PERFORMANCE CONTRIBUTORS OF BUS RAPID TRANSIT SYSTEMS WITHIN THE ITDP BRT STANDARD: AN ORDERED CHOICE APPROACH

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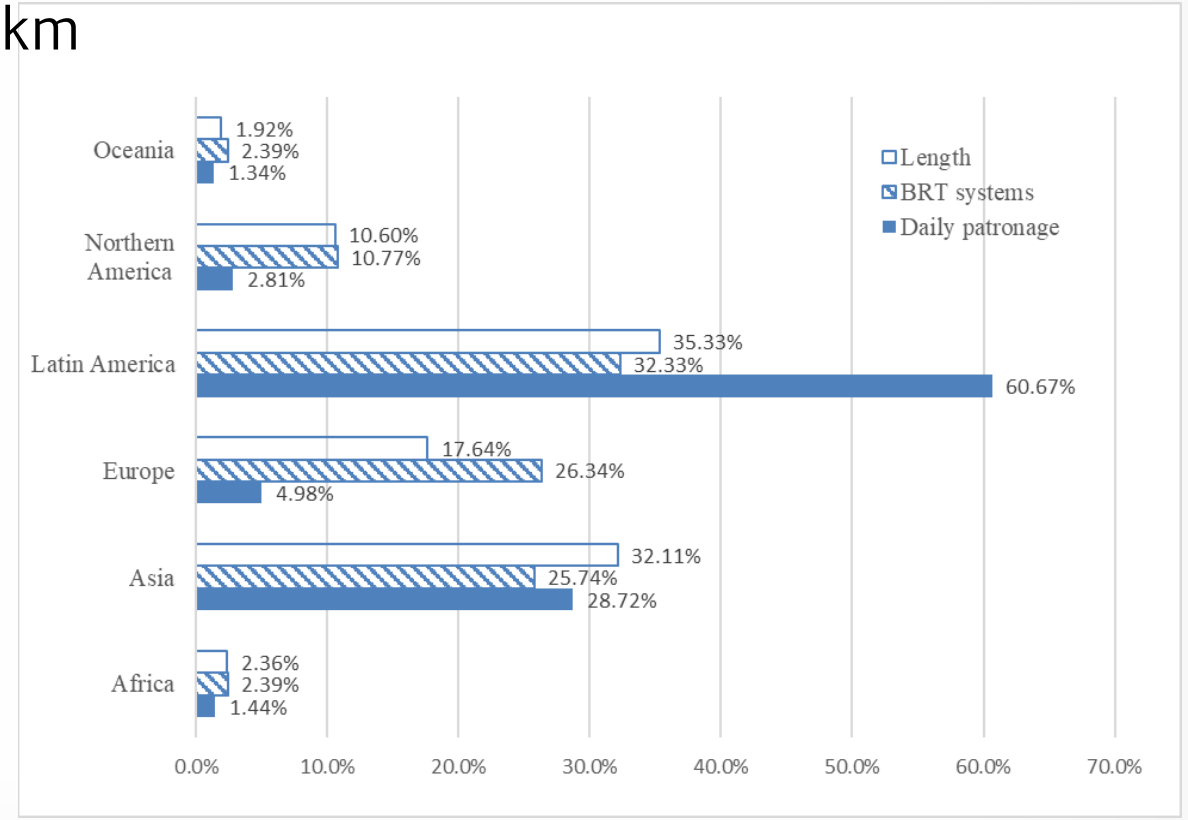
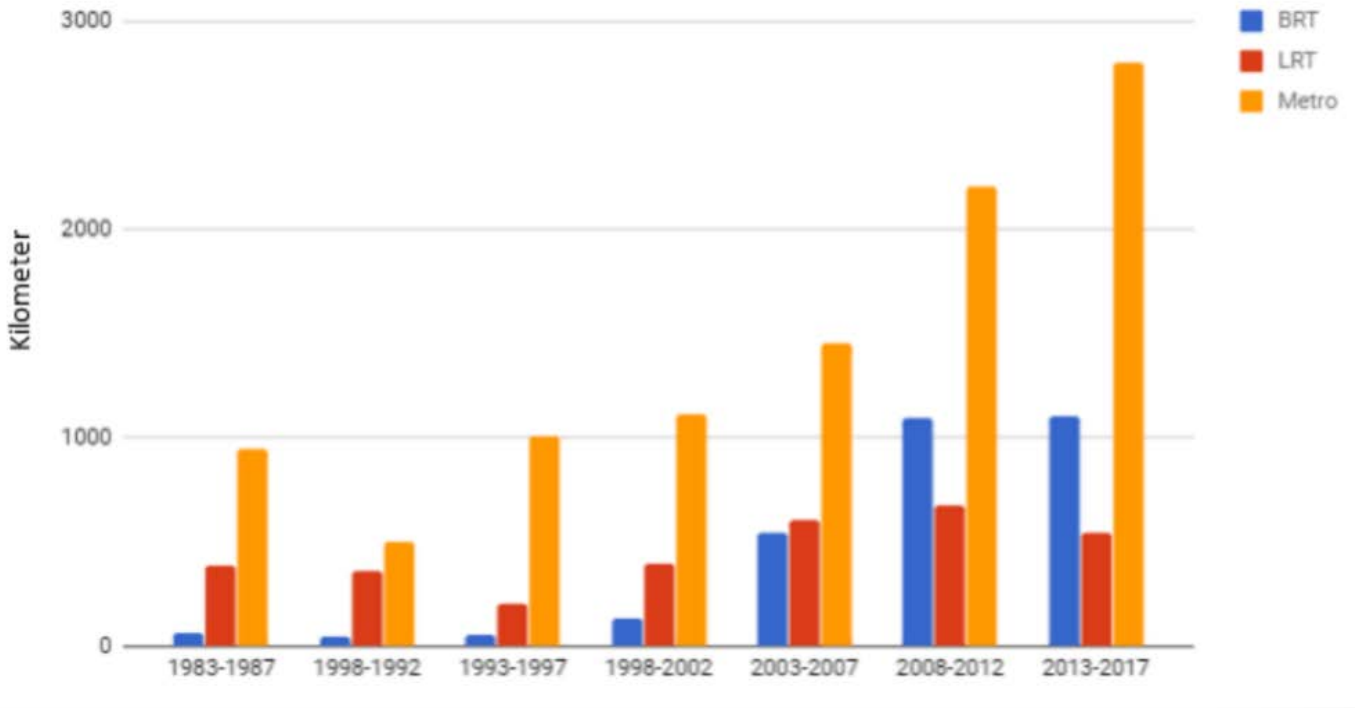
Bus Rapid Transit (BRT): Some Figures

- Global BRT network reached 5,000km
- Operating in nearly 200 cities
- Daily patronage: 32 million



BRT are Gaining Popularity



BRT, LRT and metro construction from1983 to 2017

In 2016,
Growth of BRT: 163.2km
Growth of LRT: 72.1km

ITDP BRT Standard

- Full scores of the ITDP (Institute for Transportation and Development Policy) BRT Standard 2016
- Gold = 85 or more points, Silver = 70-84.9 points, and Bronze = 55-69.9 points
- Design features (+) : six main categories
- Operations deductions (-)

Category	Max	Category	Max	Category	Max.
BRT Basics	*38*	*Stations*	*10*	*Operations Deductions*	*-63*
Dedicated Right-of-Way	8	Distances between Stations	2	Commercial Speeds	-10
Busway Alignment	8	Safe and Comfortable Stations	3	Peak Passengers per Hour per Direction Below 1,000	-5
Off-Board Fare Collection	8	Number of Doors on Bus	3	Lack of Enforcement of Right-of-Way	-5
Intersection Treatments	7	Docking Bays and Sub-stops	1	Significant Gap Between Bus Floor and Station Platform	-5
Platform-level Boarding	7	Sliding Doors in BRT Stations	1	Overcrowding	-5
				Poorly Maintained Infrastructure	-14
Service Planning	*19*	*Communications*	5	Low Peak Frequency	-3
Multiple Routes	4	Branding	3	Low Off-Peak Frequency	-2
Express, Limited-Stop, and Local Service		Passenger Information	2	Permitting Unsafe Bicycle Use	-2
Control Center	3	*Access and Integration*	15	Lack of Traffic Safety Data	-2
Located in Top Ten Corridors	2	Universal Access	3	Buses Running Parallel to BRT Corridor	-6
Demand Profile	3	Integration with Other Public Transport	3	Bus Bunching	-4
Hours of Operations	2	Pedestrian Access and Safety	4		
Multi-Corridor Network	2	Secure Bicycle Parking	2		
		Bicycle Lanes	2		
Infrastructure	*13*	Bicycle-Sharing Integration	1		
Passing Lanes at Stations	3				
Minimizing Bus Emissions	*3*				
Stations Set Back from Intersections	3				
Center Stations	2			4	
Pavement Quality	2				

Scored BRT systems using the IDTP scorecard

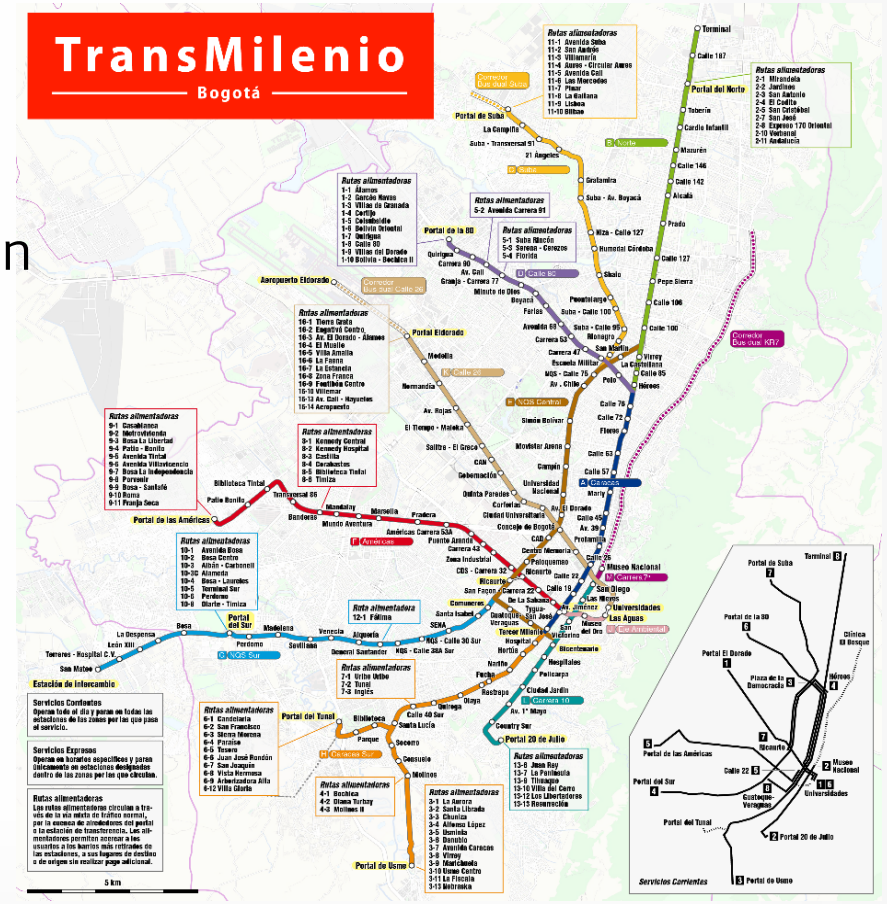
Standard	BRT system
Gold (3)	Bogotá, Lima, Yichang
Silver (14)	Cali, Istanbul, Johannesburg, Leon, Chengdu, Mexico City, Brisbane, Curitiba, Lanzhou, Xiamen, Guangzhou,
Bronze (19)	Ahmedabad, Los Angeles, Nantes, Quito, Yancheng, Zhongshan, Cape Town, Jakarta, Kuala Lumpur, Lianyungang, Bangkok, Buenos Aires, Guayaquil, Islamabad, Jinan, Nanning, Yinchuan, Zhengzhou, Changzhou
Basic (7)	Beijing, Dalian, Hefei, Zaozhuang, Zhoushan, Changde, Seoul

One Gold BRT System: Bogotá's TransMilenio

- One of the most successful and complex BRT
  - 11 corridors and over 100 routes
  - over 2.2 million passengers
  - Peakload: 35,000 passengers per hour per direction
  - One in four Bogotá's residents uses TransMilenio

	TransMilenio	London Tube
Started in the year of	2000	1863
Network length	110km	406km
Commercial speed	26km/h	33km/h
Demand per km	20,000 passengers/km	9031 passengers/km

Note: Population: 8.2 million for Bogotá and 8.8 million for London



Ordered Choice Model

Latent, continuous: $y^* = \boldsymbol{\beta}'\mathbf{x}_i + \varepsilon_i$

Observed, discrete:

$$
\begin{aligned}
y_i &= 0, \text{if } y^* \le \mu_0; \\
&= 1, \text{if } \mu_0 < y^* \le \mu_1; \\
&= 2, \text{if } \mu_1 < y^* \le \mu_2; \\
&\dots \\
&= \mathrm{J}, \text{if } y^* > \mu_{J-1}
\end{aligned}
$$

- In this study, Gold BRT=3, Silver BRT=2, Bronze BRT=1;
- Unequal differences among these preference scales or outcomes

Model Performance

Ordered logit vs. ordered probit

	Gold	Silver	Bronze	Basic	Log-likelihood	Pseudo-R^2
Actual standard	*3*	*11*	*19*	*7*	n/a	n/a
Ordered logit prediction	2(+1)	11	20(-1)	7	-17.395	0.640
Ordered probit prediction	2(+1)	12(-1)	19	7	-17.445	0.638

Note: Forecasting errors (=Actual - Prediction) in parentheses

BRT Standard contributors- the order logit model

Variable	Coefficient	*t*-Ratio
Constant	-38.2799	-4.13
Peak-hour speed (km/h)	0.8280	4.50
Peak frequency (bus/hour/direction)	0.0268	2.84
Length of dedicated busway (km)	0.0473	2.15
Average distance between stations (m)	-0.0048	-1.82
Over 50% of stations with passing lanes (Yes)	2.5507	1.80
Pre-board fare collection and fare verification at all stations (Yes)	11.8419	4.39
Fully integrated network of routes and corridors (Yes)	7.0538	3.78
All stations being enhanced station, not just bus shelters (Yes)	9.3139	2.79
Automated fare collection and fare verification at all stations (Yes)	5.1833	2.44
Covered station access at all stations (Yes)	3.5787	1.93
Threshold parameters		
Mu (1)	12.1830	5.02
Mu (2)	18.3130	5.45
Log-likelihood	-17.395	
Pseudo-R^2	0.640	

Business-as-Usual Projection

	A	B	C	D	E	F	G	H	I	J	y*	Threshold	Predicted Standard
Amsterdam	34	18	45	1750	0	0	0	0	1	0	-10.69	y*<0	Basic
Nagoya	25	12	7	810	0	0	1	1	1	1	4.33	y*<12.183 (Mu1)	Bronze
Paris	25	52	19	620	0	0	1	1	1	0	3.29	y*<12.183 (Mu1)	Bronze
Utrecht	23	8	8	680	0	0	1	0	1	0	-9.63	y*<0	Basic
Pune	22	40	23	990	0	0	1	1	0	0	-6.26	y*< 0	Basic
Shaoxing	15	15	12	1,580	0	1	0	1	1	0	-6.10	y*< 0	Basic
Guiyang	31	16	31	1,250	0	1	0	1	1	1	13.25	12.183(Mu1)<y*<18.313 (Mu2)	Sliver

A: Peak-hour speed (km/h)
B: Peak frequency (bus/hour/direction)
C: Length of dedicated busway (km)
D: Average distance between stations (m)
E: Over 50% of stations with passing lanes (1 or 0)
F: Pre-board fare collection and fare verification at all stations (1 or 0)
G: Fully integrated network of routes and corridors (1 or 0)
H: All stations being enhanced station (1 or 0)
I: Automated fare collection and fare verification at all stations (1 or 0)
J: Covered station access at all stations (1 or 0)

Marginal effects: what if?

Variable	P(y=0) Basic	P(y=1) Bronze	P(y=2) Silver	P(y=3) Gold
A: Peak-hour speed (km/h)	-0.0002	-0.0192	0.0194	.443D-04
B: Peak frequency (bus/hour/direction)	-.557D-05	-0.0006	0.0006	.143D-05
C: Length of dedicated busway (km)	-.983D-05	-0.0011	0.0011	.253D-05
D: Average distance between stations (m)	.989D-06	0.0001	-0.0001	-.255D-06
E: Over 50% of stations with passing lanes (Yes vs. No)	-0.0004	-0.1162	0.1163	0.0003
F: Pre-board fare collection and fare verification at all stations (Yes vs. No)	-0.8680	0.7704	0.0973	0.0002
G: Fully integrated network of routes and corridors (Yes vs. No)	-0.0237	-0.1720	0.1951	0.0005
H: All stations being enhanced station (Yes vs. No)	-0.4760	0.4172	0.0586	0.0001
I: Automated fare collection and fare verification at all stations (Yes vs. No)	-0.0167	-0.0339	0.0504	0.0001
J: Covered station access at all stations (Yes vs. No)	-0.0004	-0.3070	0.3063	0.0010

Summary

- Key BRT Standard contributors
  - Speed, peak frequency
  - Accessibility, system capacity
  - Infrastructure (passing lanes and enhanced station environment)
  - Network integration
- Decision support tool
  - where a BRT system might be positioned in the ITDP standards table
  - promoting the virtues of BRT against best practice

Thank you!

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