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APPROPRIATE MASS TRANSIT IN DEVELOPING CITIES

Geoff GARDNER and Francis KUHN

Since the vast majority of people in less developed countries will continue to rely upon public transport for some considerable time, it is essential that their urban areas have the best possible mass transit system. Research recently completed has shown that the solution chosen by many cities can not always be justified on technical or economic grounds alone.

Buses, which are the predominant mode of public transport in most developing countries, suffer because of traffic congestion. Segregated Busways provide a good service but have a poor 'image'. Rail-based systems are able to avoid congestion, but need a dedicated right-of-way, and have very high construction costs. Light Rail Transit (LRT) may offer an intermediate solution; it is thought by many to be capable of carrying high passenger flows, and to possess an appealing modern image, but without the high costs of a full metro system.

A current TRRL/INRETS joint programme has looked at seven cities operating Light Rail schemes; findings suggest that there is not always a large difference between LRT and Busways in terms of the number of passengers carried on a single corridor. Many cities appear to find it difficult to use the full capacity of rail-based systems for extended periods of time. In none of the case study cities was light rail technology being extended to its limits. The next stage of the research will be to examine exactly what these limits are. A simulation model for this purpose is currently under development.

Reasons for choice of mass transit technology are compounded by overwhelming commercial pressures from multi-national manufacturers, a desire to improve a cities image or status, and a lack of unbiased guidance. It is hoped that the results of this research programme, when completed, will improve the information available to help guide both technicians and politicians towards an appropriate solution.

APPROPRIATE MASS TRANSIT IN DEVELOPING CITIES

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1. INTRODUCTION

Many of the world's great cities face ever increasing problems of traffic congestion. This can hinder economic growth and cause severe environmental damage. Buses, which are the predominant mode of public transport in most developing countries, are forced to compete for road space with all other users in the traffic congestion and hence frequently fail to deliver an acceptable service. Rail-based systems are able to avoid congestion, but need a dedicated right-of-way, and have very high construction costs.

The selection of an appropriate mass public transport system causes problems for a developing city. Local decision makers will often be faced with overwhelming commercial pressures from multi-national manufacturers, and a lack of properly researched, unbiased guidance.

The Transport and Road Research Laboratory (TRRL) recently completed a study of heavy rail or 'Metro' transit systems in Developing Countries (Fouracre et al, 1990). This suggested that metros may be the only option capable of carrying more than 30,000 passengers per hour per direction, but that cities should exhaust all alternatives before opting for one. A parallel study by INRETS (Henry, 1990) focused on metro developments in South American cities. It noted that metros may have long-term benefits associated with the socio-economic development of a city, which are not always quantifiable or quantified in economic assessments of metro development.

One possible alternative to a metro may be a high capacity segregated bus system or Busway. TRRL research (Gardner et al, 1991) has shown that, technically, busways could be a good alternative to many potential metro systems. The low take-up of the busway option, however, suggests that their performance does not compensate for the lack of 'image' which city authorities are looking for in a transit system.

A third mass transit option is light rail transit (LRT). This has been proposed for a number of developing cities on the grounds that it can offer a mass transit solution which will be capable of both carrying high passenger flows, and have the right combination of an appealing, modern image without the high costs of a full metro system.

This paper looks at the performance and costs of these three main options, drawing on the results of earlier studies by TRRL, and on the latest results of a current TRRL/INRETS joint programme on LRT.

2. METROS

2.1. Description

A metro is often referred to as an underground railway, but can, in fact, be any grade-separated inner-city railway. The track and electric vehicles are similar to suburban railways, though with closer station spacing. Trains may have 6-8 cars, which in some cases are operated over an extensive network (in excess of 100km); more typically, however, network size in a developing city is around 20km. Many of the great cities of the western world have had metros for many decades; the major cities of developing countries are now following suit. Around twenty systems have been built in developing cities during the last 20-30 years.

2.2. Metro performance

As metro vehicles can be very long, and contain very high numbers of standing passengers, total occupancies per train can be extremely high (up to 3000 per train in some cities). When coupled with short headways, achievable through the use of high technology signalling, the total passenger flow per hour can be higher than for any other form of transit.

As shown in Table 1 flows of over 80,000 passengers per hour per direction (p/h/d) have been reported on the Hong Kong Metro. Many of the other cities achieve high flow rates which could probably be increased even further, if there were sufficient demand, and if the technology were in place.

The primary disadvantage of a metro system is its extremely high construction cost. As shown in Table 1, the construction cost of three of the twelve systems studied by TRRL exceeded \$80 million per km.

The high cost of purchase and maintenance of high technology equipment also appears to negate the inherent advantages of a low friction steel wheel vehicle; total operating costs per passenger kilometre are in the range 1.6-6.4 US cents. By comparison bus costs are around 1.1-2.0 US cents per passenger km (Fouracre et al, 1990).

2.3. Metro achievements and expectations

One of the greatest disappointments with metros is that rarely do they seem to meet their expected performance targets. In the three key areas of construction cost, construction time, and passenger demand, almost all the systems in the TRRL study fell short of expectations.

All underground projects are subject to unforeseen problems of ground condition and service diversion. Metro construction sites also tend to be so large that management and cost control can be a problem.

Table 1: Capital costs, passenger demands and operating costs per passenger of several metro systems

System	Capital cost \$/km	Passenger demand/h/d	Operating cost/pass. US cent	Operating cost/pass./km US cent
Cairo	13	22,000	-	?
Calcutta	26	~5,000	28	4.7
Hong Kong	131	81,000	81	3.3
Mexico	30	65,000	14	1.6
Porto Al.	10	~11,000	71	6.4
Pusan	32	13,000	33	4.3
Rio de J	83	22,000	32	6.4
Santiago	36	20,000	17	3.1
Sao Paulo	80	57,000	27	3.8
Seoul	45	?\	18	2.0
Singapore	37	14,000	-	?

Notes: 1. Figures taken from Fouracre et al,1990.

2. Operating costs include depreciation on equipment, but exclude initial capital cost repayment.

Passenger demand is crucially linked to the location of the metro and its alternatives. If, as is often the case, the track is located just off the main corridors of demand in order to save on land acquisition costs, then the passengers may be unwilling to walk the extra distance to the stations. Once required to use a bus to reach the station, they are then susceptible to competition from bus services that serve the same areas as the metro but without the inconvenience of an interchange between modes.

3. BUSWAYS

3.1. Description

The concept of a bus-lane is well-known, being an area of road space reserved for buses only by the use of paint and signs. This gives buses priority over other vehicles, leading to fewer delays. A busway (as shown in Figure 1) includes some form of physical segregation. A Busway Transit system might have many of the attributes of a metro; that is fixed routes (which are clearly named, for example 'central line', 'green line' etc.), dedicated named station/stops, a corporate image for vehicles, timetables, and publicity material.

3.2. Busway Performance

The maximum line-haul passenger throughput recorded in the TRRL study was 26,100 p/h/d on Ássis Brasil, Porto Alegre. The Sao Paulo busway also achieved a high throughput with 20,300 p/h/d. Both of these Brazilian busways were well designed and operated: more basic busways in Turkey and in Africa carried flows in the region of 7,500 to 19,000 p/h/d.

Average bus commercial speeds along the case study busways ranged from 12.0 to 24.6 kmph during the morning peak and from 8.0 to 29.3 kmph during the evening peak (Figure 2). Bus stop and intersection spacing, and the provision of special operating features, would appear to be the main influence on bus speeds. All bus stops surveyed which had overtaking facilities had lower overall delay times than those without. Overtaking also permits the introduction of limited-stop and express services, making overtaking bays at stops one of the most cost-effective measures to improve capacity and commercial bus speeds under normal circumstances.

COMMONOR (Szasz et al, 1979) is a technique which involves assembling buses at the start of the busway into a sequence corresponding to the route and stand order at individual bus stops along the busway. Buses then proceed along the busway in a manner similar to a train; boarding of buses at all stands takes place concurrently,

thus coordinating the time lost through deceleration etc. and reducing the queuing time associated with loading buses at the first stand holding up all others. The use of bus ordering (a less rigid form of COMMONOR) was found to improve busway performance.

The use of trunk-and-feeder services can also improve throughput. With trunk-and-feeder services, a dedicated busway fleet maintains very short headways on the trunk routes. Other off-line buses provide a feeder service to the trunk routes at intermediate and terminal points, rather than travelling through to the city centre.

3.3. Busway achievements

About forty operational busways are in existence worldwide, with many more planned. There are, however, few schemes planned in the developing world, despite the fact that much of the pioneering work in busway development has been undertaken in Brazilian cities.

The results of the busway study suggest that in terms of costs and benefits, busways should be in use in far more locations than they currently are. The fact that they are not, and that in many instances metros have been built instead, can only satisfactorily be explained by the busway's lack of image. A busway lacks the high profile of a metro project, and is not something with which the politicians can readily be identified.

4. LIGHT RAIL TRANSIT

4.1. Description

There are many conflicting views of what constitutes a Light Rail Transit system. As the term implies, LRT usually employs vehicles and track construction which are less substantial than a full metro. Some systems, including those in Manila and Istanbul, use lightweight vehicles on a system which has an exclusive track and high platforms similar to many metros. Trams are a basic form of LRT which have limited rights of way, sharing roadspace with ordinary traffic.

4.2. LRT performance

4.2.1. Modern light rail vehicles

Actual passenger flows are difficult to obtain, and field surveys form an important part of the present TRRL/INRETS study. Table 2 gives some estimates of LRT performance from a previous study of passenger flow levels, based on the operators' own statistics for a range of modern systems using light rail vehicles (Barbieux and Kuhn, 1990). In none of these cases is LRT exceeding the passenger

performance achieved by the best busway transit systems. This is subject to verification, but suggests that many cities may find it difficult to use the full capacity of an LRT for extended periods of time.

4.2.2. Tramways

Tramways were used extensively in many cities of the world until competition from motor-vehicles forced them off the streets. Of the systems still in existence, some, like Cairo and Calcutta are very old systems that are not now fully utilised; others, particularly those in East/Central Europe continue to make an important contribution to public transport. Table 3 gives passenger volumes for selected systems; the high annual volumes are representative of the extensive networks in these cities. Individual corridor flows are not very high, however. As Figure 3 shows, flows of less than 5000 p/h/d were recorded during the present study in Prague and Budapest (although in both of these cities the highest demand corridors are now served by metros.)

One interesting example of a tramway being intensively used is reported in a study by Ruger(1984). He records how the spectators at the giant sports stadium in Leipzig were transported home from the East German games by a specially arranged fleet of trams. Operating at minimum headway, and with police providing priority at all junctions, the trams were measured as carrying passenger flows of 16,300 passengers per hour per direction.

4.3 Potential performance

The TRRL/INRETS study of tram/LRT performance has, as its immediate aim, to determine the potential performance of this mode of transport, and to examine what features critically affect performance. The study team have so far visited tram/LRT systems in Cairo, Alexandria, Tunis and 7 East European cities. None of these appeared to the team to be extending light rail technology to its limits. The next stage of the research will be to examine exactly what these limits are.

The cities which have the most modern vehicles and the most efficient operations (and therefore the highest potential capacity) are almost all in West European cities with high car-ownership and low public transport demand. Where public transport demand is high, in developing cities, poor quality vehicles, inefficient operations and bad maintenance often prevent optimum capacity being reached.

As there are no suitable high capacity case studies, it will be necessary to use other methods to investigate the potential performance of a good LRT system. A simulation model which can replicate the operations of a mass transit system is

currently under development and will be used to examine how performance may be improved.

Another approach has been to collect data on LRT performance in association with details describing the LRT network; some of these, such as the ability of the driver, cannot be easily measured but others, such as the number of stops, can easily be obtained from maps. The influence of the selected factors will be examined using multiple regression analysis.

5. CONCLUSION

Since the vast majority of people in less developed countries will continue to rely upon public transport for some considerable time, it is essential that the best possible mass transit system should be in place. Research recently completed, or in progress at TRRL and INRETS has shown that the solution chosen by many cities cannot always be justified on technical or economic grounds alone. As shown in Figure 3, there is not always a large difference between modes in terms of the number of passengers carried on a single corridor.

The choice of system falls into three main categories; metro, busway, and light rail. Metros can carry high passenger flows, but are expensive: busways carry moderately high flows at low cost, but have a poor image. The current research on LRT, although not yet completed, does not suggest that it will be a perfect intermediary between these two options. In any event, no one mode may be suitable for a city, or even a complete corridor; it may be better to select a combination of modes to match localised needs.

Reasons for choice are compounded by overwhelming commercial pressures from multi-national manufacturers, a desire to improve a cities image or status, and a lack of unbiased guidance. It is hoped that the results of this research programme, when completed, will help to improve the information available to help guide both technicians and politicians towards the right solution.

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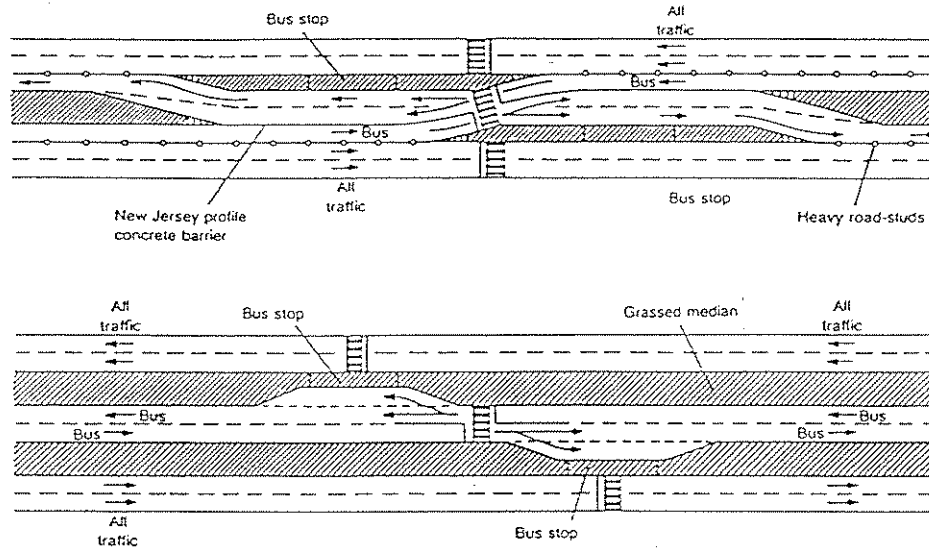


Figure 1: Typical Busway Layout

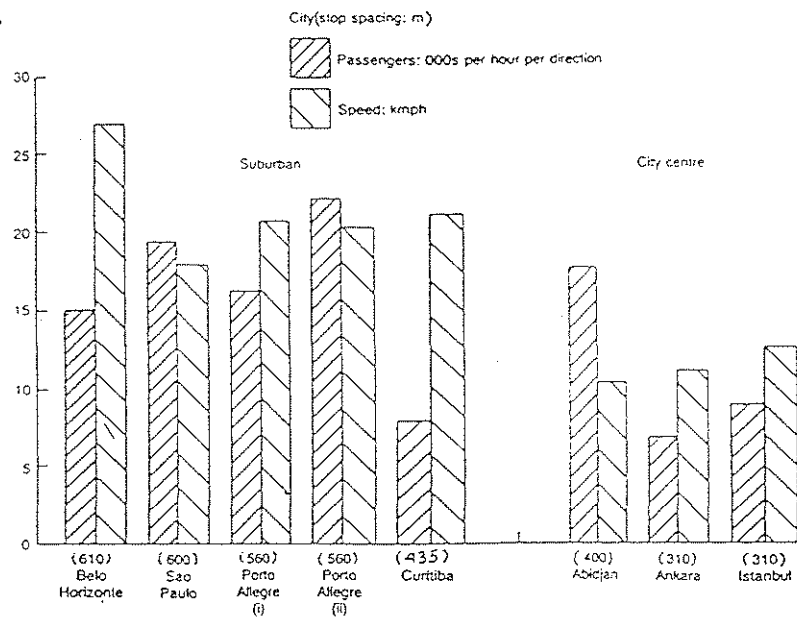


Figure 2: Summary of Busway Performance

City	HEADWAYS in min., secs.		EQUIVALENT PASS FLOWS at Nominal Capacity pas./h/direction	
	Design (1)	Actual (2)	Design (3)	Actual (4)
MANILA	1' 30"	2' 30"	39 840	15 936
TUEN MUN	1'	2'	22 800	11 400
TUNIS	2'	4'	17 160	8 580
ISTANBUL	2'	5'	20 970	5 592

Courtesy of:

International Symposium Istanbul 05/1988: data of light rail transit of Istanbul.

Der Stadtverkehr, Von Krug 02/1986: data of the light rail transit of Tunis.

International Railway Journal, J. Sembrano 07/86: data of the light rail transit of Manila.

Modern Tramway, Runnacles 07/1986: data of the light rail transit of Tuen Mun

1. The design headway is the headway which could be adopted by the operator when all the necessary conditions will be realized: safety signalling, blocks signalisation and the number of rolling stocks to transport the important demand of passengers.

2. Actual headways are dependent of the amount of investment on the track (lights coordination, separated right of way in the CBD) on the fleet of rolling stocks.

Table 2: Estimation of Modern LRT Performance.

City	Passengers / year millions pas.	Commercial Speed km / h	Comments
Saint Petersburg	956 (1)	16, 5	58 lines and 569 km
Leipzig	208 (2)	18, 7	19 lines and 201 km
Prague	418 (2)	16, 2	34 lines and 504 km
Budapest	415 (1)	14, 7	37 lines and 176 km

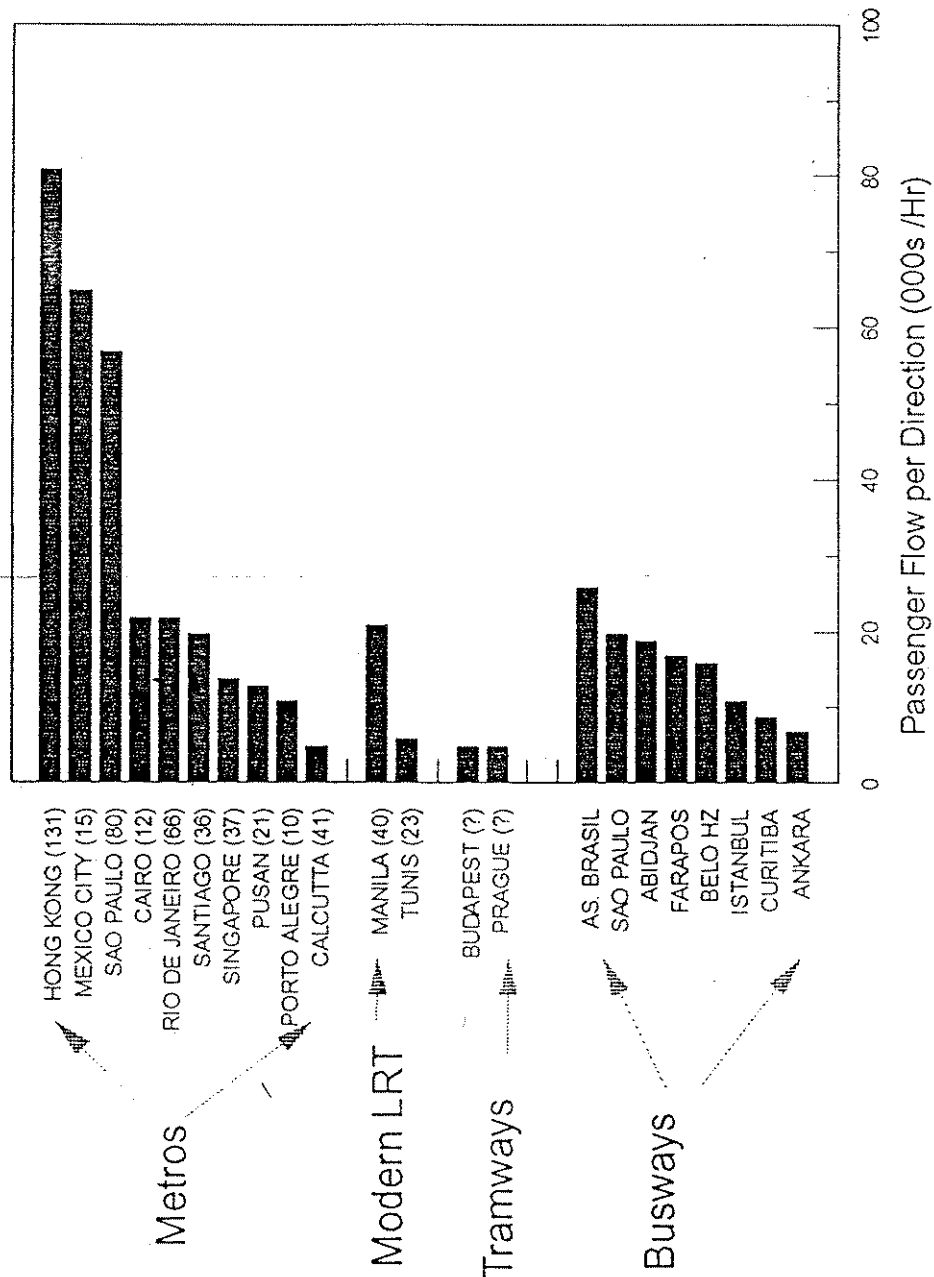
Courtesy of:

- 1. UITP Handbook of Public Transport 1985-1986, by Lee Rogers.

- 2. Data of 1990 given by operators.

Table 3: Performance of Selected Tramways.

Fig 3: Passenger Flows on Selected Mass Transit Systems



Figures in Brackets show Capital Cost per Kilometre, where known
 Comparable Busway costs in region of 1M US\$ plus vehicles and depots.
 Metro and LRT Figures from Fouracre (1990) Busway figures -
 from Gardner (1991). Tramway estimates are from present study