drink and beer cans, and 40% of plastic soft drink bottles, lead acid batteries top the list of the most highly recycled consumer products[vi].

Reduction in use of fossil fuels

EBikes use could dramatically less fossil fuels and reduce South Africa's dependence on oil.

Table 4: Hypothetical savings in fuels by using ebikes

Estimated no of Ebikes	50,000	
Average distance travelled per day (km)	30	
Petrol consumed by a car per day	R 13.82	
Litres petrol consumed by car	2.4	liters
Petrol saved per month if 50,000 ebikes	R 14.96	Rands (millions)
Petrol saved per month if 50,000 ebikes	2598	KL
Emissions saved (CO2) pm - tons	6,160	tons CO2
Power needed to charge ebikes pm	349,106	kW.hrs
Cost of electricity pm	R 132,660	Rands
Notes		
For every litre of fuel consumed, 2.5 kg CO2 is emitted		
Assumed 8l/100km for car, 16l/100km for taxi with 8 passengers		
Assumed 3l/100km for m'bke		
Eskom (SA utility) produces 0.89 kg C02 per kWhr		
Assumed petrol price is R5.76 per litre		
Assumed need 430 Watt.hrs to travel 50 km on a bike		
Assumed charging efficiency of 80%		
Electricity R0.38 per kW.hr		

In Table 4, we show what the estimated saving in fuel could be if more users were using electric vehicles. If there were 50,000 ebikes commuters every day in South Africa, 6,160 less tons of C02 per month can be emitted and almost R15 million rands less of fuel per month would be used. It must be noted that the cost of electricity would be R132,660 which is less than 1% of the equivalent cost of the petrol or diesel to the consumer, and the 349,106 kW.hrs of electricity (costing R2.65 per user per month) would not effect electricity supply in any way (This represents just 0.01% of the electricity produced by Eskom) especially as charging would probably not take place during peak loads.

Crude oil is South Africa's single largest import, and the vast majority of the downstream products are utilised by the Transport Sector [vii]. The use of ebikes thus fits in with the DME white paper on reducing South Africa's energy needs in a positive way, and helping our unhealthy Current Account deficit.

Convenience

Ebikes are as quick in rush hour traffic, being able to easily maintain 30 km/hr in most conditions, pretty much the same speed that cars can maintain and in many cases faster as traffic often comes to a standstill.

Ebikes are only starting to take off in the US and this despite it not being a bicycle nation with few bicycle paths. The take off can be attributed to the fact that their legislation started allowing 1000 W motors recently as long as they are with a bike with working pedals.

Furthermore, no licensing is required. The EU which has the most to gain as it has more of a bicycle culture is losing out as they have enforced rules limiting power to 200 Watts (no license is required), and as a result consumers feel that there are not many advantages to ebikes. At this stage SA does not have legislation regarding ebikes though restrictive legislation could restrict this mode of transport.

Conclusions

So if ebikes are so much more environmentally friendly, efficient and cheap to run, what will inhibit the uptake of this form of transport.

1. Lack of cycle paths.

   This is the major negative for ebikes (and bicycles) and unless SA commits to cycle paths, transport for South Africans will be disproportionately expensive. Bicycle paths are far cheaper per km than normal roads (by area) because minimal foundations are needed, but this will need an investment by the department of transport and planning to ensure that new roads and current roads have bicycle paths
2. Initial purchase of ebike is still out of reach of many consumers.

   This is an ongoing problem within South Africa where consumer (especially the poor) cannot afford the upfront cost, even when on this case the trip cost is far cheaper than even public transport (see Table 2)

SA needs to ensure that they take advantage of ebike transport, by ensuring bicycle paths are developed and consumers will then follow. Compare this cost to the infrastructure needed for public transport and one can easily see that ebikes should have a place on every transport forum.

Further Research needed

This paper is a concept paper but it shows the potential of ebikes within South Africa. It will need the support of government to ensure cycle paths are more common.

It is believed that ebikes in many cases are even a better and cheaper option than public transport and should be part of the SA government's transport strategy. Further research needs to be done on issues such as overall cost of ebikes (including cost of new bike paths), cultural acceptance of ebikes and a pilot programs should be put in place to see what the take up of ebikes in South Africa would be and issues surrounding their use. It must be remembered, that for the price of one 30-seater bus, 130 – 150 ebikes could be purchased and then be run cheaper than the bus. Ebikes are a realistic option for public transport in certain applications and we need to take this into account now and plan for this rather than in 3-5 years time when the technology and price make it viable but the facilities are not available.

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[i] Golden Power Battery

[ii] Based on AA South African rates for a 1500cc-1800cc petrol engine, and petrol price of R5.76/l (Nov 2005)

[iii] Wicking-Baird, De Villiers, Dutkiewicz, 1997 Brown Haze Study [online]. Available www.eri.uct.ac.za

[iv] Eskom Annual report 2005 [online]. Available: www.eskom.co.za/about/Annual%20Report%202005/index.html.

[v] Justin Lemire-Elmore. April 2004, The Energy Cost of Electric and Human-Powered Bicycles'

vi An overview of Lead Recycling in South Africa", Mr. Kevin Joseph, Chief Mineral Economist, Department of Minerals and Energy).

vii Energy Efficient Strategy in South Africa, March 2005 [online]. Available: http://www.dme.gov.za/publications/pdf/ee_strategy_05.pdf