Mass Transit in Developing Cities

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Using case study material, this paper examines the relative merit of metros and high performance bus systems in use in Third World cities. It demonstrates that buses with suitable priority measures are capable of meeting high passenger demands. The paper also shows that despite the poor financial performance and other shortcomings of metros, they can yield a respectable economic return. The paper draws on studies undertaken as part of the research program of the Overseas Unit of the Transport Research Laboratory.

Introduction

In the context of the increasing problems of urban traffic congestion and pollution, and the great dependence on public transport for access and mobility, many developing city authorities are searching for cost-effective ways of providing mass transit facilities. Over the last two decades some 20 developing cities have implemented metro systems, and many others are actively planning to do so. During the same period some cities (including a few which have built metros) have adopted a less costly approach to enhancing mass transit provision, giving priority to buses in order to increase effective public transport capacity.

To put these options in context, Figure 1 shows the results of a survey of transport policies in major Third World cities where metros are currently in operation or are planned (Thomson et al., 1990). The use of traffic management was universal in the 21 cities surveyed, and most had some form of urban traffic control (UTC). Parking restrictions were common, but generally not well enforced; futhermore, parking fees were usually too low to have any significant impact on car-use. Only Singapore made a serious attempt to restrain the use of cars, though Hong Kong, and to a lesser extent some other cities, imposed high motor taxes in order to restrain car ownership. Bus priority measures, as part of traffic management schemes, were little in evidence; six cities had actually abandoned bus lane schemes because of poor enforcement.

All the 21 cities in the survey were investing a high proportion of their resources on transport infrastructure, involving major highway

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construction, suburban rail upgrading and metro development. Few cities had opted for the cheaper public transport options of light rapid transit (LRT) and buses on reserved tracks.

	No. of Cities Adopting Measure
Policy measures:	
traffic engineering	21
bus priorities	5
bus ownership (public/private)	varies
paratransit	13
fares control	20
quantity control (of buses)	7
restraint measures (parking/other)	3 / 2
Investment measures:	
busways	4
light rail at-grade	6
metro (grade-separated)	14
suburban rail upgrading	13
major highway construction	17

Figure 1. Transport Strategy in 21 Major Developing Cities.

This paper examines the performance of two quite different options for mass transit: buses with some form of priority, and metros. Buses provide the cheaper option, are often the main existing carrier, but have capacity limitations. Metros are expensive to construct, but provide very high quality and quantity of service along their operating corridors. The paper draws on studies undertaken by the Transport Research Laboratory (Allport and Thomson, 1990, Cracknell et al., 1990).

Bus Priority

During the 1970's bus priority systems were implemented in many cities. Measures included with-flow and contra-flow bus lanes, bus streets and spot improvements. While some schemes were very effective, many (as indicated earlier) were ineffective due to enforcement difficulties, poor design and other factors (see, for example, Walker et al., 1988).

The main feature of bus priority schemes is the separation of buses

from other traffic, either at selected locations (like bus-stops) or along running sections. *Bus lanes* involve "paint and signs" to demonstrate the bus priority while *busways* involve construction which physically segregates lanes from other traffic. A busway may be implemented as a traffic management measure, without complementary improvements to bus operations and managements, but *busway transit* involves a package of such measures with the general aim of promoting high output from bus-based transit. Thus busway transit includes a right-of-way for the exclusive use of buses, with at least one section of busway and some additional features like well designed bus stops, special operating methods (bus convoys or express operations) and efficient fare collection methods.

Busway schemes have been proposed for a number of reasons, the main advantages and disadvantages being as set out in Figure 2. The earliest schemes were introduced in Europe in the early 1970's but in the late 1970's and early 1980's a series of innovative busways was implemented in various Brazilian cities, many with World Bank encouragement and assistance. Other examples of Third World city busways are in Abidjan, Ankara, Bogota, Istanbul, and Lima; plans exist for others in Bangkok, Jakarta, Karachi, Nairobi and Shanghai.

Advantages:	
Low Cost	- likely to be no more than US$1 million per km, for basic infrastructure
High local content	- infrastructure requires little extra expenditure of foreign exchange
High capacity	- maximizes achieveable output from buses
Good commercial speed	- reduced interaction with other traffic
Flexible routing	- buses can access the busway at point along its length
Incremental benefits	- busway can be developed in stages
Disadvantages:	
Poor image	- not a 'high profile' system like light rail or metro
Environmental hazard	- diesel buses are major source of particulate emissions
Traffic impact	- reduces available road space to other traffic
Fleet compatibility	- only a problem if special vehicles are purchased for busway operations
Institutional	- requires exceptional co-ordination between various authorities

Figure 2. Advantages and Disadvantages of Busways.

Surveys undertaken as part of the TRL study (Gardner and Fouracre, 1990) have indicated that some existing busways achieve very high bus and passenger throughput (numbers of buses and passengers handled per direction per hour). Maximum recorded passenger flows were 26,000 per hour per direction (in Porto Alegre, Brazil), at speeds of around 20 kmph. Figure 3 shows, for those busways surveyed, some of the key peak performance figures. From an analysis of each busway it is apparent that the main factors associated with average speed are bus stop and intersection spacing. In the city center sites where stops and junctions occurred frequently, average speeds were around 11 kmph. On the suburban busways where longer distances between stops existed, averages of around 21 kmph were achieved. Furthermore, the provision of special operating features (overtaking bays, bus-ordering and trunk-and-feeder systems) was also associated with relatively higher speeds.

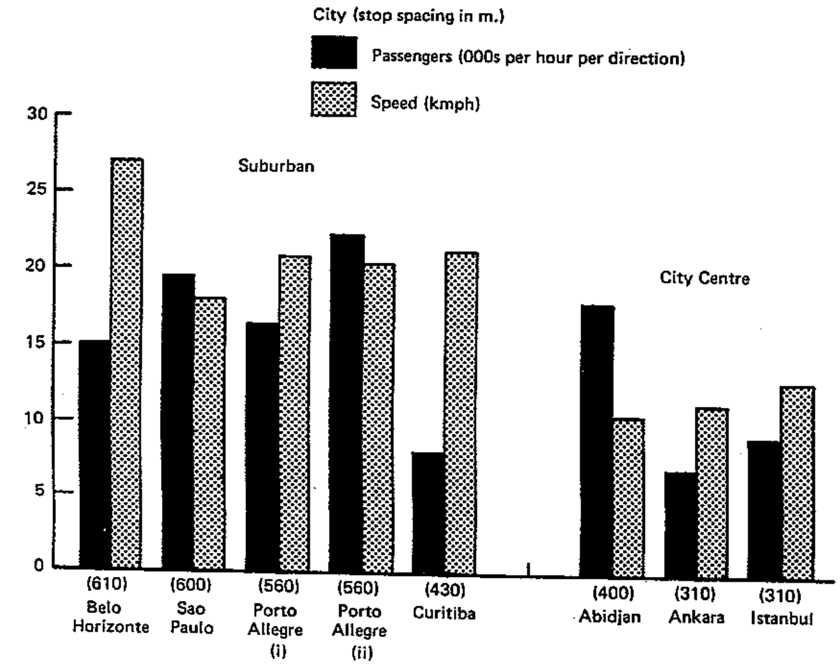

Figure 3. Summary of Busway Performance.

Metros

The earlier metros installed in Third World cities were heavy systems with 6-8 car trains, capacity for up to 75,000 passengers per hour per direction at speeds in excess of 30 kmph, and largely underground. More recent developments including Manila, Istanbul and Tunis have adopted lighter and cheaper technologies with 2-3 car trains, capacity for 14-28,000 passengers per hour per direction at speeds of around 25 kmph, and on tracks which may be on the surface or elevated. The main distinguishing feature between LRT and surface metro is that the latter is grade-separated along its whole alignment.

Metros have been justified for a variety of reasons, the two most consistent being that the metro would improve the quality of public transport (the existing bus services being slow, crowded and uncomfortable) and that the metro would relieve traffic congestion problems by replacing buses and attracting motorists from their vehicles. There can be little doubt that the first objective has been achieved, but there is little evidence of any long-term reduction in road congestion. None of the metros covered in the TRL survey (Fouracre et al., 1990) attracted more than a very small proportion of motorists, and any road space consequently released was quickly taken up by suppressed demand.

Metros have rarely matched the expectations of their planners. Apart from the problems of implementation which have often led to substantial time and cost over-runs, the ridership on metros has usually been below that forecast. This can often be attributed to poor alignment (perhaps choosing an 'easy' alignment at the expense of potential catchment) or to poor attention to integration and fares issues. Whatever the reasons, the financial performance of metros has been largely poor: both capital and operating costs have generally exceed estimates, often by a large margin, while patronage and revenues have fallen short.

Metros, like any other major city investment, can be used to influence land use development. With a few exceptions however, little development has been positively promoted by governments, or by the private sector to exploit the metro facilities of Third World cities; the real impact is permissive in that the metro permits the city center to develop freely in response to market forces. The alternative, decentralized development, also has attractions, but can also entail costs in terms of continuing, chronic overcrowding of buses on the main radials and additional transport costs caused by cross-city traffic generated by the location pattern.

While metros are poor investments in financial terms (revenues covering costs), in the wider economic sense (taking account of, for example, the valuation of time savings to both users and non-users) most Third World metros have been quite successful. Figure 4 summarizes the results of an economic analysis of 13 metros and Figure 5 describes the characteristics of the cities in which these metros are located. The best returns were in Singapore and Hong Kong, which no longer merit developing country status. However, the majority of cities have achieved economic internal rates of return of between 10-15%, which is respectable, though not outstanding. The beneficiaries of the metro investment are largely existing public transport users: either those who switch to the metro, or those who remain on the bus transport. Together their time savings account for almost 75% of the benefits.

Evidently metros can be justified in economic terms where certain conditions hold. These include: the existence of a high-demand corridor (probably above 700,000 passengers per day) which can no longer be served by bus transport alone; a high city income (probably above US$1800 per head) with good growth for both income and population; a record of achievement in transport developments.

City	Capital Cost $mn	Trips/day in metro corridors (000s)			EIRR %
		base year (without metro)	evaluation year: total trips	evaluation year: by metro	
Cairo	526	830	4963	2110	16.8
Calcutta	684	736	992	400	2.8
Hong Kong	5051	2059	9121	3489	18.5
Manila	563	2250	3309	853	11.4
Mexico City	1974	4056	10184	6003	11.4
Porto Alegre	278	567	850	375	8.9
Pusan	680	2273	3616	664	14.2
Rio de Janeiro	2219	2100	4299	1700	7.1
Santiago	940	2302	2700	900	13.5
Sao Paulo	2280	2368	11245	3651	10.7
Seoul	5240	1127	12705	2897	14.7
Singapore	2502	1391	3961	1260	20.5
Tunis	231	162	1728	700	12.4

Notes: 1) capital costs are in 1986 dollars and refer only to the lines tested;
2) base year is first full year of operation; evaluation year is 20 years after completion of investment.

Figure 4. Economic Evaluation of Metros in Case Study Cities

Comparing the Options

The degree of segregation between transit vehicles and other traffic is reflected in both the capacity and speed of mass transit operations. Busways allow buses to carry perhaps double the passengers of an equivalent on-street system, and at twice the speed. Similarly metros (even those using light technologies) have a significant advantage over

City	Population million (1986)	Per capita income US$ (1986)	Vehicle ownership (per '000 pop)	City structure and form
Cairo	10.0	1100	80	Linear/polynuclear
Calcutta	13.0	500	35	Circular/polynuclear
Hong Kong	5.3	6700	50	Semi-circular/polynuclear
Manila	8.9	1000	75	Semi-circular/polynuclear
Mexico City	18.0	2800	210	Circular/polynuclear
Porto Alegre	3.1	2100	90	Semi-circular/polynuclear
Pusan	3.8	3100	45	Linear/mononuclear
Rio de Janeiro	10.0	2100	100	Semi-circular/polynuclear
Santiago	4.0	1700	95	Circular/mononuclear
Sao Paulo	16.0	2100	140	Circular/polynuclear
Seoul	8.1	3400	40	Circular/polynuclear
Singapore	2.6	8200	185	Semi-circular/mononuclear
Tunis	2.0	1900	40	Semi-circular/mononuclear

Figure 5. Characteristics of Case Study Cities.

trams which share road-space.

The superior passenger handling performance of urban rail systems is related to the fact that station spacings are typically longer than bus stop spacings, and also because rail systems are purposely designed to offer very high passenger transfer capacities in short time intervals. Modern train control equipment and efficient passenger handling allow minimum headways between trains of 120 seconds with transfer rates at stations of perhaps 1,000 passengers per train. Fares on metros are pre-paid and passengers have easy access to and from the metro from high level platforms, and through multiple access doors. Buses may have only one entrance and one or two exists, with difficult stair access and inefficient ticketing arrangements. The maximum transfer rates on an efficient bus system have been observed to be of the order of 5,000 passengers per hour.

The additional capacity which metros offer must be off-set against very much higher investment costs. It is difficult to make strict comparisons because metros tend to be 'closed', whereas busways often form part of an 'open' system in the sense that they may be used by many routes sometimes over the whole length, and sometimes over only short lengths. An at-grade, partially segregated busway track (excluding vehicles and terminals) may cost in the order of US$1 million per Km; an elevated track may be ten times this. Metro costs may range from around US$20 million per km for an at-grade system using light technologies, to US$100 million per km for an underground heavy system.

Operating costs of metros are similarly higher than comparative bus costs. Armstrong-Wright (1986) estimated that bus costs range from 2-8 US cents per passenger-km, whereas metro costs range from 10-25 US cents per passenger-km. Perhaps not surprisingly, few metros cover even their direct operating costs (excluding depreciation on assets).

The great advantage of busways over metros is in their flexibility: the ability to change alignments relatively quickly in response to changing demands; the ability to implement progressively as demand increases or as funds become available; the ability to implement piecemeal projects in key areas; the ability to penetrate development, not necessarily where the main rights-of-way exist. Perhaps most important of all, the development of busways builds on the cities existing wealth of experience in bus operations; the majority of public transport provision in most developing cities is, and will remain, bus-based.

The paradox remains, however, that despite the importance of buses, they receive very little support in the way of priority measures. It seems that because neither the suppliers of buses or bus services, nor

any single public transport agency control the provision of track, busway transit has no natural promoter in the way that metro schemes have. Bus operators clearly have an interest, but some are very conservative in what they believe buses can achieve, and in other cases the bus operating industry is too fragmented and has no clearly represented voice on operational requirements. Furthermore, there are few examples of busway transit which can demonstrate to transport decision-takers what can be achieved; the performance of the few successful busway schemes has perhaps not received sufficient attention.

The Future

The construction of a metro is a very costly way of upgrading public transport, particularly so in a developing city with very scarce resources. Despite this, and despite the further evidence relating to the problems of metro implementation and performance, many cities have gone along this road; furthermore, virtually every developing city which has built a metro wants to extend it.

There are important city corridors (particularly in large cities) where, if demand is to be met, there is no technical alternative to a metro. And in the right conditions, it is likely that such a metro would achieve a respectable economic rate of return. In smaller cities and along lower demand corridors busway transit could equally well meet the requirement. It seems reasonable to accept that passenger flows of 20-25,000 per hour per direction can be achieved by busway transit with appropriate infrastructure design and operational characteristics. The authorities in Sao Paulo are trying to squeeze even more capacity out of busways by making passenger transfers more simple, using metro techniques - high level platform and wide access doors to buses.

Technological developments may add to the basic choice between bus and metro; guided busways, at-grade LRT, and lighter metro systems are increasingly being considered as possible development options. Until more research is undertaken to establish their performance under different conditions, it is not possible to say whether they are exact substitutes for bus or metro, or whether they offer advantages for a particular range of passenger handling needs, perhaps somewhere in between bus and metro.

Funding sources will obviously be critical to any new development. Finance packages from the aid agencies and manufacturers of industrialized countries seem readily available for metro projects, but there seems little encouragement for busway projects, probably (as indicated earlier) because recipients cannot yet be convinced of their worth. The evidence from the TRL study suggests that there should be greater support for busway projects.

In the longer term investment in a metro is likely to have a much more profound effect on the development of city structure than a busway. Urban rail tends to accentuate or enhance existing trends in land-use; it cannot, of itself, promote development, but will feed on and fuel existing growth. Urban rail will inevitably help support the development of a highly centralized city, because it will be developed to cater for existing high corridor movements which are likely to be radial in nature. Whether this is the best development option for a city is a contentious issue and beyond the scope of this paper. It is an issue, however, which must be addressed.

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Multiobjective Pricing of Bus-Subway Services in Santiago, Chile

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Presently, the surface transit system in Santiago, Chile is private and atomized. It operates in competition with the subway, covering long distances and causing congestion in the central business district. As the subway operates below capacity, integrated services with a common fare have been identified as both operatively and financially possible, making better use of resources and avoiding negative externalities. A multi-objective approach is formulated and applied to determine the price of the combined service, accounting for both users' benefits and operators' profit. The role of different parameters in the financial and operative constraints is analyzed in particular, as well as the conflicting nature of the objective functions. The non-inferior set of solutions is constructed and analyzed both in the decision variables space and in the objectives space, and solutions are compared against the present conditions.

Introduction

The experience in different urban areas teaches us that the transportation system should be looked at as a whole. It operates to satisfy the need for displacements of the individuals and, at the same time, it influences the style of development of a city. This does not mean that a centralized operation of the system is necessarily optimal; rather, this view means that the interrelation among modes should be understood, such that advantages and disadvantages of competition or complementarity are detected in order to promote actions towards the efficient use of resources on one hand and towards an adequate service to the passengers on the other. Thus, transport projects that might imply both saving resources *and* faster, cheaper or more comfortable trips, are indeed worth analyzing.

The transportation system in Santiago, Chile, seems to admit medium term improvements in the sense just described. It operates with two subway lines that intersect near the CBD, and a fairly dense (highly connected) network of bus lines that serve practically every O-D pair without transfers, and generally passing through the CBD. The bus fare is flat and about 30% higher than the subway fare, which is nearly flat

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