Bus rapid or light rail transit for intermediate cities?

Francis Kühn
INRETS, Institut National de Recherche sur les Transports et leur Sécurité, Arcueil, France

ABSTRACT: Performances and costs of BRT & LRT systems are examined. A variety of benefits and disbenefits is considered. An analysis of planning, design, passenger satisfaction and development potential try to compare them. In conclusion, BRT presents an investment opportunity for intermediate cities in developed and developing countries: some cities have already adopted it with success. In a second term, when the BRT attains a high patronage on some well identified corridors, an LRT could be adopted while buses operate as feeders.

RÉSUMÉ : Les performances et coûts des systèmes d'autobus en site propre et métro léger sont examinés. Une panoplie d'avantages et désavantages est considérée. Une analyse de la satisfaction des usagers et du potentiel de développement essaie de les comparer. En conclusion, les autobus en site propre présentent une opportunité d'investissement pour les villes intermédiaires : quelques villes les ont déjà adoptés avec succès. Lorsque le site propre atteint un haut niveau de fréquentation sur un axe bien identifié, le métro léger pourrait y être installé, les autobus opérant alors sur le réseau d'alimentation de ce métro léger.

1. INTRODUCTION

Selection of the most appropriate mass transit mode can be difficult to all those who are interested in a new medium to high-capacity transit system for their city and want to manage the investment and maintenance costs of their new public mass transit system. Buses are the backbone of the public transport system for many cities, and will remain so, for the foreseeable future. A positive reallocation of road space from cars to buses will assist operations and will capitalise on the efficiency of buses in using that road space: we find bus lanes in cities worldwide and some well-known busways in South and North America.

Rail-based systems are able to avoid congestion, but need an exclusive or separated right of way (RoW), and have very high construction costs.

This paper looks at the performances of these two main options, Bus Rapid Transit (BRT) and Light Rail Transit (LRT), drawing on the results of earlier studies about Tunis, Curitiba, Bogota and Quito cases, there are also, however, additional important considerations which are discussed below.

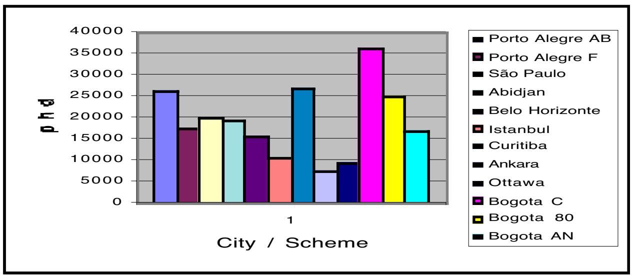
2. THE BUS RAPID TRANSIT

2.1 *Busway Performance*

2.1.1 *Capacities*

The maximum line-haul passenger throughput recorded nowadays is 36,000 passengers per hour per direction (phd) on Caracas Avenue busway in Bogota, with a 2-lane each-way. The São Paulo busways also achieved a high throughput with 20,300 phd, and Assis Brasil busway, Porto Alegre, 26,100 phd. Latin American busways are well designed and operated: more basic busways in Turkey and Côte d'Ivoire carry flows in a range of 7,500 to 19,000 phd. Gardner et al. (1991)

Figure 1. Busway Passenger Flows.



Source: Gardner et al. (1991), pour Bogota SDG (2001) Nota: For Bogota there are three busways, Avenida Caracas C, Calle 80 and Autopista Norte ; for Curitiba this is a maximum flow.

2.1.2 *Speeds*

Nowadays, the average commercial speed is 20 kmph on the Bogota, Curitiba, Porto Alegre and Quito busways, 18 kmph in São Paulo for omnibus bus services. Express bus services have an average operating speed around 30 - 32 kmph in Bogota and

Curitiba (see Table 2 below " Performance & Capital cost " of some BRTs).

The essence of BRT is that bus operating speed and reliability on arterial streets can be improved by reducing or eliminating the various types of delay. Boarding time can be reduced by improvement of the fare collection process, e.g. pre-payment of fares, self-service fare collection, greater use of passes, smart cards, etc. and by easing the boarding process with low-floor buses together with high platforms. Delay can also be reduced if stop spacing is increased and the number of stops are reduced. There is a trade-off between stop spacing and convenience to passengers. Table 3 in § 3.1.2 LRT Performance Speed shows some examples of average commercial speeds on LRT & BRT lines in USA and Europe.

2.2 *Infrastructures*

Busways typically provide a two-way roadway in a segregated RoW designated for the exclusive use of buses. While most of the Transitway is fully segregated from other traffic, the downtown segment consists of reserved lanes on a one-way couplet. This section tends to be slow and congested. Most busways tracks have been created by the reallocation of existing road space. Kühn (2000)

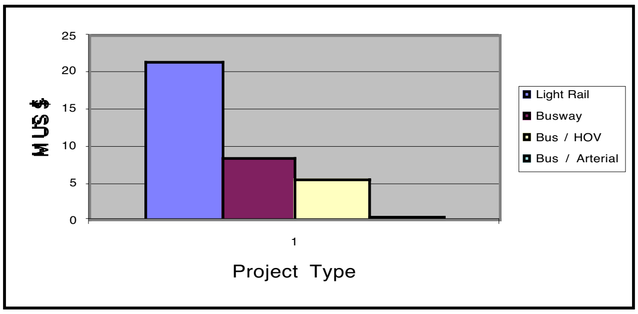
The Brazilian experience suggests that busways in the median are preferable to curbside busways. The standard and minimum desirable lanes' widths on which standard buses operate are, respectively, 3.66 and 3.05 meters in America, 3.50 and 3.00 m in most European countries. Operation on narrower lanes is possible, but only with reduced speed and safety. Two-lane roadways for buses traveling at moderate speeds should be 7.50 m wide (e.g., Av. Caracas in Bogota two-lanes per direction are 15 m wide) ; high-speed (freeway-type) operation exceeding 70 km/h requires a median separation or a physical divider such as a guardrail and 5.50 m width for one lane and a shoulder on each side. Very frequent bus service on the Transitway is accomodated by dividing the bus routes between one to six berths at each station, which varies from 40 to 190 meters in length (e.g. Avenida Caracas, Bogota). Wynne (2001)

2.3 *Busway costs*

2.3.1 *Capital cost*

BRT comprises a system of busways, generally using high capacity buses (articulated or bi-articulated diesel or trolley buses), with some form of management or control organisation. Various means of collecting and distributing passengers beyond the busway facility may be employed. With special operational measures, busway transit can provide a highly efficient and cost effective system of mass transit. The BRT systems generally had lower capital costs/km than the LRT systems in the cities reviewed by US General Accounting Office (GAO), although neither system had a clear advantage in operating costs. The capital costs for various types of BRT systems on busways (Houston, Los Angeles, Miami, Pittsburgh), on HOV lanes (Dallas, Denver, Houston, Seattle, San Diego) and on arterial streets (Los Angeles and Orlando) appear in figure 2 below.

Figure 2: Capital Costs of recent LRTs and BRTs in USA in M US $/km val. 2000.



Source: US General Accounting Office, sept.2001
Nota : Cost escalated to fiscal year 2000 US$. 1 US$ (2000) = 7 FF/1.067€. Average LRT capital costs are for 13 cities that built 18 LR lines since 1980. Busway capital costs are for nine busways built in four cities. Capital costs for buses using HOV lanes are for eight HOV facilities in five cities, and using arterial streets are for three lines in two cities.

Table 1. Performance & cost of some BRT systems in M $ 99.

Characteristics	Bogota Phase 1	Curitiba	Porto Alegre	Quito	São Paulo
Length in km	38	56	27	16.1	250
Bus Fleet	470art. trunkal diesel	108biart & art. diesel	1,600 diesel	113 trolleys	1,1000 & 600 trolleys
Ridership in millions	146 0.8/day	320 1.3/day	325 1/day	0.25/day	3.2 /day*
Vertical Segregation	At grade	At grade	At grade,	At grade,	At grade
Operational Measures	Trunk-Feeder	Trunk-Feeder	Bus Ordering	Trunk-Feeder	Trunk-Feeder
Capital Cost	388***	264.3	25	137	N.A.
Capital Cost per route km	10.2	4.7	1	8.5	N.A.
Infras/Equipt Cost per km	5.76	1.35	1	3.54***	3
Vehicles Cost per km	4.45	3.37	N.A.	4.97(4)	N.A.
Max. Cap.phd	35,000	22,000	20,000	15,000	20,000
Ave. Comm. Speed kph	20 30 exp.	20 32 exp	20	20	18
Busway Width (6) in meters	Median HP T=15	Median T=9.6	Median T=9.7	Median T = 10	Median HP* T=10

Source : Ceneviva (1999), Montezuma (2001) HP: High Platform; * On major corridors; N.A. non available; ** Infras. only; *** (4) for 113 articulated trolleybuses; exp: express; http://www.quito.gov.ec/homequito/municipio/transporte/trole.htm (6) Width is given for a 2-direction busway without platform stations

Capital costs/km decrease from 21.62 US M$ for LRT to 0.42 US M$ for BRT on arterial streets. Costs of BRT projects include the cost of the busways or bus lanes, station structures, park and ride facilities, communications and improved traffic signal systems, and vehicles, if additional or special buses are needed for the project. In Table 1 above, Capital costs/km are in a range of 4.7 to 10.2 M US $ 99 for at grade RoW. The difference between the costs is in relation with different capacities phd (number of vehicle per km & 2-lane each way in Bogota) and from the technology between trolleybuses (Quito) and diesel buses.

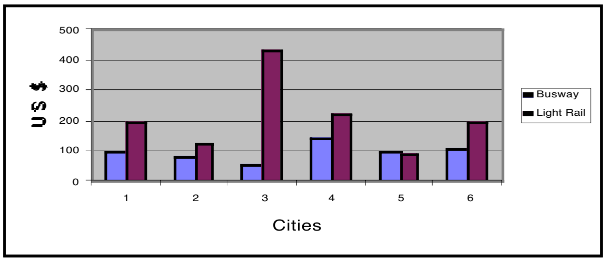
2.3.2 Operating cost

The US GAO report, comparing the Operating & Maintenance (O&M) costs for BRT and LRT in each of the cities (1-Dallas, 2-Denver, 3-Los Angeles, 4-Pittsburgh, 5-San Diego, 6-San Jose) that operated both types of systems, found mixed results. Figure 3 below, represents operating cost per vehicle hour in 1999, BRT had lower costs in five cities and LRT in one. Figure 4 below, represents operating cost per vehicle revenue km in 1999, all six cities' BRT systems showed lower costs per vehicle km than LRT routes. According this report and one transit expert : " BRT lines often run only during the busiest rush hour periods while LR systems typically offer all-day service, which may in part explain this result." Figure 5 below, represents operating cost per unlinked passenger trip in 1999, four of six BRT routes had lower operating costs per passenger trip than did LR systems. The wide disparities in operating costs and ridership levels are likely due to the variety of BRT and LR systems. In addition, vehicle sizes and passenger capacity can vary greatly between LRVs and bus vehicles, which can affect vehicle-based comparisons. US GAO (2001)

The Bogota's BRT service currently carries almost 700,000 passengers each weekday. Since Dec. 18, 2000, 168,655,984 riders have been carried until April 14, 2002. So operating costs have been estimated at 1.47 US $ / vehicle-km (depreciation included) and an O&M cost per passenger trip of 0.28 US $ val. 2002. These costs are estimated with a frequentation and a number of buses, which are not optimized, (e.g. the price of a trip is 0.373 US $). http://www.transmilenio.gov.co

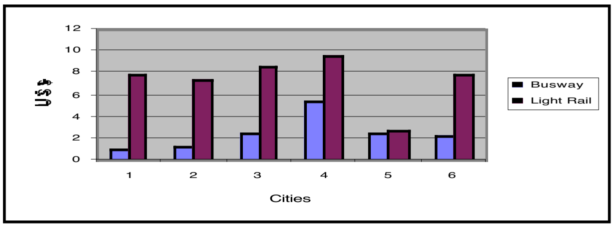
Curitiba O&M costs are summarized in the Table 2 below. This table classifies conventional, direct, articulated express and bi-articulated express lines.

Figure 3: Operating Cost per vehicle revenue hour of LRT & BRT project in USA in $ 99.



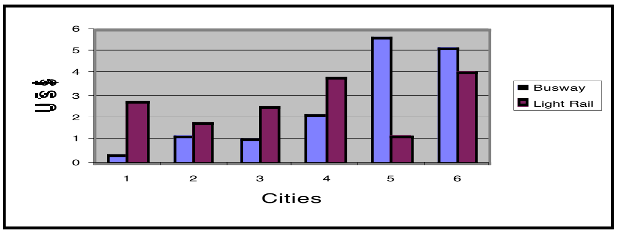
Source: National Transit database and 6 transit agencies

Figure 4: Operating Cost per vehicle revenue km of LRT & BRT project in USA in $ 99.



Source: National Transit database and 6 transit agencies

Figure 5: Operating Cost per unlinked passenger trip of LRT & BRT project in USA in $ 99.



Source: National Transit database and 6 transit agencies

Table 2. Comparative summary of O&M costs in Curitiba US $ val. 98.

Cost/Veh.km	Norm line	Dir line	Art.Exp	Bi-art.Exp
O&M. Cost	1.21	1.29	1.41	1.67
Cap. Cost	0.74	0.75	0.90	1.83
Total Costs	1.95	2.04	2.26	3.50
Cost / Pass.	0.68	0.39	0.39	0.21

Source: Ceneviva (1999).

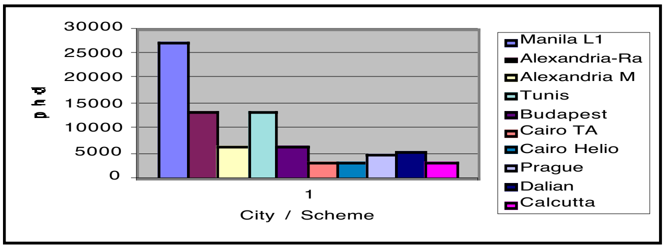
3. THE LIGHT RAIL TRANSIT

3.1 *LRT performance*

3.1.1 *Capacities*

TRL/INRETS 1994 research has questioned the generally accepted idea that LRT has a higher capacity than busways. In fact the opposite appears to be true. Even in Manila, where the LRT was operating under near-saturated conditions, and where there is full segregation from other traffic, passenger flows were less than on several busways. (See Fig 6)

Figure 6: LRT & Tram passenger flows.



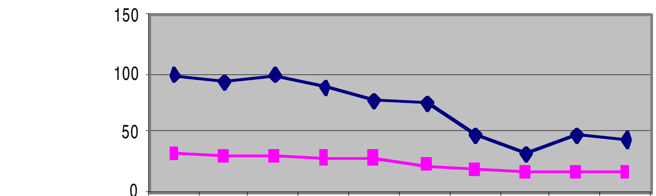
Source: Gardner et al. (1994) Nota : For Tunis Godard & & al. (2000) ; For Manila survey after upgrading L1 IRJ (1994).

In order to attain high capacities, LRT needs short, regular headways: the 1994 survey in Manila showed passenger flows of 18,900 phd and after upgrading the line 1, in 1998, 27,000 phd and more than 35,000 phd nowadays. Gardner & Kühn (1992) In Tunis, the 1994 survey showed passenger flows of 9300 phd, in 2000, the passenger flows have reached 13400 phd. These two last surveys show that, LRT requires a level of control and regularity that most developing cities find difficult, especially with on - street operated trams.

3.1.2 *Speeds*

Taking the example of LRT network of Köln, the Figure 7 below, shows the direct relation between percentage of separated RoW and commercial speed.

Figure 7: Commercial speeds & percentage of exclusive & separated RoW in Neumarkt (Köln center) on Köln LRT.



	1-Bensb	9-Königs	11-Slabys	9-Chorw	7-Zündo	2-Freche	5-Ossen	12-Zollst	3/4-Bockle	6-Marien
Exc+separRoW	99,9	93,3	99	89,6	78,1	75,5	48,5	33,4	48	45,2
Vc	32,2	31,5	30,4	29,5	28,4	23,7	19,6	18,4	18,2	17

Source: Kühn (1987) & (1988)

The commercial speed influences the service that can be provided for customers, but also determines the number of vehicles and drivers that will be needed. The commercial speed is also related to the maximum speed of the vehicle, and to braking and acceleration characteristics. It might thus be expected that electric trains would be significantly faster than buses. In practice, TRL/INRETS field surveys revealed little difference and research using multiple regression analysis, to allow for factors such as station spacing, suggests that the inherent difference between busways and LRT is not statiscally significant (Gardner & al.1994). LRT achieves high speed by using a signalling system to avoid bunching, and by obtaining priority at traffic signals over other traffic; and it achieves high capacity by having large vehicle, which takes advantage of the signal cycles. However, LRT systems are operationally vulnerable to the everyday events that happen in the centre of developing cities, while bus systems are often able to get round the problem (they can overtake, leave the busways, etc), LRT is not.

In Table 3 some average commercial speeds of LRT and BRT lines are given. (Hass-Klau et al.2000)

Table 3 Av. Com. speeds on LRT & BRT lines in kmph.

LRT	Buffalo	Bremen	Denver	Essen	L.A.
	29.3	28	23.2	28	36 / 57
BRT	Bergen	Dublin	Malmö	Ottawa	Pittsburgh
	25	24	24	50	53 / 37

Source : Hass-Klau et al. (2000)

3.2 *Infrastructures*

For one line, we can find all the types of sites. A hierarchy going from the exclusive RoW in the city centre, where the urbanization is in general very dense, to the separated tracks in peripheral districts, where road space allows them, and some sections remaining, however, in shared RoW.

The normal railway gauge is 1,435 mm. The LRT rolling stocks have a gauge in a range of 2.20 to 3.00 meters. The width of 2-track RoW is in a range of 6.00 to 7.20 meters wide less than for a 2-lane busway. Geometric insertion of an LRT RoW is easier than for a busway RoW, interesting for CBD.

3.3 *Light Rail Transit costs*
3.3.1 *Capital cost*

LRT capital costs and line haul trip speeds both increase as the fraction of RoW that is grade separated increases. LRT feasibility studies all too often claim the capital costs savings obtainable from limited grade separation and at the same time assume the speed and reliability that can only be obtained in a rail system with complete grade separation. Kain et al. (1987) e.g., Manila 1st line completely exclusive RoW on viaduct has a cost/km of 28.23 M US $ (cost escalated to fiscal year 98) compared with Tunis LRT, on a private at-grade RoW whose cost/km is 13.3 M US $ 98.

LRTs reviewed by US GAO vary considerably in their capital cost per km. Included in costs are the stations, structures, signal systems, power systems, utility relocation, RoW, maintenance facilities, transit vehicles and project oversight. In the Table 4 below, we show the project cost components from a study of 8 LR lines in five cities (Dallas, St. Louis, Denver, Salt Lake City and Portland) verified by the data of the FTA Report Laver & Schneck (1995).

Table 4. LRT Capital Cost's components of US Lines.

Project Component	Average Cost/km in MUS$ 98
Signal-Communication-Power	3.50
Ballasted double Track	1.45
Vehicles & Maintenance	3.3
Major Structure: at grade	1.18
grade separated	7.21
Station: at grade	1.70
grade separated	3.70
tunnel	19.90
Total LRT Ave. project Cost	21.62

Source: Pilgrim (2000)

The higher capital costs/km for LRT compared with BRT arise from several factors. LRT typically requires train signal, communications, and electrical power systems with overhead wires to deliver power to trains at an Av. cost of 3.50 M US $ per double-track km (Pilgrim, 2000). A ballasted, double-track cross section at an average cost of 1.45 M US $/km. Average cost for vehicle and maintenance was 3.3 MUS$/km with a Standard Deviation 2.4 M

US$/ km. Finally, LRVs, while having higher carrying capacity than most buses, also cost more, about 2.5 M US$ each. A LRV carries 174 passengers at normal capacity (4 standees/m^2), an articulated bus carries 110 passengers, the LRV cost is six times more than the bus cost with the same unit capacity. A two-lane busway required a RoW about 7 to10 meters wide for a one-lane per direction busway and 14 to 19 m (without fences) for a two-lanes per direction busway (e.g. Bogota), compared with 6.00 to 7.20 meters wide RoW for respectively a 2.30 and 3.00 m gauge LRT. For the systems reviewed the cost per km for Light rail averaged 21.62 M US$/km, ranging from 7 to 49.5 M US$/ km (Pilgrim, 2000). These costs are detailed line after line according to type of RoW. We present in Fig. 8 the cost line by line with each type of RoW: the Av. cost/type/km appears in Table 5 below.

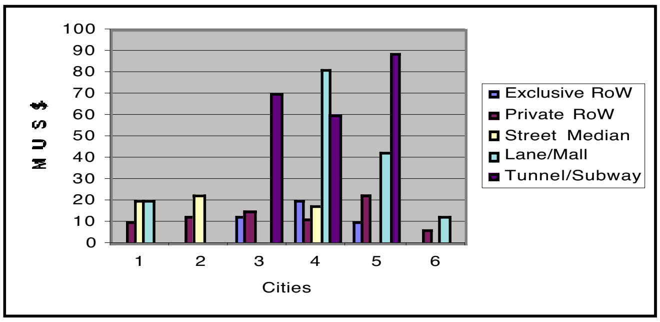
In Table 6 below, we give the LRT vehicle cost in 6 US cities, taking in account a mean vehicle cost of 2.5 M US $. These costs are enclosed in the total average cost per km of Table 5. So, the total cost/km by RoW type in Table 5/Fig.8 minus the vehicle cost/km in a range of 2.5 to 5.75 M US$ gives the cost/km of Infrastructures, Equipments & RoW.

Table 5. LRT Total Cost by RoW Type in M US$ 98.

RoW Category	Average Cost/ Km in MUS$ 98	Standard Deviation
Exclusive	17.9	0.51
Private, at grade	13.9	21.0
Street/Highway	24.3	10.5
Reser.Lane/Mall	39.1	31.1
Tunnel/Subway	82.9	10.8

Source: BRW, Inc in Pilgrim (2000)

Figure 8: Total Cost of LRT Lines by RoW of 6 lines.



Source: (Pilgrim, 2000). Nota: 1-Salt Lake; 2-Denver; 3-St Louis; 4-Dallas; 5-Portland; 6-San Diego.

Table 6. Vehicle Cost per km in 6 US cities in M US$ 98.

Per km	S.Lake	Denver	St Louis	Dallas	Portland	S.Diego
Vehicule	1	1.4	2	2.3	1.4	1.7
Veh.Cost	2.5	3.5	5	5.75	3.5	4.25

Source: Schuman (2000).

In Table 7 below, are the capital costs of the last new lines opened or under construction in France: the number of LRVs are in relation with the patronage projected per day, the mean cost is 19.3 MUS$/km.

Table 7.Capital costs & n° of vehicles/km in 5 French cities.

Network	Length	Veh/km	Cost/km	Patronage
Montpellier	15.2	1.84	23.2	75,000
Orleans	18.0	1.27	16.0	45,000
Lyon	18.7	2.30	18.9	110,000
Valenciennes	10.9	1.56	17.2	N.A.
Bordeaux	22.5	1.69	20.5	N.A.

Source: Bottoms (2000) 1 US $ = 6.50 FF.

To conclude, the cheaper capital cost of LRT network, is for a private, at grade RoW type. The average cost in 6 US cities is 13.9 M US $ 98. The Tunis LRT, 5 lines network, 32 km total length of private, at grade RoW type (200 m tunnel only), a 121 vehicles fleet, has a cost of 13.3 M US $ 98 per km (Godard & al. 2000). Infrastructures and equipments costs are in Tunis 7.1 MUS$ 98/km when they are 10.6 MUS $ 98/km for a private, at-grade RoW in 6 US LRT (See Table 5) and 16 MUS$/km val. 2000 in 5 French cities (See Table 7). As for vehicle & maintenance workshop the cheaper cost is in relation with the patronage: it is 3.3 MUS $ 98/km in 6 US LRT, 3.2 MUS$/km in 5 French LRT, and 6.6 MUS $98/km in Tunis (13,000 phd at peak hour).

3.3.2 *Operating cost*

These costs are typically of different systems. In Table 8 below, we give O&M costs of some French Tram and Tunis'LRT networks. Costs are not comparable between Nantes, Grenoble, Saint Etienne because characteristics (length, fleet, density) of networks are different. If we compare the range of O&M cost per vehicle revenue km in USA (see Fig.4 above), they are in a range of 7 to 10 US $ lightly higher than French O&M costs. San Diego O&M costs are out of range with only 2.61 US $ per vehicle-km. The vehicle-km of Tunis'LRT (two car-train) is 5.00 US$ (depreciation excluded) and 7.08 US$98 (depreciation included). Of course, driver's salaries, electricity, maintenance of vehicles and track system costs are different between France, USA and Tunisia so we stay only in the range's comparison.

Table 8. O&M costs of 4 French LRT networks and the Tunis' LRT network in US $98, depreciation excluded.

Costs	Grenoble 19 km	StEtienne 9 km	Nantes 27 km	Rouen 18km	Tunis 32 km
Veh*.km	6.35	4.66	5.59	4.48	2.50
Trip	0.57	0.46	0.43	0.475	0.148
OSK	0.038	0.035	0.024	0.026	0.010

Source: Godard & al. (2000) Nota: OSK: Offered Spaces km. 1 US $ 98 = 5.87 FF. * Vehicle-km = 1 car –train x km

4. A bus-based transitway or 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 LRT rather than BRT is the way to go? Comparing LRT & BRT in several ways could make a clear distinction between the two transit modes.

4.1 *Planning*

Coordination of land-use planning with transportation planning is an important factor in achieving high transit ridership. Such coordination will produce few short-term results, but will have great long-term benefits. Busways, like LRT, provide opportunities for coordinating land-use planning with transit service. BRT generally has the advantage of having more flexibility than LRT, being able to phase in service rather than having to wait for an entire system to be built, and being used as an interim system until LRT is built. The analysis of basic criteria enables the decision-makers to be supplied relevant data on which to base their choice. The analyse of the particular city characteristics has to be done:
- its size, topography, history, space organisation, spontaneous trends, the existence of a master plan,
- the existence of resources,
- situation of public / individual transport systems.

4.2 *Costs*

In terms of construction costs, an at-grade integrated BRT system can be expected to cost (see Table 1) between 1 MUS $ / km (Porto Alegre) to 5.76 M US $ / km (2 x 2 lanes, in Bogota) in exclusive corridors. In contrast, construction costs of LRT in the same private at-grade RoW context are between 7.11 MUS $98/km in Tunis to 16 MUS $/km val.2000. in 5 French cities (see § 3.3.1 Table 7). So, LRT construction costs are generally higher than those of BRT either in USA or Latin America, even between Latin American BRT and Tunis' LRT.

It is commonly stated that LRT requires fewer operators for a given level of ridership based upon the ability of each LRV to carry about twice and even four time as many passengers. So, 700 passengers per train could be carried in Tunis vs. 270 passengers per bi-articulated bus in Curitiba and 160 passengers per articulated bus in Bogota, Quito, etc. However, LRT requires staff in other job categories, such as track crew, structures crew, switch maintainers, overhead lines crew, signals and communications crew and substation maintainers. This increases the staff requirements for LRT thereby contributing to higher operating costs. Although LRT costs per passenger km are often argued to be lower than for bus systems (see Table 9 below), 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 maximize patronage on each trip. If this is the case, the advantage of LRT on operating costs per passenger-km is eroded (Biehler, 1988). If we examine the O&M costs of Tunis LRT, Curitiba and Bogota BRT, we have respectively in Tunis, Curitiba and Bogota the vehicle-km costs of 7.08 US$, 3.50 US$, 1.47 US$ for a unit capacity of 700, 270 and 160 spaces respectively. If we admit a ratio passengers / spaces of 50 % all day long for LRT in Tunis (a 2 car-train all day long) and 70 % for Curitiba BRT and 80 % for Bogota BRT, the initial figures become in the Table 9 below:

Table 9. Vehicle-km cost according to different ratio trip/space in one LRT and two BRT in US $ 98.

Items	Tunis LRT	Curitiba	Bogota
Spaces/vehicle	700	270	160
Veh.km Cost in $	7.08	3.50	1.47*
Ratio	50 %	70 %	80 %
350 pas.-km Cost	7.08	6.48	4.02

Source: Godard & al (2000); Ceneviva (1999); * this vehicle-km cost was estimated in US$ 2002.

The vehicle-km cost of LRT's Tunis stays 10 % higher than Curitiba BRT costs with a ratio pass./spaces equal to 50 % : it seems that labour, energy and replacement of materials costs are lower in Tunisia than in Brazil & Colombia and the limited fleet of LRVs and a short headway all day long increases the number of vehicle-km run during one year, which optimizes the vehicle-km cost. The trip cost in Tunis is 0.148 US$ 98 and in Curitiba 0.21 US$ 98. In spite of a higher capital cost than BRT of Curitiba and Bogota, Tunis'LRT shows a competitive vehicle-km and trip costs. The high ridership all day long in Tunis is one reason of this cost effectiveness.

4.3 *Capacity*

In interpreting comparisons between LRT and BRT, it is important to note the contrast between "theoretical" capacity and capacity achieved. Table1, Figure1 and Figure 6 above illustrate this capacity by a comparison of the volumes achieved by busways in Bogota, Curitiba, Porto Alegre, etc. with a number of LRT corridors in Manila, Alexandria, Tunis, etc.. So, the existing busways can provide an equivalent capacity to an LRT system, at a fraction of the capital costs. We saw that LRT operates at a maximum flow of 28,000 phd with two-car trains; in Manila three-car trains are operated on viaduct, the maximum flow should be over 28,000 phd. These systems, when operating at design capacities, will present characteristics usually found in metro systems, i.e., no at-grade interface with other traffic.

It is relatively easy for two buses to use a single off-line station at the same time, thereby doubling capacity. Then, through buses which pass buses stopped at a station increase capacity even more (e.g. Av. Caracas in Bogota with high platform and 6 bus berths per station and two-lane busway per direction, with express buses the maximum flow is 35,000 phd at peak hour. Therefore, although light rail has a greater theoretical capacity, busways can easily carry the expected ridership in the great majority of urban corridors and even more in intermediate cities.

4.4 *Design and Construction*

The flexibility of busways for partial implementation contrasts sharply with a rail system, which requires a fully connected line before the first train can operate. LRT has some complicated design characteristics: e.g., electrification, train control, computerization, rail alignment requirements, weight, and specifications of LRVs. Generally, in the centre of the city, LR lines have sections in subway, leading to special design and construction requirements.

Busways are essentially simple highways and can be designed and built as such. Sometimes some civil - engineering is needed to build pedestrian bridges and station with high platform (190 m long) like in Bogota and Quito. So more design and construction firms are experienced in highway and civil-engineering design than LRT design.

4.5 *Operation and Maintenance*

Busways permit far more flexible operation than ligth rail. The system using the same vehicle for neighbourhood service and the corridor connection into downtown eliminates the need for a transfer. But using separate vehicles for the feeder and the trunk route, allows for the design and capacity of the vehicle to be tailored to busway operation: small buses are more appropriate for the narrower streets of neighborhood. Nevertheless, the passenger amenities available at the transfer point, the service's frequency and the time-meets' possibility between feeder and trunk buses must be considered.

When they have a breakdown LRVs are much more likely to tie up the system. Busway are simpler to operate and maintain than light rail systems, but they need an important driving staff. The requirement for separate but interrelated communication, signal, power, and propulsion systems for LRT also contribute to their complexity for training, operating and maintenance.

4.6 *Passenger Satisfaction / Image*

While busways and LRT provide equivalent levels of service in term of travel time and vehicle comfort, busways have an edge in that transfers to and from feeder bus are less likely to be required. BRT is essentially designed to eliminate delays and provide faster service on better vehicles. One of the challenges faced by BRT is the negative stigma potential riders attach to buses regarding their noise, pollution, and quality of ride. Spending funds for cleaning up present technologies (with low-sulfur diesel fuel or clean CNG) and improving existing bus systems, would provide far more cost-effective benefit in the near term. Then operating a few advanced technology buses that can cost several times the price of a conventional diesel bus could progressively adopted: advanced bus propulsion -- fuel cell and hybrid buses running on a variety of fuels – could provide even greater relief from pollution problems.

LRT benefits from a better image than public transport generally. Image is a difficult characteristic to define, but it includes shiny, modern vehicles bearing a special livery (swallows on Montpellier's LRVs), a simple route structure with clearly identified stops, readily available information, penetration of shopping centres, dedicated marketing, and many other factors. Many of these advantages could be realised with a bus route. (e.g., Curitiba, Bogota). The best well-known example of LRT image is given by the success of Zürich's public transport system, one of the most efficient in Europe; Zurichers, on average, use their system 550 times a year compared with 320 times by the average inhabitant of Amsterdam, 190 in Bruxelles, 160 in Marseilles and 100 in Rouen.

4.7 *Development Potential*

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. Implementation of rail systems is an incentive to development according to rail advocates. The message from Ottawa, Curitiba and Bogota is that a metropolitan strategy can fixed an effective bus-based system within its overall land use / transport plan that can produce the same types of impacts as rail. E.g. Ottawa has had success with siting of busway stations in pre-existing shopping malls. All forms of transport infrastructure have some impact on land use, be it freeways or public transport. On the basis of their expected level of ridership, BRTs are as attractive to potential development as LRTs. The emerging new technologies, demonstrated in Karlsruhe and Saarbrucken in Germany, of LRT sharing heavy rail track and infrastructure, presents a clear opportunity to reduce costs yet access parts of the urban fabric normally inaccessible to heavy rail operations : the choice of LRT rather than BRT in the case of existing railway corridors in urban centre or in the suburbs of a city becomes an opportunity to catch.

5. CONCLUSION

In cities with up to 1 million, BRT is a serious alternative to the LRT system. Depending upon site-specific conditions, the transitway options might be the best choice from the perspectives of cost-efficiency, level of service offered to users and overall cost-effectiveness. Current success stories like BRTs of Curitiba, Bogota, Ottawa, etc, can provide models for other cities in the future. The use of evolving new advanced technologies such as automatic vehicle location and control will further improve the cost and service of BRT. BRT can be implemented in a short period of time with modest initial costs. Also, it enables with ease, the matching of supply with demand. Probably the greatest advantage is their price: because construction and equipment costs are much less than LRT, cities can more easily afford to build and maintain them without accumulating huge debt or siphoning off funds from other badly needed services.

The main advantages of LRT are its commercial speed, its capacity, its attractiveness to car users and a number of qualitative factors, which are called "image". LRT is not only seen as a means of transport, but also a tool of urban design and improvement of public space. LRT also has the important advantage of running on electricity. Unlike petrol or diesel powered vehicles, LRT is non-polluting at the point of use. There is now considerable evidence that LRT attracts car users.

Surveys of passengers on new LRT systems in France, Canada and UK have shown that although the majority of passengers were drawn from other public transport, around 15 to 20 per cent formerly made their journeys by car, with about the same number making new journeys. In the right location, LRT can be very successful and can justify its costs.

In conclusion, we think that for intermediate cities in a first term adopting a BRT could be a good choice. The three different types of service, dedicated, express and local would create a "network effect" in the city, which will increase patronage. After some years, when ridership increases, city can extend the stretch of roadway, as needed, when it find the funds to make the investment. In this way, additions can be made incrementally, which means less drain on the budget than with LRT where large expenditure occur at once. Also, the infrastructure can be built in such a way that the roadway and stations can be converted to rail at a relatively minimal cost. On specific high density corridors, to solve problems of insertion of the wide necessary busway RoW in CBD, Decision makers could decide to build an LRT on a trunkal corridor, existing buses being operated as feeders. A part of capital investment of the new LRT line being done during the first phase with BRT (private at-grade or separate RoW with civil-engineering), it will remain in a second phase to invest in the realization of the track, energy, communication, power, vehicles and maintenance.

REFERENCES

Biehler, A.D. 1988.The Great Debate: Exclusive Busway vs. Light Rail, a comparison of new fixed guideways. In TRB National Conference on LRT, San Jose, California, May 8-11, 1988, 14 p.

Bottoms, G.D. 2000 . Recent Developments in Light Rail Transit in Western Europe, France and Italy . In Eight National Conference on LRT in Dallas Texas ,16 p. APTA & TRB .

Ceneviva, C.1999. Curitiba and its Integrated Transportation Network. In the proceedings of the 1st international Conference *Urban Public Transportation Systems*, March 21-25, 1999, Miami, Florida, ASCEE, 12 p.

FTA, US DOT. 1998. Issues in Bus Rapid Transit. Document in support of *the FTA Bus Rapid Transit Demonstration Program* January 15, 1998, 27 p.

Gardner,G. Cornwell,P.R. & Cracknell, J.1991. The performance of busway transit in developing cities. In TRRL Research Report n° 329 , Crowthorne.

Gardner, G. & Kühn, F 1992. Appropriate Mass Transit in Developing Cities. In proceedings of 6° WCTR Lyon, 1992, 11 p.

Gardner, G. Rutter, J. Kühn, F.1994. The performance and potential of light rail transit in developing cities. In TRL Project Report N° PR69, TRL, Crowthorne.

Godard, X. Kühn, F. Belaïd, S. et al. 2000. Evaluation a posteriori du Métro Léger de Tunis. In report INRETS–SMLT for World Bank, 144 p.

Hass-Klau, C. Crampton, G. Weidauer, M. Deutsch, V. 2000. Bus or Light Rail: making the Right Choice. In a research report published by *Environmental and Transport Planning* Brighton, 126 p.

Halcrow Fox, 2000. World Bank Urban Transport Strategy Review – Mass Transit in Developing Countries, Final Report for World Bank, Dept for International Development .

Kain, J.F. 1987. Choosing the Wrong Technology: or how to spend Billions and reduce transit use. In Journal of Advanced Transportation Vol. , p 197- p 213.

Kühn, F.1987. Les Transports Urbains guidés de Surface : Situation Actuelle et Perspectives. In Synthesis Report INRETS N°4, 84 p.

Kühn, F.1988. Guided Urban Surface Transport. In an article in RTS review, English issue n°3, June 1988, p36-p46.

Kühn, F.2000. São Paulo: a challenge for the bus and intermediate systems. Dans Les Cahiers de l'IAURIF *Les transports dans les grandes métropoles, Réflexions actuelles* Tome 2 N° 128, 3° trimestre 2000 p 29 p 44.

Montezuma, R. 2001. Ciudad y Movilidad, La transformacion de Bogota 1995-2000, entre redefinicion ciudadana y espacial. Informe final para el IRD, Bogota.

Pilgrim, R. D. 2000.Are we pricing LRT Systems out of range ? A comparison of cost experiences. In a paper published at the 8th Joint Conference on Light Rail, Dallas, Texas, November 2000, sponsored by the TRB and the APTA, 13p.

Schumann, J. 2000. Status of North American Light Rail Transit Systems, Year 2000 Update", in Eight National Conference on LRT in Dallas Texas,,15 p., APTA & TRB.

Steers, Davies, Gleave. 1999. Diseño Operacional Proyecto Transmilenio. In Volumen 9, Evaluacion Economica, Costos de Inversion, Operacion y Funcionamiento, 22 p.

TRB, 2000. This is Light Rail Transit. In booklet first distributed in Eight National Conference on LRT in Dallas Texas, November 2000,24 p., APTA & TRB

US GAO, 2001. Mass Transit : BRT shows promise. In a report to Congressional Requesters of US General Accounting Office, GAO-01-984, 54 p.

Wynne, G.G. 2001. Bogotà's BRT achieves Farebox Coverage of Operating Costs. In Passenger Transport, weekly newspaper, Vol. 59, n°44, p4, APTA.