A Review of Technological Improvements in BRT and BHLS

Dario Hidalgo and Juan Carlos Muñoz

CASPT 12, Santiago de Chile, July 23-27, 2012

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BRT

"flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways and information technologies into an integrated system with strong identity"
(Levinson et. al, 2003b)

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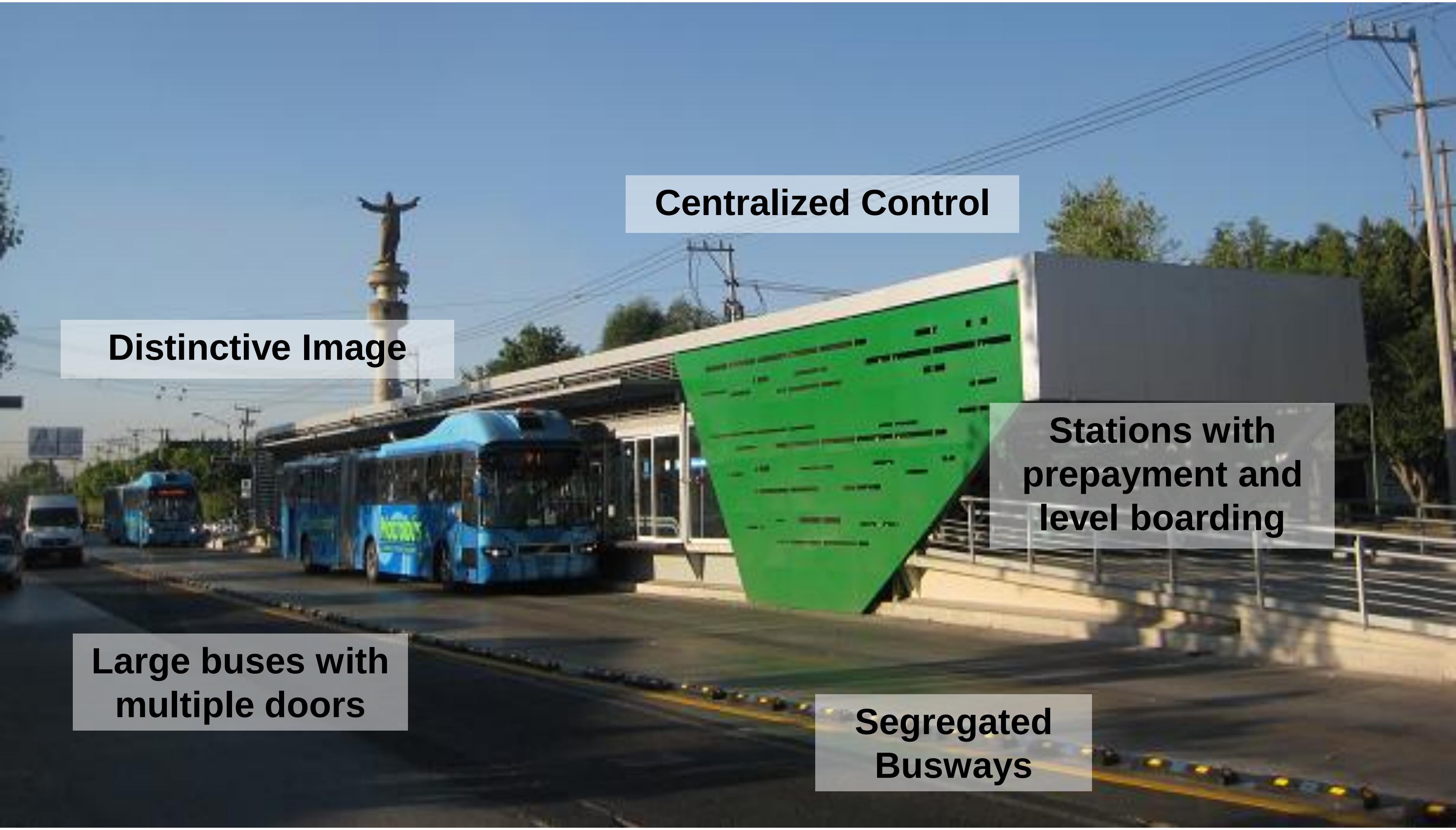
Key BRT Components



Macrobús – Guadalajara

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Cambridge, UK

BHLS

"is an urban transport system integrating a bus, but within new conditions providing an increase in performance thanks to a triple optimization of:

- ***The internal characteristics of the technical and commercial offer.***
- ***The integration of this offer into the whole public transport network.***
- ***The integration of this network into the urban area"***

(Finn et. al, 2011)

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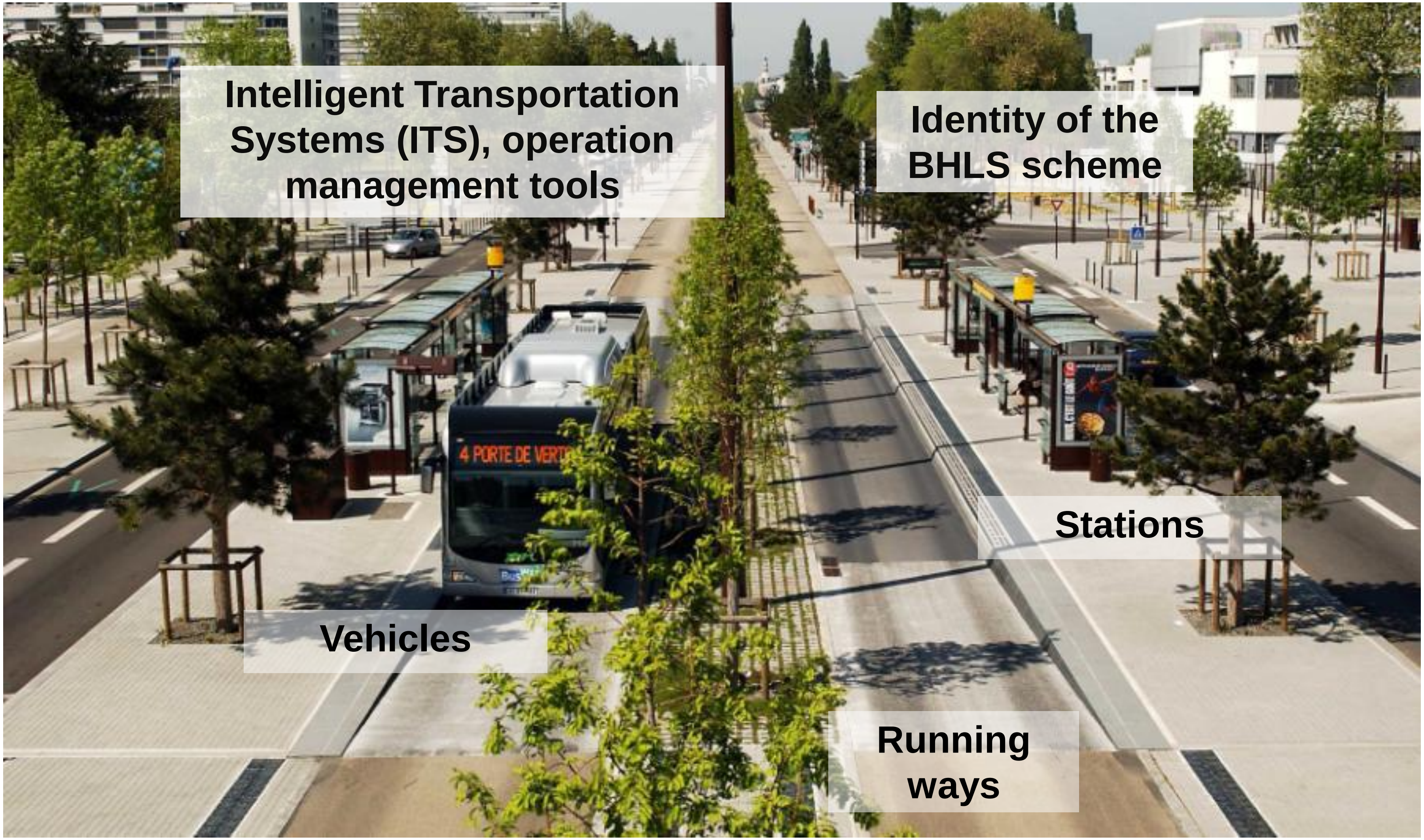
Key BHLS Components (for better performance)



The Busway – Nantes

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142 cities with BRT/ Bus Corridors/ BHLS
3,740 km, 23,486 passengers per day

Regions	Passengers / day	Number of cities	Length (km)
Latin America	15,050,098 (64.1%)	48 (33.8%)	1,278 (34.2%)
Northern America	677,986 (2.9%)	18 (12.7%)	534 (14.3%)
Asia	6,255,872 (26.6%)	24 (16.9%)	888 (23.7%)
Europe	936,970 (4.0%)	42 (29.6%)	632 (16.9%)
Africa	238,000 (1.0%)	3 (2.1%)	62 (1.7%)
Oceania	327,074 (1.4%)	7 (4.9%)	347 (9.3%)

http://brtdata.org/

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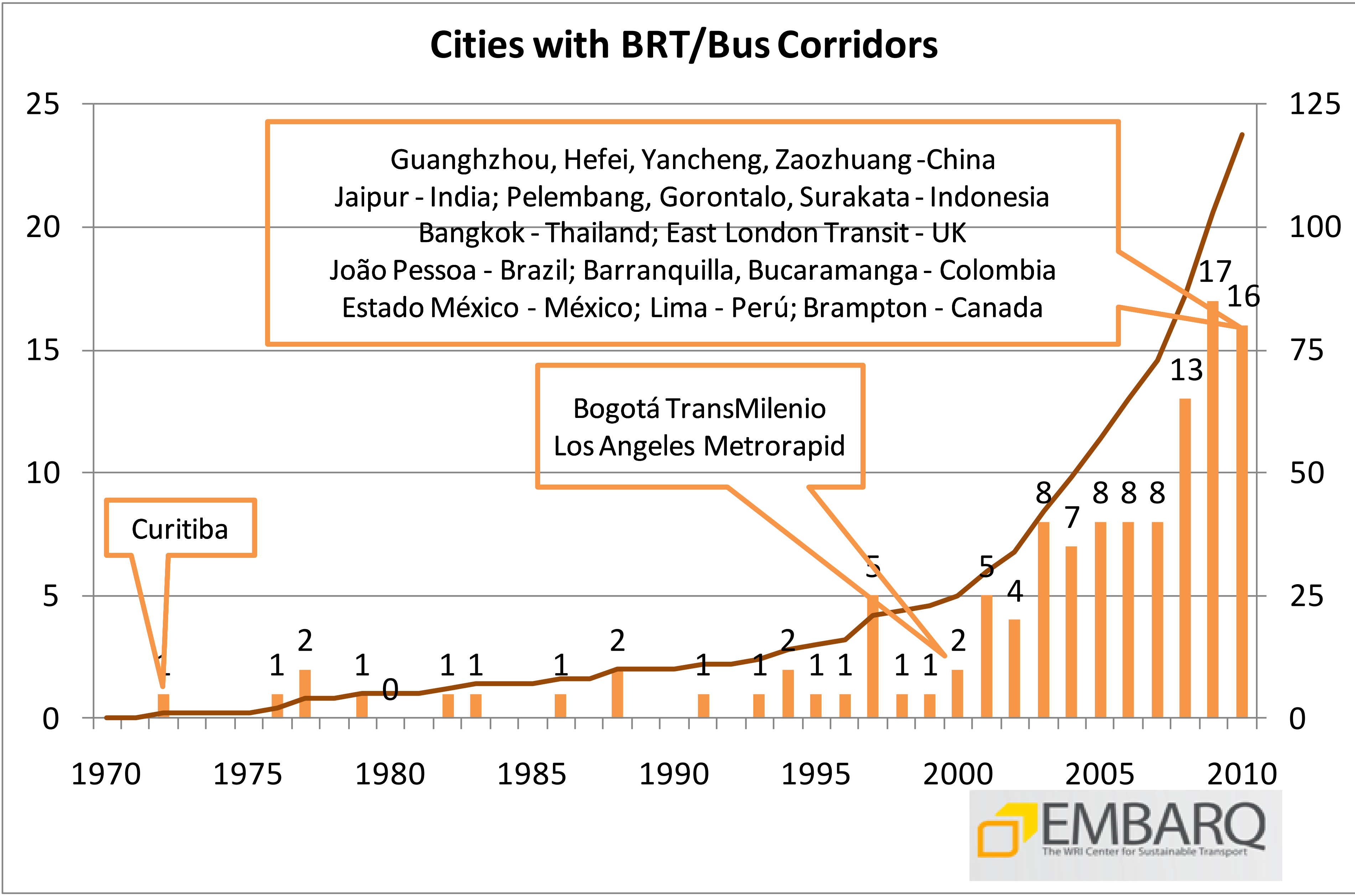


Source: EMBARQ BRT/Bus Corridors Database, January, 2011

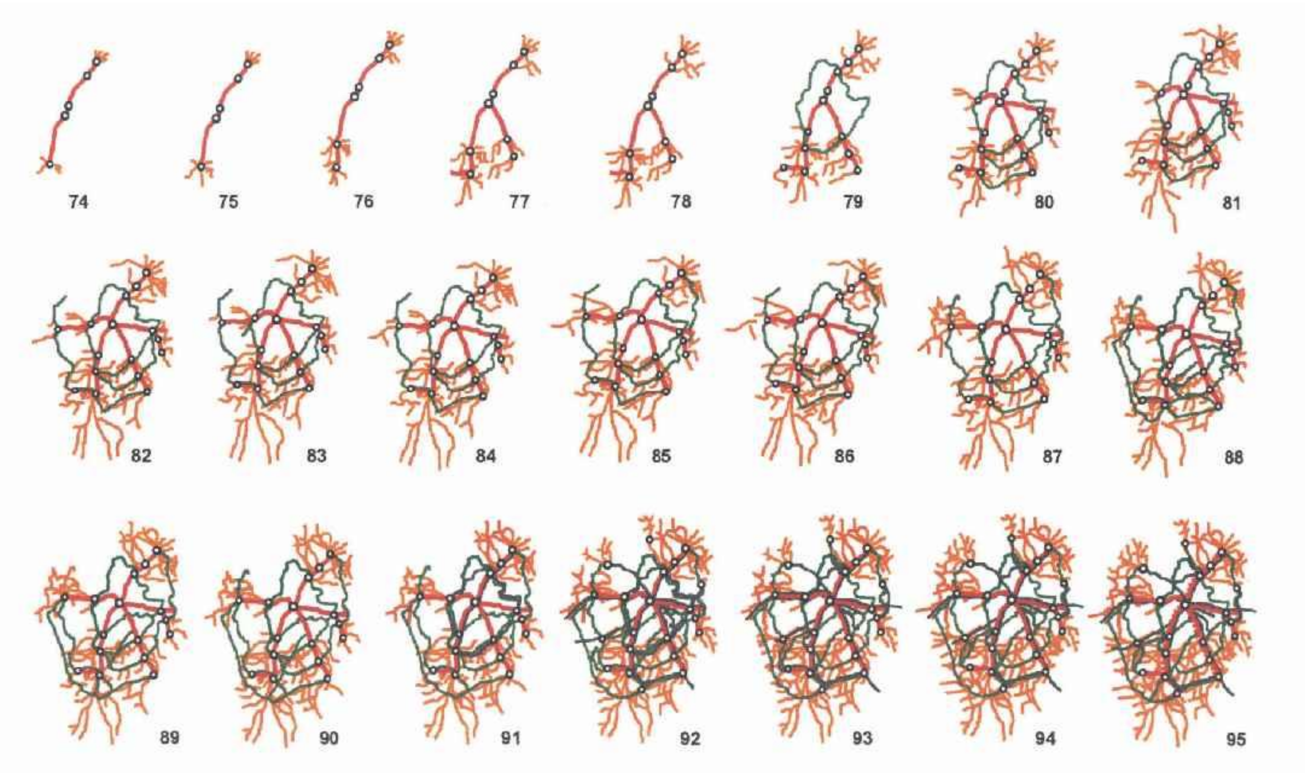
Curitiba, RIT, 72 km median busways
1.2 million passengers per day
Initial Bus Corridor 1972

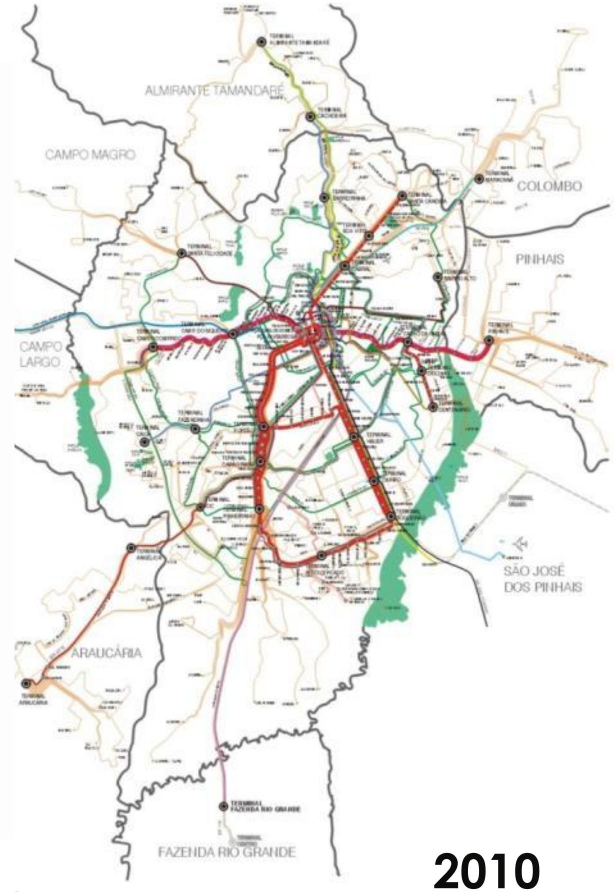
Full BRT in 1982

1. Making buses run like surface metro – Curitiba 1982

- median bus-ways longitudinally segregated
- tube stations with fare prepayment and level access
- physical and fare integration
- dispatch control at terminal stations.
- differentiated services:
  - Expresso, Ligerao, Ligeirinho, Interbairros, Alimentador
  - Special services downtown, hospitals, touristic bus, schools

Evolution of the Integrated Network





2010

Source: Prefeitura de Curitiba, Parana

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“Linha Verde” Curitiba
Corredor de 18 Km
2009

Fotos: Prefeitura de Curitiba, Parana

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Foto: Prefeitura de Curitiba, Parana

Expansión de Capacidad
“Corredor Boqueirao”
2010

2. Implementing buses of high level of service, The Trans Val de Marne TVM – Paris 1993

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Implementing buses of high level of service, The Trans Val de Marne TVM – Paris 1993

- Is the most used BHLS
- 1993 (13 km) and 2007 (7 km)
- 20 km bus lanes, 95% dedicated, mostly central segregated
- 29 stations (@ 700m)
- 39 articulated buses, specially designed and branded for the system

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Implementing buses of high level of service, The Trans Val de Marne TVM – Paris 1993

- Information systems
- 23 km/h
  17 km/h minimum peak
- 3.5 min headway (peak)
- Interval plus 3 minutes for 96% of the pax
- 66,000 trips/day, growing 7% per year
- Good integration with pedestrians and rail (4 RER and 1 subway)

New vehicle Créalis for the BHLS routes

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Quito, Metrobús-Q

Initial corridor 1995

Trolebus in Historic Disctrict

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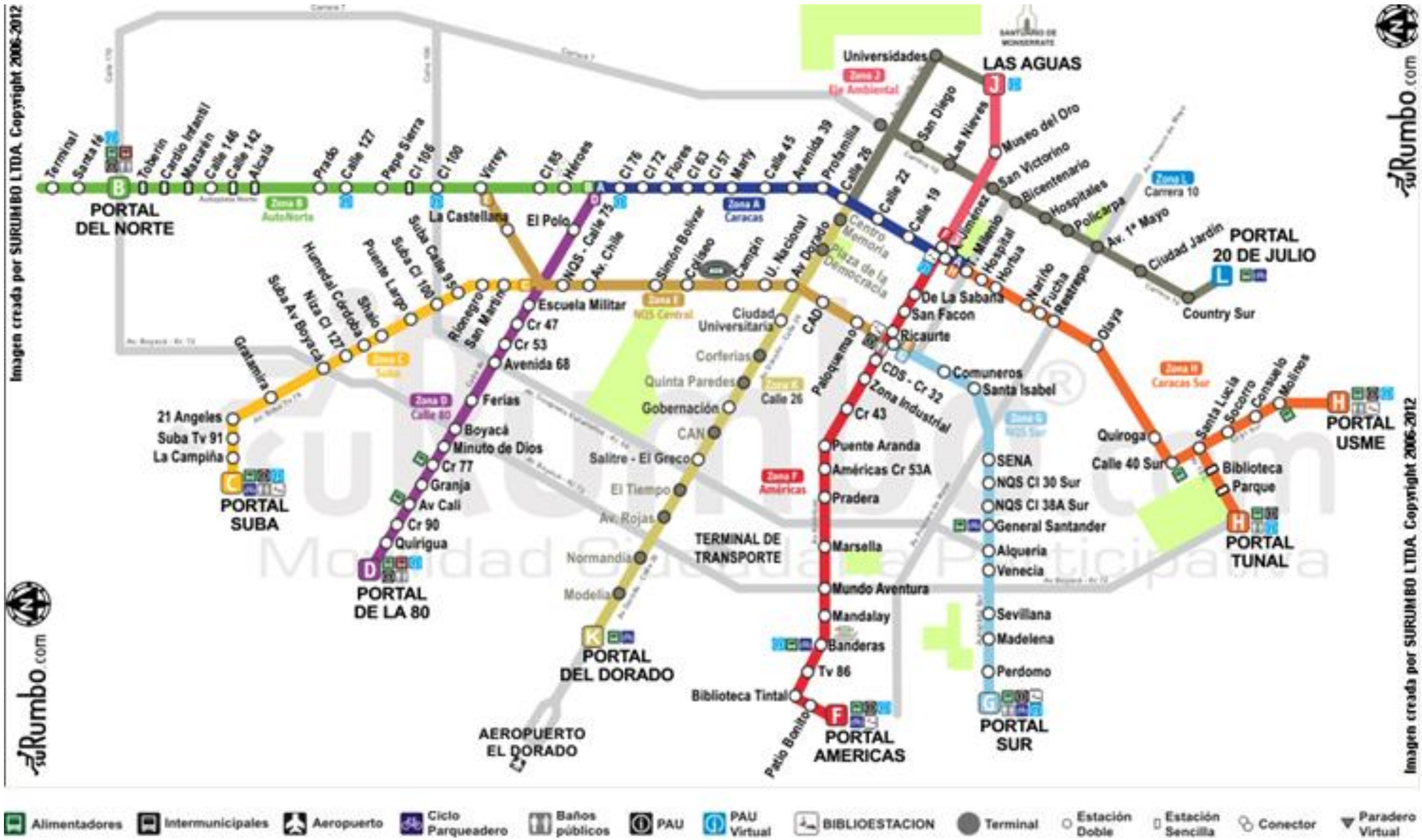
3. Expanding capacity with advanced operations

Bogotá, 2000
Very high capacity
48,000 pphpd



Bogotá, TransMilenio, 90 Km busways

1,8 milion pax/day


A03S
1057

Photo ITDP

Bogotá TransMilenio
Eje Ambiental Avenida Jiménez

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Express Way Lanes
TransMilenio, Bogota

4. Integrating transit services across modes and services – Santiago 2007

- Single process (¿big bang?)
- Fare integration
- Route optimization
- Formalization of providers
- Elimination of “competition on the street”

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The planning and implementation team was too optimistic - the reform resulted in serious difficulties

- Lack of proper infrastructure for the trunk services
- Stations without prepaid area
- Inadequate transfer facilities
- Lack of centralized dispatch and control
- Large subsidies

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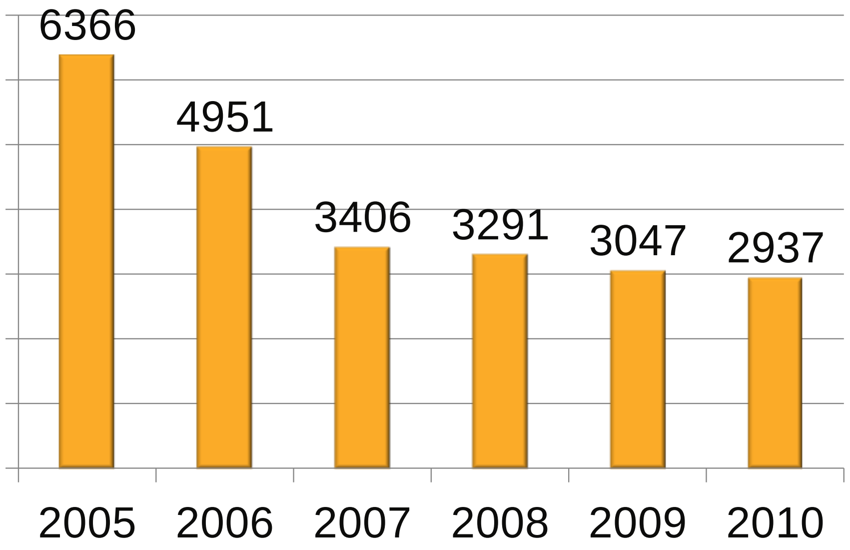
Despite the initial difficulties, Santiago has risen to a higher level of performance

- The current system is better than the one it replaced
- Travel times have reduced
- Large decreases in emissions
- Substantial reductions in fatalities and injuries
- <u>Still a lot to improve</u>



Traffic Fatalities in Santiago
Source: CONACET

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5. Introducing high speed buses on expressways – Istanbul 2008

High commercial speed
42 km/h

- 45 Km central bus ways on expressway (100% segregated)
- Long station platforms -90m, separated 1.1 km on average
- Non-grade queue jumpers to access the Bosphorus Bridge, (mixed traffic)
- Low floor buses (articulated and bi-articulated)
- 30,000 passengers/ hour/ direction, 15 sec interval
- 600,000 passengers/day

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Expresso Tiradentes – Sao Paulo

Foto: SPTrans

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6. Reducing transfers with direct services – Guangzhou 2010

35,800 pax/day/km

- 22.5 km corridor
- Long stations –from 55m to 260m, with overtaking lanes
- Combines multiple direct services on the same infrastructure.
- 27,000 pphpd
- 350 buses phpd
- 800,000 passengers per day

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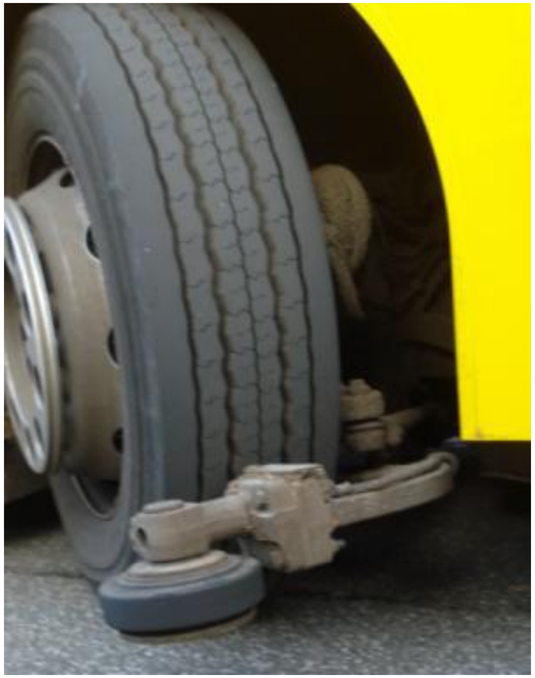
Future of BRT

- Running way guidance
- Vehicle propulsion technologies
- Information technologies
  - Fare collection
  - Planning and controlling operations

Running way guidance

Mechanical	Optical	Magnetic
		
Essen since 1980, Leeds, Cambridge since august 2011	Rouen, France (2001), Castellón de la Plana, Spain (2008), Nimes, France (2010) and Bologna, Italy (2010).Tested in Las Vegas, Nevada	Eindhoven (2004)

O-Bahn, Adelaide, Australia

Opened in 1986

12 Km, guided, $98 MM Aus (including buses), up to 18,000 pax/hour

Running way guidance costs

	Km (Pax/Day)	Type of Guidance	Capital Cost (M€)	Cost/Km (M€)
Teor – Rouen, France	30 (49,000)	Optical	Infra 165 Buses 28 Total 193	Infra 5.5 Buses 0.9 Total 6.4
Spurbus Essen, Germany	16 [4] (17,000)	Kerb Guided	Infra N.A. Buses 0.35/ unit	N.A.
TVRCAS Castellon, Spain	2 (3,200)	Optical (trolleybus)	Infras 22 Buses 8 Total 30	Infra 11.0 Buses 3.8 Total 13.8
Cambridge, UK	25 (20,000)	Kerb Guided	Infra 85 Buses N.A.	Infra 3.4

Source: Finn et al, 2011

Vehicle propulsion technologies

- Diesel - reduction of the fuel´s sulfur content, engine improvements and filters and catalysts
- Compressed natural gas CNG
- Liquefied natural gas LNG
- Electric (trolleybuses), since 1911, in 315 cities
- Hybrid-electric drives
- Hydraulic Hybrids
- Battery Electric
- Hydrogen powered buses

Examples of Costs of Different Vehicle Technologies in Europe (Thousand €)

Propulsion	Standard	Articulated	Double-articulated
Diesel	200	300	600
CNG	250	350	650
Hybrid	300	500	850
Trolley	400	650	1,000
Fuel Cell*	> 1,000	-	-

Source: Finn et. al (2011) * Not yet in commercial operation

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Reference costs for Euro 5 Vehicles in Mexico (Thousand USD)

	Standard	Articulated	Double-Articulated
Diesel	12 m	18 m	25 m
High Floor with stairs	90-150	NA	NA
High Floor without stairs	130-160	330-365	490-500
Low entry	150-180	NA	NA
Low floor	280-310	430-460	630-650
CNG	+ 20-30%		
Hybrid	+40-60%		
Air Conditioned	+15	+35	

Source: Suarez, 2011

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Qualitative Comparison of Emissions

	CNG	CNG + Oxidation Catalyst	Conven-tional Diesel	Ultra Low Sulfur Diesel	Ultra Low Sulfur Diesel + Particulate Filters	Hybrid Diesel+ Electric
PM-10	Low	Very Low	Very High	High	Low	Very Low
NOx	Very High	Very Low	High	Medium	High	Very Low
NMHC		Very High	Medium	Medium	Low	Very Low
CO	Very High	Very Low	Medium	Medium	Very Low	Very Low
GHG	High	Medium	Low	Low	Very High	Very Low
Formaldehydes	Very High	Low	Low	Low	Very Low	
Acetaldehydes	Very High	Medium	Medium	Very High	Very Low	
Cost	Medium	Medium	Very Low	Low	Low	High

Source: The authors based on Martínez et al, 2010

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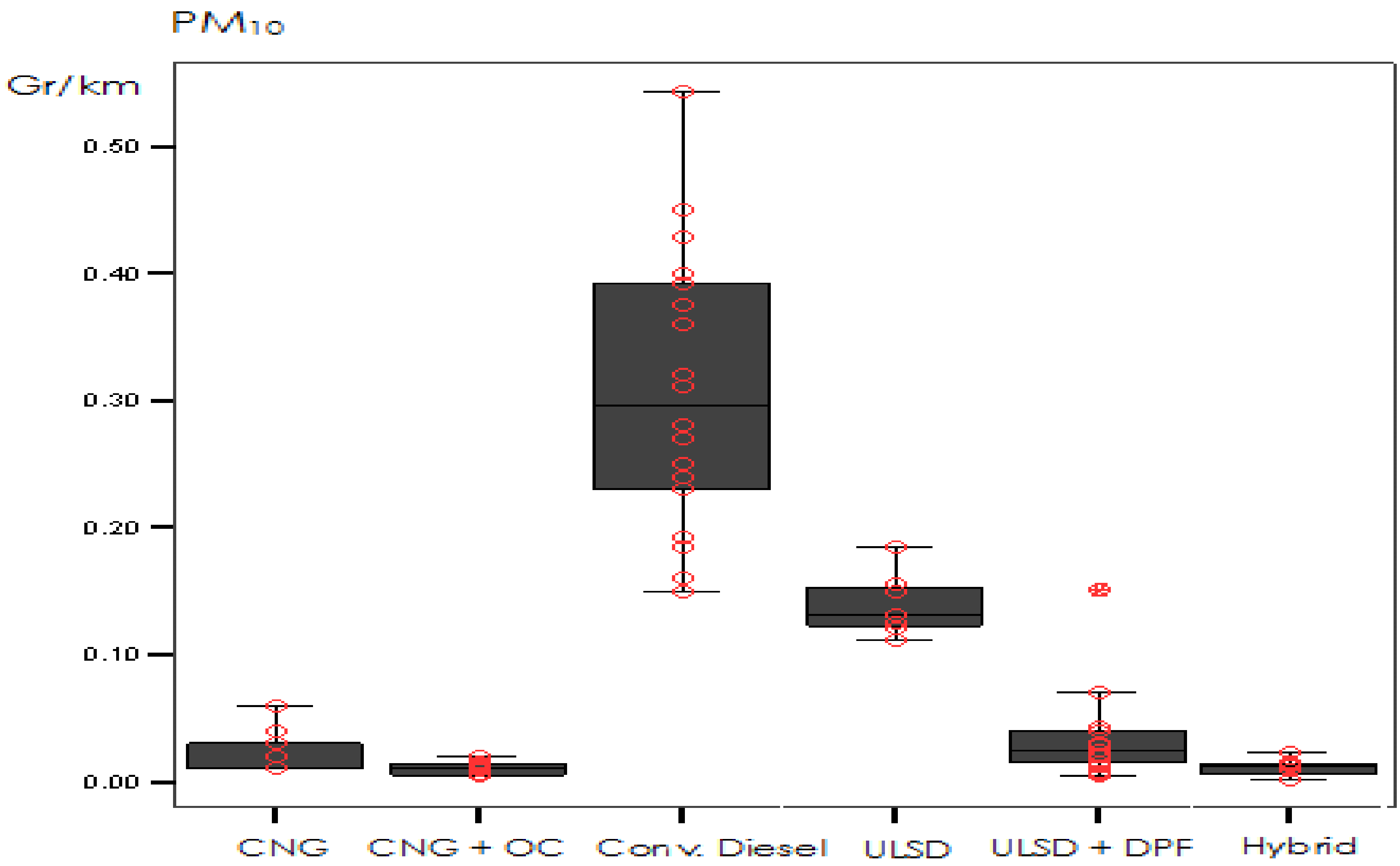

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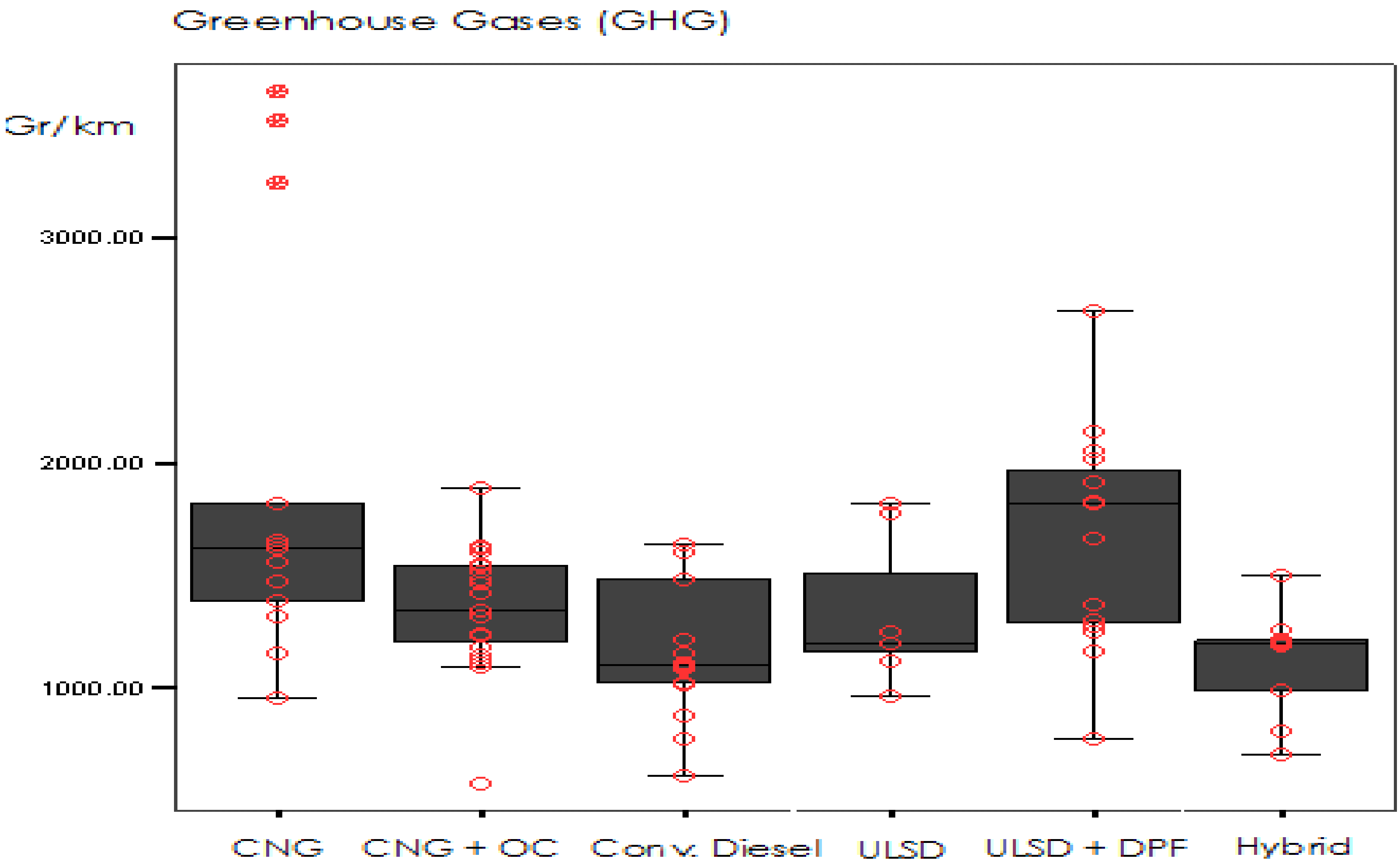

Greenhouse Gases (GHG)
Gr/km
3000.00
2000.00
1000.00
CNG
CNG + OC
Conv. Diesel
ULSD
ULSD + DPF
Hybrid

ITS – Fare Collection

- Advanced contactless smart cards are the most common media; flexible, secure, convenient
- Technologies:
  - MIFARE, introduced in 1994, market share of more than 70%
  - Octopus, in Honk Kong since 1997: applications in the Netherlands, Dubai and New Zealand
  - Cubic, in 40 markets around the world
  - Visa/Mastercard
- New: NFC and EMV; for use with cellular phones; under development in 80 countries

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ITS – Planning and Operations

- Advanced route design – heuristics
- Bus and crew scheduling
- Advanced bus and crew scheduling
- Advanced operational control AVL/CAD
- Control: holding, early doors closing, TSP
- Traffic Signal Priority TSP

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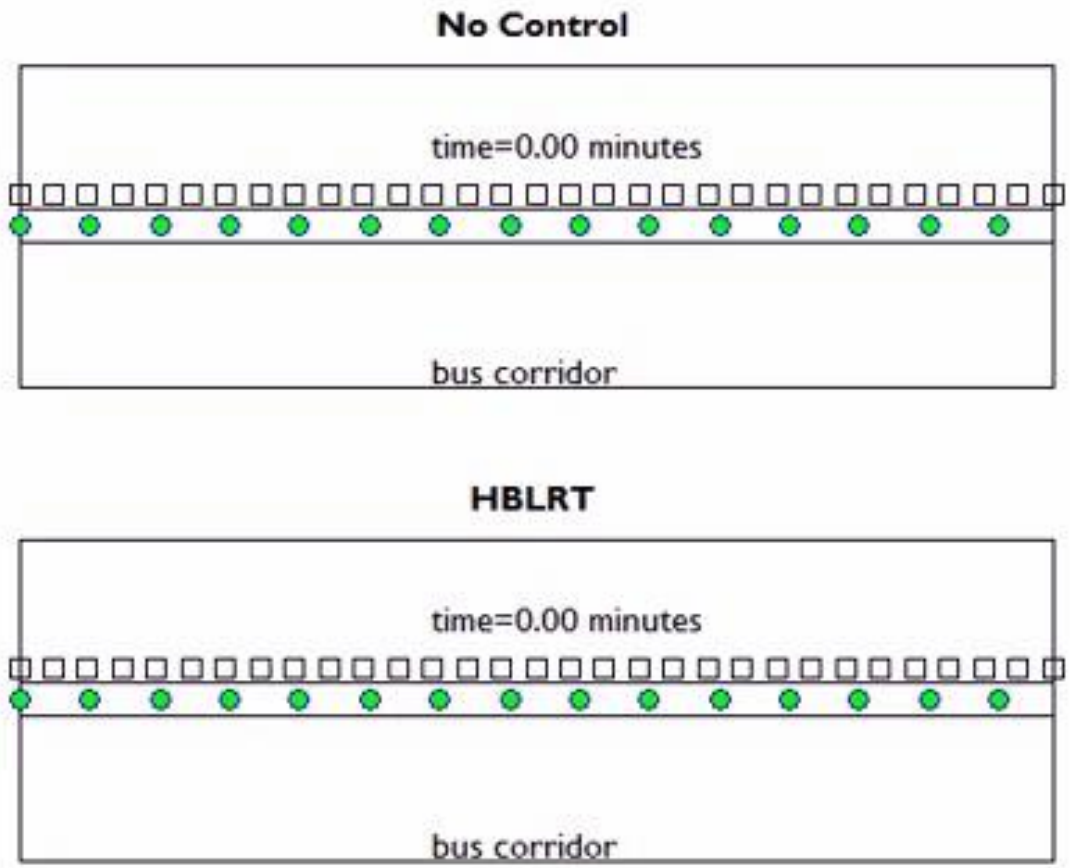
Avoiding Bus Bunching through Real Time Control Strategies

Delgado, Muñoz, Giesen

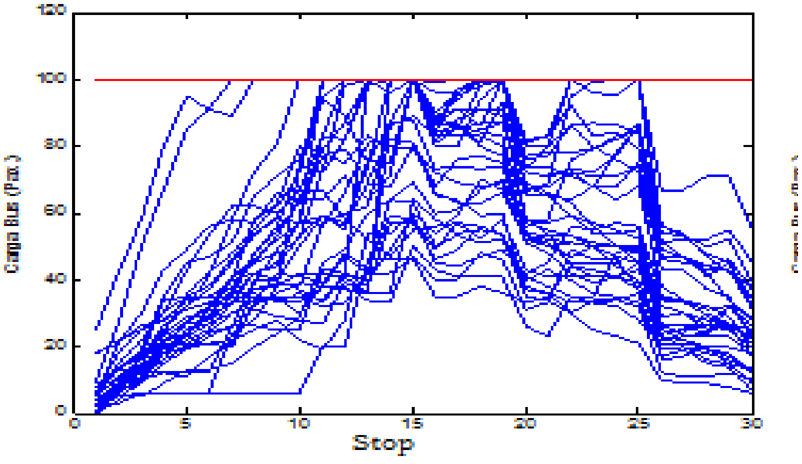


Results: High frequency scenario

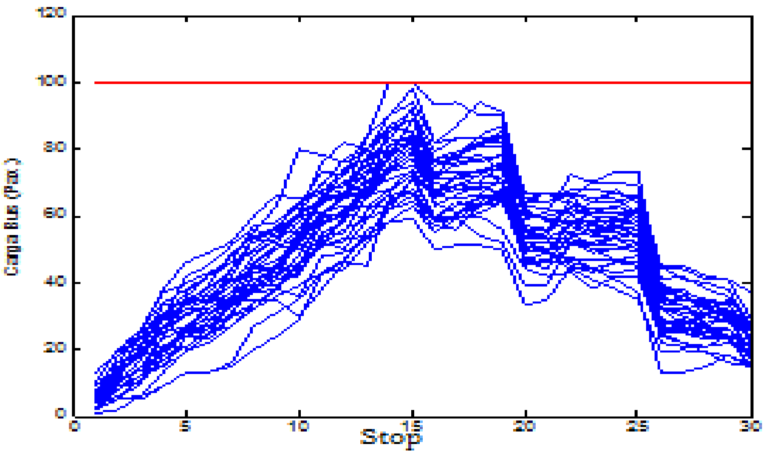
Transit Users

	No	
	Control	Proposed
W_{first}	7636.32	1438.62
Std. Dev.	649.36	146.56
% reduction		-81.16
W_{extra}	6218.71	1010.52
Std. Dev.	2265.24	82.04
% reduction		-83.75
$W_{in\text{-}veh}$	175.32	1561.34
Std. Dev.	31.69	77.3
% reduction		790.55
W_{t_light}	4052.81	2965.1
Std. Dev.	88.27	110.27
% reduction		-26.84
Total	18083.16	6975.58
Std. Dev.	2600.63	275.12
% reduction		-61.42

5. Results: Bus Loads (Capacity reached & high frequency)

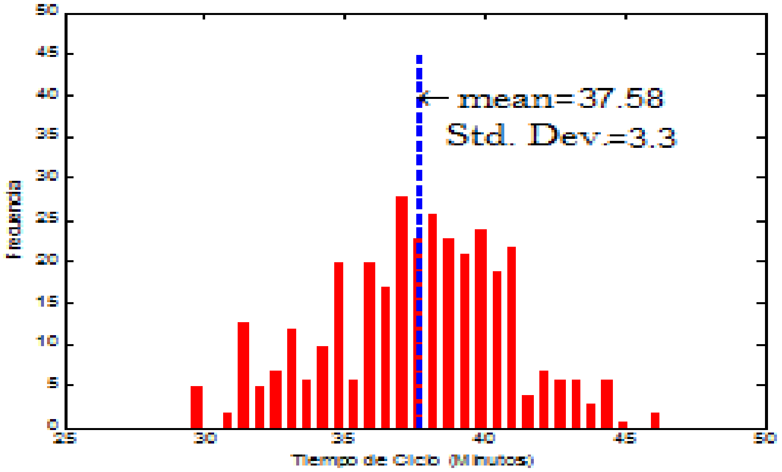


a) No control

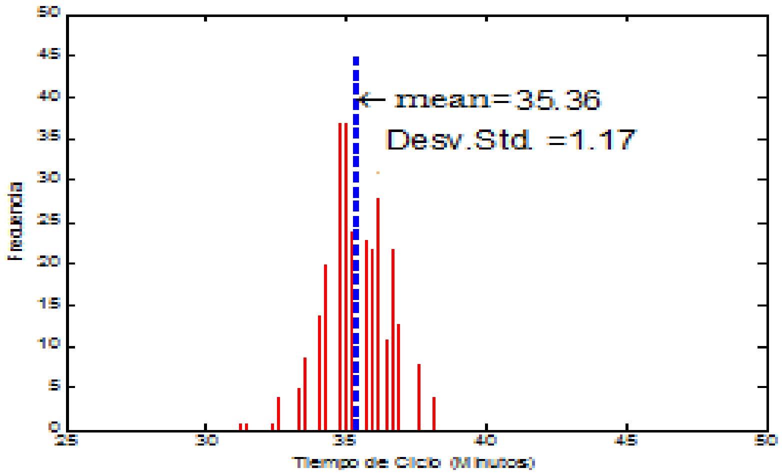


c) Proposed

5. Results: Cycle Time (Capacity reached & high frequency)



a) No control



c) Proposed

C

Results: Waiting time Distribution Scenario 1 (Capacity reached & high frequency)

	% of passengers that have to wait between:					
	Period 15-25			Period 25-120		
	0-2 min	**2-4 min**	**> 4 min**	**0-2 min**	**2-4 min**	**> 4 min**
No Control	57.76	29.60	12.64	63.46	27.68	8.86
Threshold	78.15	20.64	1.21	82.52	16.46	1.02
H	79.24	20.29	0.47	87.30	12.62	0.08
HBL	78.47	21.33	0.20	89.40	10.59	0.01

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¡Muchas Gracias!

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