

# **EBike Performance in Urban Commuting. How does it compare to Motorised Modes?**

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## **Abstract**

The current technology for Electric Bicycles (sometimes referred to as “Pedal Assist” (Pedelec) Bikes or EBikes) is exceptionally well resolved, to the point where their range is not that far off electric cars. Mainstream EBikes now offer a pedal assist range on full charge of up to 110km, and provide amazing operating endurance with continuous average speeds of at least 25km/h throughout their range when operating in assist mode, even when negotiating gradients which would reduce a human cyclist to walking pace. The manufacturers of mid-market EBikes also claim outstanding operational performance more akin to what one would expect with a motor vehicle than a bicycle, with electric assist motors built to provide a serviceable life of 100,000km and battery life of up to 20,000km. Given the fact that cyclists use commuter bicycles for short to medium length urban trips, this impressive serviceability means that an E Bike can provide a potential service life that is on par with the expectations for a conventional motor vehicle. With all the advantages that an E Bike offers, why have they failed to make significant inroads as a modal choice in Australian urban areas? If Ebikes were widely adopted (at least by the cycling fraternity), what changes to our transport system would be needed to make them a realistic urban travel mode? How effective is the road and cycling network in catering to EBikes?

This paper compares the performance of EBikes as a travel modal choice compared to other travel modal choices in terms of travel efficiency and discusses the implications for Adelaide’s transport networks to accommodate this travel mode. Finally, this paper concludes with transport policy recommendations for improving the modal share of electric bicycles for urban commuting in Australian cities.

## **1. Introduction**

Bicycle commuting and the infrastructure required to support cycling has grown in popularity in recent decades in Australian cities, nevertheless, the modal share for cycling is still very low (Infrastructure Australia, 2015), this is despite the fact that bicycle related industry research suggests a boom in cycling, with 3.7 million Australians (16%) in 2015 claiming to cycle at least occasionally (Roy Morgan, 2015). In the 2011 ABS Population and Housing Census, the modal share for cycling for the journey to work commute in Australia’s capital cities (i.e. Adelaide, Sydney, Melbourne, Brisbane, Perth, Canberra and Hobart) averaged a mere 1.05% compared to 59.89% for car drivers. The density of commuter cyclists across the same greater metropolitan areas for the journey to work commute averaged 77.1 car drivers/km<sup>2</sup> compared to 1.36 cyclists/km<sup>2</sup>, with motorists 57 times as numerous on Australia’s urban roads as cyclists. The variation in cycling modal share does not appear to vary greatly across Australia’s cities ranging from 0.8% for Sydney to 1.5% for Canberra, despite a clear dichotomy emerging in urban form (based on densities and polycentricity) between the larger (i.e. Sydney, Melbourne and Brisbane) and smaller capital cities (i.e. Perth, Adelaide Canberra, Hobart). In Sydney and Melbourne in particular, urban form is becoming more polycentric, with high density residential, retail and commercial development occurring around public transit nodes and interchanges, whereas in the smaller cities such as Adelaide and Perth, despite metropolitan planning strategies advocating future transit oriented developments, centres in the suburbs tend to be limited to retail centres mostly anchored by the metropolitan arterial road network or suburban transit interchanges (either bus or

commuter rail). It could of course be argued that none of Australia's cities are genuinely polycentric (i.e. where centres have mixed uses and high density living), at least not as a level that would support cycling as a significant mode of travel for the journey to work commute. In the case of Sydney, most of its middle to outer suburbs are still dominated by low residential densities that are synonymous with car dependent urban environments, and where centres in middle to outer suburban locations do occur, these are usually no more than big box retailing centres, occasionally accompanied by community facilities, a transit interchange and a junction of suburban arterials.

The large expanse of Australia's greater metropolitan areas, is on a daunting scale, even to the motorist. Australia's largest cities span over 10,000 km<sup>2</sup> (Sydney, Melbourne and Brisbane) or 100km by 100km, and whilst some this also includes natural reserves, the overall weak polycentric form of these cities with their dominant CBDs, and the dispersed nature of employment across their metropolitan areas, results in long commuting trips, typically averaging 12km from home to workplace (Allan, 2011). For the person wishing to cycle to work or to access any attraction within a metropolitan area, the tyranny of distance and the lack of continuous cycling networks allowing safe cycling conspires to inhibit cycling as a modal choice.

In Australian parlance, the bicycle in colloquial speech is often referred to in what almost seems a slightly derogatory term as a 'push-bike', which creates a mind image of the emphasis on the personal physical effort involved in this choice of travel mode. Cycling can be an invigorating form of exercise as evidenced by its popularity as a recreational activity amongst Australians but in many of Australia's cities (Sydney and Brisbane in particular), hilly terrain, hot summers and high humidity can make cycling a daunting prospect for even reasonably fit and active people. The characteristic of the road network in most of Australia's cities is largely designed to facilitate relatively high speed motor vehicle traffic and is poorly suited to cyclists whose speeds range from 8km/h negotiating a steep incline to 65km/h down a steep hill and rarely average much more than 28km/h on level ground. The primary safety challenge for cyclists is the large speed differential that they have with motor vehicle traffic, which is exacerbated when steep terrain reduces a cyclist's progress to a crawl. At low speeds, a cyclist's movements and balance can become erratic and the lack of contrasting movement with the background can result in an inattentive motorist not recognising the cyclist as part of the traffic flow, but rather an almost stationary object at the side of the road. The recent implementation of 'share the road' cycling road safety legislation in Queensland and recently South Australia, that mandates a 1.0 metre gap between a motorist passing a cyclist at speeds of 60km/h or less or 1.5m where speeds are higher, highlights the inherent safety risks when cycling on roads primarily designed for motor vehicle traffic. Negotiating intersections also poses significant safety risks for cyclists because a cyclist of average fitness may not have the strength or power to accelerate out of difficulty or merge with traffic.

In the past, Australian transport policy has operated on the assumption that as a mode of transport, the physical travel limitations of cyclists (or 'push-bikes') would necessitate either dedicated separate 'right of way' bike paths, completely or partially separated from road traffic, or on road cycling infrastructure in the form of painted bike lanes, safety crossing points and cycling actuated traffic signals (either operated manually or with in-road magnetic induction loops). Austroads (2010) provides guidelines for conventional manual cycling, but lacks policies in regard to EBikes. EBikes or 'pedelec' as it is referred to in Europe, may require a change in the way that people think about cycling as a modal choice, and in the way that transport policy-makers cater to cycling as a legitimate transport mode. Globally, the market for electric bicycles is currently 40 million units annually, dominated by demand in China (Fishman & Cherry, 2016). Unfortunately, reliable statistics for the number of EBikes in Australia, and annual sales, are currently impossible to find. This is partly because, EBikes can be privately imported, and unlike motor vehicles which have to be registered, EBikes can find their way into the Australian market without being audited.

The long range of pedelecs means that for longer urban trips that would have previously been the domain of motorised private or public transit, pedelecs now have the speed and endurance to be a realistic alternative. One of the interesting road safety regulatory issues with Ebikes, is at what point do they become a motor vehicle requiring licensing for both the rider and the vehicle, whilst allowing the level of functionality expected in a bicycle under human power. Currently Australia's road rules have clearly set performance limits for pedelecs, with two standards: one is that the power limit for powered assistance is 200 watts or speed limited to 25km/h if the continuous power assistance is up to 250 watts, and in both cases the assistance has to be in conjunction with the rider pedalling (i.e. placing some load on the pedal crank with their own muscle power). Australian rules do allow for full assistance up to 6km/h (i.e. a brisk walking pace). Ebikes that exceed these performance parameters become classed as mopeds that require vehicle registration and the rider to have an appropriate driving license. The current design and product rules for Pedelecs in Australia essentially adopt the European standard. As an owner of a Pedelec, and having cycled 2000km in urban road conditions and off-road shared cycle paths, the level of electric powered assistance, appears to be an ideal compromise between effortless cycling whilst retaining the sense of control that is associated with riding an unassisted bicycle. Most cycling infrastructure (on road cycle lanes and off-road shared pathways), are designed around a 30km/h design speed, hence the level of electric assistance and performance boost in pedelecs are consistent with the inherent design limitations of cycling infrastructure.

On paper, these performance limitations would appear to render a pedelec as a poor substitute for motorised urban transit options, but as the research in this paper demonstrates, urban speeds for a pedelec are competitive in the north-east of metropolitan Adelaide in largely unobstructed traffic conditions with average speeds for a 21.5 km suburban trip from the city centre to Golden Grove of up to 32km/h for an Ebike (using urban arterial roads), 24km/h for an Ebike using the shared bike path network along the Torrens Linear Park, 31 km/h for buses utilising the OBahn and 55km/h by private car. Despite the performance restrictions placed on Ebikes, to ensure that they remain classed as bicycles, the trade-off in transport functionality is not substantial, with speeds up to 58% of that of travel speeds for private cars, and as quick as travel by bus. The performance of Ebikes in inner city suburbs (i.e. suburbs up to 10km from the city centre), relative to motorised modes becomes even more impressive, given that Ebikes can exploit dedicated cycling infrastructure with rights of way separate from other motorised modes, and door to door journey capability. It has to be acknowledged however, that the scarcity of commuter cycling in Adelaide's northeast means that the few cyclists there are, can set their own pace, largely unencumbered by other cyclists. If cycling trip densities on conventional roads and shared off-road paths were to increase to levels necessary to make cycling a substantial modal share, average cycling speeds would drop to the level of the slowest riders, due to the single file nature of much of the cycling infrastructure in Australian cities. Whilst lower traffic flow speeds of bicycles will not necessarily affect the volume of bicycles if the gap interval between cyclists is based on a consistent time interval of 2 seconds, journey times would be dramatically affected, by as much as 50% (i.e. 30km/h for a fast commuter cyclist versus 15 km/h for a slow cyclist).

## 2. Methodology

The methodology applied in this research essentially used a Garmin Edge 705 bicycle computer to data log various trips across the North-east of metropolitan Adelaide in 2016, from an outer north-eastern suburban location 21km from the city centre and the north-eastern quadrant of the city centre and spatial analysis using Google Earth Pro. The residential address was located 1.5km from the local bus interchange in a large district shopping centre with a multi-campus school complex and community services to represent the average distance of dwellings for the commuter/retail catchment around Golden Grove Village. There are local bus feeder routes within 200m of most homes in Golden Grove, however, these

services have poor service frequencies and often only operate in peak commuter periods. The residential location for the commuter trip comparisons in Golden Grove was chosen to be a more realistic representation of the average access distance of households within the typical commuter catchment of the Golden Grove interchange. Bus based public transit can perform competitively if commuters reside close to or over the interchange, however, few residents in outer suburban locations in the north-east of Adelaide enjoy this benefit because bus interchanges are often within large sprawling suburban retail precincts, or in parkland settings or surrounded by commuter car parking or non residential areas.

Three types of urban trips by three modal choices (car, EBIke and bus) were compared. Local trips from a residential address representing an average local trip distance for dwellings in the retail catchment of the Golden Grove Village shopping centre (a radius of 1.1km), commuter trips between a residential address at an average local trip distance for dwellings within the retail catchment of the Golden Grove Village shopping centre and Gate 4 of the UniSA City East Campus on Frome Road in the north-eastern quadrant of the Adelaide CBD; and a typical local CBD trip (by car) from the UniSA City East campus to UniSA's City West Campus.

The Garmin Edge 705 data logger was used to obtain average and maximum speeds over 100m intervals for the duration of each trip. The data logger also noted three-dimensional GPS coordinates (i.e. latitude, longitude and altitude) and mapped each data logging event. To simplify the analysis, only major changes in elevation were broadly noted and these were obtained through Google Earth Pro. This was partly due to technical and time limitations in converting the raw GPS data into 3 dimensional positional data. As can be viewed from the data results for the EBIke, gradients when compared over long commuting distances do not significantly commuting speeds, although EBIke battery life is affected. The impact on EBIke battery life of gradient was beyond the scope of this research study. However, there is a 170m+ difference in elevation between the two locations, and the bike computer indicated that the descent consumed around 20% of a full battery charge compared to half of the battery charge on the ascent in the opposite direction.

Smaller trip intervals as small as 1m were possible but the memory limitations of the unit necessitated the choice of the 100m interval over a total distance of 23km or more. The data logger did not record delays when stopped due to traffic signals or traffic congestion due to the limited battery life of the unit. Over the arterial road route there are approximately 26 sets of coordinated traffic signals that add approximately 6 minutes of delays in optimal travelling conditions. Each trip was undertaken in the quickest time possible and during times when congestion was minimal. This was done to present the "best performance" case for each mode. Despite this, some delays to the 'optimal' trip times arose due the road-works for the OBahn tunnel project on Hackney Road, which resulted in reduced speeds along 2km of roads approaching the city centre and closure of a 1.0km stretch of the Torrens Linear Park under the Hackney Bridge, necessitating a minor detour and between 2-5 minutes of delays. The car mode was not affected by this delay, however roadworks to repair burst water mains affected the route in two locations along North-East Road. The city location for each of the trips was the author's workplace, located at Gate 4 of the University of South Australia's City East Campus on the north-eastern edge of Adelaide's CBD on Frome Road. The research did not involve any additional human subjects, apart from the author who carried out the trip recordings hence human research ethics approval by the university was not required in this research. Tables 1-3 illustrates the trip types and modes compared in this research. The data logs compared door to door travel times as close as possible to the optimum free-flow traffic situation for the route concerned.

The Garmin Edge 705 GPS unit resembles small pre iPhone mobile phone handset, and was secured to the EBIke bicycle rack, which allowed almost uninterrupted access to GPS satellite signals. When travelling on a bus, the GPS unit was held as close to a side window as possible for the duration of the measurements. The operation of the GPS unit in a car was more problematical. GPS satellite signals were occasionally interrupted with a few erratic instantaneous speed readings (including one of 4000km/h!). These occurred when either high

sided vehicles or trees obstructed satellite signals and inspection of the associated map readouts confirmed a loss of satellite signals. Erroneous readings were excluded from the final analysis and estimates made using readings before and after the erratic reading and spot maximum readings.

There are numerous EBikes now available on the Australian market that range from after-market motor and controller kits, to fully integrated EBikes. The entry price is usually about \$1000, however, most specialised bicycle retailers charge at least \$1500 for a basic EBIke without accessories from a reputable manufacturer. The EBIke used for the performance testing of EBIke performance was a BH Emotion EVO mountain bike fitted with a 12 volt 36A.h (432Wh) Samsung Lithium Ion battery pack. This particular model is a mainstream offering in the European EBIke market, and is neither entry level or particularly expensive at around \$4000 (including all accessories).

The factory weight of this bicycle is 23.4 kg but in modified form with high output lighting accessories (including a Serfas 2500 lumen headlight system), rear lights, sliding removable double panniers, seat post bag and side mirror, the weight increased to 27.4kg. The manufacturer rates the maximum road weight for this transport system of 165kg allowing a net payload for the rider and luggage of 137.5kg. In hot weather a backpack hydration water bladder kit was used to ensure adequate hydration of the rider adding 2-3kg in weight. This type of bike has front shock absorbers, useful in negotiating the uneven surfaces encountered on on-road cycle lanes and on the Linear Park off-road shared bike route. The rear wheel is fixed (described as a 'hard tail') and encompasses a 350watt hub electric motor restricted to 250 watts of output and pedal assistance up to 25km/h, however on steep downhill runs it is capable of 60km/h under supplemented human power and gravity. The electric motor has regenerative braking feature that captures energy normally lost through braking to improve battery endurance on a charge from 20% to 35%, to provide a range of 90km. Subsequent models have improved with a range of 110km. Electrical energy consumption is 4.8 W.h/km, approximately 17c/100km at current prices for electricity bought off the grid and not including the access charge to the grid to access electrical energy.

The rear gear derailleur has 10 gear cogs, whilst the pedal cranks have 3 cogs. There are models of electric bicycles that dispense with gears because the high torque of the electric assistance allows good acceleration in most conditions, however, because of the steep gradients involved in the test trips (up to 25%), a geared EBIke was considered essential. The EBIke was purchased approximately 1 year ago (June 2015), and has now covered 2000km. The electric motor assistance is controlled through a removable LCD-panel mounted on the handle bars, which has 6 stepped modes ranging from no assistance, through to full assistance up to 6 km/h without pedalling, then eco, standard, sport and boost. Security is achieved by removing the LCD panel which when removed, renders the motor inactive, although the EBIke can still be ridden without assistance. During the tests, the sport mode was used in most situations, with boost applied to all gradients that were encountered. These settings appeared to provide the highest commuting speeds without undue fatigue although after an hour, one can still come away with more than double your resting heart rate. The EBIke did have a few teething problems with a non-standard front wheel resulting in vibrations, and a rear puncture after covering about 1600km. The puncture was problematical to repair requiring specialist technical assistance because of the need to ensure that rear hub motor was correctly reinstated. Moving the EBIke to a Bike Repair shop was also problematical because of its weight. EBikes with pedal crank motors would avoid this complication, but are more expensive.

BH is a Spanish bicycle manufacturer and this particular model of EBIke complies with the European standard EN15194 for electrically power assisted bicycles. This standard has also been adopted by Australian regulators through Australian Design Rules (Johnson, 2012) allowing such EBikes to be imported to Australia and ridden on Australian roads. The concept of the EBIke is not a particularly new concept. However, what has revolutionised the EBIke as a practical form of transport is the advanced nature of the electronic electric motor

management using a torque sensor and fine manufacturing tolerances that allows power and/or speed to be restricted and phased in to complement the human power strokes applied through the pedal crank, and progressively reduce assistance when the 25km/h speed limit is reached. The high quality of manufacturing also ensures outstanding component durability and longevity, with the electric motor and battery rated to provide 100,000km and 20,000km of service life respectively.

There is still a learning curve required for the rider, however, most EBike assistance systems phase in power in such a progressive and natural manner, that an EBike feels little different to ride compared to a manual bicycle, apart from a the rider feeling considerably more energetic. High acceleration requires strong and sustained pushing on the pedal cranks, and assistance cuts out completely if the brakes are applied. The nature of the electric motor controller is such that there is little risk of unintended acceleration, and once the rider has chosen their preferred power setting, the EBike is ridden without having to manage the power system, in contrast to a powered vehicle where the motor vehicle travels at speed and the driver has to manage this through steering, gears, cruise control settings, an accelerator or brake.

The unexpected benefit of an EBike is that in situations requiring quick acceleration from a standing start such as when merging with traffic or making a right turn on the road, the rider can complete these manoeuvres with much greater certainty and confidence than on a manual bicycle. The downside of the EBike however, is poor manoeuvrability at low speeds and significant deadweight if it becomes necessary to manually lift the bicycle up stairs as a pedestrian or for transporting. Table 1 details the trip survey parameters and basic survey findings for the EBike trips conducted (i.e. local suburban; long distance commuting both directions via the road network; long distance commuting via a mix of suburban arterial and the Linear Park shared cycle path in rainy weather; and long distance commuting in both directions via the Linear Park). Secure parking of an EBike is its Achilles Heel, in that it is sufficiently mobile to be moved by a person, and therefore poses more of a theft risk than would be the case for a standard manual bicycle. The EBike used in this test came with a manufacturer serial number prominently stamped on the frame, which may deter theft. Table 2 details the survey parameters and basic findings for the EBike trips undertaken.

The car used for the road trips in this research was a 2016 model 2 litre 6 speed DSG automatic VW group passenger car product, rated at 162kW, with engine auto stop function when stationary and average fuel economy of 7.8l/100km in suburban motoring. The car used for the tests was a 5 passenger vehicle with a payload of around 600kg and an unladen kerb mass of around 1475kg. The car's Bluetooth connectivity now allows Adelaide's traffic controllers to anonymously measure the car's speed between traffic signals using the car's Media Access Control (MAC) address, to optimise traffic signal phasing accordingly and provide traffic alerts through a mobile phone app called Addinsight that operates via the handsfree phone function in the vehicle's Bluetooth enabled stereo. Whilst the car can accelerate to 100km/h in 7 seconds and achieve a maximum speed of over 240km/h, there is actually little opportunity or sense in exploiting this level of performance in Adelaide's suburban road environments. Energy consumption is 748 W.hr/km, or 156 times more than for the EBike, although this ratio would drop to 47 if the car's passenger capacity is fully utilised to carry 5 people. Direct energy costs are around \$9.90/100km or 58 times more expensive than an EBike (dropping to 12 times if the full passenger capacity is utilised). The competitive edge of the car for suburban commuting is the capability when traffic conditions permit, to travel at the prevailing speed limit on a road system with traffic flows and speeds that are optimised using Bluetooth connectivity. The time required to park the car upon reaching its destination and walking the remainder of the distance to the office destination (essentially crossing a road and walking 150m), was not included in the trip recording nor were the costs of parking (up to \$30/day) factored into this comparison, however, with EBike parking costs being negligible, this would be substantial. Table 1 details the basic trip survey parameters and survey findings for the local (*city and suburban*) and long distance commuter trips made by car.

Cyclists can benefit from Bluetooth technology too if they have their mobile phone on, however, the system is usually optimised for motor vehicles travelling as close to the speed limit as possible. With all of the cycling test trips, a mobile phone was carried, which may have allowed the same traffic efficiency and safety benefits from the phone's MAC address. The safety benefit of traffic management authorities utilizing Bluetooth connectivity for law abiding attentive cyclists and motorists alike is that traffic signal changes are perfectly timed to hold a green signal if at the tail of a convoy of vehicles or phase a red signal in sufficient time to allow a safe stop without the risk of running a red traffic signal.

The buses utilised on the two trips measured, were 235kW diesel 67 seater Scania bi-articulated buses. Buses of this type typically consume about 40-60 litres/100km full laden, equating to 87 W.hr/km at maximum passenger occupancy (i.e. 12-18 times that of an EBike). The trips were taken late on a Sunday with an average passenger occupancy of about 30% for the city bound trip and 5% for the outwards bound trip to Golden Grove Village. OBahn service speeds were originally as high as 100km/h but this has been reduced to 85km/h because of a track vibration issue. Despite the posted maximum speed limit on the track now reduced to 90km/h, the lower travel speeds have only added 2-3 minutes to commuting trip times. Table 3 details the basic trip parameters and survey findings for the long distant commuter trips made by bus.

**Table 1: Car commuting trip characteristics in north-eastern metropolitan Adelaide**

Mode	Route	Trip start	Trip end	Length (km)	Moving Average speed (km/h)	Max. speed (km/h)	Date	Start time of trip & moving trip time	Traffic conditions
<b>Car</b> (Car1)	Local streets, Atlantis Drive, The Grove Way, The Golden Way, McIntyre Road, NE Road, Bundeys Rd, War Memorial Drive, Frome Rd	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Adelaide City-Frome Rd RAH carpark, UniSA City East Campus	21.3	55.1	78.6	3/6/16	11.21am 23.2 minutes (moving)	Free-flowing. Level of service (5)
<b>Car</b> (Car2) (Adelaide CBD-Local)	Frome Rd, Grenfell St., Currie St., Light Square, Morphett St, Hindley St.	Adelaide City-Frome Rd RAH carpark	Adelaide City-Wilson Car park, UniSA City West Campus	2.7	26.5	45.3	3/6/16	Midday 6.1 minutes (moving)	Light congestion. Level of service (3)
<b>Car</b> (Car3) (local: Golden Grove suburb to Golden Grove Village)	Maygar PI-Partridge Crt-Cutler St.-Valour Crt-Atlantis Dr.	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Golden Grove Village (nearest junction-Atlantis Dr and The Grove Way)	1.6	35.9	51.2	2/6/16	11am 2.7 minutes (moving)	Free-flowing. Level of service (6)
<b>Car</b> (Car4)	The Grove Way-The Golden Way-	Golden Grove Village (nearest	Golden Grove (residence 1.5km	2.3	44.0	62.3	2/6/16	11.15am	Free-flowing.

<i>(local: Golden Grove Village to Golden Grove suburb)</i>	Asgard Dr- Atlantis Dr-Valour Crt-Cutler St- Partridge Crt- Maygar Pl	junction- Atlantis Dr and The Grove Way)	northeast of Golden Grove Village)					3.1 minutes (moving)	Level of service (6)
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**Table 2: EBike commuting trip characteristics in north-eastern metropolitan Adelaide**

Mode	Route	Trip start	Trip end	Length (km)	Moving Average speed (km/h)	Max. speed (km/h)	Date	Start time of trip & moving trip time	Traffic conditions
<b>EBike</b> <i>(EB1)</i> <i>(Arterial roads only)</i>	Golden Grove to city- Atlantis Drive, Grove Way, Golden Way, McIntyre Rd, NE Rd., Stephens Tce, 1 <sup>st</sup> Ave, Harrow Rd, Richmond Rd, Plane Tree Drive, Hackney Rd	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Adelaide City- Gate 4, Frome Rd City East Campus, UniSA	20.8	31.9	59.6	14/6/16	11.00am (39 minutes)	Free-flowing. Level of service (6)
<b>Ebike</b> <i>(EB2)</i> <i>(In torrential rain: Golden Grove suburb via McIntyre Rd and Linear Park)</i>	Golden Grove to city- Atlantis Drive, Grove Way, Golden Way, McIntyre Rd, Linear Park cycleway	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Adelaide City- Gate 4, Frome Rd City East Campus, UniSA	23.0	28.3	57.8	2/6/16	1pm (48.8 minutes-moving)	Free-flowing. Level of service (6)
<b>EBike</b> <i>(EB3)</i> <i>(From city via road network to Golden Grove)</i>	City to Golden Grove- Stephen Terrace - Walkerville Terrace – Vale Street – Harris Road – Fife Street – Wilpena Avenue - O.G. Road - The Golden	Adelaide City- Gate 4, Frome Rd City East Campus, UniSA	Golden Grove (residence 1.5km northeast of Golden Grove Village)	21.9	26.1	45.0	3/6/16	11pm (50.3 minutes-moving)	Free-flowing. Level of service (6)



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	Way – The Grove Way – Atlantis Drive								
<b>Ebike</b> (EB4) <i>(Golden Grove to city via linear park)</i>	Golden Grove to city	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Adelaide City- Gate 4, Frome Rd City East Campus, UniSA	23.4	23.8	58.5	19/6/16	12pm (59 minutes-moving)	Free-flowing. Level of service (6)
<b>Ebike</b> (EB5) <i>(From city via linear park)</i>	City to Golden Grove	Adelaide City- Gate 4, Frome Rd City East Campus, UniSA	Golden Grove (residence 1.5km northeast of Golden Grove Village)	23.2	23.3	43.0	19/6/16	11pm (59.7 minutes-moving)	Free-flowing. Level of service (6)
<b>Ebike</b> (EB6) <i>(Local: Golden Grove suburb to Golden Grove Village)</i>	Maygar Pl-Pisani Crt-Cuthbert Crt-Olympiad Crt-Atlantis Dr	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Golden Grove Village (nearest junction-Atlantis Dr and The Grove Way)	1.0	20.3	35.6	14/6/16	10.46am (3.0 minutes-moving)	Free-flowing. Level of service (6)
<b>Ebike</b> (EB7) <i>(Local: Golden Grove Village to Golden Grove suburb)</i>	Atlantis Dr-Olympiad Crt-Cuthbert Crt-Turtur Crt-Partridge Crt-Maygar Pl	Golden Grove Village (nearest junction-Atlantis Dr and The Grove Way)	Golden Grove (residence 1.5km northeast of Golden Grove Village)	1.1	23.7	45.0	3/6/16	11pm (2.8 minutes-moving)	Free-flowing. Level of service (6)

**Table 3: Bus commuting trip characteristics in north-eastern metropolitan Adelaide**

Mode	Route	Trip start	Trip end	Length (km)	Moving Average speed (km/h)	Max. speed (km/h)	Date	Start time of trip & moving trip time	Traffic conditions
<b>Bus</b> <b>B1</b> <i>(Golden Grove Village Inter-change to city (Royal Adelaide Hospital stop))</i>	C1 Bus route, the Golden Way-The Grove Way-Golden Grove Rd-OBahn-Hackney Rd-North Tce	Golden Grove (residence 1.5km northeast of Golden Grove Village)	Adelaide City-Frome Rd RAH carpark, UniSA City East Campus	22.9	31.5	91.0	5/6/16	4pm (43.6 minutes-moving)	Free-flowing. Level of service (5)
<b>Bus</b>	C1 Bus route,	Adelaide City-	Golden Grove	23.3	31.5	87.9	5/6/16	9pm	Free-flowing.

<b>B2</b> (Golden Grove Village Inter-change to city (Royal Adelaide Hospital stop))	North Tce-Hackney Rd-OBahn-Golden Grove Rd-The Grove Way-The Golden Way	Frome Rd RAH carpark, UniSA City East Campus	(residence 1.5km northeast of Golden Grove Village)					(44.2 minutes-moving)	Level of service (5)
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Maps of the routes examined in this research are presented in the discussion of results.

### 3. Analysis and discussion of results

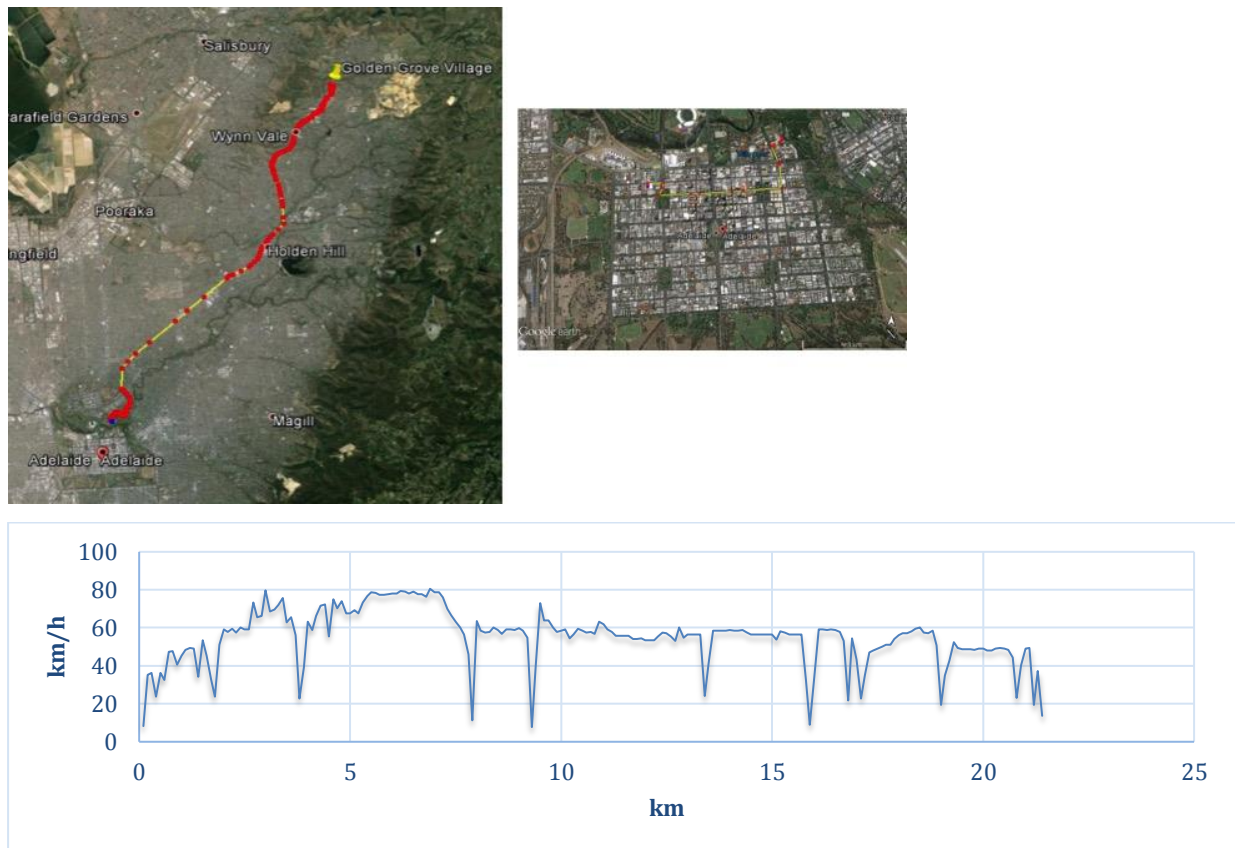
This research set out to investigate the capability of EBikes as a commuter option in an outer metropolitan Adelaide suburb, by comparing its performance with the private car and buses. The novel aspect of this investigation is that four bicycle route options were explored, two completely reliant on the road network, a hybrid blend using lightly trafficked outer suburban arterial roads with the Linear Park shared cycle path and the other using the Linear Park shared pathway for almost all of the route. Challenging changes in elevation (170m+) and distance (+20km), which make conventional cycling virtually impossible for ordinary cyclists, were an additional test of the EBIke. The discussion that follows compares EBIke performance for the routes discussed against other modes, for local suburban and long distance urban commuting, as set out in tables 1-3 above.

The private car in outer suburban Adelaide, is still the quickest form of travel, however, the margin is not dramatically better than for the other modes. The moving average speed in free-flowing uncongested traffic conditions was 55km/h over a distance of 21km, achieved in off-peak driving conditions in late morning on a weekday. A maximum travel speed of 79km/h was reached on McIntyre road, an 80km/h arterial road in the outer suburbs. The fastest EBIke performance (EB1) (table 2) by comparison, attained a moving average speed of nearly 32km/h travelling over a similar route, 60% of the performance of travel by car.

The car moving average speed dropped to 26.5km/h in the CBD for an east-west trip across the Adelaide CBD on the same day. Local area speeds, in Golden Grove, a suburb with a hierarchical road system designed to maximum motor vehicle speeds and local area road safety by restricting high speed motor vehicle traffic to through routes and liberal use of cul-de-sacs, resulted in moving average speeds of 35.9km/h from a Golden Grove residence (located an average catchment distance to the Golden Grove Village) using the most direct route on local roads and 44.0km/h using a longer different route (2.3km versus 1.6km) with faster roads. Peak speeds were 51km/h and 62km/h respectively for these routes. An EBIke of the kind used in this research would provide competitive journey speeds and travel times in the city, providing that bicycle parking is as close to the start and end of the trip as possible. Analysis of the car trips is presented in figures 1-3. City testing was not done in this research because of the lack of safe east-west routes across the commercial heart of the Adelaide CBD for cycling, where bus lanes create an exceptionally hostile cycling environment.

**Figure 1: Car commuter route-Golden Grove to City and within Adelaide CBD**

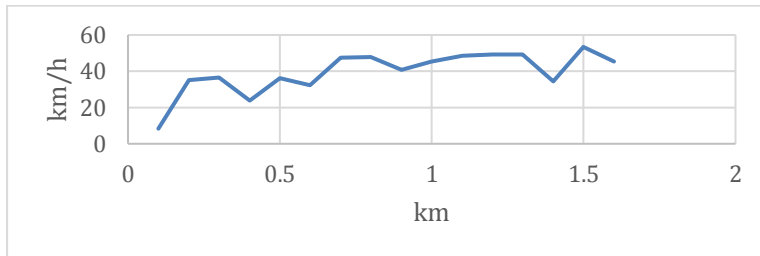
## EBike Performance in Urban Commuting. How does it compare to Motorised Modes?



**Figure 2: Local car commuter routes utilising arterial road-Golden Grove**



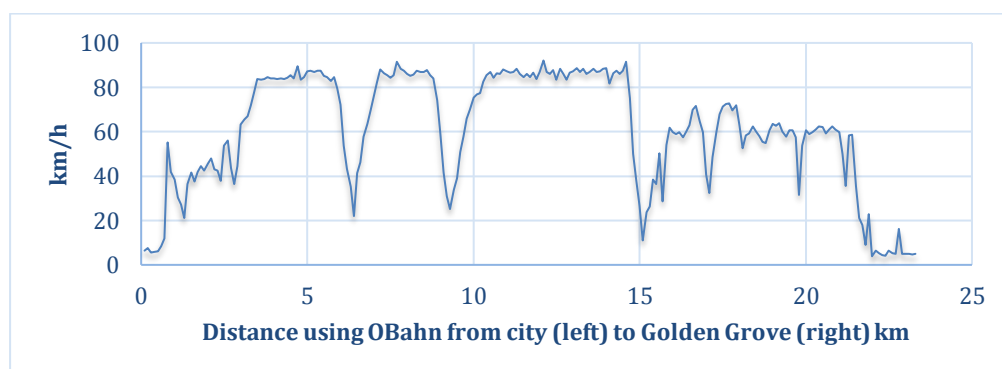
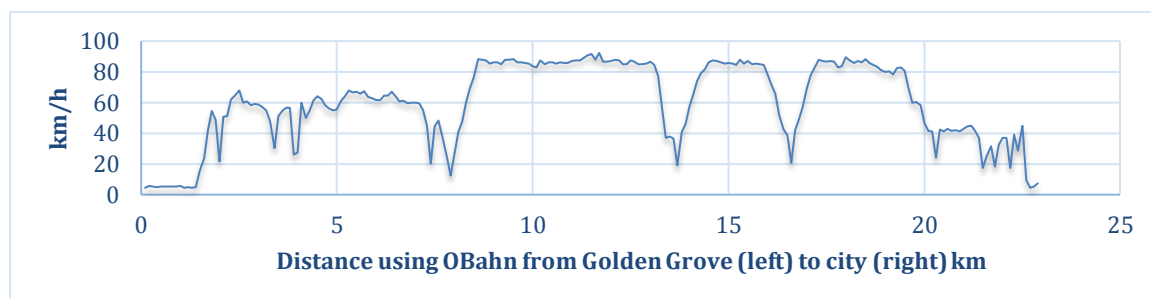
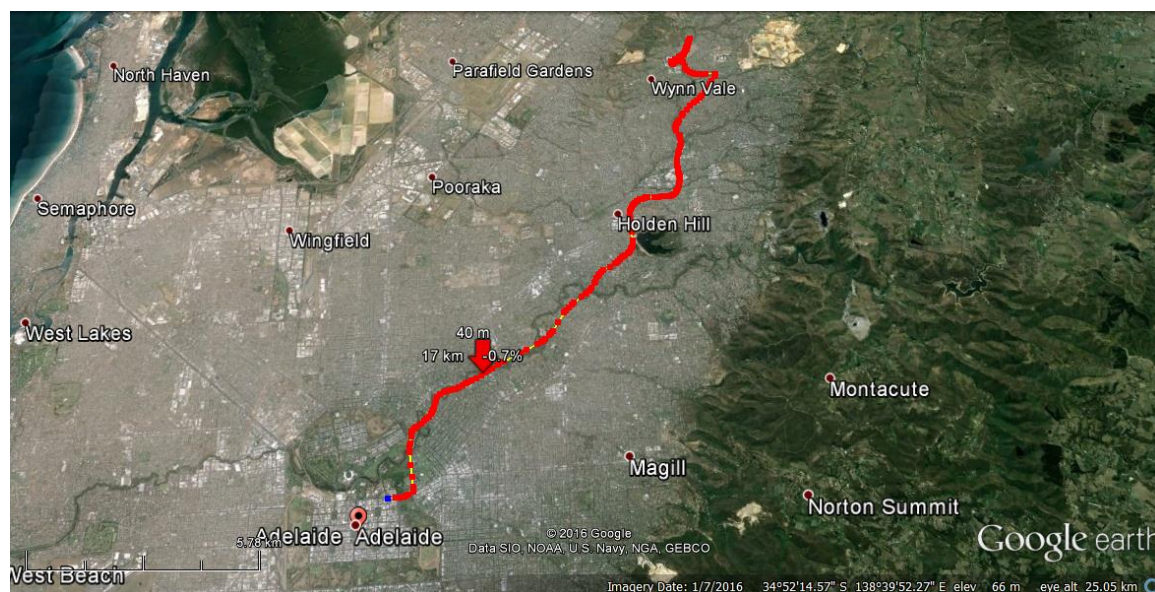
**Figure 3: Local car commuter routes utilising local road network-Golden Grove**



Adelaide's bus services in the north-eastern suburbs take advantage of the 13 km long OBahn, a high speed concrete guided bus track that allows semi-autonomous operation with steering controlled by the guideway. Despite the large change in elevation, overall travel times for the bus services between the Golden Grove Village Bus Interchange and the city were hardly affected, with moving average speeds in each direction (including walking time to the interchange or bus stop), identical at 31.5km/h (figure 4). Speeds are carefully controlled on the OBahn, hence these results are likely to be a reliable indication of service speeds at any time. Congestion rarely affects OBahn services, except when they leave the OBahn and have to join traffic on Hackey Road (at the city end), or beyond the Tea Tree Plaza interchange at the suburban end of the OBahn. The EBike on-road performance exceeded the moving average speed of the OBahn with a moving average speed of 31.9 km/h (EB1 in table 2), admittedly with the benefit of a steep drop in elevation in the run down to the city using McIntyre Road on the arterial road network, a strong tail-wind allowing a peak speed of 60km/h and utilising shortcuts at the start and end of the route that were only available to pedestrians and cyclists (figure 5).

**Figure 4: OBahn bus commuter route, Golden Grove to Adelaide CBD**

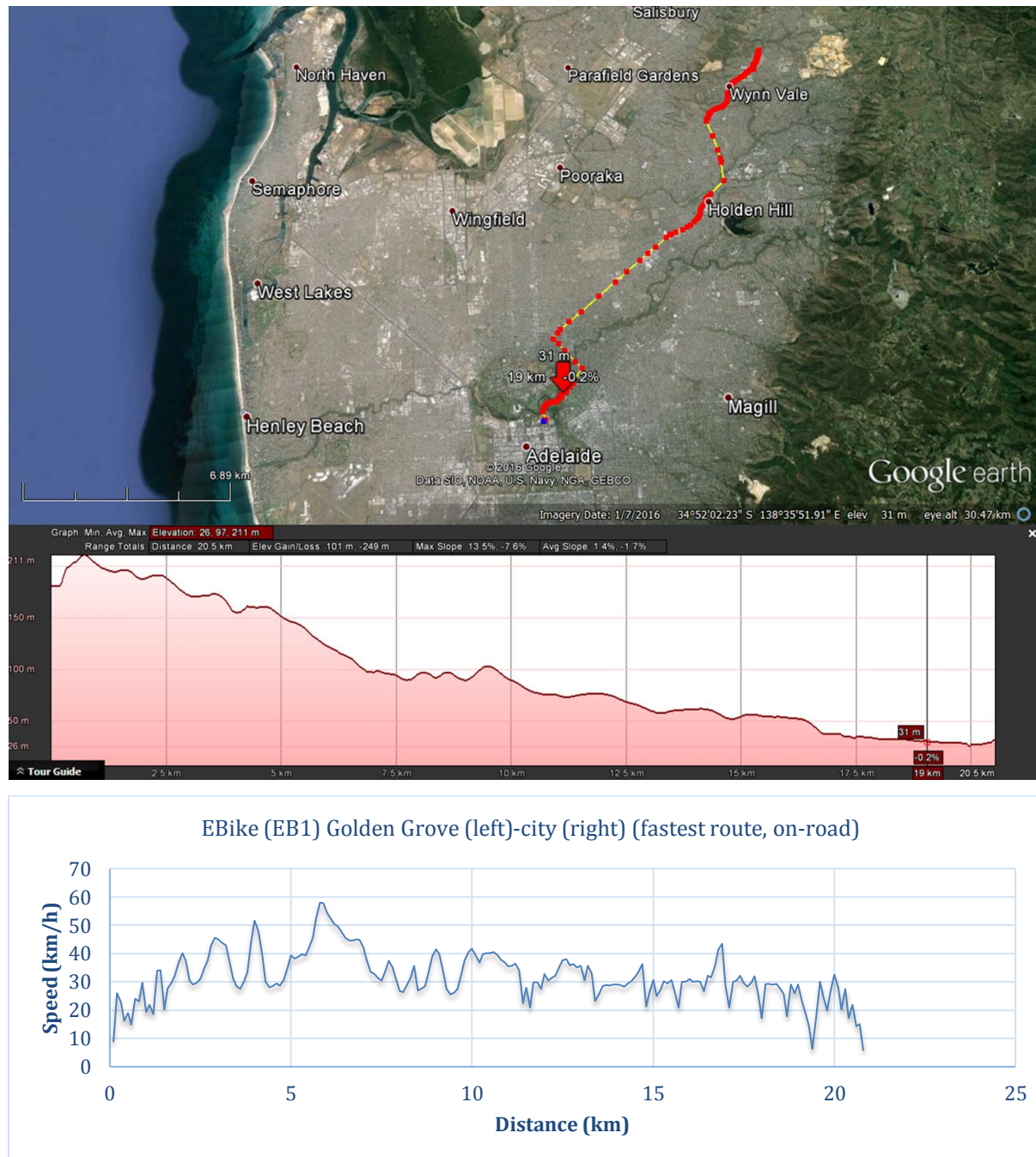




The long distance routing options are varied for the EBike. For the city bound trip from Golden Grove, up to three main route options exist. The arterial road network can be used exclusively, or a mixture of quiet local back streets with some major arterial roads are an option or an alternative (actually numerous alternatives) is to use sections of the Linear Park shared pathway ranging from 30% to 85% of the 22.5km route in conjunction with the road network. The arterial road network has on-road cycling lanes for 70% of the route, however, it is extremely dangerous to use when traffic densities result in all lanes being used by motor vehicles. Northeast Road has a chokepoint where a historic hotel at Windsor Gardens encroaches on the road reservation and the cycle lane stops, there are 8 major intersections unsuited to cyclists and the last 4km of this arterial road are without cycling lanes and it narrows down to two lanes each way within a 60km/h undivided road environment. The compromise route involved leaving North-East Road in the last 4km and travelling on a suburban distributor, local back streets and part of the Linear Park shared cycle path to reach the city. This research compared three routing options, EB1, EB2 and EB4 (table 2). Routing option EB1 utilized the main road network as much as possible and avoided any shared pathways, EB2 was a hybrid route joining the Linear Park shared cycle path where it intersects

with Northeast Road at Modbury whilst EB4 utilized the Linear Park shared bikeway as much as possible.

**Figure 5: Fastest EBike commute from Golden Grove to city achieved via arterial road**



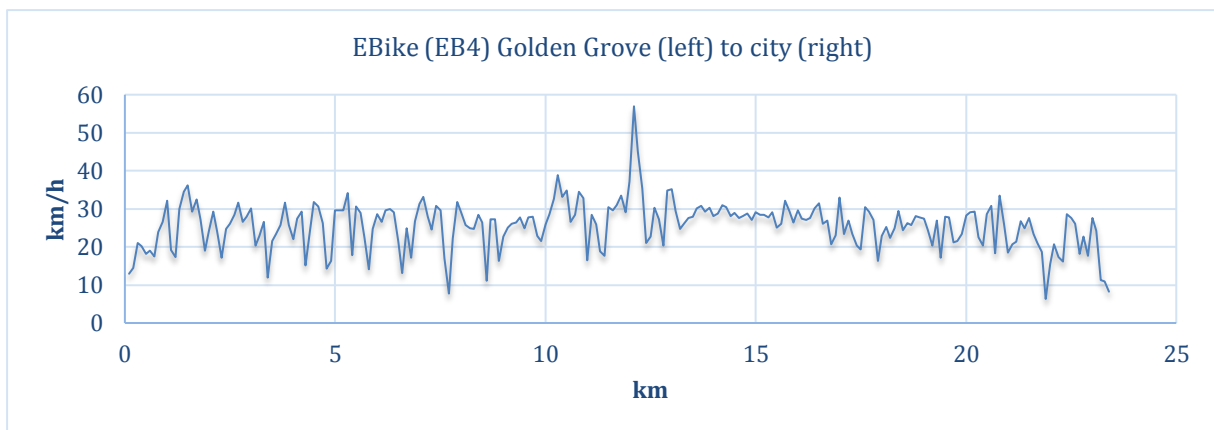
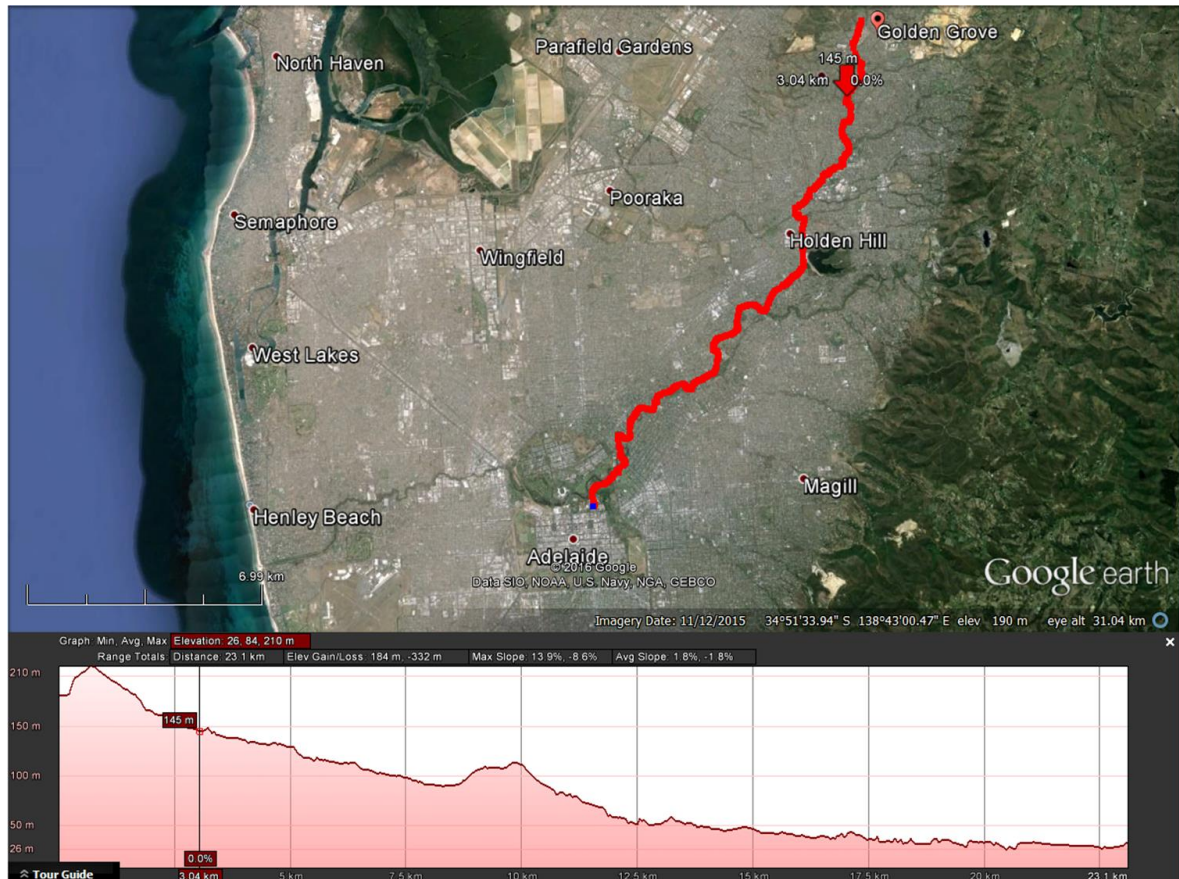
Two routes using the road network are possible for the city-Golden Grove trip by EBike, one using North Terrace – Payneham Road - O.G. Road - North-East Road – McIntyre Road – The Golden Way – The Grove Way –Atlantis Drive, and the other using Stephen Terrace - Walkerville Terrace – Vale Street – Harris Road – Fife Street – Wilpena Avenue -O.G. Road - The Golden Way – The Grove Way –Atlantis Drive (route EB3 in table 2). The former route largely uses cycle lanes on arterial or sub-arterial roads whilst the latter uses local residential through streets that are approximately parallel to the Torrens Linear Park shared cycleway. In high traffic densities, the sensible cycle route to take is the Linear Park shared path (route EB5, in table 2), however, with many parts of the route unlit, its confusing route continuity as

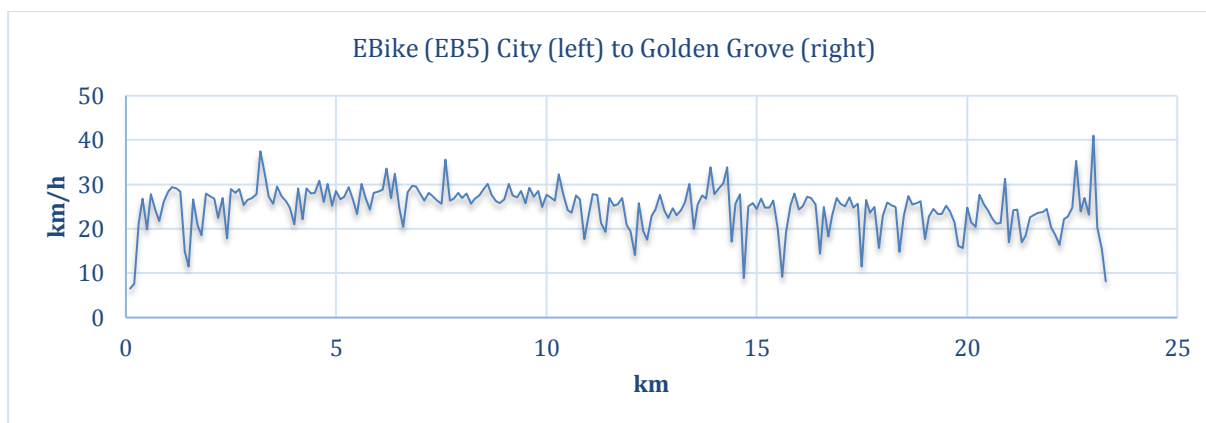


## EBike Performance in Urban Commuting. How does it compare to Motorised Modes?

the path switches river banks without warning, an absence of signposting, numerous sharp curves and abrupt changes in elevation create a constantly demanding riding experience. Figure 6 illustrates the EBike route along the Linear Park, the elevation profile and speed profile.

**Figure 6: EBike commute route using Linear Park for 85% of journey**





Whilst the route to the city using the Golden Way and McIntyre Road is a high speed road environment (70-80km/h), the steep downward gradient allows speeds of 40-60km/h to be reached, however, for the return trip, it is virtually impossible for cyclists to safely negotiate the intersection of McIntyre Road and the Golden Way, because to access the turn right lanes requires crossing two traffic lanes on a steep uphill gradient with an 80km/h speed limit. A safer option is to turn off McIntyre Road at the previous junction with Milne Road, which allows cyclists to rejoin The Golden Way several kilometres further on at a much safer junction, and where a dedicated on-road cycle lane is provided, although still on a potentially dangerous road with a 70km/h speed limit. The paradox of high speed arterial roads is that whilst they have cyclists mixing with dangerously fast traffic, they do allow extraordinarily high continuous cycling speeds and outstanding point to point journey times to be achieved when compared with the shared off-road bike paths which are usually longer (12.5% in this case) and slower (up to 25% slower). The jagged speed profiles for travel on the Linear Park compared to travel on the main road, illustrates why shared off-road cycle pathways are relatively hard work (compare the speed profile of figure 5 (on-road) with figure 6 (Linear Park)).

The safety risk of using an EBike on an arterial road can be reduced through constant use of a rear view mirror to maintain full awareness of traffic conditions behind, a strong headlight (although not so strong that it is blinding), a safety helmet, fluorescent ankle straps, high visibility strobe lighting and reflective clothing. A motor vehicle licence is also a considerable asset, in that it inculcates a better sense of road-craft and expectations of motorists' behaviour. The advantage of the cycling options in the north-east corridor of Adelaide, is that the cyclist has many opportunities to leave the main road route if it is uncomfortable because of congestion, and join the Linear shared cycle-path, provided that the cyclist has a high level of familiarity with the road network. Local and State Governments have not made much of an effort in publicizing the Linear Park as a commuter cycling corridor, and this is reflected in negligible cycling activity beyond incidental recreational cycling with children on weekends on very short stretches of the Linear Park shared cycle path (i.e. 2km or less), particularly at distances greater than 8km from the city centre.

For local EBike trips in the Golden Grove Village residential catchment, the local transport network is oriented towards the pedestrian and cycling networks having direct routes to the Golden Grove Village shopping/Schools campus/Community facilities precinct. A hierarchical road system results in more lengthy and circuitous routes, and this is reflected below in figure 7. Although the car is the quickest mode from a residential address to Golden Grove Village, the margin is small (2.1 minutes versus 3.5 minutes over a very steep climb) and indeed, with the longer car route, the EBike can match the car (3.1 minutes), by virtue of the shortcuts through cul-de-sacs and a more direct route for the EBike (with less than half the road distance required).



Figure 7: Local EBike travel, Golden Grove Village catchment

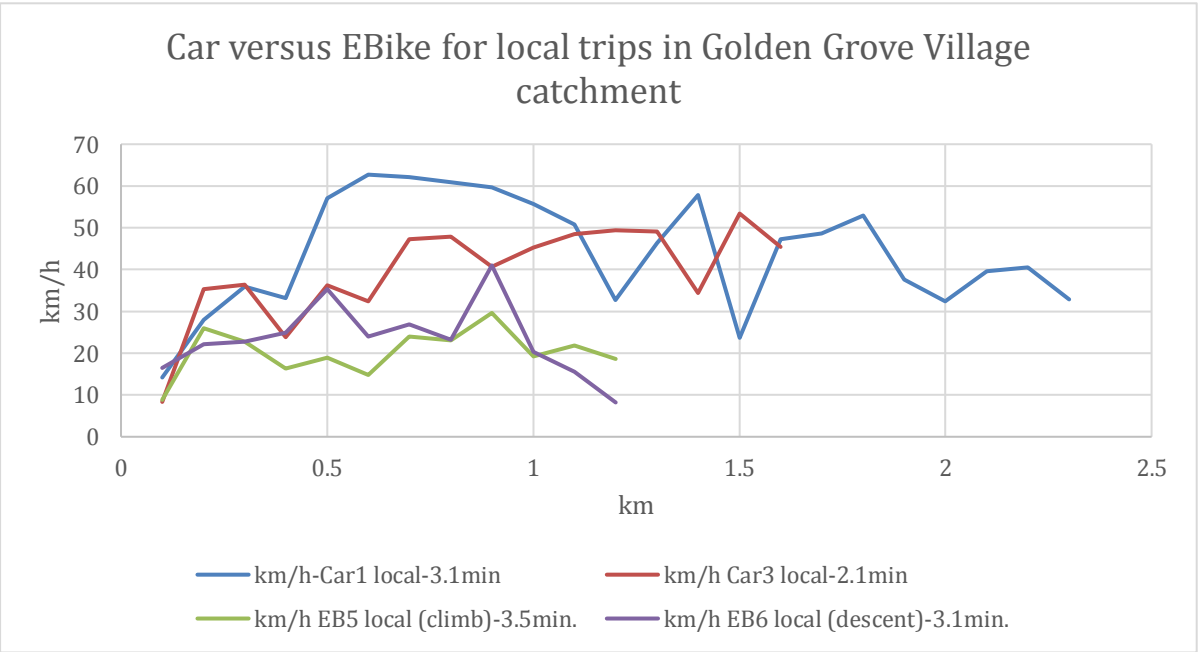
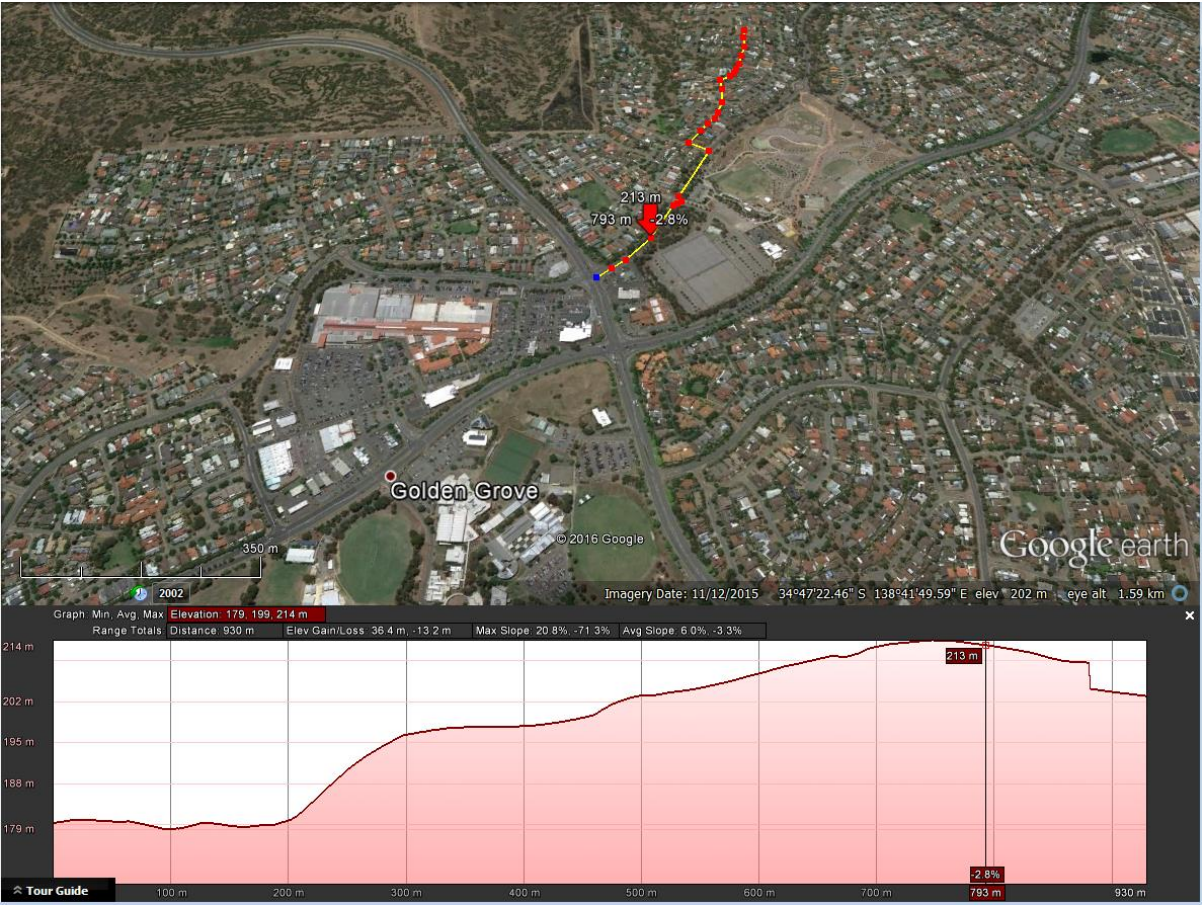
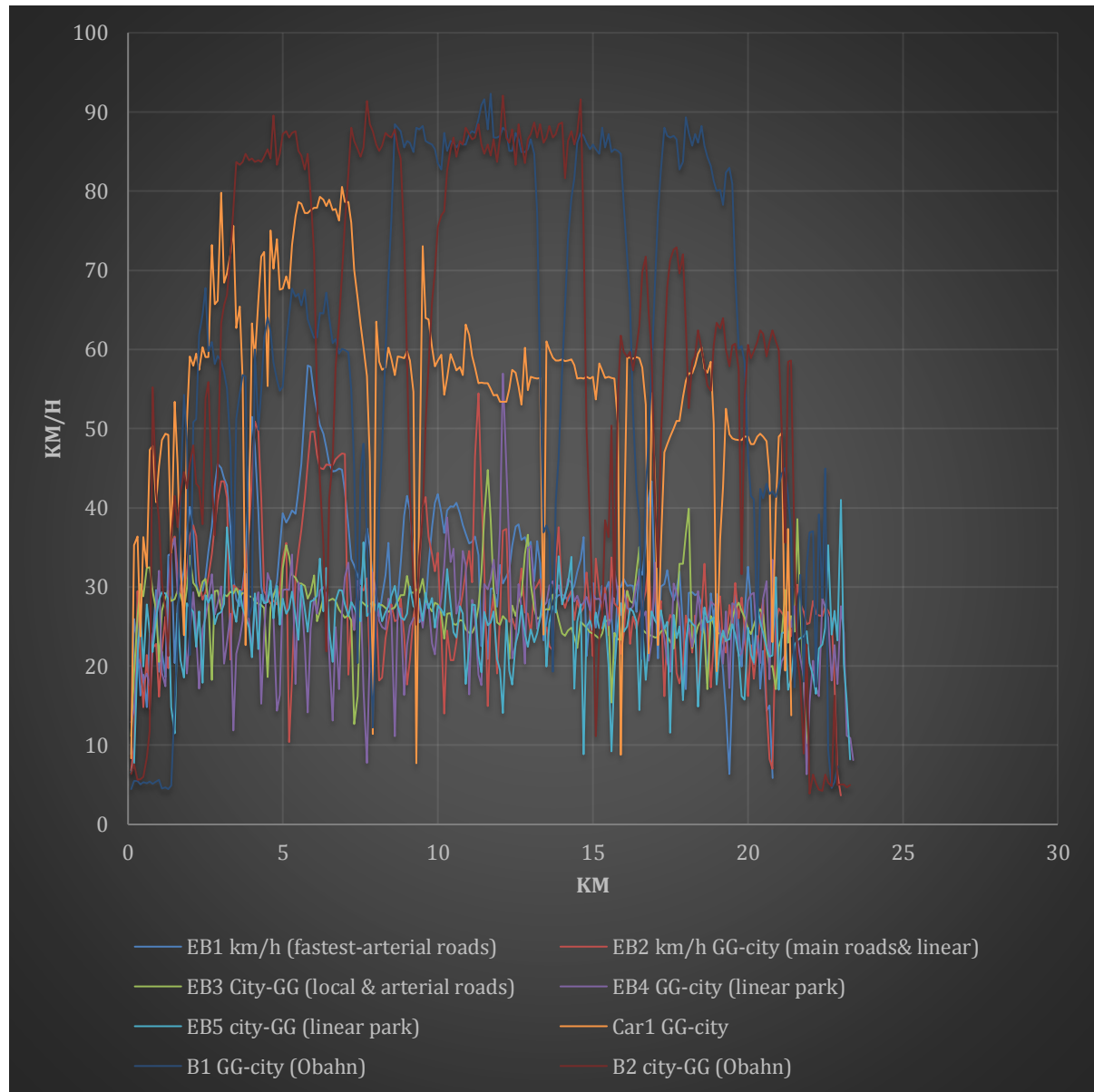


Figure 8 compares all of the commuting options compared in this research, dramatically highlighting the performance profiles of EBike commuting with motorised commuting. Whilst EBike commuting is a stretch at distances of 20 or more kilometres, for distances of half this length, it offers a viable commuting option both in terms of travel time, speed, payload capacity and door to door journey flexibility.

**Figure 8: EBike commuting versus car and bus (OBahn) between Golden Grove and city**



## 4. Conclusion and Policy Implications

EBikes (or Pedelects) are a relatively new phenomenon in Australia. Whilst for consumers, there appears to be plenty of choice of EBikes, the take up of EBikes has been low, which partly reflects the low level of commuter cycling in Australian cities, and the high cost of entry into the EBike market. This research has shown that EBikes are a competitive alternative to bus public transit, even so-called express services in a metropolitan context such as Adelaide's OBahn and can compete with motor vehicle trip performance (in terms of travel times and door to door capability). However, a caveat to EBikes and cycling generally, is that if cycling were to increase in popularity to a level where a cyclist cannot set their own pace

either on the road or on dedicated cycling paths, where the pace of cycling is set by the slowest rider because of the single file nature of cycling infrastructure, then the impressive trip performance speeds and times achieved in this research with an EBIke would not be possible, resulting in the mode unable to provide a competitive alternative to motorised forms of transport for medium to longer distance urban commuting in the volumes required. Recreational cycle paths such as Adelaide's Torrens Linear Park, which provides an off-road cycling route spanning the entire east-west width of metropolitan Adelaide, albeit shared with pedestrians, work very well from a traffic safety perspective in minimising the potential for conflict between cyclists and motor vehicle traffic, however it is limited to single file cycle traffic at very low cycling densities. A further caveat to this research is that an EBIke relies on competitive trip times with motorised modes only if there is door to door trip functionality (i.e. where the EBIke pick-up and drop off parking locations are collocated with the trip origin/destination, as was possible in this research. In reality, many commuters may not have convenient bicycle parking co-located at their workplace or intended destination. A final caveat is that safe cycling does require time consuming preparation that does not factor into travel by car or public transit. Adding lighting and wearing appropriate safety equipment (i.e. helmet, high visibility clothing and legging straps, personal hydration in hot weather), setting up panniers, stowage of charging and security equipment, can add 2-4 minutes to each trip. EBIke manufacturers could assist in minimising cycling preparation time by providing products that have fully integrated accessories and built-in security measures. Charging infrastructure may be required at the end of a destination for EBIke commuters undertaking a very long commute. In the EBIke tests conducted, the EBIke was charged at the end of each trip (i.e. at the author's office in the city), although during tests not described here, it is possible for the EBIke to complete a 46km round trip commute on a single charge, even when using the 'sport' and 'boost' modes. However, maintaining high speeds on the Linear Park was found to be very draining on the battery, with what appeared to be a one third reduction in range, because of the difficulty in maintaining a high constant speed.

The key policy implications of EBikes relate to on-road infrastructure, shared path infrastructure, secure EBIke parking, EBIke riding skills and EBIke charging infrastructure. A rider of average fitness can easily maintain speeds of 30km/h over most terrain using the Sport and Boost modes on an EBIke, which creates potential conflict with slower 'manual' bicycles. The single file approach to cycling provisioning needs updating to accommodate faster commuter cyclists on both off-road shared cycle-paths such as Adelaide's Linear Park and on the road network. The analysis of travel along the Linear Park demonstrates the attention demanding nature of recreational cycle paths and their inherent inefficiency both in the overall length of the trip made (10-20% longer) and the continual variation in speeds which are energy sapping. Commuter cycling might best be served by utilising existing main road routes, however, bicycle rider safety remains a real risk. A better approach would be to have dedicated urban commuter cycle routes, with the directness and modest gradients of the suburban arterial road system. The issue for policy-makers is where these can be provided. London's 'bicycle highways' utilize existing urban roads but are still compromised by being restricted to largely single file travel. Upgrading pathways through urban linear parks may be the most feasible option, and where this is not possible, either elevated or underground cycle routes along arterial road alignments may be worth considering. At the very least, there needs to be an effort invested in improving the continuity of commuter bicycle routes and in ensuring that there is adequate wayfinding. In Adelaide's north-east, most of the bicycle routes are highly fragmented and a keen cyclist needs to undertake considerable prior planning to work out safe, reliable and direct routes (and contingency plans).

In the future, each EBIke could be fitted with a mobile phone MAC address to enhance safety when approaching intersections and which when combined with vehicle to vehicle communications, would warn of potential hazardous traffic conflict. Ebikes are quite different compared to a conventional bicycle, and cannot be easily lifted, hence EBIke parking requires specialised parking arrangements, ideally with the option of electric charging. For cycling to more effectively compete with motorised modes, EBIke parking options in centres and the

CBD need to be ubiquitous so that end destinations are no more than a few minutes' walk away from where a bicycle is parked.

EBikes do require a high degree of rider confidence, especially geared bicycles and because of their much greater speed potential, rider education on rider safety, the road rules, correct use of lighting and etiquette should be considered as essential for riders without a motor vehicle licence. The technical design standards of EBikes in Australia follow the European standards, hence Government would not need to provide additional regulation. Nevertheless, there is the potential for illegal modifications that could result in performance that approaches that of mopeds or small motorcycles, and enforcement could become an issue if there was widespread take-up of EBikes. Hostility to EBikes from pedestrian lobby groups may also need to be managed. In South Australia, the recent introduction of the 1m safe gap rule on roads with a speed limit of 60km/h speed limit or less (1.5m above 60km/h) and allowing cyclists to ride on the footpath, provoked sustained and vociferous protest in the popular local print and radio media and amongst state politicians since its introduction in late 2015.

However, appropriate development of policy and infrastructure for EBikes and cycling are hampered by a dearth of information on the nature of the bicycle fleet (including what the actual sales of EBikes are), comprehensive reliable statistics on usage and reliable documentation of cycling infrastructure assets both in terms of what is currently in the public domain and its quality. Australia still has a long way to go in effectively planning for EBikes and cycling generally, however, recent work in Halmstad, Sweden (Lundh, 2016) and London's transformation towards a cycling friendly city provides an interesting insight and inspiration into how EBikes and cycling more generally can be promoted as an urban transport mode in the community.

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