

Bus Rapid Transit for Developing Countries : Limitations and Alternatives

Master Thesis

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Overview

BRT Definition

Background and History of BRT

BRT Infrastructure Requirements

BRT Models

Limitations of BRT Model - Bogota

Conclusion

BRT Definition

"an innovative, high-capacity, lower-cost public transit solution that can achieve the performance and benefits of more expensive rail modes. This integrated system uses buses or specialized vehicles on roadways or dedicated lanes to quickly and efficiently transport passengers to their destinations, while offering the flexibility to meet a variety of local conditions"

Federal Transit Administration

"an innovation that could transform cities and the way people move. While they constitute a first step towards integrated public transport networks (IPTN) and could be a catalyst for urban development they should not be treated in isolation as a mere substitute for rail infrastructure where public funds are scarce."

UITP

"a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective services at metro-level capacities. It does this trough the provision of dedicated lanes, with busways and iconic stations typically aligned to the center of the road, off-board fare collection, and fast and frequent operations."

ITDP

Background and History of BRT

Development of traditional bus priority measures

Earliest form in 1937 as designated busways and bus lanes
First “BRT” term in 1966 in the United States

Further Development

1972 in Lima
1973 in Runcorn, United Kingdom and 1973 in Los Angeles, United States

Earliest Complete Implementation in 1974 in Curitiba, Brazil

Background and History of BRT - Curitiba



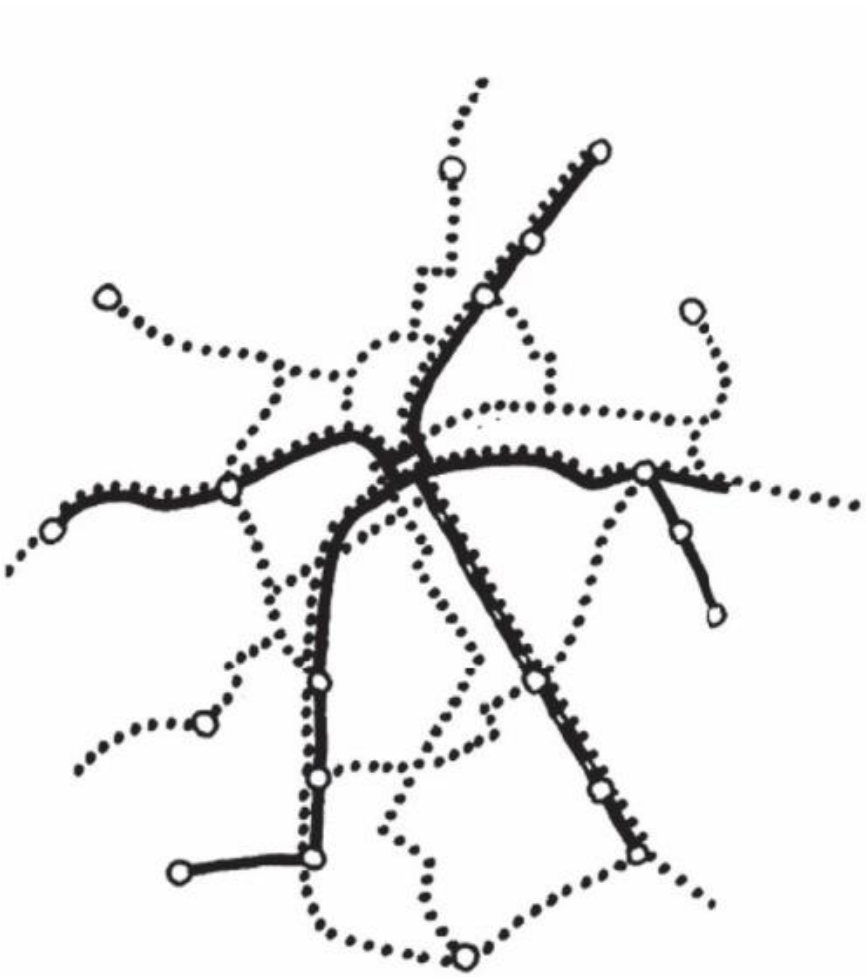
Based on Curitiba Master Plan

Created by Jaime Lerner

Accommodating future population growth

Identify several problems especially transportation

Background and History of BRT - Curitiba



Planning

1964 Plan supersedes 1943 Plan
Radial road system of 1943 is replaced

Linear Road System

TOD axes
Growth on four corridors

Planning Institute

IPPUC – Institute of Urban Planning and Research of Curitiba

Jaime Lerner

Three times mayor of Curitiba
Alumni of IPPUC

Background and History of BRT - Curitiba

1970s	1980s	1990s	2000s
Bus stop shelters	Tube stations		
Conventional buses	Articulated buses	Biarticulated buses	Cleaner buses
Open terminals	Closed terminals (paid area)		
Paper and coin-based ticketing (manual)			Electronic ticketing
Trunk-and-feeder services	+Interneighborhood +Direct (Ligeirinho)	+Special services	+Overtaking at busway stations
Urban services		Metropolitan services	

BRT Infrastructure Requirements



Vehicles

Articulated and Bi-Articulated
Special interior configurations

Stops and Stations

Resembles rail stations

Rights-of-Way (ROW)

Mixed, on- and off-street

Fare Payment

Prepayment

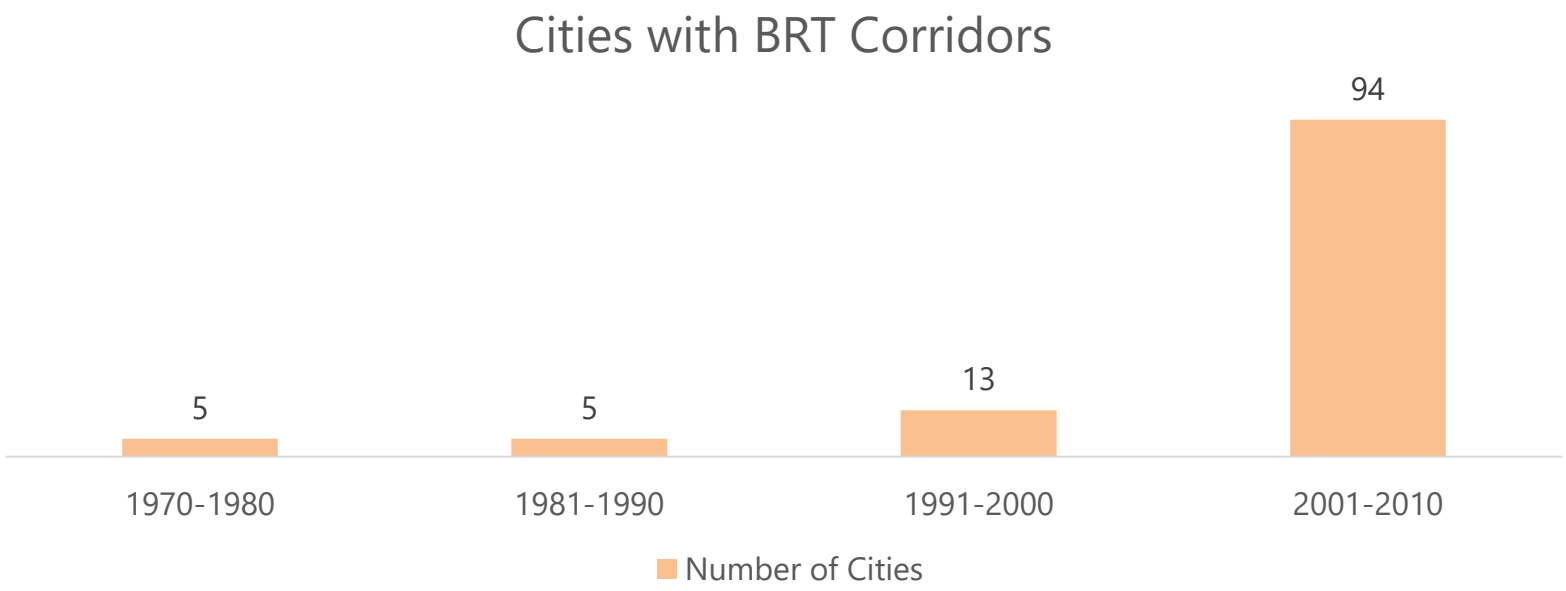
Information and Communication Technologies

Real-time

Services

Headway of 10 minutes for 16 hours a day

Background and History of BRT - World



1970s-1999

Based on the Curitiba Model
11 of 21 systems are located in South America

2000-2010

Based on Bogota
Strong growth in Asia, Europe, USA, and Canada

Methodology

Best-Case

- Calculations based on TCQSM
- Descriptions of three BRT models

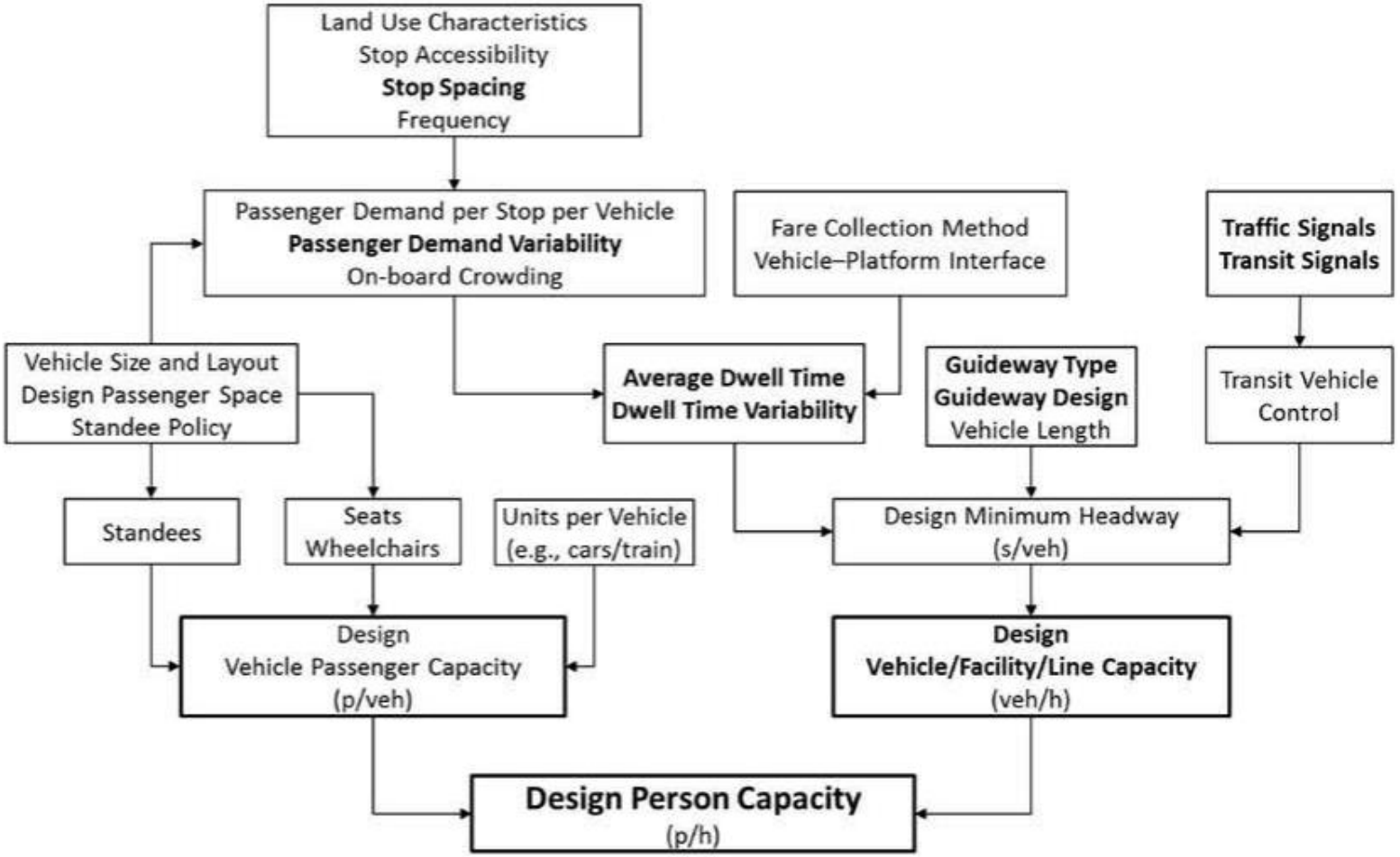
Real-World Examples

- Calculations based on TCQSM
- Technical limitations

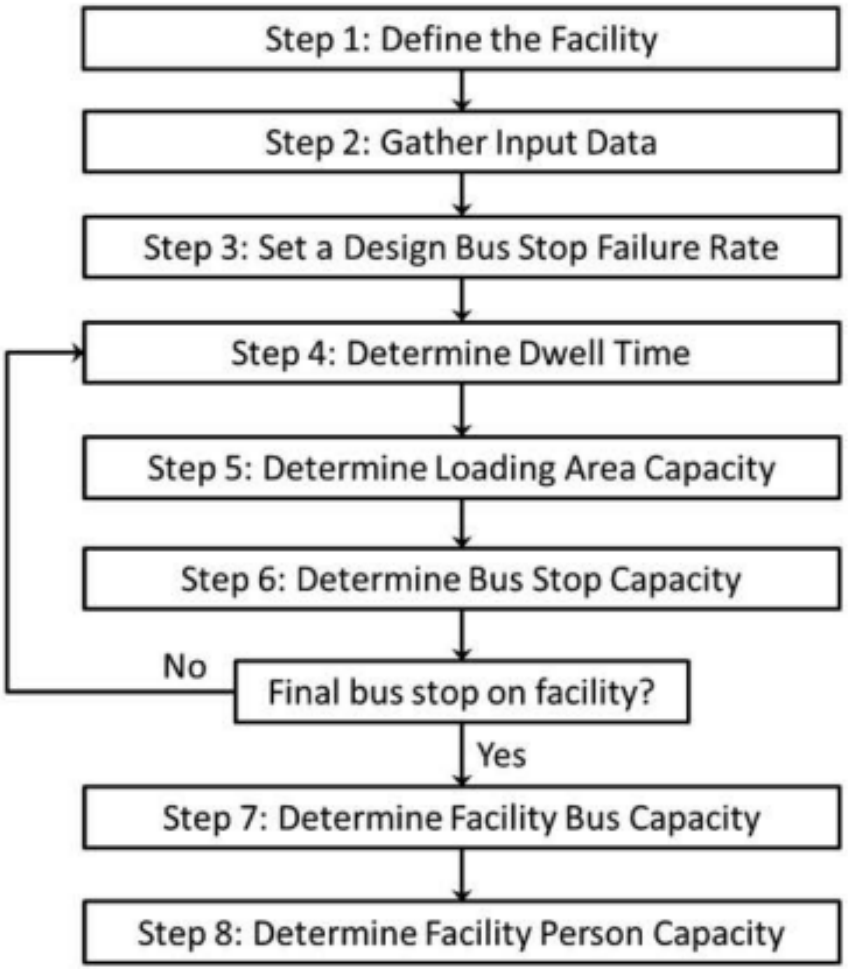
Real Limits

- Determinations of economic and societal limitations
- Calculations based on TCQSM

Methodology



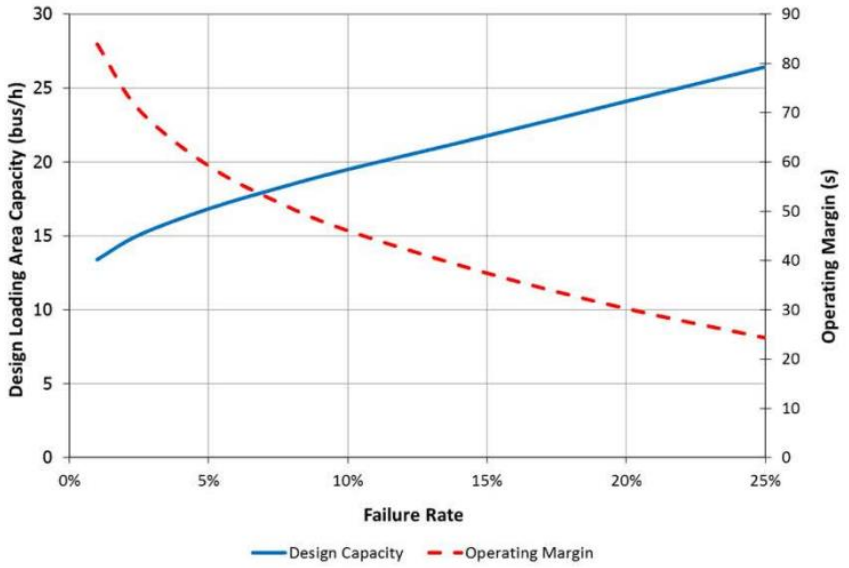
Methodology



Methodology – Specific Concepts

	On-Line Loading Areas				Off-Line Loading Areas	
	Random Arrivals		Platooned Arrivals		All Arrivals	
Loading Area #	Efficiency %	Cumulative # of Effective Loading Areas	Efficiency %	Cumulative # of Effective Loading Areas	Efficiency %	Cumulative # of Effective Loading Areas
1	100	1.00	100	1.00	100	1.00
2	75	1.75	85	1.85	85	1.85
3	70	2.45	80	2.65	75	2.60
4	20	2.65	25	2.90	65	3.25
5	10	2.75	10	3.00	50	3.75

Sources: *TCRP Report 26* (*21*) and *TCRP Research Results Digest 38* (*37*).
Notes: On-line values assume that buses do not overtake each other.
Values apply only to linear loading areas; non-linear designs are 100% effective.



BRT - Models

Bogota

- High Capacity BRT
- Popularized the BRT Concept

Jakarta

- Medium Capacity BRT
- Largest BRT Network

BHLS

- Low Capacity BRT
- European BRT

BRT Model - Bogota

Key Facts

Capacity of between 37.000 passengers per hour per direction (pphpd) to 45.000 pphpd
36 months from an idea to start of operations
143 stations in 12 corridors (current operations)
114,4 km of exclusive bus lanes

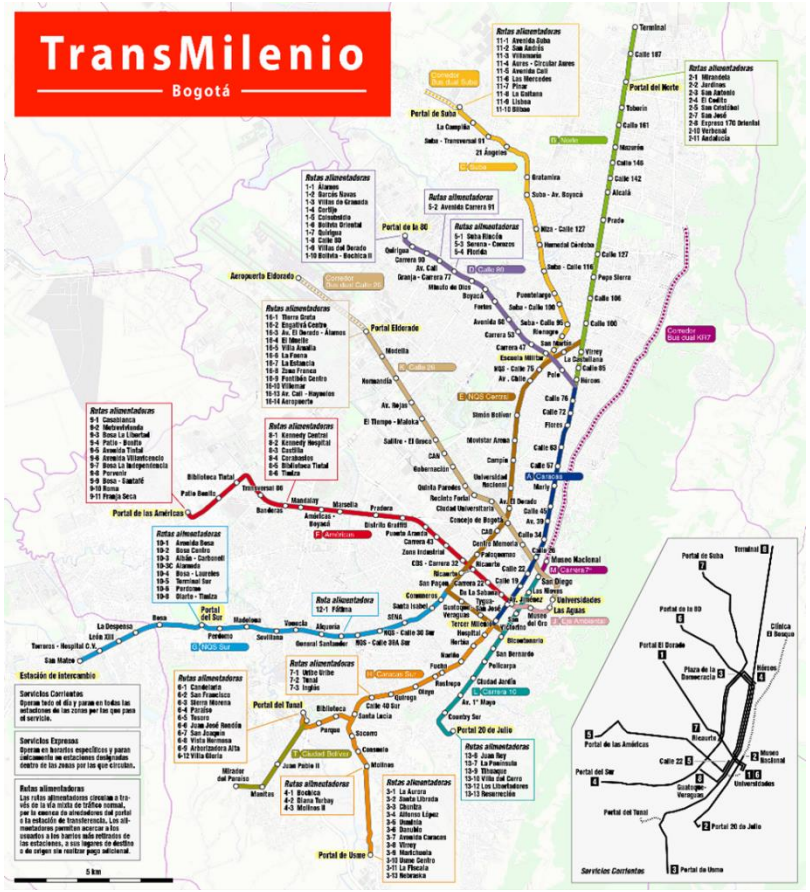
Service

Normal services – stops at 100% of stations
Express services – stops at 40 to 60% of stations
Super-express services – stops at 20% of stations

Buses

Normal buses – 90 passengers
Articulated buses – 160 passengers
Bi-articulated buses – 270 passengers

BRT Model - Bogota





Technical Limitations of the Bogota Model - Basis

Model Basis

25% Failure Rate
Passenger Demand Peak-Hour Factor of 0,85
Dwell Time Variability 0,6
Passenger Load Factor of 65%

Bus Stop Configurations

Median Stations
On-line
Mid-block and linear
2 loading areas for each sub station
3 sub station

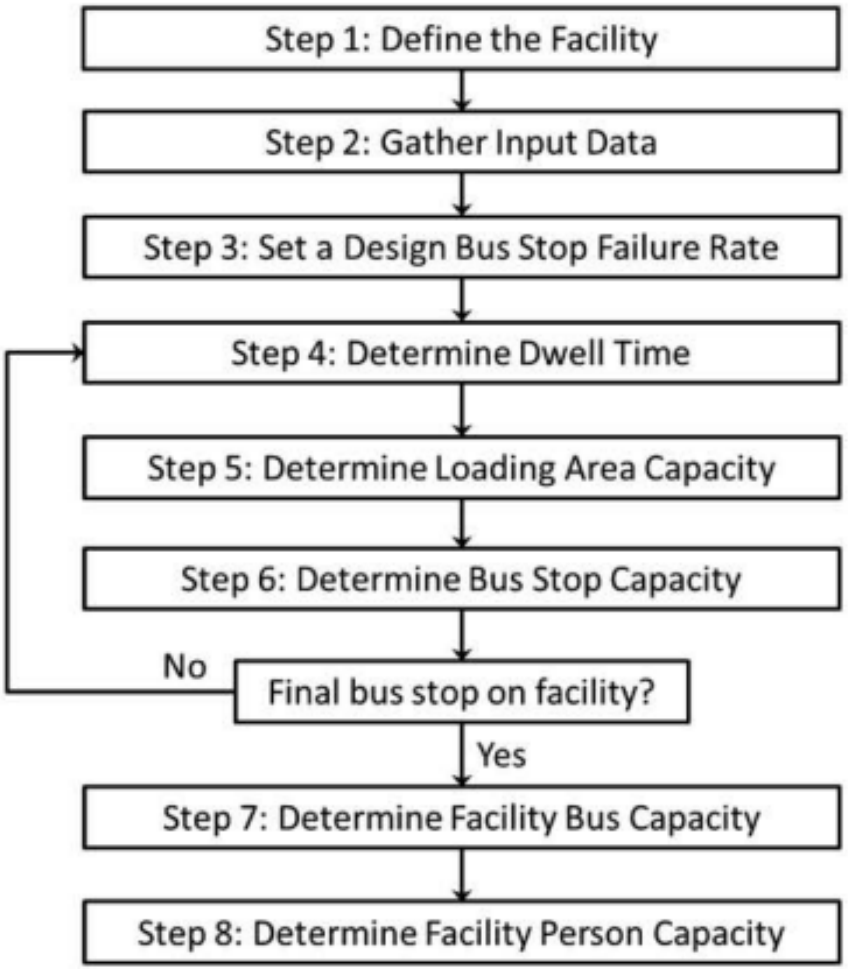
Service Configurations

50% bi-articulated and 50% articulated

Technical Limitations of the Bogota Model - Basis



Methodology



Technical Limitations of the Bogota Model - Calculations

Passenger Distribution

Door	1	2	3	4
Boarding	21,67%	35%	21,67%	21,67%
Alighting	21,67%	35%	21,67%	21,67%
		Number of Passengers		
Boarding	4,33	7	4,33	4,33
Alighting	4,33	7	4,33	4,33

Technical Limitations of the Bogota Model - Calculations

Dwell Time

Door	1	2	3	4
Boarding	5,62	9,07	5,62	5,62
Alighting	6,86	7,06	4,37	4,37

Technical Limitations of the Bogota Model – Loading Capacity

$$B_{l,articulated} = \frac{3600\ (^{g}/_{C})}{t_c + t_d(^{g}/_{C}) + t_{om}}$$

$$B_{l,articulated} = \frac{3600\ (0{,}5)}{6{,}4\ s + 16\ s\ .\ (0{,}5) + 6{,}48 s}$$

$$B_{l,articulated} = 86\ buses/h$$

$$B_{l,bi-articulated} = \frac{3600\ (^{g}/_{C})}{t_c + t_d(^{g}/_{C}) + t_{om}}$$

$$B_{l,bi-articulated} = \frac{3600\ (0{,}5)}{7{,}6\ s + 16\ s\ .\ (0{,}5) + 6{,}48 s}$$

$$B_{l,bi-articulated} = 81\ buses/h$$

Technical Limitations of the Bogota Model – Loading Capacity

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$$B_{l,bi-articulated} = \frac{3600\ (0{,}5)}{7{,}6\ s + 16\ s\ .\ (0{,}5) + 6{,}48 s}$$

$$B_{l,bi-articulated} = 81\ buses/h$$

Technical Limitations of the Bogota Model – Bus Stop Capacity

$$B_{s,articulated} = N_{el} B_l f_{tb}$$

$$B_{s,articulated} = 5{,}55 \,.\, 86 \frac{buses}{h} . 1$$

$$B_{s,articulated} = 477 \; buses/h$$

$$B_{s,bi-articulated} = N_{el} B_l f_{tb}$$

$$B_{s,bi-articulated} = 5{,}55 \,.\, 81 \frac{buses}{h} . 1$$

$$B_{s,bi-articulated} = 449 \; buses/h$$

Technical Limitations of the Bogota Model – Facility Person Capacity

$$P_{articulated\ 50\%} = P_{max} \,.\, PHF \,.\, B$$

$$P_{articulated\ 50\%} = 104\ passengers \,.0{,}85 \,.\, 238{,}5\ \frac{buses}{h}$$

$$P_{articulated\ 50\%} = 21.083\ passengers\ /h$$

$$P_{bi-articulated\ 50\%} = P_{max} \,.\, PHF \,.\, B$$

$$P_{bi-articulated\ 50\%} = 156\ passengers \,.0{,}85 \,.\, 224{,}5\ \frac{buses}{h}$$

$$P_{bi-articulated\ 50\%} = 29768\ passengers\ /h$$

$$P_{system\ total} = 50.852\ passengers\ /h$$

Technical Limitations of the Bogota Model – Other Limitations

Economical Limitations

- Limited subsidy
- Government build and operates infrastructure, private companies operate buses
- Actual cost per km almost twice as high as reported

Societal Limitations

- Huge road cross section is needed
- Worse life quality within 150 m from BRT corridors

Limitations of Other Models

Jakarta

7.247 pphpd
High subsidy demand for current fare pricing

BHLS

7.680 pphpd
Special taxing system is needed

Conclusion

BRT as a Alternative

- High-capacity rapid transit is achievable with buses
- Cities with budgetary constrains should look into BRT as an alternative

Challenges

- Creating a high quality BRT along with its operational and infrastructure requirements
- High hopes for BRT with problem for BRT-creep

BRT Development

- Curitiba as pioneer in 1974
- Bogota as modern day pioneer in 2000
- Modern evolutions and additions such as BHLS in France



“Many cities end up putting off things because they want to understand everything. They don’t understand that innovating is about starting”

Jaime Lerner