Light Rail and Bus Priority Systems: Choice or Blind Commitment?

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Abstract

The debate over light rail transit (LRT) systems is often a confrontation between advocates and opponents of LRT systems. It is difficult to separate real evidence from opinion about LRT. We review evidence and viewpoints about LRT systems in comparison to bus priority systems (BPS), the latter often combined with high occupancy vehicle (HOV) lanes. Bus-rail comparisons are difficult because people tend to think of existing bus services which are constrained to share congested roads with cars for most of their routes. But there are a few examples of extensive dedicated busways or HOV lanes, these bus operations are more akin to LRT systems. BPSs are capable of moving comparable volumes of people at less cost than LRT. Where BPS and HOV systems are in use, they appear to move more people than are being moved in established LRT systems. LRT systems may have an advantage in influencing land-use in a way which will promote greater reliance on public transit. But it appears that similar impacts can be achieved by bus-based systems.

There is a need for closer study and analysis of busways and HOV lanes. It is also important to recognize that neither BPS nor LRT are likely to have much impact on overall mode split unless substantial steps are taken to discourage single occupant motor vehicles.

I. Introduction

The debate on the role of light rail transit (LRT) in urban transportation has evolved into a "yes it is" and "no it isn't" confrontation (Brindle 1992). The *"yes it is"* supporters might be described as having a belief that fixed track and dedicated right-of-way mass movement technology is consistent with the objectives of reducing the dominance of the automobile and in increasing the density of urban living. There is a fundamental belief that planning controls must be used to override individual preferences for use of the motor car, and a further belief that, once in place, an LRT will reshape urban density and foster life styles more conducive to reliance on public transport. The *"no it isn't"* critics are seen essentially as economic rationalists who emphasize the accommodation of market forces, i.e., accommodating people's preferences regarding urban transportation. They acknowledge that there are market failures to overcome, chiefly the under pricing of motor cars because incremental congestion and pollution costs are overlooked by motorists, possibly along with the true opportunity costs of roads and parking facilities. The economic rationalists argue for better pricing policies to provide more accurate signals for both users and providers of transport services. Then a combination of market forces and cost benefit analysis of public projects would guide the development of an efficient urban transport system. Critics probably would respond that this is a recipe for continued reliance on the motor car.

Advocates of buses and bus priority systems (BPS) fall in between these two polar positions. BPS is promoted as a more flexible system than LRT, capable of providing high volume movements close to LRTs' at lower cost, and generally superior at collecting and distributing passengers at the hubs along high volume corridors. But LRT advocates see buses as an outmoded technology incapable of providing a satisfactory alternative to car use, and not capable of reshaping land use and life styles conducive to greater reliance on public transport.

The future of our cities and role of transport in them is of wide interest. People have desires about the future shape of cities and opinions about how transport options will contribute to or interfere with their vision of the future city. When we debate future plans for cities and transport, all of us have preconceptions. It is difficult to distinguish desires or wishes from objective evidence on what will actually happen. In this paper, we attempt to identify key areas of debate among advocates of alternate public transport systems and try to more clearly distinguish beliefs versus real evidence about LRT versus bus-based public transport systems.

One must discuss alternate public transport systems fully cognizant of the continued preference for the motor car by those able to drive and who can afford it, which are the majority in the population. There are pricing distortions which have artificially stimulated growth and reliance on cars, but they did not need much stimulation. The latent demand was there. In a democracy, it is difficult or even impossible to adopt policies fundamentally conflicting with the majority. This is a handicap facing planners of any urban transport system, bus or LRT. Public transport systems must be constantly compared with the attractiveness of the motor car. Transit systems which are fundamentally unattractive relative to the car will suffer from low utilization except perhaps during the busiest peak hours along major corridors. This is not an argument in favor of the motor car, merely recognition that it is going to remain prominent in the urban landscape.

What is important is that an understanding of consumer preferences, incentives and disincentives in the determination of the demand for passenger transport modes is central to arguments about the viability of all modes of transport. A productive strategy should emphasize the identification of the best collection of alternatives, alternatives which provide for a variety of informed choices of life-style, land-use and transport, including the automobile. We note that unless some sort of penalties are imposed on urban motorists to correct the implicit subsidies for automobile travel, the prospects for either LRT or BPS are very limited. The need for and methods for discouraging car use are not addressed here; we confine attention to the relative merits of LRT versus bus-based systems. The broader issues of how public transport might be positioned relative to the automobile is discussed in Hensher (1993) and Brindle (1992).

This paper is organized as follows. We begin with a commentary on the merits of light rail and bus systems, followed by a critique of some of the most controversial points. The issue of land use impacts is considered, given its high profile as a justification of light rail over bus systems. The paper concludes with a summary of the major points. The role of public transport for downtown circulation is not considered explicitly.

II. Alternative Forms of Public Transport: Making the Comparisons Meaningful

One very positive outcome of the ongoing light rail "debate" is a 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), Biehler (1989), Nisar et.al. (1989), Richmond (1991), Pushkurev and Zupan (1980), Pickrell (1984) and Taylor and Wright (1984). In the current paper, we consider the evidence on the costs and benefits of light rail and bus systems, with particular attention given to the biases in the positions taken by advocates of either form of public transport.

We limit the comparison to light rail and bus priority systems (the latter often referred to as busways, transitways or exclusive bus lanes, including guided busways), since this represents the most useful context in which to illustrate the way in which a non-rail public mode can offer a comparable type of service. That is, a bus system which has many of the characteristics of rail systems as well as a number of significant distinguishing features.

Defining Bus Priority Systems

Bus priority treatments take the form of (i) exclusive bus lanes on major roads, including contra-flow bus lanes (ii) bus-only streets and automobile free zones and (iii) signal preemption capability and banned turned exemptions of buses. Bus priority gives public transport both real and perceived advantages. It enables buses to pass traffic queues and to deliver/pick up passengers from locations which can be denied to the automobile. Such priorities also indicate to car users how society values the bus traveller.

With increasing traffic congestion, the lack of priorities for buses leads to greater problems for both buses and cars. The need for long, reserved, clearly marked and enforceable bus lanes, possibly combined with assured priority through traffic controls, becomes very important to enhance bus service quality. Important side issues are (1) whether or not bus lanes should be shared with other vehicles (i.e. high occupancy vehicle or HOV lanes) and (2) whether it is wise to develop a bus lane as a "take-one-lane" strategy rather than "add-one lane" strategy. Addressing the latter first, because of the loss of road capacity under already congested conditions, most advocate introducing bus lanes via new facilities rather than converting existing lanes to bus (or HOV) use. The merits of sharing busways are more debatable. Bus service is the senior partner of HOV systems. Multiple-occupancy cars and vans have increasingly been introduced in the USA, although the majority of passengers are bus passengers (Pratt, 1991). The extent to which mixed traffic should be allowed to use a bus priority system will depend on the objective of the action. If there is a case for demonstrating that a bus priority system can have the characteristic of dedication/permanence argued for light rail (below), then access by non-bus vehicles may be denied; if however the interest is in providing efficient utilization of infrastructure, then the case for mixed traffic (especially in the off-peak) is strengthened.

Bus priority systems can be provided at the very local level right up to the regional level. In reviewing the range of ways available to improve the serviceability of buses, one has to make a distinction between strategies which are effective at a very local level and those which have systemwide impact. This distinction is not necessarily confined to the types of facilities - it can be as much a function of the scale of the facility. For example, an extensive application of signal preemption capability and banned turned exemptions can have very substantial benefits to the overall efficiency of the bus service. It may not increase patronage significantly, but will save on costs quite substantially. However, it may reduce capacity of the road system and make society worse off, given that car users are in the majority.

The majority of bus priority schemes in Australia and overseas 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) 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 busway operations in the USA, Canada, Brazil and Australia. The longer busways such as the Shirley Highway into Washington DC from Virginia is 19.2 kilometers with 2 reversible priority lanes in the median. The San Bernardino busway in California is 18 kms (Gordon and Muretta 1983) and the Route 55 HOV lane in Orange County is 20 kilometers (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). A series of express busways covering 55 kilometers 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 busways. The relevant comparisons between bus and LRT should focus on examples of lengthy bus priority lanes.

III. What is the Evidence: Light Rail and Bus Priority Systems?

Evidence consists primarily of two types: the costs of alternate systems and their effectiveness at attracting patronage. There is a third criterion which is often implicit rather than explicit: the impact on land-use and future travel patterns. This is alleged to be an important advantage of LRT systems.

III.1 The cost of alternative systems

Pickrell (1984) compares actual bus system costs with best practice light rail costs, where buses are local services operating on congested roads. He 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 5 miles (8 kilometers), and bus operating speed of 12 mph. Pickrell shows that the bus/light rail break even 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 time 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.

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 kilometers 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 busways 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 percent to 50 percent. 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 utilizes the existing dual track structure and bridges in the first 12 kilometers of the rail corridor, with new single track and bridges being built to complement the remaining 13 kilometers 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 are necessary to build the parallel guideway. While both options have approximately the same travel time, the bus priority system costs 30 percent 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 favoring higher ridership (an issue which is controversial, although see the Ottawa experience through regulation, discussed below). The inherent lower cost of the busway reduces financial risk while its off-guideway flexibility automatically broadens service opportunities.

A recent study of public transport options in Canberra (Denis Johnston and Associates - DJA 1992) suggests that a busway is more cost efficient than light rail. All operating and maintenance costs excluding depreciation and interest are $3.00 - $3.50 per vehicle km for a busway and $3 - $5 per vehicle km for light rail - Table 5.1, and capital costs are approximately 50 percent lower for a busway. They argue in support of light rail because it has the advantage of permanence because of 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 (see below) 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. The DJA study indicates that there is no strong evidence that patronage would be significantly different for a busway 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 busway, given Canberra's urban strategy.

A cost benefit comparison of LRT and an exclusive busway applicable to Sydney (Ip 1992) under peak loads varying from 1500 pcu per hour to 4500 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 busway. In all cases, the busway had a benefit-cost ratio significantly higher than LRT, even allowing for a 25 percent higher level of patronage using the LRT than the bus priority system. The usefulness of these figures is critically dependent on patronage assumptions.

Curitiba, in Brazil, introduced a bus priority system at a cost of $US54 million, 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).

Pittsburgh opted for exclusive busways in preference for LRT. The two busways are the South Busway and the East Busway. 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" (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 busways have been evaluated are still making adjustments to maximize patronage, in particular utilizing the bus-feeder concept as part of an overall public transport system.

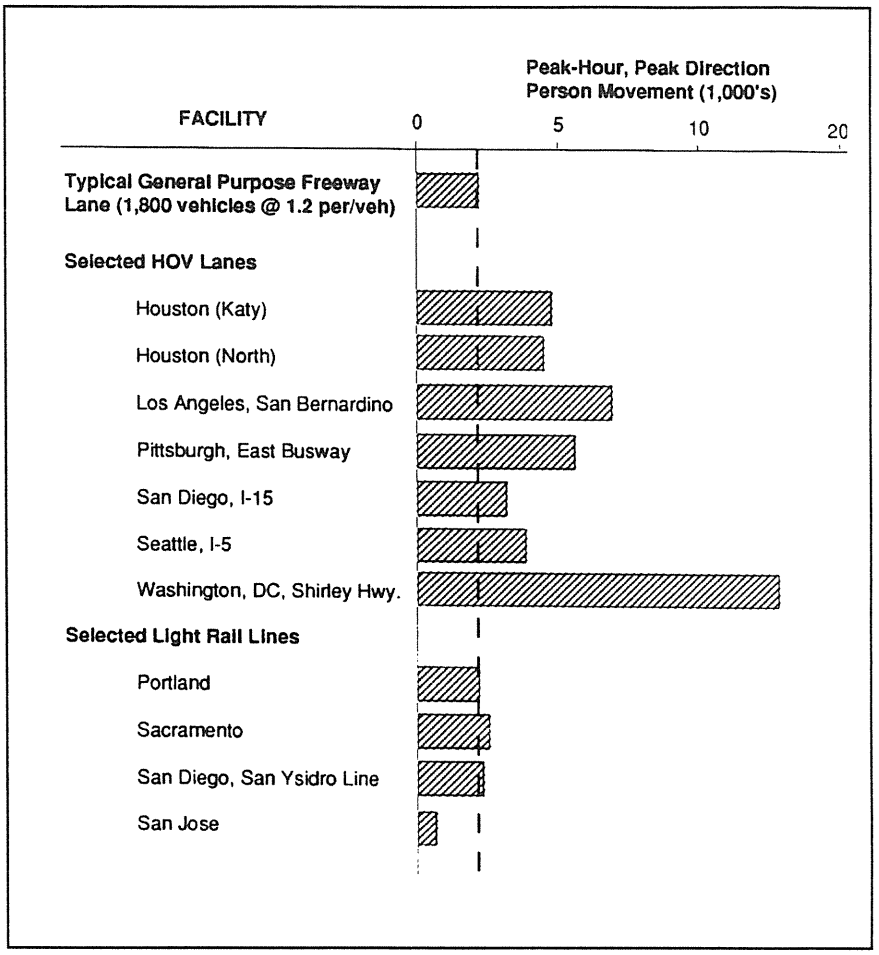
Although any comparison of systems located in different urban areas is problematic, nevertheless some amount of comparison is permissible in order to form a judgment on the relative merits of each system. As of 1987, the unit operating costs for each system are $0.43 for Pittsburgh East and $0.56 for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

The important implications of this comparison are: (i) the busways 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 - see Table 1), and (iii) they cost about the same per kilometre to construct as the lower

cost LRT systems.

Table 1 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 utilization 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.

Figure 1: A Comparison of Ridership Rates of a Number pf BPS and LRT Systems



III.2 What about patronage?

An obvious consideration in any debate on modal futures is the capability of a mode to attract patronage. The previous section 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 subsidized fresh air. It is somehow assumed in most commentaries on LRT that there is a sufficiently strong demand to justify a (subsidized) 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 (often cited by Peter Newman as an example of best practice) was only 45 percent of the official forecast (Gordon and Wilson 1985).

The Portland-Oregon light rail line, for example, 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 percent 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 and Love, 1991). The overriding evidence suggests that up to 70 percent of new rail ridership is diverted from bus (an experience reproduced in Sydney), with buses

rerouted to serve rail interchanges.

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 20 years to attract significant levels of new patronage to rail is in large measure due to the lack of disincentive to using the car.

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).*

The same arguments, but for lower cost, may well apply to bus priority systems.

III.3 Easy money and toy trains

The USA transit experience, often cited to support the revival of public transit, is clouded by the availability of cheap money and the absence of any effort to provide incentives to attract patronage. Much of the debate 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 recognize 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 and Love, 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 sensitizes us to the growing emphasis on opportunities for raising and spending large sums of money on nicely visible infrastructure such as 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 (1991, 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. We must be wary of the view that a rail system is by definition a transport of delight, a symbol of progress at which all can marvel, whatever the reality of its actual performance in enhancing social mobility, alleviating congestion, or reducing pollution (Richmond 1991). It has even been suggested quite explicitly that the major part of the appeal of rail transit is a childish fascination with electric trains (Richmond 1991, Kain 1988). Other forms of public transit such as bus systems are viewed as lacking visibility, permanence and status. We rarely speak of the "set of buses" we acquired in our youth.

IV. 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 which are different from busways, 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 center near a station which showed a 25 percent 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 likely to have an impact on land use in the western areas of Sydney and hence increase land values. Washington DC Metrorail which has a 26 percent 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. A recent inquiry by Brindle (1992a) into the Toronto experience, (a city extensively cited by Newman and Kenworthy, 1989, as an example of how rail systems encouraged reurbanisation), 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 1992a, 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, 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 busway infrastructure is not in place, especially infrastructure built specifically for exclusive bus use. Ottawa's new busway system combined with strong land use regulatory powers illustrates what can be done for busways 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 center/transitway station has recently been opened.

Over $US700 m 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.

A Lesson: *The message is very clear: a metropolitan strategy can embed an effective bus-based system within its overall land use/transport plan which can produce the same types of impacts as rail. What is required is enabling legislation with a mandated land use/transport plan which explicitly prioritises the role of bus-based systems.*

The arguments in favor 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 busway) 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 line haul service without transfer; (iii) general urban area-wide 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 busway 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 recognizing 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 decentralization 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).

Curitiba, a city of 1.6 million located 400 kilometers 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 center. 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 busways 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 Ottawa and Curitiba experiences are worthy of special investigation. They appear currently to offer the best examples of how a bus-based system might 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 favoring bus and LRT systems has not met with success as well summarized by Henry (1988):

> *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).*

V. A Summary of Current Experience

This section pulls together various points gleaned from the reviews of current experience and the arguments in the bus - 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 systems.

1. Busway 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, although the dis-utility of a bus-rail transfer penalty is lower than for a bus-bus transfer. This provides some basis for promoting the design of busways in the context of the entire collection and distribution task, ensuring that the exclusive busway combines with the entire matrix task of buses to minimize transfers, as successfully executed in Curitiba (Herbst 1992).

2. We know that transfers are a major constraint on use of public transport (Horowitz and Zlosel 1981, Charles River Associates 1989). 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 minimize travellers' dis-utility, *including transfer penalties* (i.e. not just time but the act of transfer) will look substantially different from those planned to minimize overall travel time.

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 computerized traffic control system gives priority to buses. There are 100 tubular bus shelters, with passengers paying fares 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 busway, where comparisons are possible. The most cost-effective LRT is 60-80 percent higher than a busway. The

comparison must be qualified by the fact that LRT trip lengths are longer, but that the busway component of the bus trip only is used in the comparison. The level of patronage will be critical to the outcome.

4. Bus priority systems are simpler to operate and maintain than LRT systems, the latter typically attracting a sizeable support system such as an operations control center 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 for busways.

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 maximize the use of the excess capacity in the off-peak in particular is a more attractive proposition than LRT.

6. Bus priority systems permit far more flexible operation (Moffat 1991). Buses travelling in the one direction can pass more easily than LRT, especially when off-line busway 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 busway, 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, line haul (busway), 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 motor car. Critical issues will always center on the factors which influence the choice between automobile and public transport.

8. Although LRT can be entrained creating multiples of base capacity per hour, busway 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 busway can also serve as the guideway for local bus services which have collected patronage locally and then become express non-stop to the CBD.

On a number of reasonable assumptions the ridership potential for a busway can be as high as twice that of LRT. The relativities will be determined by the sophistication of the design of the busway 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 priority scheme. This arises because of *the*

difficulty of finding very similar circumstances in which both LRT and a geographically comparable bus priority systems are in place. Certainly the performance of the dedicated busway systems in Curitiba and Ottawa deserve closer scrutiny.

VI. Conclusions

Western societies in the main have an attitudinal problem in regards to the relevance of buses in contrast to railways as serving more than local area markets. We pay a very high price for this cultural constraint. The current very public campaign to inform the public about the virtues of light rail is a campaign of misleading information, notably in respect of capital and operating costs, levels of subsidy and prospects for reducing the dominance of the automobile and changing the spatial structure of our cities. Bus priority systems make no strong claim to accommodating all of these desirable outcomes either - but they do offer an equivalent service for a lower cost:

> *I continue to be puzzled by the persistent popularity of light rail transit. LRT seems to me to be nothing more than a slow and expensive bus that cannot pass and is unable to operate on the city streets (Kain 1988, 202).*

Exclusive bus lanes or high occupancy vehicle lanes of sufficient length to establish bus travel as a line haul option (and not just a feeder facility) can return high dividends *within* the set of public transport options. It may not produce significant change in overall modal shares even though the absolute number of bus users can be substantial; but neither is LRT bringing about shifts in modal shares.

The land use impacts of bus systems have not historically been as noticeable as that attributable to rail (with notable exceptions), primarily because the idea of a bus hub is relatively new. There is no reason why bus systems cannot secure the land development benefits attributable to rail when dedicated long distance busways are in place: the only difference to rail then is that the track is not steel (Stokes et .al. 1991). The Ottawa and Curitiba experiences are exemplary. The flexibility of bus service onto and off of the fixed "track" should give the bus system appeal not available to train (provided travellers in the main do not have to transfer or transfer with minimal effort).

Although BPS's can have a permanence of their own, as documented above, in some situations exclusive busways and LRT can be substitutable investment options. The choice will hopefully not be determined by technological bias (" trains are sexy, buses are boring" - Richmond 1991). It is difficult to evaluate the empirical evidence because selection of particular results can favor the reporter's specific biases. What the literature does suggest unambiguously, is that exclusive bus lanes can in some contexts have a role as a transitional public transport facility, allowing time for patronage levels to reveal a market for LRT. Transitional status should be linked to thresholds of patronage levels required before moving from exclusive bus to LRT, and not the suitability of maintaining a service in the selected corridor. The flexibility of a busway permits a whole range of future options including reversion to mixed freeway traffic (with road pricing/tolls) as well as modified bus services, and LRT (even heavy rail). Flexible directional capacity can be offered by bus priority together with a greater mix of express, limited-stop and all-stop services, compared to other forms of public transport. The challenge however is to make potential users aware of this.

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