A Bus-Based Transitway or Light Rail? Continuing the Saga on Choice versus Blind Commitment

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7 December 2004

Abstract

Over the last twenty years, we have seen the (re)introduction of trams (or light rail) as a suggested 'solution' to delivering public transport at a lower cost than heavy rail in the low to medium density trafficked corridors. An alternative, bus-based transitways are also coming into vogue, but are often compared with light rail and frequently criticised in favour of light rail on the grounds of their lack of permanence because of the opportunity to convert the right-of-way to a facility for cars and trucks In this paper, we consider the evidence on the costs and benefits of light rail and bus-based transitway systems, with particular attention given to the biases in the positions taken by advocates of either form of public transport. The lessons to date reinforce the importance of delivering seamless transport services with good geographical coverage and sufficient flexibility to respond to changing market needs if we are to make a difference to the dominance of the automobile.

Introduction

In most cities, buses move more public transport passengers than any other public mode. Buses however operate mainly on mixed-mode infrastructure, competing with cars and trucks, a regime that has not, in general, favoured bus services. This has provided a strong argument in support of rail systems on dedicated right-of-way, free from the movement constraints of competing modes. The rail emphasis however has often come at a great expense (with non-commensurate benefits), especially in corridors where the traffic levels are quite low (Richmond 1998, Mackett and Edwards 1998), and door-to-door connection is a major influence on mode choice.

Over the last twenty years, we have seen the (re)introduction of trams (or light rail) as a suggested ‘solution’ to delivering public transport at a lower cost than heavy rail in the low to medium density trafficked corridors. Very few light rail systems have proven ‘successful’ on the criteria used to justify their construction and operation such as reducing car use (see below), raising fundamental questions about the viability of public transport in general and light rail in particular. The lessons to date reinforce the importance of delivering seamless transport services with good geographical coverage and sufficient flexibility to respond to changing market needs if we are to make a difference to the dominance of the automobile. The potential for dedicated bus-based infrastructure along major corridors with efficient interchanges and bus distribution deep into suburbia is recognised as having such potential, yet has been neglected internationally (with few exceptions such as Ottawa and Curitiba) relative to light rail. London Transport Buses in its Annual Review 1998 has recently renewed the call for the ‘establishment of segregated busways’ stating that ‘... it is now time to be more positive in taking road space from the private car’.

Bus-based transitways are often compared with light rail and frequently criticised in favour of light rail on the grounds of their lack of permanence because of the opportunity to convert the right-of-way to a facility for cars and trucks (Smith and Hensher 1998). Hensher and Waters (1994) and Richmond (1998) have put the case for bus-based transitways as a preferred option in most urban contexts where light rail has been evaluated. For many years the arguments for and against light rail and bus-based transitway systems have persisted, with light rail often the victor on ideological grounds. Unfortunately, Light Rail is increasingly the purveyor of substantial debt and operating subsidy (Mackett and Edwards 1998, Richmond 1998).

One very positive outcome of the ongoing light rail ‘debate’ is recognition of the need to consider a larger set of public transport options than has traditionally been the case (including non-investment outcomes such as pricing and regulation) under a reasonable set of patronage assumptions. Notable comparative studies include Stone et.al. (1992), Kain (1988,1990), Biehler (1989), Nisar et.al. (1989), Richmond (1991, 1998), Pushkurev and Zupan (1980), Pickrell (1984, 1991, 1992), Smith and Hensher (1998), Mackett and Edwards (1998) and Taylor and Wright (1984).

The majority of bus-based schemes in most countries have generally been tried on a smaller scale than is necessary to give real advantages to buses (Stokes et al. 1991, Batz 1986, Pettigrew and Angus 1992, Richmond 1998) and to compare them meaningfully with light rail. Typical lengths for transit lanes are usually not long enough to have a competitive effect with alternative public transport options or the automobile. It is not valid to compare the impact of short bus lanes with longer dedicated-way transit systems. However, there are some important examples of longer distance bus-based transitway operations in the USA, Canada, Brazil and Australia. The longer bus-based transitways such as the Shirley Highway into Washington DC from Virginia is 19.2 kilometres with 2 reversible priority lanes in the median. The San Bernardino bus-based transitway in California is 18 kms (Gordon and Muretta 1983) and the Route 55 HOV lane in Orange County is 20 kilometres (Giuliano et.al. 1990). The 12 kilometre Adelaide O-Bahn (or Northeast Busway) and the system in Rochefort (Belgium) are fully grade-separated from all other roads, and passenger interchanges are widely spaced, allowing running speeds of up to 100km/h (Chapman 1992). The M2 tollroad in Sydney has 16 kilometres of dedicated busway with buses running at capacity patronage during the peaks. A series of express bus-based transitways covering 55 kilometres are in place in Curitiba (Brazil) which occupy the median of each road, separated from slow-moving traffic lanes by pedestrian islands (Herbst 1992). Ottawa, Canada has installed extensive dedicated bus-based transitways. The Brisbane Bus Rapid Transit system opened in recent years has shown what can be done to grow public transport patronage through a cost effective bus-based system offering levels of service as high as a rail system but at a lower cost. The relevant comparisons between bus and LRT should focus on examples of these lengthy bus-based transitways.

We consider the evidence on the costs and benefits of light rail and bus-based transitway systems, with particular attention given to the biases in the positions taken by advocates of either form of public transport.

Taking a Closer Look at Light Rail and Bus-Based Transitways

- A Return to the Past or a Genuine advance in Technological-led improved Accessibility?

> *'Yet another male politician, Alliance's list MP Grant Dillon, comes out in favour of light rail as the panacea to Auckland's transport problems, overlooking the fact that a lot of relatively cheaper bus lanes are failing to eventuate, due to cost. Buses are, therefore, neither as full nor frequent as they should be in a city of over 1 million people. I wonder if these men have ever given up playing with their Meccano sets? 'Jan O'Connor, Takapuna, letters to the editor, New Zealand Herald, March 7, 1997.*

An increasing number of 'new' urban public transport systems are being developed in cities around the world, particularly light rail. The main objective of building such systems is to reduce car use, and so reduce road congestion and environmental damage. In many cases the systems are expected to stimulate development.

As a way of achieving these objectives what is the evidence that light rail rather than a bus-based transitway system or a less technologically driven 'solution' to improved public transport services is the way to go? The evidence consists primarily of two types: the costs of alternative systems and their effectiveness in attracting patronage (especially from car use). A third criterion, often implicit, is the impact on land-use and future travel patterns. This is alleged to be an important advantage of LRT systems.

Strong views exist on the merits of light rail as a preferred alternative to dedicated bus-based transitway systems. Why did many of these cities supporting and building light rail not consider having a very flexible bus system on the dedicated alignment which has the capability of offering much better door-to-door service than a very inflexible fixed rail system? The answers are relatively simple - the adage that 'trains are sexy and buses are boring' (quoted from the Mayor of Los Angeles) says it all. I have previously described this as 'choice versus blind commitment' (Hensher and Waters 1994).

When the evidence suggests that one can move three times as many people by dedicated bus-based transitway systems for the same cost or the same number of people for one-third of the cost as light rail, one wonders about the rationality of urban planning. For example, Wentworth (1997) concludes from a review of the proposal to extend the light rail system in Sydney between Central Railway and Circular Quay, that a re-designed bus system would provide a better immediate result at a greatly reduced cost. He asks:

> *'... perhaps the investors themselves may have been taken for a ride by professional promoters... Or is it just an innocent mistake? The only thing clear is that there is something fishy about the whole affair'.*

The NSW Government chose a bus-based transitway in preference to LRT for a 20km transitway between Parramatta and Liverpool, two of the major regional centres in Sydney. The Liverpool-Parramatta Transitway (LPT) is an innovative development in the provision of infrastructure tailored to the specific needs of bus transport. Existing transit ways (T2, T3 lanes) make a contribution, but they are limited in their ability to deliver sizeable benefits through time savings and seamless transport service to passengers and operating cost savings to bus operators. The LPT provides a real opportunity to deliver substantial benefits to operators and passengers. With appropriate planning and design, the opportunity exists to provide almost seamless door-to-door public transport services, with buses on the existing networks connecting into the LPT. Although patronage growth is slow but sustainable, a rail system would not have done better, given the location of the corridor.

The LPT feasibility study compared light rail with a bus-based transitway and concluded that the bus system was significantly better in delivering higher levels of frequency (typically every three minutes compared to every nine minutes for LRT) with lower incidence of transfers compared to using a feeder bus to connect to light rail. Since transfers are a major source of dissatisfaction, this is a crucial issue in attracting patronage. Although LRT costs per passenger kilometre are often argued to be lower than for bus systems, these comparisons are usually spurious because they are based on theoretical capacity and not on actual patronage. For LRT to provide an effective level of service it most likely has to operate at a frequency which does not maximise patronage on each trip. If this is the case, the advantage of light rail on operating costs per passenger kilometre is eroded. On construction costs, an integrated bus rapid transit system in Sydney can be expected to cost, at grade (in $2004M/km), based on the Brisbane Busways experience, from $0.12M/km with shared use of existing road, $1.1M/km with widening of an existing road and $1.7M/km in an exclusive corridor. In contrast LRT under the same three corridor contexts is respectively (on advice from GDH Transmark, March 1998 and updated to $2004) $3.6M/km, $2.20M.km and $2.12M/km.

The experience of Curitiba, Porto Allegre and Sao Paulo supports the contention that, under appropriate regulation, organisation and capital investment, bus based transit systems are capable of transporting large volumes of passengers at reasonable speeds for minimal capital and operational costs. Table 1 illustrate this capacity by a comparison of the volumes achieved by bus-based transitways in these cities with a number of heavy rail corridors in the Sydney metropolitan region.

On the evidence, bus-based transitways function as efficient high volume transport corridors where the operations are adapted from traditional bus practice and where substantial infrastructure investments are made in bus stops, terminals and vehicle types. Advantages of bus-based transitways over rail based systems such as the avoidance of transfers at terminals and the use of standard equipment, may correlate negatively with the capacity the bus-based transitway can achieve. Certainly the most successful high-volume bus-based transitways in Brazil require both passenger transfer and specialised equipment. On the other hand, where bus-based transitway systems are based merely on providing road space for operators to utilise (as in Porto Allegre), this results in low operating speeds and low productivity.

Table 1 Volume of Passengers Using Transport Corridors in The Peak Direction of Travel During The Peak Hour

CITY	MODE	LINE	PAX/HOUR
Curitiba	**Busway**	**Pinheirinho**	11000
Porto Allegre	Busway	Assis Brasil	20000
Sao Paulo	Busway	Santo Amaro	25000
Sydney	Heavy Rail	Carlingford	400
Sydney	Heavy Rail	Bankstown	5700
Sydney	Heavy Rail	Bondi Junction	6200
Sydney	Heavy Rail	Chatswood	11900
Sydney	**Heavy Rail**	**Parramatta**	**14800**
Sydney	**Heavy Rail**	**Strathfield**	**28000**
Sydney	**Bus Lane**	**Military Road**	**6700**

Source: Smith and Hensher 1998

Although previous research has suggested that bus-based transitways on the Porto Allegre model could efficiently transport 39,000 passengers/hour (Cornwell and Cracknell 1990), operating experience in Brazil does not confirm this figure. The current maximum volume carried on an efficient bus-based transitway (i.e. with an average speed greater than 20km/h) is 11,000 pax/h in Curitiba, and where volumes exceed this, the average bus speed drops towards that of the surrounding traffic flow. It remains to be seen whether the Curitiba 'surface subway' and the new systems in Sao Paulo will be capable of both moving 22,000 pax/hr volume and maintaining average speeds in excess of 25 km/h, as predicted.

Nevertheless, the existing bus-based transitways can provide an equivalent capacity to an LRT system, at a fraction of the capital costs. As Cornwell and Cracknell concluded:

> *'The capacity of a well designed and efficiently managed busway can be equivalent to that of an LRT, on a comparable basis (for example, degree of segregation; stop spacing)'*

(Cornwell and Cracknell 1990, 195)

and that

> *'... it should be noted that despite the current wave of LRT proposals, and the considerable resources which have been invested in various LRTs (Manila, Hong Kong, Rio de Janeiro etc.), the consultants know of no LRT in a less-developed country which outperforms the busways surveyed in terms of productivity (passenger volumes x speeds)' (Cornwell and Cracknell 1990, 200).*

In interpreting comparisons between LRT and bus-based transitway systems, it is important to note the contrast between 'theoretical' capacity and capacity achieved.

In summary, the evidence from a survey by Mackett and Edwards (1998) suggests that, in general, the impacts of light rail compared to bus-based systems are very limited in scale. The difference occurs because the evaluation framework that is often used as part of the development process usually ignores the latent (i.e., unsatisfied) demand for car use and so is liable to predict higher levels of patronage on the new system, and greater reductions in car use and consequential effects, than will be the case. Furthermore, the forecast patronage on the new systems often do not justify the construction of light rail (except where estimates have been inflated), but the planning and legislative framework under which schemes are developed (notably in Britain and the USA) militates against innovation and more cost-effective systems (Edwards and Mackett, 1996). This suggests that there is a need to adopt funding formulae that relate levels of local and non-local expenditure to the overall benefits more carefully. There is substantial evidence from the literature that expenditure on new rail-based schemes diverts resources away from bus routes used by the lower-income segment with no alternative mechanised mode of travel (eg Richmond 1998).

More on the Cost of Alternative Systems

Pickrell (1984) updated by Richmond (1998) compared actual bus system costs with best practice light rail costs, where buses are local services operating on congested roads. Pickerell uses Pushkarev and Zupan's concept of a rail/bus threshold, defined in terms of passenger miles per lane mile and peak hour passengers in the peak direction assuming an average trip length of 8 kilometres, and bus operating speed of 12 mph. Pickrell shows that the bus/light rail breakeven point for little or no grade separation is 21,000 peak hour passengers in the peak direction, 37,000 with considerable light rail grade separation, and 61,000 where grade separation is accompanied by a one-fifth tunnel. When buses are assumed to operate on exclusive or congestion-controlled right-of-ways, they are able to attain speeds equal to or higher than light rail (Kain 1988) and hence the break even peak hour passengers will be much higher. Pushkarev and Zupan (1980, xiii), a much cited report by advocates of light rail, suggests in a comparison with high-performance bus systems, a break even for LRT of two to three times as high as the thresholds reported above. i.e., 42,000 to 180,000, depending on grade separation of light rail and level of service. The choice of base line bus alternative is extremely important in any comparison.

Comparing light rail with the average for buses is not very useful because it fails to compare the performance of equivalent types of service and fails to demonstrate the impact of implementing new rail service on total system financial performance. It is essential to compare rail performance to that of equivalent density bus services and to include the productivity of new feeder bus routes whose costs are 'caused' by light rail but which light rail management never includes with light rail costs in assessing the rail system's financial performance. The evidence suggest that bus services which are typical of those replaced by rail services have much higher productivity than bus systems in general (benefiting from economies of density); in contrast the new feeder bus services to support the rail network run at much higher costs and hence lower productivity than the bus system as a whole (derived from the Institute of Transport's International Benchmarking subscription program for the bus and coach industry).

A comparison of the life cycle costs of providing bus services compared to light rail in Los Angeles (using the construction and budgeted operating costs of the LRT Blue Line) leads to a conclusion that for the same level of funding, Los Angeles can either afford to build and operate the Blue Line for 30 years or operate 430 buses for 33 years, including the cost of building the operating divisions to support these new buses. For the same cost, however, the buses would produce over four-and-one-half times as many passenger kilometres and carry over nine times as many passengers (Rubin 1991). The decision to go with rail transit appears to have little economic or social basis. One can only surmise that there may be a physical planner's implicit assumption in the decision -- that rail systems, unlike bus systems, can shape land use and that this alone is sufficient reason for justifying high levels of rail subsidy. As discussed in a later section, we find the 'evidence' that rail per se is more powerful than bus-based transitways in shaping land use is somewhat questionable. There are ways of combining any form of transport with incentives/disincentives through land use legislation and/or pricing to achieve an outcome supportive of public transport.

Stone et al (1992) compare a guideway bus priority system and light rail in an active rail corridor, under modal splits ranging from 0.5% to 50%. The LRT system operates on the existing rails with new bridges and track as needed for the dual guideway system. Thus we have a situation of a relatively expensive bus priority system and a relatively inexpensive light rail system. The LRT system utilises the existing dual track structure and bridges in the first 12 kilometres of the rail corridor, with new single track and bridges being built to complement the remaining 13 kilometres of single track. The dual guideway (similar to O-Bahn in Adelaide) requires separate structures at all existing and new grade separations. Some additional cut and fill is necessary to build the parallel guideway. While both options have approximately the same travel time, the bus priority system costs 30% less than the LRT system. Stone et al. state that the high capacity of light rail cannot be exploited without future increases in transit demand (something which plagues all public transport), a feeder bus system, and land use changes favouring higher ridership (an issue which is controversial, although see the Ottawa experience through regulation, discussed below). The inherent lower cost of the bus-based transitway reduces financial risk while its off-guideway flexibility automatically broadens service opportunities.

A study of public transport options in Canberra (Denis Johnston and Associates 1992) suggested that a bus-based transitway is more cost efficient than light rail. All operating and maintenance costs excluding depreciation and interest are (in $92) $3.00 - $3.50 per vehicle km for a bus-based transitway and $3 - $5 per vehicle km for light rail, and capital costs are approximately 50% lower for a bus-based transitway. They argue however in support of light rail because it has the advantage of permanence due to its fixed track characteristic, the latter providing greater confidence for developers and other investors in ways which aid public transport use. The legislated procedures implemented in Ottawa and Curitiba however provide strong examples of how bus systems can also achieve such benefits, without relying on the argument of fixed track in order to secure the characteristic of permanence (Smith and Hensher 1998).

The Canberra study indicates that there is no strong evidence that patronage would be significantly different for a bus-based transitway or light rail, throwing doubt on the reported operating costs per passenger kilometre (4.5 cents and 3 cents respectively for conventional on-road bus and light rail) which assume higher loadings for light rail. The opportunities to achieve patronage levels in the ranges supportive of light rail are remote indeed. Any visitor to Canberra will notice the general absence of traffic congestion and existing bus services with unacceptably low passenger loads, throwing doubt on the wisdom of any major investment in light rail or a bus-based transitway, given Canberra's urban strategy. Twelve years on, no decision has been taken on light rail although the popular view in a growing number of planning circles in 2004 is that a bus-based system on *existing* roads makes eminently better sense, given the low patronage estimates.

Curitiba, in Brazil, introduced a bus priority system at a cost of $US54million, 300 times less than a subway and also less expensive than light rail (Herbst 1992). Curitiba's buses transport 1.3 million passengers per day, four times the number of subway passengers in Rio de Janeiro (a city of 10 million residents, more than six times the size of Curitiba).

Pittsburg opted for exclusive bus-based transitways in preference for LRT. In a comprehensive review of the Pittsburgh experience contrasted with a number of LRT projects in Buffalo, Pittsburgh, Portland, Sacramento and San Diego, Biehler (1989) concludes that

> *'... busways offer an advantage over light rail for many applications due to their attractiveness to riders, cost-effectiveness, and flexibility' (Biehler 1989, 90).*

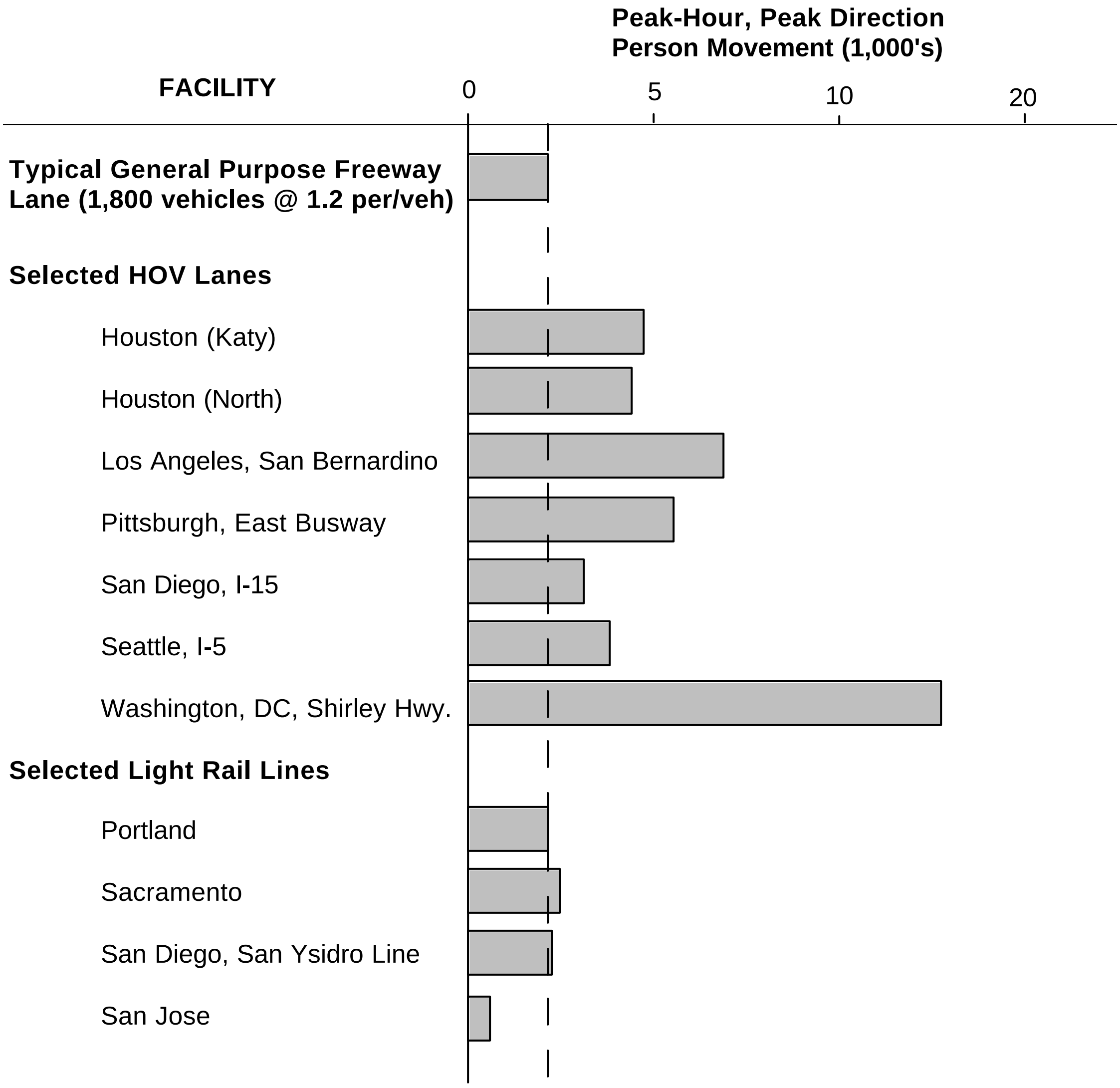
The South Busway, opened in 1977, is 6.4 kms, primarily at grade with one section in a tunnel. The East Busway, opened in 1983, is 11.2 kms entirely at-grade except for a one-third kilometre elevated section. The LRT systems against which the bus-based transitways have been evaluated are still making adjustments to maximise patronage, in particular utilising the bus-feeder concept as part of an overall public transport system.

Although any comparison of systems located in different urban areas is problematic, nevertheless some amount of comparison is permissible in order to form a judgment on the relative merits of each system. As of 1987, the unit operating costs for each system are $0.43 for Pittsburgh East and $0.56 for Pittsburgh South. These estimates compare with the LRT range of $0.85 (San Diego) to $1.50 (Pittsburgh). We recognise the inadequacy of such a measure of effectiveness, despite the striking differences in costs.

The most telling evidence is provided by Kain and Liu (1995) who compare the operating and capital costs of San Diego light rail with an equivalent bus system. Most comparisons between systems (especially in the USA) use operating costs per boarding as their performance indicator, in contrast to a total cost per boarding, the latter including capital costs. Kain and Liu (1995) conclude that San Diego's LRT operating cost per trip is substantially lower than any of the bus operators. In contrast the San Diego bus transit system has the lowest fully allocated capital and operating cost per boarding by a significant margin.

Table 2 shows that LRT systems are not moving any more people per hour during the peak than could be handled by one lane of a freeway. In contrast, bus and HOV lanes do move more people than would a freeway or an LRT with modest ridership. The HOV lanes look particularly good since they achieve higher utilisation of the facility than one restricted to transit vehicles only. But note that even bus-only lanes (e.g. Houston, Pittsburgh) outperform the LRT lines listed. The important implications of this comparison in Table 2 are: (i) the bus-based transitways are shorter in length than the LRT lines, (ii) they carry about the same number of passengers per day (at higher rates of ridership because of shorter length), and (iii) they cost about the same per kilometre to construct as the *lower* cost LRT systems.

Table 2 A Comparison of Ridership Rates of a Number of USA Bus-based transitway Systems and LRT Systems (the LRT systems selected are regarded as the most 'successful', especially San Diego)



More on Patronage?

An obvious consideration in any debate on modal futures is the capability of a mode to attract patronage (see Appendix for an overview of the challenges). The previous sections noted several examples showing that bus systems can service more passengers per dollar than LRT systems. Much of the literature on LRT ignores the demand side of the picture, concentrating on issues of costs and technology. Presumably the basic purpose of urban passenger transport is to provide the technological basis for mobility in order to give people the accessibility they require. It is not to transport subsidised fresh air. It is somehow assumed in most commentaries on LRT that there is a sufficiently strong demand to justify a (subsidised) public transport service, and that the consequences on the environment are net positive. Indeed official projections of light rail system ridership have erred substantially on the high side. For example, the actual ridership on the Portland LRT (cited by Newman and Kenworthy (1999) as an example of best practice) was only 45% of the official forecast (Gordon and Wilson 1985).

In the United States there have been many instances of massive over-forecasting of the impacts of new rail systems. It has been suggested that local politicians and planners are so keen to obtain a new light rail or metro system that their enthusiasm has outweighed their judgement (Richmond 1998).

The Portland-Oregon light rail line diverted 6,500 daily trips from the automobile out of a total of nearly 4 million daily trips (Hensher 1992). This is equivalent to less than 50 days of natural travel growth in total person trips over the last 10 years in the metropolitan area. In Los Angeles, the number of new rail transit trips since the entire Blue line opened is 21,000 out of 38 million daily trips (with 63% diverted from bus). The days gained from the Blue Line in Los Angeles are estimated as equivalent to fewer than 5 days of natural travel growth over the last 10 years. The implication is that the entire proposed light rail investment of nearly $US2 billion in Portland and $US6 billion in Los Angeles might ‘buy’ a year's growth (Cox 1991).

The overriding evidence suggests that up to 70 percent of new rail patronage is diverted from bus (an experience reproduced in Sydney and Perth), with buses re-routed to serve rail interchanges. The blue line in Los Angeles is indicative of one such outcome. The Blue Line has a taxpayer cost of $US21 per rider per day. Since few of its riders are former drivers (as opposed to bus users), the system costs taxpayers $US37,489 per year for every car it currently removes from the freeways. A comparison of the life cycle costs of providing bus services compared to light rail in Los Angeles (using the construction and budgeted operating costs of the LRT Blue Line) leads to a conclusion that for the same level of funding, Los Angeles could have either afforded to build and operate the Blue Line for 30 years or operate 430 buses for 33 years, including the cost of building the operating divisions to support these new buses. For the same cost, however, the buses would produce over four-and-one-half times as many passenger kilometres and carry over nine times as many passengers (Rubin 1991). This result is reached even though the assumptions made tended to favour the Blue Line on several important issues.

The Northern Suburbs Transit System (NSTS) in Perth, West Australia which opened in 1992, attracted both previous car and bus users, with 64% of its patronage coming from bus. When the impact of road traffic is calculated, we find that the vehicle volumes per week day have dropped by less than 2,800 vehicles out of a total of 100,000, or 2.8% (Luk et al 1998). This is very small indeed and raises questions about the value of an expensive heavy rail system which impacts significantly on a bus system and little on car demand. A dedicated bus-based transitway on the existing expressway may have been a better proposition? The Gold Coast railway in Queensland is another example of a failed effort to attract drivers out of their car - its primary source of patronage is ex-bus travellers. Is this really the way to redress the imbalance?

Sydney has also embraced the *old idea* of inflexible public transport with the return to its streets of a steel-on-steel light rail system between Ultimo and Pyrmont in southern central Sydney. We are now seeing the mingling of trams with cars and buses as the street system struggles to cope with another form of old public transport which competes with walking and buses far more than it has attracted individuals out of their cars. Even with high parking prices in and near the Central City of $8-$12 per day on average (see Hensher and King 1999), this increased accessibility offered by more public transport technology has done little more than provide an interesting tourist attraction and satisfy the needs of those who believe in trains as the only form of public transport. The proposal to extend LRT should up to Circular Quay in the CBD of Sydney makes no sense on both benefits and costs compared to a bus-based system on dedicated roads.

The Sydney Star City casino has become a major traffic generator for the LRT. Indeed, so important was the Casino in early discussions with Government that a risk provision in the privatisation contract stated that 'If the permanent Casino opens for trading more than 12 months after the light-rail is completed, or after 31 March 1998 if this is a later date, the Department of Transport will be liable to pay the Pyrmont Light Rail Company $8,219 per day until the Casino opens'. This says a lot about patronage risk from other sources. Although patronage is steadily increasing, they are below forecasts. In the early 2000's the peak occurred in the very early hours of the morning as casino staff return home. Mees (1998) undertook a survey of Sydney light rail passengers in mid-1998 to investigate the sources of patronage and found that the main passenger groups are tourists and Star City employees. She also found that '…light rail in Sydney has limited impact on reducing car use, and the majority of passengers are attracted from pedestrian or other public transport services, hence is directly competing with other sustainable modes' (page 13). Regardless of the actual patronage levels, one must ask why such an expensive investment (which operates in part in mixed traffic) was chosen over a flexible bus-based system?

A cost benefit comparison of LRT and an exclusive bus-based transitway applicable to Sydney (Ip 1992) under peak loads varying from 1,500 pcu per hour to 4,500 pcu per hour and total daily one-way flow from 15,000 pcu to 70,000 pcu, produced benefit-cost ratios varying from 0.94 to 5.43 for LRT and 1.09 to 7.32 for a bus-based transitway. In all cases, the bus-based transitway had a benefit-cost ratio significantly higher than LRT, even allowing for a 25% higher level of patronage using the LRT than the bus-based transitway system. The usefulness of these figures however is critically dependent on patronage assumptions.

Limited consideration is given in the literature to incentives required to get people out of their cars and to increase rail use to a level which does not require massive subsidy. There is a strong presumption that the argued merits of rail systems such as environmentally-friendly high capacity with typically low fares will provide the necessary incentives. Despite the best of intentions, the failure in the last 25 years to attract significant levels of new patronage to rail is in large measure due to the lack of disincentive to using the car (Hensher 1998, 2004).

A common conclusion from many investigations of new light or heavy rail in the major western capitals with densities typical of USA and Australian cities *and* inefficient prices is that rail systems cannot attract sufficient patronage to justify them:

> *'Unfortunately, the more we learned about the cost and ridership of this proposal, the more convinced we became that it does not deserve legislative or public support. Our opposition is dominated by one simple, general conclusion -- Metropolitan Council and Regional Transit Board projections establish clearly that LRT would attract so few people from driver-only cars that it could not* ***significantly*** *increase transit ridership.' (Citizen's League, 1991).*

Richmond's 1998 update for the USA and Canada reinforces and extends the conclusions of Pickerell (1984). In the words of Richmond:

> *'Optimistics claims that new urban rail systems would increase transit patronage, reduce congestion, and improve the environment while at the same time improving the financial performance of transit systems have proved incorrect in most instances. …The evidence shows that the capital funds spent have generated few benefits.' (page 39)*

One of the most disturbing features of the rail bias is the damage it has done to bus operations.

> *'While rail's contribution to increasing transit ridership … has been mostly minimal, changes in bus operating practices designed to accommodate rail have generally had a negative effect on the financial productivity of the transit systems concerned' (page 39).*

A growing concern in any comparisons between bus-based transitways and light rail is the quality of the data on patronage. In the USA most data is unlinked trips (or boardings) and not complete journeys (ie linked trips). This means that a previous bus traveller who may have had a single bus trip but now is forced through loss of service to use the new bus to rail station and rail alternative is actually recorded as two unlinked trips. Such reporting has tended to inflate the true amount of travel by public transport. It is ironical that a degradation of service levels creates an increase in the number of unlinked trips which are used by proponents of light (and heavy rail) to promote the virtues of rail as a attractor of increased patronage.

Indeed when linked trips data is used, there usually is a noticeable loss in patronage to public transport due to the dimunition of service levels through being forced to change modes consequent on a loss of the cross-regional bus services. Rail ridership in the USA and UK has been encouraged by the simple expedient of taking alternatives away. The general pattern has been to discontinue through bus services and instead terminate them at suburban light rail stations. The number of passengers attracted to rail who are 'new' to transit are in most cases insubstantial. The Denver experience is an excellent example of this outcome:

> *'In no case has new rail been shown to have a noticeable impact upon highway congestion or air quality; although the Denver light rail system has satisfied the objective of removing from center-city streets buses diverted to terminate at light rail stations.' (Richmond 1998, page 40).*

Gross ridership figures for light rail in places such as San Diego and Portland may seem impressive. However a total systems perspective shows that the total impact on public transport patronage is not only slight, but equal or better results can be obtained from relatively minor adjustments of fare levels and low cost improvements to existing bus services. The West Australian heavy rail, and the Gold Coast and Sydney Light rail investments are very good examples of this outcome. Hardly something to be proud of and giving great civic pride. A common comment in Sydney is how few people seem to be using the light rail system – many almost empty carriages parading the streets of Sydney promoting the virtues of transporting fresh air!

The argument that light rail (in contrast to bus-based transitways) is needed to catalyse changes in travel patterns is very questionable. The Eastern Busway in Brisbane has certainly blown this myth away. While it is the case that the Blue (South) Line in San Diego is a very successful project in providing the rallying point for transit development (and its financial performance is impressive), it is the exception than the rule. It is however well behind the Ottawa bus-based transitway on financial performance. However, Pittsburgh's busway system, like Ottawa and Curitiba in particular, provide impressive counterarguments to the claim that light rail is needed to catalyse changes in travel patters. Originally built with the idea of using a bus-based transitway as a transition plan towards light rail (like so many of the proposals), its success has resulted in management loosing interest in light rail and pursuing further development of the bus system. Ottawa, Pittsburgh and Miami all contradict the notion that buses cannot provide the capacity of light rail. As Richmond says '… The moral is that high-performance but less glamorous projects can gain local acceptability once success has been demonstrated' (Richmond 1998, 44).

One wonders why we are investing such large sums into rail systems when the returns are so poor and expensive per additional passenger trip, and the success in attracting people out of their cars is so miniscule. The same arguments, but for lower cost, may well apply to bus-based transitway systems but the financial risk is considerably less.

Impacts of Public Transport Facilities on Land Use

All forms of transport infrastructure have some impact on land use, be it freeways or public transport. The real issue is to what extent there is a linkage between the provision of particular types of public transport and land use. In particular does LRT have land use impacts that are different from bus-based transitways, and is the difference substantial and desirable?

Using property values as a surrogate for land development impacts, not an unreasonable assumption, a survey of 2,500 properties in San Diego concluded that property values are determined by factors other than LRT (Urban Transportation Monitor, August 21, 1992). The study compared similarly developed properties adjacent to the transit facilities, properties that were outside the influence of LRT, and properties that were operating prior to the advent of LRT. There was no impact on residential properties, with most commercial uses having no impact, except for one motel and one small retail centre near a station that showed a 25% increase in lease rates attributed to LRT. Access overall was a far more important consideration.

> *Our conclusion from the limited evidence is that any transport infrastructure investment will have a significant impact on land use where it contributes in a non-marginal way to accessibility, regardless of its nature.*

The M4, a tolled motorway in Sydney, for example, is already having an impact on land use in the western areas of Sydney resulting in increased median land values. Washington DC Metrorail which has a 26% modal share for downtown travel has impacted on land use around stations and contributed to property values in some locations, although other factors have in general dominated the shape of land use - in particular the quality of the location overall. An inquiry by Brindle (1992) into the Toronto experience, (a city extensively cited by Newman and Kenworthy (1989, 1999) as an example of how rail systems encouraged re-urbanisation), concluded that:

> *'the experts interviewed in Toronto were hesitant to claim 'proof' of a close relationship between transit and land development, or that the transit-supported centres ... had so far produced significant improvements in travel efficiency and lifestyle' (Brindle 1992, 23).*

When one reviews the evidence on the role of public transport in stimulating particular land uses, the overriding feature for development-stimulus is the permanence and volume of public transport system increases. This is the claimed basis for preferring LRT over bus systems. Although buses take people to where activities are and follow the movement of activities over a wide geographic pattern (Paaswell and Berechman 1982), in contrast, some argue that rail systems have a more active land use/transport relationship because of their perceived permanency.

The begging question is: what makes for permanence? One of the arguments frequently propounded by supporters of LRT is that it cannot be taken away, whereas a bus system can, although we cannot find any cities where this has actually occurred. The cost of producing flexible service capable of potentially responding to changing geographic activity patterns is the price of reduced commitment to the facility. There is greater truth in this statement where dedicated bus-based transitway infrastructure is not in place, especially infrastructure built specifically for exclusive bus use. Ottawa's busway system combined with strong land use regulatory powers illustrates what can be done for bus-based transitways to have a significant impact on land use. The system operates just like any other rail system with vehicles stopping at each 'station'. Ramp access is provided for express and limited stop routes so that a direct no-transfer service is provided between the residential and major trip generator locations. High rise in Ottawa-Carleton is already occurring at some stations and an integrated shopping centre/transitway station has recently been opened. Over $US700m in new construction is under way around Transitway stations (Henry 1989).

Ottawa's legislatively mandated land use and transportation plan gives precedence to public transit over all forms of road construction or road widenings, with planning regulations requiring developers to concentrate developments near transit, to orient buildings and private access to transit stops, to provide walkways and transit-only roadways through developments, and to enter into agreements with the municipality on matters such as staging construction to accommodate transit.

The message from Ottrawa, Curitiba, Bogota and Brisbane, is that a metropolitan strategy can embed an effective bus-based system within its overall land use/transport plan that can produce the same types of impacts as rail. Based on the Ottawa and Curitiba experience, what is required is enabling legislation with a mandated land use/transport plan that explicitly prioritises the role of bus-based systems. If we look at the experience in Perth (Western Australia), the only noticeable development impacts after nearly a decade of electrification and 12 years of the new Northern Suburbs Rail System, occurred where a government development agency has taken the running in East Perth, Subiaco and Joondalup.

The arguments in favour of rail-systems are mainly premised on the absence of such legislation. It may be that bus-based systems require much more directed assistance via legislation than does a rail system in order to have an impact on land use. Of course, contradictory legislation and zoning could thwart rail impacts on land use. The implication is that appropriate zoning and possible legislation should be an integral part of transport and land-use strategies. If this coordination is done, bus systems are all the more attractive because they are considerably less expensive for a given amount of returned benefit and more flexible in responding to change. It may be that the bus-based system must be seen as having the essential characteristic claimed by rail - permanence and dedication. The value of HOV lanes with multiple-occupant automobiles must be weighed against this perception of 'rail characteristicity' if bus-systems are to act as catalysts for land use planning as well as providing a high level of service.

The Ottawa transitway (or bus-based transitway) is unlike a bus lane in that it provides (i) rapid service between 'stations' (similar to a rail rapid service); (ii) direct express services via transitway providing the local feeder as well as the linehaul service without transfer; (iii) general urban areawide transit service that uses the transitway for a part of the overall route and thus enhances not only its average overall speed but also the frequency of service between some stations on the transitway; and (iv) local service to stations provided by feeders.

In designing a bus-based priority system which has an effective collection and distribution capability deep into suburbia, the density of passenger movement through bus-based transitway stations as well as fewer stations (compared to rail) might act to reduce the attraction of land use development at and/or near the bus stations in contrast to the LRT stations. Nevertheless, the appreciation of land values and the agglomeration of activity close to stations should not be seen as of higher priority in an overall metropolitan strategy, in contrast to improving mobility and accessibility. A mix of objectives is necessary.

Ottawa may well have got it right (Henry 1989, Nisar et.al. 1989). Transportation service provision should foremost cater for the dispersed travel needs of the population, as well as recognising the desirability of agglomeration economies spread throughout the metropolitan area, aided significantly by legislative reform. There is scope in the longer term to encourage the decentralisation of activities (which is happening anyway) and hence reduce the reliance on the central core of urban areas, and hence reduce average trip lengths (Hensher 1993, 1998, 2004).

Curitiba, a city of 1.6 million located 400 kilometres south west of Sao Paulo, implemented a master plan in the late sixties which restricted high-density growth to several slender corridors radiating from the city centre. The traditional core has given way to a cluster of high rises and scattered outlying development with all tall buildings arrayed along five transportation axes. Express bus-based transitways occupy the median of each road. To achieve this, the city brought or condemned a substantial amount of land along or close to the transportation axes and enacted zoning regulations that restricted high-density development to a two-to four-block corridor on both sides of the road. Flower street, an auto-free downtown pedestrian zone was created, banishing cars in a 17-block area.

The Brazilian experience supports the key interrelationships that exist between successful bus-based transitway operation and long term planning, land use, appropriate regulation and political stability. Where bus-based transitways have been implemented in isolation from coherent planning and land use strategies, the results have been either partial, inefficient systems (as in Sao Paulo) or overcrowded systems that cannot adequately meet demand (Porto Allegre and Sao Paulo). The outstanding feature of Curitiba is that an integrated system of bus service types has developed in response to a clear and structured urban plan. This combination of a planning driven 'bus-friendly' urban form and a marketing driven, innovative bus operation has provided

Curitiba with an excellent transport system. The bus-based transitways are no more than an important element in this process.

Furthermore, the contrast between Curitiba and Sao Paulo is not so much in the preparation of plans, but in their consistent implementation over a thirty year time frame. Political stability has enabled the planning and innovation in Curitiba to deliver results. Similarly, the effective use of bus-based transitways is also dependent on an integrated regulatory regime. The decline in the effectiveness of the Porto Allegre busways results from the removal of the 'umbrella' regulation of EBTU. Although the multiple operators have effectively developed an system wide fare system, they have not been able to maintain the efficiencies of the bus-based transitways. Similarly, a major restraint on the Santo Amaro bus-based transitway in Sao Paulo is the presence of 'pirate' bus operators, who overload the capacity. An efficient bus-based transitway requires a firm and coherent system of regulation.

The bus-based transitway systems in Curitiba, Porto Allegre and Sao Paulo provide an illustration of the strengths and weaknesses of this transport mode. Although these systems have operating weaknesses, and although many aspects of their operation are not transferable to other national contexts, they nevertheless provide working examples of the capacity of the bus to provide cheap and efficient solutions to major urban transport problems.

Table 3 CMTC Busways In Sao Paulo - 1994

	Paes de Barros	**Santo Amaro Avenue 9 de Julho**	**Vila Nova Cachoeinha**
Year of Opening	1980	1987	1991
Type of Bus	Trolley	Trolley & Diesel	Diesel
Length	3.4 km	14.6 km (1)	11.0 km (2)
Terminals	1	1	2
Overtaking Lanes	No	Yes	No
Busway Rtes (3)	6	27	14
Number of Buses	61	372	159
Buses/Peak Hour	30	250 (4)	75
Pax Capacity/Hr	3000	25000	8250
Peak Hr Op Speed	N/A	AM: 21.0 km/h PM: 11.2 km/h	AM: 23.0 km/h PM: 16.0 km/h

Sources : SMT 1993a and SMT 1993b.
Notes:
(1) Of the 14.6km, only 11.0km is exclusive bus roadway.
(2) Of the 11.0km, only 5.5km is exclusive bus roadway.
(3) Includes both Trunk Routes (using the corridor) and associated Feeder Routes.
(4) In addition, up to 50 illegal buses use this corridor per hour.

The Ottawa, Curitiba, Bogota and Brisbane experiences are worthy of special investigation. They appear currently to offer the best examples of how a bus-based system can be a major alternative to light rail in terms of the wider range of criteria used to justify a rail-based public transport system. It is easy to be critical about the strong arm approaches to legislated zoning, (some supporters of LRT suggest that zoning legislation is not required to achieve these types of land use reforms), but it did achieve the objective using a more cost efficient form of public transport. The success of legislative regulation depends very much on a commitment. The USA experience in legislative reform in order to achieve efficient and effective reform of public transport favouring bus and LRT systems has not met with success as well summarised by Henry (1989):

> 'While such formidable land use controls [as in Ottawa] may be envied by many U.S. planners, it is most unlikely that the massive legal, political, and other obstacles to their implementation in U.S. cities could be overcome' (Henry, 1989, 177).

It is encouraging however to note the success of Pittsburgh who succeeded in introducing a bus-based transitway system in contrast to light rail without the imposition of legislative zoning. Markets can be and often are stronger instruments in achieving outcomes if properly managed.

An Assessment of Current Experience

This section brings together various points gleaned from the reviews of current experience and the arguments in the bus transitway - LRT debate. The main point is that the enthusiasm (almost blind commitment) for LRT has caused many to overlook the potential for more cost-effective bus-based systems and even simpler improvements to bus services that do not require dedicated right of way.

1. Bus-based transitway systems can be shorter in length than LRT because the routes that use them can fan out into residential and commercial areas for closer collection and distribution. Transfers and transfer time are reduced. LRT can have feeder buses but with added time delay (and often higher unit operating and capital costs than an integrated bus system), although the disutility of a bus - rail transfer penalty is lower than for a bus - bus transfer. This provides some basis for promoting the design of bus-based transitways in the context of the entire collection and distribution task, ensuring that the exclusive bus-based transitway combines with the entire matrix task of buses to minimise transfers, as successfully executed in Curitiba (Herbst 1992), Brisbane, Bogota, Ottawa and Pittsburgh.

2. We know that transfers are a major constraint on the use of public transport (Horowitz and Zlosel 1981, Charles River Associates 1989, Richmond 1998). The act of changing buses or between bus and LRT produces a large penalty that is independent of the amount of time involved in transferring. This suggests that long-term strategies should include the provision of a better mix of more direct but less frequent bus routes and more frequent services, adding branches and opening loops. Public transport networks that are planned to minimise

travellers' disutility, *including transfer penalties* (i.e. not just time but the act of transfer) will look substantially different from those planned to minimise overall travel time. LRT appears to work against this objective.

A three-tiered bus system, arguably one of the most efficient in the world, was introduced in Curitiba which allows passengers to transfer without charge from the red express services along the axes to the yellow feeder services that circulate through outlying districts and bring passengers to transfer stations, and to the green inter-district buses that travel in concentric circles to connect outlying areas. A computerised traffic control system gives priority to buses. There are 100 tubular bus shelters, with passengers paying fares using smartcards at a turnstile at the end of a clear tube and then waiting inside, entering the bus from sliding doors in the tube. Boarding and alighting is considerably speeded up.

3. The total operating costs per passenger of LRT are typically higher than the typical bus-based transiway, where comparisons are possible. The most cost-effective LRT is 60-80% higher on unit operating costs than a bus-based transitway. The comparison must be qualified by the fact that LRT trip lengths are longer, although the bus-based transitway component of the bus trip only is typically used in the comparison. When the fully integrated bus-LRT or bus-bus systems are compared on unit operating and capital costs the latter is even more attractive financially. The level of patronage will be critical to the outcome.

4. Bus-based transitway systems are simpler to operate and maintain than LRT systems, the latter typically attracting a sizeable support system such as an operations control centre and maintenance facilities. The interrelations between communication, signal power and propulsion systems for LRT is more likely to contribute to complexity and bureaucracy which is significantly less (but not absent) for bus-based transitways.

5. We seem to have accepted the division between the ownership of the infrastructure for bus provision and the operation of the buses. We are struggling with this dichotomy for rail-based systems. The issue of subsidy cannot be ignored in both systems. If we draw on the property rights argument, there is a very clear case for allowing any bus operator to access the bus priority infrastructure; and hence a case for having the infrastructure owned by a non-local bus operator. Although this division can also apply for rail, it is more likely to gain acceptance for bus systems because of the perception of a more ‘natural’ division than for rail. Indeed access by non-bus vehicles to share the infrastructure to maximise the use of the excess capacity in the off-peak in particular is a more attractive proposition than LRT. The NSW Government has been struggling with this dictotomy with the Liverpool-Parramatta Bus-based Transitway.

6. Bus-based transitway systems permit far more flexible operation (Moffat 1991, Hensher 2004). Buses travelling in the one direction can pass more easily than LRT, especially when off-line bus-based transitway stations are used. Fouracre and Gardner (1992) note that the provision of overtaking facilities at bus stops is found to be a particularly effective way to increase throughput (up to a theoretical estimate of 30,000 passengers per hour in one

direction) and to decrease journey times, particularly when limited-stop or express services are operated. As bus use builds up the opportunity for bus-chaining (especially as a guideway technology) becomes feasible.

7. Although it is argued that LRT operates at a greater theoretical capacity than a bus-based transitway, this has been questioned under closer assessment (Goodwin et.al. 1991). Biehler (1989) claims that the capacity of light rail is about 200 passengers per vehicle times 40 vehicles per hour (90 second headway) or 8,000 passengers per hour. Articulated buses, operating at 60 second headway, yield 6,000 passengers per hour, assuming 100 passengers per bus. One must be conscious of the possibility of requiring a transfer where the patronage demand on a 'feeder' service is not sufficiently high to justify articulated buses. It can be argued however that the elimination of transfers will increase patronage and hence is a strong case for articulated buses in the collection, linehaul (bus-based transitway), and distribution stages.

The critical consideration here must be the success that each mode can have in attracting patronage. Time and time again we come back to the nature and success of marketing strategies in promoting the various forms of public transport *and* the importance of redressing the pricing and other distortions which encourage the car. Critical issues will always centre on the factors that influence the choice between car and public transport.

8. Although LRT can be entrained, creating multiples of base capacity per hour, bus-based transitway capacity can be greatly enhanced by multiple buses using a single off-line station as well as through-buses which can pass very easily (as can LRT but at quite an expense for additional track). The bus-based transitway can also serve as the guideway for local bus services that have collected patronage locally and then become express non-stop to the central business district or a regional centre.

On a number of reasonable assumptions the patronage potential for a bus-based transitway can be as high as twice that of LRT. The relativities will be determined by the sophistication of the design of the bus-based transitway system. Establishing actual patronage is another issue, although we have yet to find any unambiguous evidence to suggest that you can attract more people to LRT than a bus-based scheme. This arises because of *the difficulty of finding very similar circumstances in which both LRT and a geographically comparable bus-based system are in place*. Certainly the performance of the dedicated bus-based transiway systems in Curitiba, Bogota, Brisbane, Pittsburgh and Ottawa deserve closer scrutiny.

Conclusions

There is a lot of support for an attractive alternative to the car in cities. However, it is very important if public transport is the way ahead that the investment in such systems is made in a rational way. There is a need for less expensive technology and consideration of more appropriate ways of addressing the problems caused by the automobile. Although there are signs of a shift from light rail to bus-based systems, following on from the earlier shift from metro to light rail (Edwards and Mackett, 1996) there are still many examples of more sophisticated technology being used than is necessary.

This all suggests that there are three major issues to be addressed: firstly, how to counter arguments about the very expensive `image benefits' bestowed by a brand new light rail system that a bus cannot provide, secondly, how to amend the funding mechanism so that the maximum benefit is obtained from the investment of public money in urban transport, and thirdly, how to amend the analytical process so that it does not over-estimate the benefits of a new public transport system.

The first two issues are related. The usual procedure is for local planners and politicians to promote and design a scheme, and then to apply to the appropriate government for the funding. It is easier to make the case for a `high-tech' discrete rail-based system rather than upgrading an existing bus system.

The USA transit experience is clouded by the availability of cheap money and the absence of any effort to provide incentives to attract patronage. Much of the debate in the 90's on new rail systems in the USA has emanated from over-zealous forecasts of patronage at the time of seeking financial support from Capital Hill. These projects failed to recognise how difficult it is to get people out of their cars:

> *'The impetus for building rail systems in the US has little if anything to do with passenger demand. It is largely related to the availability of federal money to build such rail systems' (Cox 1991).*
>
> *'Those responsible for transportation planning seemed more concerned about raising and spending vast sums of money than with improving mobility or improving transit service and increasing ridership' (Kain, 1988, page 198)*

The quote from John Kain sensitises us to the growing emphasis on opportunities for raising and spending large sums of money on nicely visible infrastructure such as light rail systems which are 'permanent' in ways which appeal to civic pride, to owners of strategically located property investments, and to politicians who see an opportunity for historical associations with physical monuments. Newman and Kenworthy (1989, 28) puts forth the view that good rail transit systems provide the opportunity for highlighting public values in ways which give a city new pride and hope for the future. While this may have some truth, it should not deny the capability of achieving the same impact with a high quality dedicated bus-based transitway. The images created in promotion of the Liverpool-Parramatta transitway in Sydney actually are more appealing to civic pride than the existing heavy and light rail systems.

What is needed is a funding regime that permits the development of maximum accessibility for a given sum. In many cities $300 million spent on a bus system would produce more improvement in accessibility than the same amount spent on a single light rail line, because the former system would cover a much larger area and so serve more people. However, it would not be so glamorous, and so the politicians and planners might not be so willing to plan and promote it. Nor would it be so easy to finance under present funding regimes that are geared to individual projects rather than achieving maximum benefits. In fact, in Britain outside London, because of bus economic deregulation it would be almost impossible to develop a large comprehensive bus-based system. Thus there has been the irony of a national government, which was committed to reducing public expenditure, funding expensive light-rail schemes because its desire to introduce market forces to bus operations meant that local bus services could not be planned and co-ordinated (Mackett and Edwards 1996a,b, 1998). All large cities in Britain either have or are developing new light rail systems. It is likely that light rail is not appropriate for smaller cities, but bus-based systems cannot be used in the UK for the reasons cited above. Some smaller cities are considering bus-based transitways and kerb-guided buses, but none are near to implementation. The existing kerb-guided bus system in Leeds and a similar system in Ipswich are very modest.

What about the future for bus systems? Buses, especially bus-based transitway systems are arguably better value for money and if designed properly can have the essential characteristicity of permanence and visibility claimed to be important to attract property development along the route which is compatible with medium to high density corridor mobility. To achieve this, the bus industry needs a 'wake-up' call. The opportunities are extensive but the industry is far too traditional (often complacent), often lacking lateral thinking and not pro-active enough. Furthermore, despite the appeal of bus-based transitways, there is still a lot that can be achieved by simple solutions such as adding more buses, adjusting fare schedules, improving information systems, integrating ticketing which is lost in the debate on over whether special rights-of-way for buses as against light rail are better.

The message is simple and powerful: distance our thinking from an obsession with technology and move to study needs as a starting point of inquiry. Do not ask if light rail is feasible, but ask who the stakeholders are and proceed to investigate how they may best be served. Institutionally, the presence of economies of network integrity may force a review of the existing spatially bounded franchised arrangements for bus service provision in cities such as Sydney, London and Auckland. This is the challenge.

Technology at Play: A Final Reminder and Caution

The debate on light rail versus bus-based transitway systems as preferred ways of delivering high-level public transport service continues unabated, with evidence being offered in support of both technologies. We have reviewed the evidence under the banner of choice or blind commitment. Positions change as 'evidence' accumulates. For example, swayed by the research of Hass-Klau and Crampton (2002)[1] the (then) UK Deputy Prime Minister John Prescott stated (in July 2000) that "…I have changed my mind. I wasn't convinced about light rail systems, which can be expensive, but I think in some cities they are the way forward". Prescott further stated that "… people who won't use buses will go by light rail". Surely a false premise! According to Hass-Klau and Crampton, UK light rail systems meet the key criteria to attract motorists out of their cars. These criteria are reliable, frequent, efficient, safe and clean transport with affordable fares. Why should this apply to light rail and not busway systems? The latter are typically one-third of the cost of light rail for the equivalent passenger capacity or the same cost for three-times the passenger capacity. The recently opened 16 kilometre state-of-the-art South East Busway in Brisbane is an example of a busway system that has exceeded expectations in ridership. In the first six months of operation, the number of passengers grew by 40% or by more than 450,000 new passenger trips, giving a daily average of 58,000. It is reported (in The Urban Transport Monitor February 8, 2002) that 375,000 private vehicle trips have been converted to public transport. Pittsburgh's (8 kilometre) third busway, which opened in September 2000, has secured average weekday patronage growth of 23% over the last 17 months. Current Pittsburgh average daily passenger trips on the full busway system of 43.8 kilometres) is 48,000.

Hass-Klau and Crampton (2002) suggests that '[The]…high cost and inflexibility of light rail – often considered to be drawbacks – actually turn out to be its main advantages'. This is a very strange defence indeed. They argue that inflexibility is actually 'code' for security – the population is confident that a change of political power or financial situation will not result in the new system being taken away from them, and can therefore plan their lives knowing that the system will be there in the future. This seems incredulous given the copious evidence to support the demise of light rail (or tram) systems historically. Finally Hass-Klau and Crampton state that "…the infrastructure costs are closer together than has often been assumed". They quote busways at £526,000 per kilometre and light rail (and guided busways) at £561,000 to £702,000 per kilometre. From this evidence one would hardly conclude that light rail is more favourable[2]. The best case is 6.6% more expensive and it is more likely to be 23.5% on capital costs. A salient lesson from the ongoing debate on technology preference (or is it bias /ideology?) is that one should distance thinking from an obsession with technology and move to studying the needs as a starting point of inquiry.

Do not ask if a particular technology is feasible, but ask who the stakeholders are and proceed to investigate how they may best be served. Let technology assist and not lead.

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[1] Hass-Klau had circulated a number of reports prior to the 2002 publication. The media in the UK widely quoted this material.

[2] The Rapid Transit Monitor published by TAS in the UK identifies 30 projects for light rail and tramway schemes in the UK including extensions to existing systems are struggling financially. The systems in Croydon, Manchester and the West Midlands did not make enough profits in the recent financial year to cover interest charges on their loans. The Docklands Light Railway and Sheffield's Supertram required on-going subsidy to cover operating losses. These are described in the report as worrying signs for the government.

Appendix 1

Practices that Offer Patronage Opportunities

There is no shortage of literature offering advice on what matters to travellers in respect of modal choice. However, the focus is so often on broad-based generic 'solutions' to patronage growth and retention that often fail to recognise the enormous constraints preventing logical application of such advice. In this section we attempt to highlight what might be seen as some of the most promising initiatives in delivering patronage growth that are within generally recognisable achievable bounds as perceived to exist within the political, commercial and regulatory settings in Australia.

There is a tendency under existing regulatory regimes to mandate minimum spatial coverage under a minimum-service level regime that has tended often to spread a thin market even thinner[3]. As nice and equitable as this contract condition may appear, it has not worked to secure patronage[4]. Growing patronage requires identifying and servicing specific corridors where one can focus on a high quality service in terms of frequency, reliability, travel time, visibility and security. The promotion of transitway systems accords with this although one does not necessarily have to commit large sums of money to establishing well-defined and serviced corridors. There are strong signs of a move back towards this perspective in the UK (outside of London) where thinning of services for spatial coverage has been singularly unsuccessful in patronage retention and growth.

The corridor focus is not new but needs to be moved to a higher plane. It is consistent with doing a relatively few things very well and building of their successes (and even learning from the failures). The Brisbane Transit plan is such an example where regional transit's role is to serve as every household's second car (the 'second car disposal' scenario). Other best practice guidelines that emanate from the literature (with a strong strategic and tactical focus and responsibility) include:

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[3] For example, commercial bus contracts in NSW are based on a rule that requires primary routes to be complemented by secondary routes (in peak hours and shopping hours) so that 95% of the net patronage potential reside within 400 metres of a primary or secondary route." This 400m requirement is not understood well. The contracts do not specify a bus stop within 400 metres of every residence/resident. The key contractual requirements hinge on 95% of net patronage potential. NPP discounts total population according to car ownership and competing rail and bus services in the area. "A primary route is… where 95% of the net patronage potential of the contracted region reside within 800 m of those routes".

[4] It may have served the needs of politicians in being able to say that they are providing public transport for all – but at what cost to the taxpayer?

- *Design the right product for the right role.* Examples would include establishing whether one is serving the transit dependant or mode-choosers. This highlights the niche approach.
- *Differentiate on the basis of service and not mode.* For example Ottawa (Canada) has a mode-neutrality policy for service development which supports the appropriateness of any modal input unimpaired by enshrined modal regulations. A very good example is the use of taxis as buses in very thin markets (with fares charged at bus levels and the difference reimbursed by government).
- *Link the centres.* Public transport's track record on leading land use is mixed.
- *Re-invent the bus* (rubber-tyred vehicles). Bus-based systems can mimic the operating characteristics of light rail systems allowing higher-grade bus services to be provided in corridors where rail would be infeasible or inappropriate (Hensher 1999 and herein).
- *Design from the results backwards.* Begin with a set of system performance goals and design backwards to arrive at a public transport product. The Curitiba bus system in Brasil is a notable example (Smith and Hensher 1998).
- *Focus growth strategically.* Tie improvements to the bus and rail network to increases in housing and employment densities in corridors and service nodes. This is the focus in Calgary, Canada.

On a more operational level the examples of key practices and public policies favourable to public transport use can be summarised under two headings – (i) reliability and frequency of service and (ii) comfort, safety and convenience of service. Appealing initiatives under (i) are:

- Wide spacing between bus stops at a route level to increase operating speed as part of a review of the role of express or limited stop services supplemented by all-stops services in accordance with improving accessibility.
- Prepaid tickets and boarding passes to expedite passenger boarding
- Low-floor buses with wide doorways to speed boarding and alighting
- Bus priority in mixed traffic such as bus lanes and special signalisation
- Vehicle locator systems (especially use of Global Positioning Systems and other tracking tools)

Appealing initiatives under (ii) are:

- Amenities at bus stops and stations
- Clean vehicles and knowledgeable drivers
- Convenient ticket purchasing places
- Footpaths leading to stations and secure lighted waiting areas
- Uniform and simplified fare structures across all public transport modes
- Discounted public transport passes tailored to individual needs
- Widely published schedules and colour-coded matching buses and lines

- Taxi services to extend and complete public transport networks (focussing on service and not modes).

Some of these initiatives are more likely to retain than grow patronage. As a package of initiatives they highlight the importance of quality partnerships between operators and infrastructure providers (something totally consistent with the STO framework). Increased spacing between bus stops may initially raise concerns but if developed under a plan of higher frequency in a corridor with each existing bus stop being served as frequent as before, it offers a much improved service level. This initiative would struggle if spread thin, and highlights the appeal of a corridor focus. Cross-regional services in a number of Australian cities have demonstrated the virtues of the corridor emphasis[5].

[5] The State Transit Authority (STA) of NSW subscribes strongly to the "corridor" concept in service planning. Corridors are stronger in some areas than others due to topography, historical development and road networks. For example, there is a strong corridor in the Warringah peninsula area due to pattern of development along Pittwater Rd. Corridors are not as strongly defined in the STA's south-west region (e.g., inner west area).

Appendix II

Comparison of Link light rail versus Bus Rapid Transit trunk line capacity: The Seattle Debate

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March 7, 2003

This whitepaper compares the people moving capacity of light rail (LRT) and bus rapid transit (BRT) in the I-5 and I-90 corridors. It compares their ultimate trunk line capacities one against another, and it compares ultimate capacity with forecasts of how much capacity Sound Transit plans to provide, and use, in the year 2020. The objective of the paper is to determine whether trunk line capacity per se is a valid criterion for choosing one technology over the other, and if so which technology wins. The broader rail vs. bus issue is nicely treated by Hensher. (Ref 12)

All figures used herein refer to one-way capacity or volume on a single track or HOV lane. The key metric is persons/hr (or pph) past a given point, such as for example across the ship canal bridge. Data is drawn from the transportation literature, Sound Transit reports, transportation agency web sites, and personal contact with staff in non-Puget Sound transportation agencies.

Key results are summarized in three charts inserted mid document.

The capacity issue is relevant for two reasons. First, the RTA (predecessor to Sound Transit) considered ultimate capacity a key reason for favoring one technology over another in the 1993 Final Environmental Impact Statement. At the time the RTA used it as reason for dismissing light rail. (Ref 1: p. 2-49 to 2-51, 2-58, 2-59, 2-61,2-62). Although not listed as an official criterion, the Final EIS also used capacity as a way of discriminating against the Transitway alternative. (Ref 1: p.xxx)

Secondly, some people still think buses have insufficient trunk line capacity to meet the region's long-term needs along the north south "spine". At the same time they believe light rail does have adequate capacity. They see capacity as the overriding strategic reason for building light rail. Do the facts support these beliefs?

Ultimate light rail capacity

The ultimate trunk line capacity of Link light rail is limited by three major constraints: station platform length in the Downtown Seattle Transit Tunnel (DSTT), the length of trains that can operate on surface streets in the Rainier valley, and the minimum headway between trains. The first two factors limit train length to about 360 feet, which translates to four car trains. Sound Transit's Final EIS assumed each train could carry as many as 533 passengers. (Ref 2: p3-7)

The more recent Fleet Management Plan dated July 2000, assumes 74 seats per car and 63 standees for a total of 137 passengers per car. (Ref 4: p.13) This translates into 548 passengers per train. The more recent EA for the Initial Segment repeats these assumptions. (Ref 3: Appendix L, p. 23)

Sound Transit assumes trains could be operated on headways as short as two minutes. (Ref 3: Appendix L, p. 23). Using thirty trains per hour and 548 passengers per train, Sound Transit concludes Link's ultimate capacity is 16,440 persons per hour in each direction. This is Links maximum ever one-way capacity, and is based on almost half the passengers standing. It only applies only to the north line (through the DSTT and on to Northgate).

Capacities elsewhere are lower because two-minute headways are not possible on the south line or on a potential east line along I-90.

The March 1993 FEIS asserts "Conventional transit practice and highway standards suggest that when train frequencies are under 6 minutes, cross traffic on arterials will be affected to the extent that grade separation is necessary….These constraints limit the capacity of surface LRT systems as compared to grade separated systems." (93 FEIS, p2-50) These statements imply that the very minimum headway in the Rainier valley --and thus on the entire south line-- can be no less than 6 minutes. And it may be longer. Assuming six-minute headways, the ultimate capacity of the south line is 5480 pph.

Assuming that any future east line via I-90 is 100% grade separated so that sub 6-minute headways were possible, it would be theoretically possible to interleave eastside trains running on as little as 3 minute headways with south end trains on 6 minute headways thus obtaining 2-minute headways in the DSTT. In this case the east line would run 20 trains per hour and have an ultimate capacity of 10,960 pph.

It is the authors understanding that no US light rail operates at under 2.5 minute headways, and the scheduling reliability that would be needed to smoothly merge east side trains with south end trains may well mean that 2 minute headways in the DSTT are unrealistic. Thus the above capacities should be viewed as best case for light rail.

Ultimate bus rapid transit capacity

For bus rapid transit to reach its <u>ultimate</u> people moving capacity, it --like rail-- needs to operate on an exclusive "guideway". With buses this guideway is called a busway, or a pair of HOV lanes dedicated entirely to buses. Just as light rails ultimate capacity assumes a pair of rails running up and down the I-5 and I-90 corridors, this analysis of BRT's ultimate capacity assumes a pair of HOV lanes doing the same thing.

Of course a continuous set of HOV lanes on I-5 and I-90 does not yet exist. However constructing them would not require widening either freeway. Most of the concrete is already in place, in the form of the reversible express lanes. In the 1993 FEIS one of the alternatives considered was a "Transitway/TSM" alternative. It was based on converting the I-5 and I-90 express lanes into bi-directional busways. Presumably this study established that such a conversion was technically possible. (Ref 1: p 2-18). Since 1993 there have been other studies of HOV lanes through downtown. Ref 9 has a diagram showing how the westernmost of the express lanes could be permanently dedicate to southbound traffic thus creating a two-way HOV facility from Northgate into downtown. (Ref 9: Fig.3-3 and p.3-27) See also Ref 10.

For purposes of citing the ultimate capacity of BRT it is assumed these HOV lanes are dedicated to BRT. However, at realistic levels of transit demand there would be space for other HOV vehicles to intermingle with the buses. The number of these other HOV vehicles could be managed to whatever level keeps the lanes flowing at 50+ MPH. Letting other vehicles share these lanes is a boon to car and vanpool usage, and it obtains the best lane throughput until that distant day when there are enough buses to fill the lanes. Now to the matter of ultimate capacity.

There are several ways to estimate the ultimate capacity of a stream of buses on a bus-only lane. We start with bus capacity. Sound Transit's November 1999 FEIS states that a 40 foot bus can carry 40 seated passengers or with standees a total of 52. The same table states that 60-foot buses can seat 60 passengers or with standees carry 78 persons total. Next we need to know the maximum number of buses per hour. There are several ways to estimate this.

As you drive the freeway you will find that staying about 3 seconds behind the preceding vehicle feels quite safe at 50 or 60 MPH. Three-second headways translates to 1200 vehicles per hour. On page 2-2 the Transit Capacity and Quality of Service Manual assumes a freeway lane can carry about 2300 autos per hour and that a bus would be equivalent to two automobiles. If so a freeway lane could carry 1150 buses per hour.

Assuming 1150 buses per hour at 78 persons per bus means one HOV lane used exclusively for Bus Rapid Transit has an ultimate capacity of 89,700 persons per hour with standees, or 69,000 with all seated.

Elsewhere the Transit Capacity and Quality of Service Manual mentions a "minimum operating threshold of 800 to 1000 buses per hour on a HOV lane. 800 buses per hour translate to 62,400 seated plus standing persons per hour.

In the real world there is probably no place where passenger demand is high enough to require all that capacity. There may be larger numbers in Asia but the highest actual busway volume the author has seen cited in the literature is 735 buses per hour in the peak direction in New York's Lincoln Tunnel. (Ref 7, p 2-40) This source does not cite ridership but it does show that it is physically possible to move at least 735 buses per hour past a point. If max capacity were needed these could presumably be 78 passenger buses in which case capacity would be 57,330 persons per hour. Or assuming 60 seated passengers per bus, 44,100 pph.

It does not matter which of the above is more accurate since all indicate BRT capacities far in excess of what Link light rail can carry, and indeed what the region will require. To be conservative the BRT bars in the charts below were scaled to 40,000 pph, even though --as indicated on the label-- the ultimate seated capacity of BRT is almost certainly well over 50,000.

As to actual BRT passenger volumes "Many BRT lines in South American cities carry peak-hour passenger flows that equal or exceed those on many U.S. and Canadian fully grade-separated rail rapid transit lines." (Ref 8, p.5)

The highest number cited is 25,000 pph in the peak direction on Bogotá's TransMillenio system. (Ref 8, p.5) The author's reference another study, which states there are other South American BRT lines carrying from 10,000 to 20,000 pph. (Ref 8, p.20) The famous BRT system in Curitiba Brazil carries 339,000 riders per day, with the highest peak-hour peak-direction volume on one line being 11,000 pph. (Ref 8, p.21)

Brisbane's BRT system runs 200 buses per hour carrying 9000 pph at the peak load point, while Ottawa's BRT carries 10,000 pph at the peak load point. Pittsburgh is currently running 96 buses per hour at the peak load point on the east busway. The associated passenger volume is 3700 pph. (personal communication with Port Authority staff, Feb. 2003). These actual passenger volumes are plotted on the bar chart below.

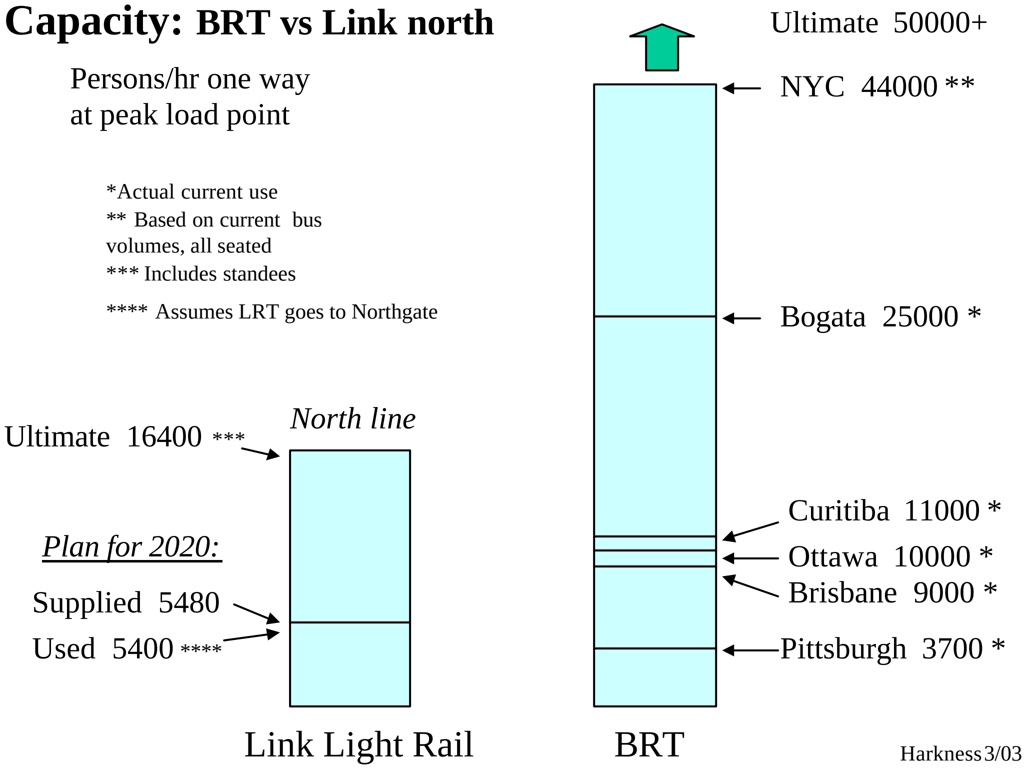
In sum, available data shows that BRT operating on an exclusive lane has a demonstrated one way capacity of 25,000 pph and a theoretical capacity well above 50,000 pph.

It is interesting to note what Sound Transit's predecessor agency said about ultimate BRT capacity in their 1993 FEIS, which compared heavy rail against a busway alternative. "The theoretical per direction capacity of a busway, or barrier separated lane for exclusive use for buses, is approximately 22,000 persons per hour in one direction past a single point." (Ref 1: p.xviii). Amazingly enough, operators of the New York busway and Bogotá's TransMillenio are already exceeding what Sound Transit asserts is the theoretical limit.

Capacity: BRT vs Link north

Persons/hr one way
at peak load point

*Actual current use
** Based on current bus volumes, all seated
*** Includes standees
**** Assumes LRT goes to Northgate



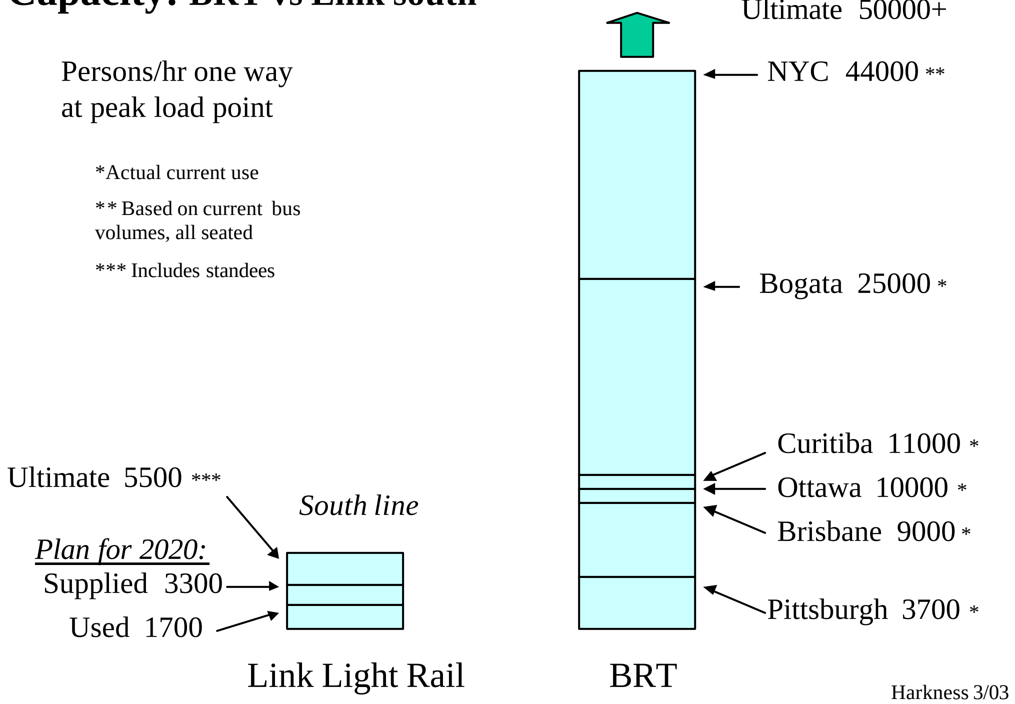
Capacity: BRT vs Link south

Persons/hr one way
at peak load point

*Actual current use

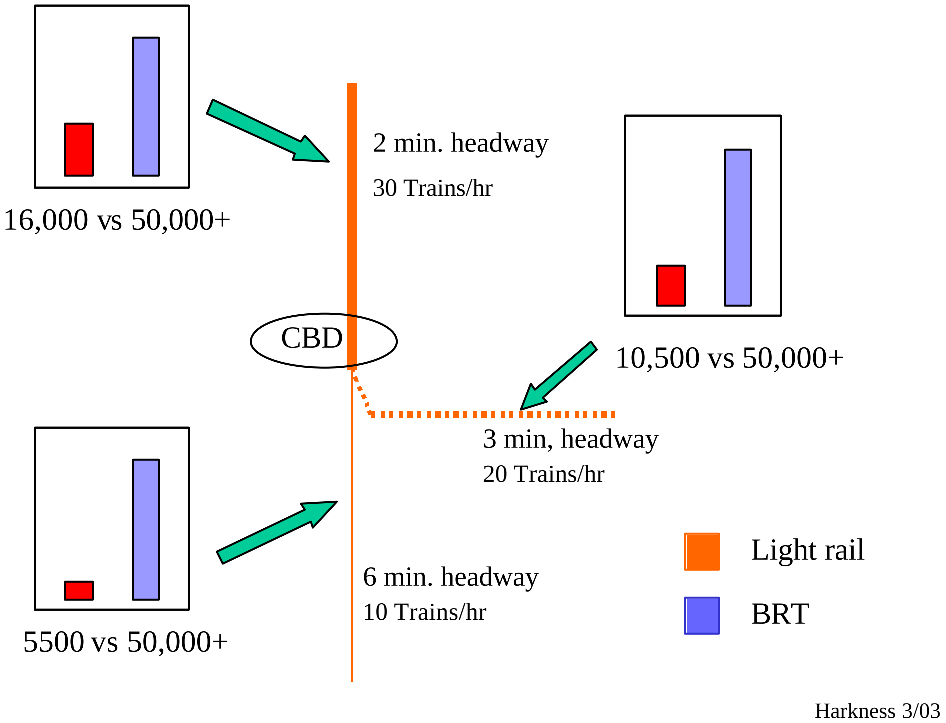
** Based on current bus volumes, all seated

*** Includes standees



Harkness 3/03

Ultimate capacity: Link vs. BRT



Forecast capacity needs

How much capacity does the Puget Sound transit backbone actually need? How much does Sound Transit actually plan to provide using light rail? Do either of these even come close to the limits of what light rail or BRT could actually provide? Is one technology able to meet the forecast demand while the other isn't?

The number of people that will actually ride transit on the core routes into Seattle is dependent on the quality of the transit system. A system that extends further out from downtown, involves fewer transfers, runs more frequently, and travels faster will garner more passengers than one that doesn't. That's the generalization. What are the specifics?

The highest forecast of estimated transit demand the author has located is for a peak demand of 15,000 pph in 2020. (Ref 1: p.2-58) That was apparently predicted in the 1993 FEIS for a 125-mile fully grade separated heavy rail system. There were no details explaining how this figure was derived. This same 15,000 pph "long range ridership projection" is repeated in the more recent EIS's for light rail, again with no indication of how it was derived. (Ref 3: Appendix L, p.23)

Sound Transit's "Operating Plan" for the original 21 mile light rail proposed a 2020 peak period headway of 5 minutes on the north line and 10 minutes on the south line using trains having a full standing load capacity of 533 persons. (Ref 2: Table 3.2-1 and Appendix M.2, page M.2-1). With a 5-minute headway the north line would have a capacity of 6400 pph, while the capacity of the south line would be 3200 pph. This is the full standing load capacity that Sound Transit actually planed to provide at the time the FEIS was published in Nov 1999.

The more recent July 2000 Fleet Management Plan assumed the line would extend to Northgate and on that basis said there would be 6-minute headways on the north line and 10 minutes on the south line. (Ref 4: p. 20) It also assumed 548 rather than 533 persons per train. The respective full standing load capacities (supply) would be 5480 pph on the north line and 3288 pph on the south line.

That same report has a chart comparing supply with demand. (Ref 4: p.24) It shows that year 2020 peak load point demand is expected to total about 5400 pph on the north line and 1700 pph on the south line. If the line did not extend to Northgate these volumes would be lower.

To put this into perspective, one 60-passenger bus every 40 seconds (with everyone seated) could handle as many passengers as Link light rail is expected to carry on the north line in the year 2020. One bus every 130 seconds could handle projected demand on Links south line. These are small numbers and could easily be carried by a BRT system. One bus every 40 or

130 seconds is nothing compared to the bus every 5 seconds running in New York's Lincoln Tunnel.

Ability to fully utilize trunk line capacity.

A comparison of ultimate trunk line capacity is only part of the overall capacity issue. As noted above there may not be anywhere enough demand to make ultimate capacity a relevant consideration. A second issue is the ability or inability to actually utilize the ultimate trunk capacity even if the demand did exist.

For rail systems to utilize their ultimate capacity, there must be sufficient feeder bus access to the rail stations, enough nearby park and ride spaces, and/or enough people within walking distance of stations. Shortcomings in any of these areas could limit rails useable capacity. For instance for rail to use its full 16,400 pph capacity on the north line it must be possible for a large number of buses to access the U District or Northgate station, and there must be large park and ride lots adjacent the stations. Since all light rail trains must transit the DSTT the ultimate useable capacity of Link light rail through downtown is 16,400 pph in each direction, assuming that there are no limits in getting people to and from the stations.

On the other hand for BRT trunk lines to reach full utilization it is necessary to have enough on-off ramps and load/unload areas on the suburban end(s) or the BRT routes. On the downtown end there must be adequate egress ramps and adequate load/unload areas. BRT has an advantage in that load/unload areas don't need to be right along the freeway. For example buses could load/unload in the center of the University District, then traverse over to the I-5 busway. On the downtown end they can split off to serve various areas.

To better image this, imagine some distant future time when the bus handling capacity of the DSTT has been exceeded and there are say 25,000 pph coming south across the ship canal on a fleet of BRT buses in the HOV lanes. In this event the buses would be organized into three groups. One for persons destined for areas near the DSTT, one for those destined to south lake union and other downtown locations not adjacent the DSTT, and a third group for those going to all destinations south of downtown. The first group would go through the DSTT to unload. The second group would exit the HOV lanes at Mercer or other downtown exits (many or most of which already exist). The final group would stay on the HOV lanes and continue south through the downtown.

If these HOV lanes and access ramps exist (as previous plans have already envisioned) the usable capacity of BRT up and down the I-5 spine is truly enormous. Certainly far greater than light rail, which is limited to 16,400 under the best of circumstances.

Bus versus rail on I-90

Although there are technical uncertainties about being able to put light rail on the existing I-90 bridge, I will assume here that the I-90 express lanes can be converted into either a two way HOV facility, or used for light rail. Used for BRT their ultimate capacity is 50,000 pph. Used for light rail their ultimate capacity is 11,000 pph. Clearly BRT is the better choice for those wishing to provide maximum transit capacity into the distant future.

In the more likely situation that mass transit demand is under 11,000 pph for many years it would still be a mistake to preempt the express lanes for light rail because it would reduce the throughput of those lanes. For instance lets assume mass transit demand were 5000 pph. That could be handled by 83 BRT buses per hour, and --assuming lane capacity is 1000 vehicles per hour -- still leave room for 917 other HOV vehicles. They would include carpools, vanpools, school buses, emergency vehicles, utility crew trucks, and other multi-passenger vehicles. The combined capacity of the lane becomes the 5000 pph carried on BRT plus whatever these other HOV vehicles handle. By definition, the total exceeds the 5000 that a rail only scenario could accommodate. In sum, HOV operations in the I-90 express lanes would provide more people moving benefit than would conversion to light rail. This is true regardless of the level of mass transit demand. It is true in the near term, the intermediate term, and the long term.

The above analysis shows why light rail will probably never be built in the I-90 corridor.

If light rail does not go over I-90, light rail in the DSTT can never reach full capacity and the DSTT will remain underutilized. But getting the best utilization out of the DSTT is a separate issue that won't be elaborated here.

Conclusions

The trunk line capacity of Sound Transit's proposed Link light rail is severely constrained by local conditions particular to Seattle, namely station length in the DSTT and on-street operations in the Rainier Valley. Link light rail has nowhere near the people moving ability of heavy rail systems like BART or the Washington DC METRO.

Capacity on Links south line is limited to one third of what the north line could carry. This forever shortchanges the entire south end in terms of regional transit capacity.

The likelihood of building light rail in the I-90 corridor is remote since it would reduce the people moving capacity in that corridor to well below what a mix of BRT and other HOV vehicles could achieve.

Buses operating on HOV lanes are capable of carrying several times more passengers than Link light rail will ever be able to carry. If ultimate trunk line capacity is the issue, BRT wins. If the intent is to invest in transit that can satisfy Puget Sound's needs far into the indefinite future, BRT is probably the answer.

Sound Transit's estimated year 2020 passenger volumes for the Link light rail, which assume it extends to Northgate, are far below the systems maximum capacity. They could easily be carried by a modest BRT system.

Understanding the ultimate useable capacity of either light rail or BRT requires additional analysis of how people will access the rail stations or how buses will access the HOV lanes under full load assumptions. (The light rail FEIS looked at access under forecast demand, not full demand, conditions.) There may be constraints that would limit how many people could actually access the line haul facility.

Demand, not supply, is the real issue policymakers should focus on. Given that the DSTT is only operating at half capacity today and Sound Transit only expects light rail to operate at about one third capacity twenty years from now, ultimate trunk line capacity, or even ultimate usable trunk line capacity, is probably not a valid criterion for favoring light rail over buses, or vice versa. This is especially true on the north line where both technologies have far more capacity (supply) than the region is forecast to demand over the next 20 years. A possible exception is Links south line. It has quite a low capacity and merits a closer look before concluding it's sufficient to meet long term needs.

The focus on capacity has been diverting attention from the real issue. The real issue is: for an investment of X Billion dollars, which technology can attract the most riders? The GAO study and other research strongly suggest that the answer is bus rapid transit, since more route miles can be built for the same cost.

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Short Bio Professor David Hensher

David Hensher is Professor of Management, and Director of the Institute of Transport Studies: The Australian Key Centre of Teaching and Research in Transport Management in The Faculty of Economics at The University of Sydney. David is a Fellow of the Academy of Social Sciences in Australia, Past President of the International Association of Travel Behaviour Research and a Past Vice-Chair of the International Scientific Committee of the World Conference of Transport Research. David is on the editorial boards of 10 of the leading transport journals and Area Editor of *Transport Reviews*. David is series and volume editor of the handbook series "Handbooks in Transport" published by one of the world's most prestigious academic publishing houses - Elsevier/Pergamon press. He has published extensively (over 300 papers) in the leading international transport journals and key journals in economics as well as five books. His most recent books are on the *Demand for Automobiles*, published by North-Holland the *Bus and Coach Business* (Allen and Unwin), *Transport: An Economics and Management Perspective* (Oxford Univeristy Press), and *Stated Choice Methods* (with Jordan Louviere and Joffre Swait – Cambridge University Press). He has recently completed a book on *Applied Choice Analysis – A Primer* (with John Rose) forthcoming with Cambridge University Press. His particular interests are transport economics, transport strategy, sustainable transport, productivity measurement, traveller behaviour analysis, stated choice experiments, dynamic discrete-continuous choice modelling, privatisation and deregulation. *David has recently embarked on a major research endeavour with Prof Stewart Jones that uses advanced discrete choice methods to study the performance of firms with a specific focus on the distress of firms.* David has advised numerous government and private sector organisations on matters related to transportation especially matters related to forecasting demand for existing and new transportation services, for example the Speedrail project, the Liverpool-Parramatta Transitway, the North-West Sydney Transport Study, the M2, M4, M5 and cross-city tunnel tollroads. David is regarded as Australia's most eminent expert on matters relating to travel demand. Appointments have included: a member of the executive committee that reviewed bus transport bids for the Olympic Games, the NSW Government's Peer Review Committee for the Strategic Transport Plan, Peer reviewer for Transfund (N Z) of the New Zealand project evaluation program, and a member of the executive committee of ATEC, a consortium promoting a freight rail system between Melbourne and Darwin.