PERSONAL RAPID TRANSIT APPLICATION IN RETROFITTING EDGE CITIES –MACQUARIE PARK CASE STUDY

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ABSTRACT

This paper investigates the implications of alternative land use and transport strategies for Macquarie Park, a typical high car-dependent “edge city” within an emerging Australian multi-centred city form. Detailed simulations compare a transport scenario that incorporates a Personal Rapid Transit (PRT) network as a feeder for the existing transit nodes to a business-as-usual projection by 2030, and one reflecting current planned transport improvements (“Planned”). The environmental and urban impacts of the three scenarios are evaluated based on estimated differences in energy use, emissions, noise, and land area required for car parks. The PRT system was found to reduce the annual CO2 emissions by more than 26,000 tonnes compared to the business-as-usual scenario and by more than 9,000 tonnes compared to the “Planned” scenario. The avoided public costs associated with emissions, noise and air pollution are US$13M per year compared to a continuation of present trends and more than US$5M compared to the planned transport improvements. A positive urban impact occurs from the smaller amount of land required for parking spaces. The greatest benefit of the PRT is a potential capital cost saving of more than US$430M from building car parks. A convenient and appealing local access solution such as Personal Rapid Transit could bridge the gap between the existing car-dependent urban forms and the transit-focused urban future.

Keywords: Personal Rapid Transit, edge cities, transport emissions, air pollution, urban impact

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Introduction

There is a broad consensus that accommodating car dependency in the 21st century’s cities is unsustainable from every perspective, local or global (Mees, 2009; Steg and Gifford, 2004; Newman & Kenworthy, 2007; UNEP, 2011). The argument for strategies and interventions for diminishing the reliance on cars is still ongoing. Planning policies for sustainable development are inherently complex not only for the low-density complex regulatory instruments. ‘Edge cities’ are some of the newly emerging city structures. These centers tend to be highly planned at the local level, but are often poorly integrated into the larger regional context and are thus highly car-dependent. Although most of the planners are dissatisfied with the urban form (Scheer & Petkov, 1998), the edge cities are a result of the development economics and thus, they are economically successful. In Australia, the concept of ‘edge city’ has not been thoroughly investigated. In this paper we suggest that this urban form can be recognised in Sydney too, identifying Macquarie Park as having all the characteristics of a typical ‘edge city’.

The Macquarie Park case study examines the potential of a non-traditional transport solution – Personal Rapid Transit (PRT) to retrofitting a key ‘edge city’ in an Australian context. This paper presents a preliminary analysis of selected environmental and urban impacts of three different transport strategies.

Personal Rapid Transit

The PRT concept gathered the attention of many policy-makers, planners and transport authorities all over the world. Its advocates consider PRT a true sustainable transport solution with benefits for the environment, society and economy, a technology that incorporates the advantages of private cars into a mass transit system (Anderson, 1996; Andreasson, 2011; Bly & Teychenne, 2011; Lowson, 2004; Muller, 2011). Its opponents consider that the system combines the disadvantages of low-capacity small vehicles and the high cost of guideways, which transform PRT into an unfeasible and non-economic transit system (Setty, 2009; Vuchic, 2007).

In the US, the most recent PRT investigations have taken place in San Jose, Portland, New Jersey, and Tysons Corner (ULTRA PRT, 2011). In Europe, various national agencies and local authorities from UK, Italy, Netherlands and Sweden commissioned extensive PRT studies between 2000 and 2010 (Carnegie et al 2007; ULTRA Global PRT 2011; Karlsson 2011; Nelstrand 2011; Konradsson 2011). A Sydney-based company developed a novel concept – Austrans - in the late 1990’s, based on its own patented concepts of ultra-light rail technology and high performance parameters (Austrans, 2005).

PRT is a passenger-transit, on-demand system, based on automated small and light electric vehicles (‘pods’) which run along dedicated guideways. The track lines can be built underground, at street level or elevated, with various design solutions available. Different materials from simple concrete bases to steel or fibreglass grid floors can be used to construct the guideway. The stations are built off-line, making non-stop travelling possible, between any two stations. The low-demand loops may have on-line stations. Stations could be easily integrated within new buildings or customised to fit into a specific area.

Passengers arriving at a station can call a vehicle, which is usually waiting at the station; otherwise the quickest available vehicle will be automatically directed from the nearest station. A software programme is designed to find the optimum path for each passenger and to enforce a minimum distance between the vehicles in order to avoid collisions. All vehicles offer high safety and security standards for the passengers through track and vehicle location systems that permanently monitor each vehicle.

The vehicles are computer-controlled and do not require human drivers. They are equipped with comfortable seats, air-conditioning, and an on-board information system with audio and video communication channels and are designed to accommodate passengers with wheelchairs, bicycles or prams. Most of the vehicle prototypes were designed for two or four passengers (Ultra, 2getthere, Taxi2000), but there are also solutions for up to nine passengers (Austrans).

Because the vehicles are electrically powered, the air pollution in the city is zero and the level of noise is very low. In addition, the light weight of the vehicles and their high efficiency mean overall low energy consumption per passenger-kilometre and thus, reduced greenhouse gas emissions. Because PRT has many of the automobile features, for instance non-stop travel from point-to-point, speed, safety and convenience, it may attract a considerable number of car passengers.

The critics of the PRT systems argue that the system cannot prove its theoretical capacity and human-safety levels unless the technology is tested on large scales (Mims, 2011; Setty, 2009). They argue the elevated guideways will be too expensive, aesthetically unacceptable and with possible negative impacts on the land use underneath them (Derrible cited in Mims, 2011; Setty 2009; Vuchic, 2007).

Between 1966 and 1999, a number of different PRT systems have been examined and full-size test tracks and vehicle prototypes have been built with governmental funds but none of them successful (Carnegie et al, 2007; Lowson & Lowson, 2010). Lowson and Lowson (2010) consider that the main reasons for failure were "an over emphasis on high capacity systems", most of them evolving into Group Rapid Transit (GRT) systems, and "inflexible (…) and unavailable technology for the demand of the system" at that time (p.5). Carnegie et al (2007) argue that besides the technical issues that limited the capacity of the systems and increased the costs, the lack of political support contributed to the cancellations of the systems.

In the last decade, several PRT applications have been tested or investigated all over the world. Except for the one study – the Cincinnati Downtown Circulator who was rejected due to lower performance and higher costs compared to an improved shuttle system (Carnegie et al, 2007), most studies concluded that, compared to buses, the PRT systems will bring considerable benefits to the selected locations and will be technologically feasible.

Other studies of PRT feasibility in Melbourne and Canberra concluded that the system is worth considering (Jones, 2009; Wyatt, 2006). The most expensive PRT network to be implemented (in the Casey LGA of Melbourne) would be cheaper than the EastLink freeway. Wyatt (2006) reported that by implementing a PRT system in Melbourne, pollution in peak hours would decrease by 16%, the amount of petrol used by car users previously commuting to the PRT serviced area would decrease by 23% and the system would significantly reduce traffic congestion during peak hours. Jones (2009) concluded that a PRT system could have a greater level of penetration for the layout of Canberra and would be more cost-effective compared to the existing bus system.

Recent studies in Sweden concluded that the PRT system would solve major issues such as congestion, noise, emissions and would release more land to build the city by requiring smaller areas for parking. However, the Swedish municipalities who commissioned these studies decided to wait for more detailed architectural and financing studies to be conducted (Karlsson, 2011; Konradsson, 2011; Nelstrand, 2011).

The very high "risk factor" for investing in an initial PRT project with limited experience and planning expertise and a lack of understanding the concept is one of the barriers to PRT implementation (Carnegie et al, 2007; Jonkind, 2003).

In 2010 two fully operational PRT systems have been built - one in Masdar City, Abu Dhabi (Figure 1) and another one at Heathrow Airport, London (Figure 2).

Source: 2getthere: Lohmann 2011, The 5th Podcar City Conference Proceedings, Masdar according to Design Trade-off, pg 10; Masdar Operations pg 21.

Fig. 1 – Masdar PRT – Construction phase and fully operational system

Source: author

Figure 2 **–** Heathrow PRT – ULTRA PRT stations

The third operational project is scheduled for opening in 2013, in the Suncheon Bay coastal wetlands of South Korea (Figure 3). The Indian historical city, Amritsar, which is home to many religious and heritage sites, recently announced that the government approved a contract for building a PRT system by 2014 (The Times of India 2012).

Source: Vectus Intelligent Transport: Pemberton M., 2011 The 5th Podcar City Conference Proceedings, Station1 and Station2

Figure 3 **–** Suncheon Bay PRT – VECTUS station design

Macquarie Park PRT Network

The PRT network was designed as a feeder for the three rail stations (Macquarie University, Macquarie Park and North Ryde) using an expert version of the ACT City Mobil software, provided by its developers (Lowson and Lees-Miller 2011, pers. comm., 14 August). At the end of the simulation, the software generates statistics for waiting time at each station and overall, percentages of passenger groups waiting less than one minute at each station. The number of passengers carried, the fleet required, the trip distances and travel times are also generated. The simulation does not optimise the fleet size, allocating as many vehicles as are required to provide the level of demand with a minimum response time. In practice, fewer vehicles might be provided leading to a longer waiting time.

The PRT network design decisions were based on the local street network and the existing layout of the corridor. Overall, the proposed PRT network is 17.8 kilometres in length, with twenty stations and two depots. The track line is a one-way single loop, of which approximately 70% is elevated. The track route follows the existing street network and the station locations have been chosen to serve zones with future high concentrations of jobs. The location of the PRT stations was based on the future land uses and employment distribution according to the LEP 2011. In residential areas, the track follows two existing roads, thus minimising the impact on dwellings even in the event of elevated guideways (Figure 4).

The concept design is only indicative at this stage, in order to test the PRT system performance at high capacity demand using simulations, and to estimate the total capital investment required.

The PRT network forms the basis for simulations that allowed us to test out the level of service provided, to compare the potential PRT system's outcomes with those of two alternative scenarios. These scenarios were developed based on government projections of a continuation in current demand and of a future scenario with greater use of conventional public transport (buses and trains).

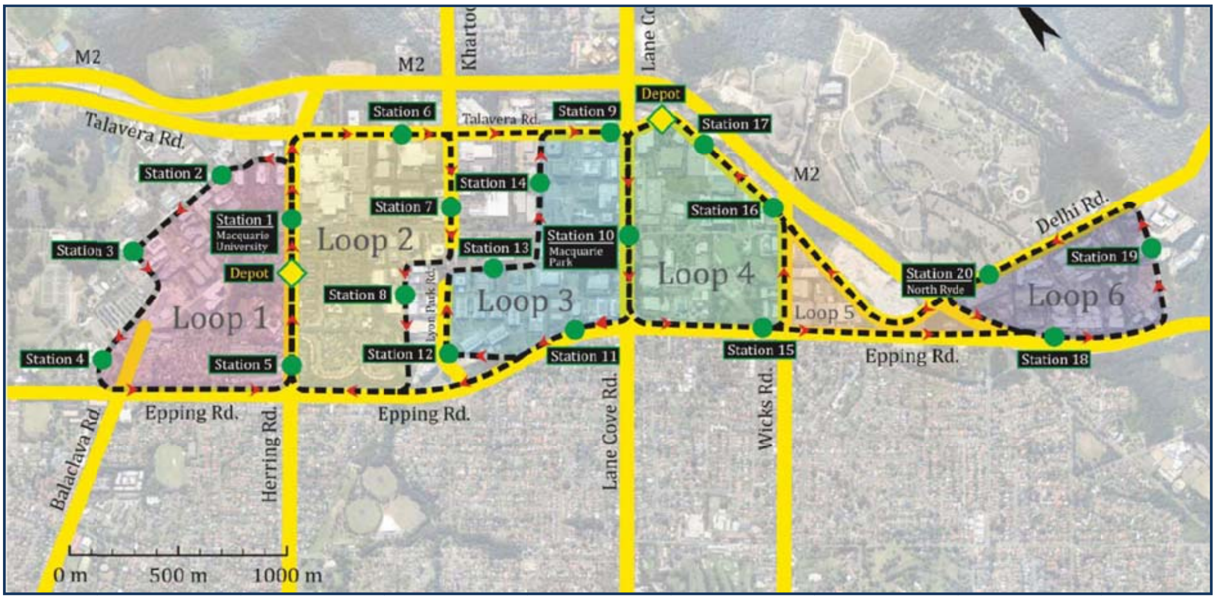

Figure 4- Schematic graphic of the network, stations and points of interest

Before presenting the trip demand, land use and transport network assumptions for each scenario, a brief presentation of Macquarie Park's geographic and strategic context is necessary along with the arguments for considering it an 'edge city'.

Macquarie Park – The Emerging Edge City

The Macquarie Park Corridor is located within the Ryde LGA, in the northwest of Sydney, approximately 12 kilometres from the Sydney CBD, two kilometres from Epping and 20 kilometres from Sydney Airport.

The corridor is situated on the Chatswood-Epping rail route which connects Macquarie Park to Epping in the northwest, Olympic Park and Rhodes in the southwest, Sydney CBD and North Sydney in the southeast and Sydney Airport in the south. The corridor is bounded by two major roads, the M2 Motorway to the north, and the Epping Road to the south and east. It is bisected by Lane Cove Road from north to south. Although these major roads are designed to increase accessibility into the corridor, they actually isolate the corridor and limit its integration within the neighbourhood urban fabric. The Lane Cove National Park borders the corridor in the north and east, but the M2 expressway limits direct access to the park. A highway and arterial street – dominated urban structure results in a car-dependent community.

Macquarie Park plays a significant regional role. The NSW Government's 2005 Sydney Metropolitan Strategy identified Macquarie Park as a Specialised Centre, occupying a prime location within the "Global Economic Corridor" (Figure 5). The key strategic goals were to strengthen the Global Economic Corridor from Macquarie Park to Sydney Airport and to promote Macquarie Park as 'Australia's leading Technology Park". The NSW Government's Metropolitan Plan for Sydney 2036 restated the importance to plan for growing the Specialised Centres and to extend The Global Economic Corridor from Macquarie Park to Parramatta as a key strategy stimulating Sydney's economy.

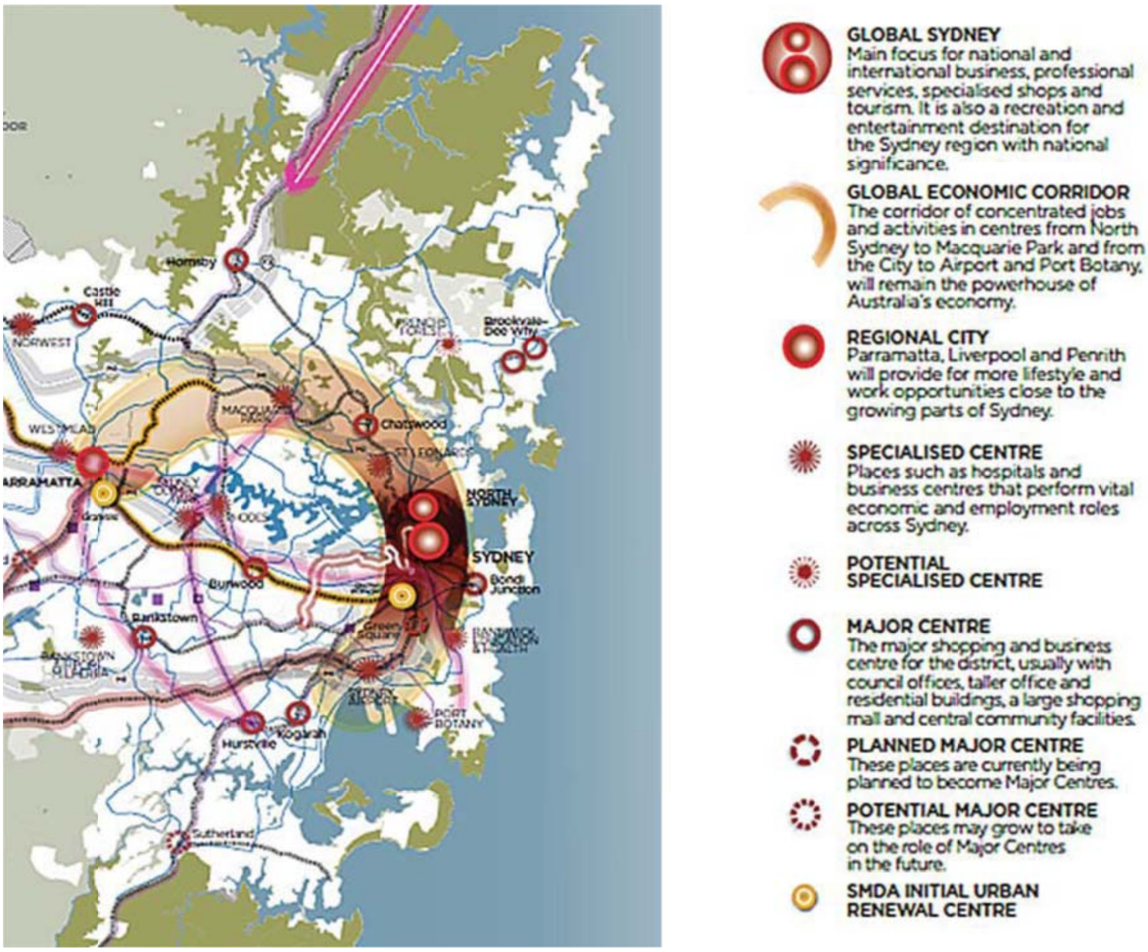

Figure 5 – The Global Economic Corridor

The original starting point of the site is the 1964 government decision to establish a public university surrounded by residential and industrial development. Since then, international and national companies have moved into the area; Johnson & Johnson, Canon, Fujitsu, Hyundai and Optus are only a few examples.

Macquarie Park has all the characteristics of a typical "edge city" defined in 1991 by the father of the concept, Joel Garreau (Table 1).

This major employment centre, combining commercial, business, research and educational activities had one of the highest growth rates in the Sydney Region between 2001 and 2006 (City of Ryde, 2009). In 2006, the total employment of Macquarie Park Centre was approximately 32,000 and the 2005 Metropolitan Strategy forecasted an employment level of 55,300 jobs by 2031 as a constant share of jobs in the Inner-North Region. The Ryde Council (2009) forecasts an even higher employment level of 78,000 jobs by 2031, based on projected build-out of available floor space, an increase in the residential population of 5098 and an additional 28,000 university enrolments by 2031.

Tab. 1 – 'Edge city' characteristics of Macquarie Park

Garreau's five functions of edge cities	Macquarie Park	Checklist Y/N
More than 5 million square feet (465.000 square meters) of office space	800,000 square meters commercial/office space	Y
More than 600,000 square feet (56.000 square meters) of retail space	73,000 square meters (Macquarie Shopping Centre only)	Y
More jobs than bedroom	32,000 jobs + 30,000 students (2006) 5599 residents (2006)	Y
Has grown and changed completely in the past thirty years	Has changed rapidly over the last 30 years from a bushland, market gardens and paddocks area to a major centre housing a well-known university, multinational corporations, and a continuously growing research and innovative hi-technology sector	Y
Is a regional end destination being perceived as an "has it all" place	Macquarie University Macquarie Shopping Centre The Riverside Corporate Park Macquarie Business Park	Y

As every 'edge city', the place is characterised by an ineffective local public transport service, large building footprints, and lack of pedestrian and cycleway access.

Historically, Macquarie Park Centre has attracted businesses by offering larger sites at lower prices compared to other regional centres, and very high levels of parking. A 2008 parking study identified over 31,500 off-street parking spaces available in commercial zones (City of Ryde, 2008). This generous car parking provision rate is strongly related to the high level of car usage – 87% journey to work mode share as vehicle driver and car passenger in 2006 (Transport Data Centre, 2009). If the existing travel patterns do not change, twice as many car parking spaces will need to be provided by 2031 for the predicted 78,000 employees.

Land use and transport scenarios

One scenario, increasing Local Access by Personal Rapid Transport (LAPRT) was developed, with a focus on increasing the accessibility of the existing public transport transit nodes by introducing a PRT network as a feeder for the three rail stations and a few peripheral bus stations. This scenario has been compared to a projection of the current transport trends by 2031 (business-as-usual BAU scenario) and a traffic study based on planned targets for accommodating the projected growth of the Macquarie Park Corridor over the next 20 years ("Planned" scenario).

The mode share assumptions for the business-as-usual scenario were based on the Strategic Travel Model (STM) data for year 2011 applied to the future demand.

However, the STM underestimates rail patronage, therefore patronage trends and barrier count data provided by the Department of Transport upon request (NSW Department of Transport 2011, request 20111808) were used to adjust the overall rail mode shares. For the "Planned" scenario, the local government targets for journey-to-work mode share were used; for the other trips mode share assumptions were based on the STM's outputs for 2031.

For the LAPRT scenario, the mode share assumptions were based on the existing transport targets, reflected in the "Planned" scenario, and reasonable assumptions were made for trips on a local access system designed to increase the accessibility of the main transit nodes.

As the PRT system is proposed as a feeder for the rail and bus stations, the access and egress trips which are usually walking trips included in the public transport mode share (known also as "walked linked trips"), have been split for this project in walk and PRT linked trips. These trips were linked to the main public transport mode. Similar to the "park and ride" model, 'Car+PRT' or "Park and Ride a Pod" could attract workers and students from the surrounding neighbourhoods who might decide to drive and park the car in the public car parks at the outskirts of the corridor instead of facing peak hours congestion and ride a pod (approximately 27% of the workforce travel from the surrounding local governments).

The mode shares proposed for PRT are very cautious, between 2% and 5% for different trip purposes, with a maximum of 8% assumed for students trips based on the performance of the system already demonstrated at two campuses, West Virginia University and Masdar Institute for Science and Technology. However, increased accessibility, safety and minimum waiting time are key motivators for choosing public transport, hence the PRT could be very attractive for local residents or for commuters who may decide not to drive and catch public transport instead if the PRT system can prove its reliability and performance.

Tab. 2 – Total home-based trips to/from and within Macquarie Park, by mode of transport

Transport Mode	BAU	PLANNED	LAPRT
Car Only (Driver)	183,906	145,122	120,150
Car Only (Pass)	39,056	38,136	32,576
Walk Only	15,408	15,772	18,098
Cycle Only	3,764	5,474	7,528
Train + Walk	14,890	41,724	37,046
Bus + Walk	20,976	31,772	30,404
Train + Local Access (PRT)	0	0	11,698
Bus + Local Access (PRT)	0	0	9,380
Car + Local Access (PRT)	0	0	4,932
Walk + PRT	0	0	6,188
TOTAL	278,000	278,000	278,000
Total car trips	222,962	183,258	157,658
Total car mode share (%)	80%	66%	57%
Total PRT trips	-	-	32,198
Total PRT mode share	-	-	12%
Total walking and cycling	19,172	21,246	31,814
Active travel mode share (%)	7%	8%	11%

The comparison between scenarios shows that:

1. A continuation of the existing travel patterns over the next 20 years will generate such a high traffic demand that the road network capacity is insufficient to accommodate the expected 223,000 car trips per day.

2. The "Planned" targets scenario, although very ambitious in establishing 40% for journey-to-work mode share, is expected to generate more than 183,000 car trips per day, with 20% more than today and hence the improved road network will face even more congestion. Moreover, the additional bus

services required to accommodate the estimated 32,000 passenger trips per day will put more pressure on traffic, worsening existing congestion and peak hour bus delays.

3. The LAPRT scenario is expected to generate 158,000 daily trips by car, based on the assumption that by increasing local access to the existing rail stations and bus nodes, the public transport system will become more attractive. This scenario draws on assumptions that the full development (2,000,000 square metres of future floor space and 78,000 future jobs) proposed by local planning policies will occur.

The Environmental and Urban Impacts

Impacts are estimated by calculating the vehicle kilometres travelled (VKT) for the car trips generated under each scenario (Table 3), based on trip demand outlined in Table 2. The average distance travelled is based on the 2009/2010 Household Travel Survey (BTS, 2011) for the conventional transport modes.

Tab. 3 – Distance travelled by mode, average weekday

Mode	BAU	Planned	LAPRT
Car Only (Driver)	1,783,888	1,407,683	1,190,115
Car Only (Pass)	292,920	286,020	244,320
Walk	12,326	12,618	19,429
Cycle	18,820	27,370	37,640
Train	262,064	734,342	857,894
Bus	136,344	206,518	258,596
Local Access (PRT) only	0	0	57,956
Total km	**2,506,363**	**2,674,551**	**2,665,951**
Total Car VKT	**1,783,888**	**1,407,683**	**1,190,115**
Total PT(buses, trains) passenger km	**398,408**	**940,860**	**1,116,490**
Total PRT passenger km			**59,244**

We estimated the demand for the PRT system by developing origin-destination matrices for morning, afternoon and inter peak daytime travel. For each time period, a one hour simulation was run using the ACT City Mobil software. In order to estimate the fleet required to service the predicted demand of 32,198 passenger trips, a ten-hour simulation was run with the origin-destination matrix for one hour morning peak as the input (Table 4).

Tab. 4 – Simulation results for peak and off-peak hours

Indicator	AM peak	Inter peak	PM peak	10-hour SIM
Mean waiting time(seconds)	16 s	16 s	72 s	20 s
Maximum waiting time(sec)	75 s	62 sec	187 s	79 s
Waiting time less than 60 sec (%)	90%	91%	50%	88%
Passenger groups per hour	1635	903	1524	16,707
Average distance travelled (km)	1.94 km	1.81 km	1.84 km	1.84 km
Average trip time (sec)	194 s	181 s	184 s	183 s
Maximum trip time (sec)	937 s	937 sec	937 s	937 s
Fleet required	204	110	197	219
Average occupancy rate	2.34	1.45	2.40	2.34

The LAPRT scenario is expected to generate 32,198 trips in a local access system over 24 hours (Table 2). The PRT system performance and its environmental and urban impact have been assessed under the LAPRT scenario assuming the same trips which are made by pods (PRT vehicles) will be made by car.

Based on the simulation results for trips during morning, afternoon and non-peak hours, the average distance travelled using the PRT system is 1.84 km. (Table 5). For the comparison purpose, the same average distance (1.84 km) and same occupancy rate (1.45) have been considered for both local access options – PRT and cars. Assuming the same trips will be made by car, the total vehicle kilometre travelled (VKT) in an average weekday is 40,858, considering local trips only. In reality, the distance travelled might be different because a car does not have the choice of selecting the shortest route that a computer controlled PRT vehicle does. However, for this study the same average distance has been considered for both local access options – PRT and cars.

Tab. 5 - Distance travelled by local access system, average weekday

Local access system trips	CAR	PRT
Trips[1]	32,198	32,198
Vehicle trips[2]	22,206	22,206
Vehicle fleet[3]	11,103	390
Passenger km	59,244	59,244
Local VKT/PodKT	40,858	40,858

Notes: 1. Trips are unlinked trips and they are converted from home based tours. In fact, a lot more local trips will occur during the day, especially from workers and students during lunch time. These trips are not considered in this analysis.

2. Vehicle trips by car are calculated considering 1.45 average occupancy rate (BTS 2011); same occupancy rate was used for pods too

3. The simulation results showed that 219 pods were required to carry 39,094 passengers, at an average occupancy rate of 2.34; considering 1.45 occupancy rate, a fleet of 353 pods is required to service more than 39,000 passengers within 10 hours. We assumed that the same number of pods will be required to a provide a lower demand of 32,198 within 24 hours; additional 10% vehicles were allowed for maintenance

3. PodKT = vehicles kilometres travelled by pods; the average distance travelled is 1.84 km as per simulation results

Increasing pod fleet to reduce occupancy is conservative as ride-sharing takes place naturally. Assuming the same fleet for smaller demand is also conservative. The ratio of 1 pod replacing 28 cars resulting from this calculation is lower than the range of 1:30 to 1:40 reported by developers of PRT systems (ULTRA 2011), showing that the PRT fleet has been overestimated. However, all the assumptions are rather cautious from the PRT perspective in this project. Nevertheless, the results presented in Table 5 show that a fleet of 390 pods will offer the same level of service as 11,100 cars and the same quality of service as offered by car: on-call service, convenience, reliability, and comfort.

Energy use and CO2 emissions

The literature review revealed different estimates of primary energy use for vehicles. The energy consumption is dependent on vehicle characteristics, for instance size and weight, occupancy rate, speed, number of starts and stops and propulsion system (Carnegie et al, 2007) and hence, caution should be used when comparing energy use among different modes of transport. For this study, the energy use for private automobiles was estimated at 3.8 MJ/VKT (Australian Greenhouse Office, 2007; Kentworthy & Laube, 2001). For the PRT system, the value of 0.47 MJ/PodKT was used based on the ULTRA system performance and its specific characteristics (ATRA, 2011).

Levels of CO2 emissions ranged from 175 gCO2/km to 237 gCO2/km for the new passenger vehicles sold in Australia in 2010 with an average value of 205 gCO2/km (Department of Infrastructure and

Transport, 2011). In order to estimate CO2 emissions for passenger cars in 2031, two assumptions have been made:

1. the same emission level by 2031 compared to 2010 and the entire vehicle fleet replaced by 2031

2. 25% reduction compared to 2010 in accordance with official targets (City of Ryde, 2007; Department of Infrastructure and Transport, 2011; Penny Wong, 2010).

For the PRT system, the emission level was estimated at 71 gCO2/km (ATRA, 2011). The emissions from energy production have not been considered in this study. The targets for 2031 are based on the current CO2 emission levels, considering no improvements in PRT technology.

Tab. 6– Annual1 Energy use and Carbon Dioxide emissions

	BAU	Planned	LAPRT	Local access by car	Local access by PRT	LAPRT vs BAU	LAPRT vs Planned
				Energy use (MkWh)			
Energy use (MkWh)[1]	567	448	378	13	2	-187	-68
Energy use (10%reduction)[2]	511	403	341	12	2	-168	-61
				CO2 equivalent emissions 9tonnes)			
CO2-e (2010 level)[3] tonnes	109,709	86,573	73,192	2,513	870	-35,647	-12,510
CO2-e (2031 target)[4] tonnes	82,951	65,457	55,340	1,900	870	-26,740	-9,247

Notes: 1. we considered 300 operating days per year

2. energy used adjusted to kWh/km using the conversion rate 1kWh = 3.6 MJ; 1.06 kWh/km for cars and 0.13kWh/km for pods

3. considering 10% reduction in energy used by cars based on different technologies and fuel switch by 2031; no reduction of the energy used by the pods

4. Carbon dioxide equivalent of GHG emissions 2010 level: 205 gCO2/km for cars and 71 gCO2/km for pods

5. target 155 gCO2/km for cars and 71 gCO2/km for pods

Assuming a carbon price of AU$25/tonne (US$27.18/tonne) CO2 equivalent, the potential savings under the LAPRT scenario are presented in Table 7. The climate change mitigation strategies to control CO2 emissions could impact on carbon prices raising the offset costs from US$100 by 2012 to as high as US$500 per tonne CO2 by 2020 in the attempt to reduce global warming in the worst-case scenario (Glazebrook & Newman, 2009).

Tab.7 - Savings on CO2 emissions

	LAPRT vs. BAU		LAPRT vs. Planned	
Energy saved (MkWh)	168	33%	61	15%
Savings on CO2 emissions (tonnes)	26,740	33%	9,247	15%
		Cost saving (USD)		
GHG Offset Cost 27US$/t	0.69		0.24	
GHG Offset Cost 100$/t	2.67		0.92	
Total environmental costs ($ million)	0.69 – 2.67		0.24 – 0.92	

Notes: Different values of cost per tonne of CO2 were assumed in various reports: $25 in Trubka et al 2010, between $38 – US$117 in Glazebrook and Newman 2009, Austroads 2003 based on IEA 2008

The environmental cost of producing energy has not been included in this study and this is a very important factor to be investigated. Although the lack of CO2 emissions from PRT vehicles is offset to some extent by the emissions at the power stations, considerable savings of GHG emissions would still occur (Bly & Teychenne, 2005; Lowson, 2004; West Virginia University, 2010).

Air pollution

The air pollution impacts of the three scenarios are compared based on the emission factors estimated by the National Pollutant Inventory (DEWAR, 2008). Of the total registered fleet in 2009, 84% were vehicles with petrol fuel, 12.8% vehicles with diesel fuel and 3.2% with LPG (ABS, 2009). Assuming a similar proportion within the passenger car fleet by 2031, the annual emissions from transport by car for each of the three scenarios are presented in Table 8.

Tab. 8 – Annual air pollution (tonnes/year)

Substance	BAU	Planned	LAPRT	Local access by car	Local access by PRT[1]	LAPRT vs BAU	LAPRT vs Planned
CO	2,144	1,692	1,430	49	0	-714	-261
NOx	414	326	276	9	0	-138	-50
PM2.5	17	13	11	0.38	0	-6	-2
PM10	17	14	12	0.40	0	-6	-2
SO2	6	4	4	0.13	0	-2	-1

The emissions are proportional to fuel consumption, driving speed and technology efficiency. It is expected that new vehicles will use more efficient technology and fuels over the next twenty years, and hence lower levels of air pollutants are expected from the new car fleet. However, the advantage of the zero emissions of PRT system will remain unchanged unless all private cars will be electric or hybrid - an unlikely transition by 2031.

The human health effect costs due to air pollution have been estimated by different studies at between AU$0.7 and AU$2.7 cents per vehicle kilometre travelled with a midpoint around AU$3 cents per VKT (Austroads 2003; Glazebrook, 2009). For this report an average cost of US$0.04 per VKT in 2011 prices was used (assuming an annual inflation index of 3% for the Australian dollar and the average exchange rate AUD/USD of 1.033853).

Tab.9 - Air pollution costs (US$ million per year)

	BAU	Planned	LAPRT	Local access by car	Local access by PRT	LAPRT vs BAU	LAPRT vs Planned
Total VKT('000 000)	535	422	357	12	12	-178	-65
Air pollution cost ($ million)	21	17	14	0.49	0	-7	-3

Noise

The World Health Organisation reported one million healthy life years lost (YLL) from transport related noise in Western Europe (Matan et al 2011) and Infras/IWW assumed a 20% increase in mortality associated with levels of noise higher than 65 dBA (Austroads 2003). The Australian threshold level of noise is 50dBA-55dBA (Austroads 2003). The noise level for PRT is 45dBA measured at 10m from a vehicle driving at 36 km/h (ULTRA PRT, 2009), which means no risk of mortality associated with the level of noise from PRT usage.

Based on willingness to pay (WTP) approach, a cost of 0.011 A$/VKT in 2001 dollars has been reported by Austroads in 2003. Glazebrook (2009) assumed an external cost of 0.02 A$/VKT for noise and water pollution combined.

Tab.10 - External costs associated with transport-related noise

	BAU	Planned	LAPRT	Local access by car	Local access by PRT	LAPRT vs BAU	LAPRT vs Planned
Total VKT('000 000)	535	422	357	12	0	-178	-65
Noise, water pollution, other cost($ million)[1]	13	10	8.5	0.29	0.00	-4.27	-1.56

Note: 1. Value used for this study is 0.02 A$/VKT (2006 prices); the total costs are estimated using the annual average inflation rate of 3% by 2011. The 2011 average exchange rate for AUD/USD was 1.033853

Urban Impact

One of the most important benefits of the PRT is the small footprint of the system and consequently, the value of land released for other uses. A one-way PRT track requires only two metres width of space compared to a width of over ten metres for a major road. The urban impacts can be measured by comparing the physical footprints of the new infrastructure required for each scenario, including the amount of land needed for car parks.

For this study, the indicator we used to compare impacts is based on the gross floor space (GFS) for the new structured car parks required for each scenario. The amount of future car parking spaces based on trip forecast under each scenario is presented in Table 11.

Tab.11 - GFS required for building new parking spaces by 2031

	BAU	PLANNED	LAPRT	Local access by car	Local access by PRT[1]	LAPRT vs BAU	LAPRT vs Planned
Trips by car only (driver)	183,906	145,122	120,150	22,206	3,402		
2030 Parking Demand							
Total car parks	91,953	72,561	60,075	11,103	1,701	-30,177	-10,785
Existing car parks	37,700	37,700	37,700	0	0	0	0
Future car parks required	54,253	34,861	22,375	11,103	2,091[2]	-29,787	-10,395
Cost of multistorey/underground car parking (USD)							
Floor space required for new car parks(sqm)[3]	1,627,590	1,045,830	671,250	333,083	62,721	-893,619	-311,859
Costs (US$ Million)[4]	**2,244**	**1,442**	925	**459**	**86**	**-1,232**	**-430**

Notes: 1. 1701 'park and ride a pod' spaces considered for trips by car + PRT;

2. Space required for PRT depots to store 390 pods was considered similar to the space required for car parking

3. The minimum floor space required for cars, including manoeuvring lanes, blind aisles and columns is 28.67 sqm (Ryde DCP 2010); for disabled parking spaces a bigger space is required; for this study an average of 30 sqm per parking space was considered.

Similar space was assumed to store 390 pods

4. Cost for a basement car space ranges between AU$27,000 and AU$40,000 per bay (City of Ryde Parking Study 2009; Newman and Scheurer 2010); for the 2031 estimates, a minimum cost of AU$40,000 (US$41,354) will be considered; if we apply the inflation index of 3% per year, the cost per bay would range between AU$48,765 and AU$72,244 by 2031 so the cost of AU$40,000equivalent to US$41,354 is at the very low end of price range; same cost per berth was considered

Once more, a cautious approach was used from the PRT perspective. The pod is 3700 mm long and 1470 mm wide (ULTRA Global PRT, 2011), smaller than a car; Holden II Cruze, advertised as Australia's smallest car" has a length of 4518 mm and a width of 1797 mm (Holden 2011). Although the space required to store a pod is less than the space required to park a car, we assumed that the same amount of land is necessary for both of them. The empty pods are stored either in stations (the PRT network has 20 stations and 58 berths, so 58 pods could be stored at stations) or in PRT depots which are simple storage spaces for the remaining 332 pods. However, we assumed that 390 storage spaces will be needed for pods at the same cost as the multistorey car parking construction of US$41,354 per bay. Hence, the benefit compared to the “Planned” scenario is of US$430 million savings from building parking spaces only. This benefit does not account for the parking spaces which should be provided if the estimated 22,206 local trips will be made by car requiring an additional 270,000 square metres of floor space for parking spaces, which will add an extra US$459 million to the total savings, raising the benefits to US$889 million.

Generally, there might be opposition from residents to elevated guideways which can be aesthetically intrusive and disturbing, especially around private dwellings. However, Macquarie Park - as any other “edge city” - is characterised by many more commercial buildings than residential houses and much less activity and travel after working hours and during night time. The network proposed in this project does not interfere with the residential area too much and it follows two existing roads on the outskirt of the residential zone. Furthermore, the low noise and no local emissions features of the system will minimise the upsetting effects on residents.

The specific character of Macquarie Park as the future “Australia’s leading Technology Park” makes it a suitable candidate for an innovative transport system which can be well integrated into new developments.

Conclusions

The operational PRT systems recently built - ULTRA Heathrow, London and Masdar, Abu Dhabi, and Suncheon, South Korea prove that the system can be appropriate and viable in some urban contexts.

The Macquarie Park case study suggests that PRT may have another urban application, as a feeder to the main transit nodes within an ‘edge city’. The simulation results showed that the overall performance of the PRT is very effective, even in the busiest hours of the morning and afternoon peak. In Macquarie Park, a 17.8 kilometre-long, one-way single loop network with twenty off-line stations and two simple depots can handle as many as 3,800 passengers per hour.

A PRT system implemented in Macquarie Park could reduce the CO2 emissions by more than 35,600 tonnes per year compared to the BAU scenario, representing a 32% decrease from current levels. Moreover, PRT could contribute to reducing CO2 emissions by 9,200 tonnes per year, representing a 14% decrease in emissions compared to the “Planned” scenario. These assumptions are relatively conservative from the PRT perspective since they accept the ambitious public transport mode share target of 40%, and the projected 25% Co2 emissions reduction for cars achieved by 2031, but no improvements of the current efficiency of the PRT system.

The PRT system could save 49 tonnes of carbon monoxide and 9 tonnes of oxides of nitrogen annually, from local trips only. Furthermore, by reducing vehicle kilometres travelled compared to a business as usual scenario, the PRT system could contribute to reducing carbon monoxide emissions by 714 tonnes, oxides of nitrogen by 138 tonnes, particulate matter by 12 tonnes and sulphur dioxide by 2 tonnes per year.

By implementing the PRT system within Macquarie Park, the avoided cost due to CO2 emissions, air pollution and noise totals approximately US$13 million per year compared to a continuation of present trends. Furthermore, considering the projected targets and transport improvements under the “Planned” scenario being achieved by 2031, the PRT could still save more US$5 million per year.

The scarcity of land is the main concern of every urban planner and yet, hundreds of hectares of valuable land are developed as car parks in every city. The urban impact analysis investigated the effect of the PRT network on the land used for parking spaces as an alternative to the current travel trends which will generate such a considerable number of car trips that more than 1,600,000 square metres will be occupied by new parking spaces. The huge benefit which might not be seemingly encountered by the policy makers is the amount of land saved: more than 890,000 square metres of floor space which might produce a better return in a development than car parks.

However, this is a desk exercise, therefore detailed civil engineering calculations and specific site factors should be further investigated when deciding about the implementation of a PRT system. Nevertheless, these preliminary findings suggest a more detailed analysis of all the financing costs, taxation, depreciation, fares elasticity and sensitivity tests for various parameters would be justified, in order to rigorously assess the feasibility of the PRT system.

Furthermore, the impact of the elevated guideways of traffic signals, street lighting, local vegetation, urban landscape, and public utilities should be further investigated.

Risk factors still exist, such as financing a new technology, untested performance under complex urban environments or negative network externalities which will surely postpone the decisions to adopt a non-traditional transit system. However, innovative solutions are needed in breaking the current unsustainable trends.

The major constraints on future growth of the edge cities are physical: size and road infrastructure. The PRT network may address these constraints and allow for future growth, while providing alternatives to the construction of new major roads and consequently having a positive impact on a variety of social goods – health, environmental quality, and urban space.

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