BUS RAPID TRANSIT PLANNING GUIDE

2016 Edition

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Walter Hook, PhD

MAIN CHANGES

- Bigger dataset
- BRT standard as quality indicator
- Developed v. Developing country systems
- Service Planning Chapter
- Institutional and Contractual Structures

DATASET

Average Cost Comparison, BRT, LRT, HRT

Type	Developing Countries (2013 $/km)	Developed Countries (2013 $/km)
BRT Average	$10,869,000	$10,055,000
BRT Gold	$16,311,000	n.a
BRT Silver	$7,654,000	$9,730,000
BRT Bronze	$8,335,000	$10,380,000
LRT	$25,374,000	$37,496,000
HRT	$87,429,000	$433,661,000

- Larger dataset establishes typical average costs and correlates to the BRT standard.

CONCLUSIONS

- Minor BRT cost differences between developed and developing countries.
- LRT costs between 2 and 3 times more than BRT per kilometer on average for equivalent system quality.
- Main difference between BRT and LRT capital cost includes:
  - Cost of rails
  - Cost of electric catenary
  - Cost of the vehicles
  - Cost of a depot near the tracks

MODAL COMPARISON APPROACH

Variable Dwell Times

Mode	Seconds per passenger per door
HRT & LRT alighting at level	1.39 - 2.0
HRT & LRT alighting with steps	3.36 - 3.97
HRT & LRT boarding at level	1.11 - 2.61
HRT & LRT boarding with steps	2.91 - 4.21
BRT boarding TransMilenio	1.2
Standard at-level BRT boarding	1.6

MODAL COMPARISON APPROACH

Theoretical capacities of different rapid transit alternatives

	Vehicle Capacity	Load Factor	Frequency (s)	Hourly Capacity one dir
HRT 8 car single track	1,408	0.85	30	35,904
HRT 8 car double track	1,408	0.85	60	71,808
LRT 8 module, no turning restrictions, 2 minute signal	632	0.85	15	8,058
LRT 8 module, no turns allowed, 90 second signal*	632	0.85	20	10,744
LRT 8 module double track	632	0.85	40	21,488
BRT largest bi-articulated	220	0.85	60	11,220
BRT with passing lanes	220	0.85	193	36,000
BRT with passing lanes and limited bypassing bottleneck station	220	0.85	241	45,000

*TCQSM 3rd Edition p. 8-87 provides 20 as the number of trains that can be processed at grade with a 90 second signal. They reach a capacity of 12,000 pphpd by assuming trains with larger capacity than is commercially available or operable in most on-street contexts.

CAPACITY DIFFERENCES

Single lane BRT and LRT have very similar capacities

LRT

- LRT has larger vehicles with more doors
- Capacity limitation due to:
  - Train length cannot exceed block length (max 200 ft) or it will block intersection
  - Only one train set can pass through a signal cycle (min 90s)

BRT

- More BRT vehicles can pass through intersection in 1 signal phase so BRT has higher max frequency
- Bottleneck for BRT is only the station

BRT with PASSING LANES AND EXPRESS SERVICES

There are currently no LRT systems with passing lanes. BRT systems can quadruple their capacity with passing lanes at stations

Reasons

- Higher frequencies
- Many buses boarding and alighting at multiple sub-stations
- No constraint at the traffic signal
- Saturation of the critical station can be reduced
- These possibilities can be measured (formulas in Chapter 7) in the BRT Planning Guide, but are not acknowledged by TCQSM 3rd Edition

BRT v. LRT v. HRT

Passengers per hour per peak direction (PPHPD) observed

BRT

Corridor	PPHPD	Level	Lanes
Bogota	37,700	Surface	2
Guangzhou	27,400	Surface	2
Lima	13,950	Highway	2
Mexico City	7,550	Surface	1
Johannesburg	4,500	Surface	2
Beijing	2,750	Surface	1
Los Angeles Orange Line	2,357	Surface	2
Pittsburgh MLK Jr. East Busway	1,714	Surface	2

LRT

Corridor	PPHPD	Level	Tracks
Tunis - LRT	13,400	Underground intersections	1
Portland MAX Blue Line LRT	4,741	Surface	1
Phoenix Metro LRT	2,985	Surface	1
Pittsburgh “The T” LRT	2,017	Surface	1
Toronto Spadina	2,000	Surface	1
Denver Southwest Corridor LRT	1,268	Surface	1
Portland Streetcar	814	Surface	1

HRT

Corridor	PPHPD	Level	Tracks
Hong Kong - Subway	84,000	Underground	2
Sao Paulo Line 1	60,000	Underground	2
NYC Green Lines Combined	56,100	Underground	2
Manila MRT 3	26,000	Elevated	1
London – Victoria Line	25,000	Underground	1
Washington DC Red	12,700	Underground	1
SF BART	6,200	Underground	1

EMPIRICAL DATA CONCLUSIONS

There are no dual-track LRT systems

There are no surface LRT systems with an observed capacity over 6,000 PPHPD

Maximum observed single-lane surface BRT was over 10,000 PPHPD in Curitiba

Maximum observed BRT capacity (two lanes per direction at all stations) remains TransMilenio in Bogota with 37,700 PPHPD

EMPIRICAL DATA CONCLUSIONS

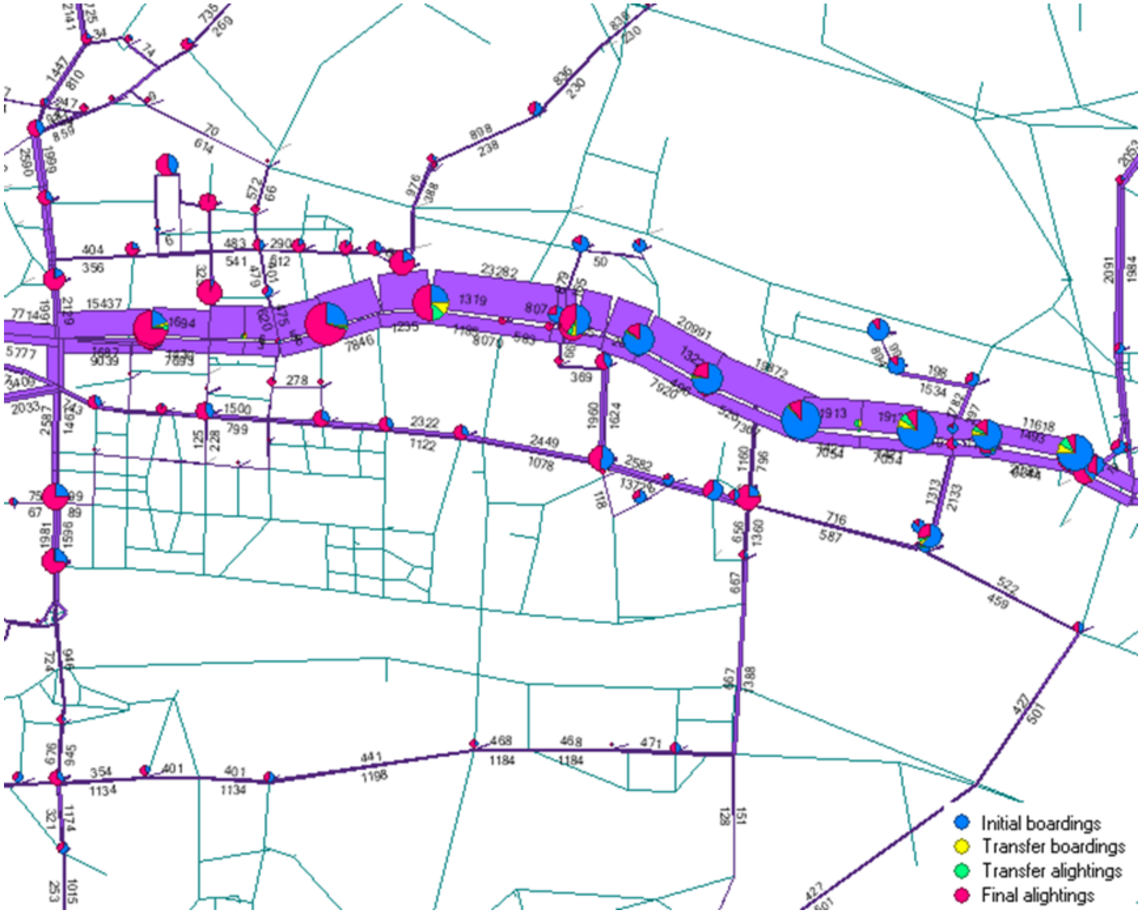
- Observed differences in speed have little correlation with mode.
- Speed differences driven by distance between station stops and degree of grade separation.

Comparative Observed Speeds

Corridor	Speed (km/hr)
BRT	
Pittsburgh West Busway Pennsylvania	54
Orange Line, Los Angeles	32
Bogota Colombia, TransMilenio	27
Curitiba, Brazil, Linha Verde	25
Cleveland HealthLine	18
LRT	
Sound Transit Central Link, Seattle	40
Portland MAX Blue Line LRT	30
Phoenix Metro LRT	19
Budapest, Hungary, Grand Boulevard LRT	18
HRT	
Manila MRT 3, Philippines	48
Expo/Millennium Lines, Vancouver, Canada	43.5
Tren Urbano, San Juan, Puerto Rico	33.2

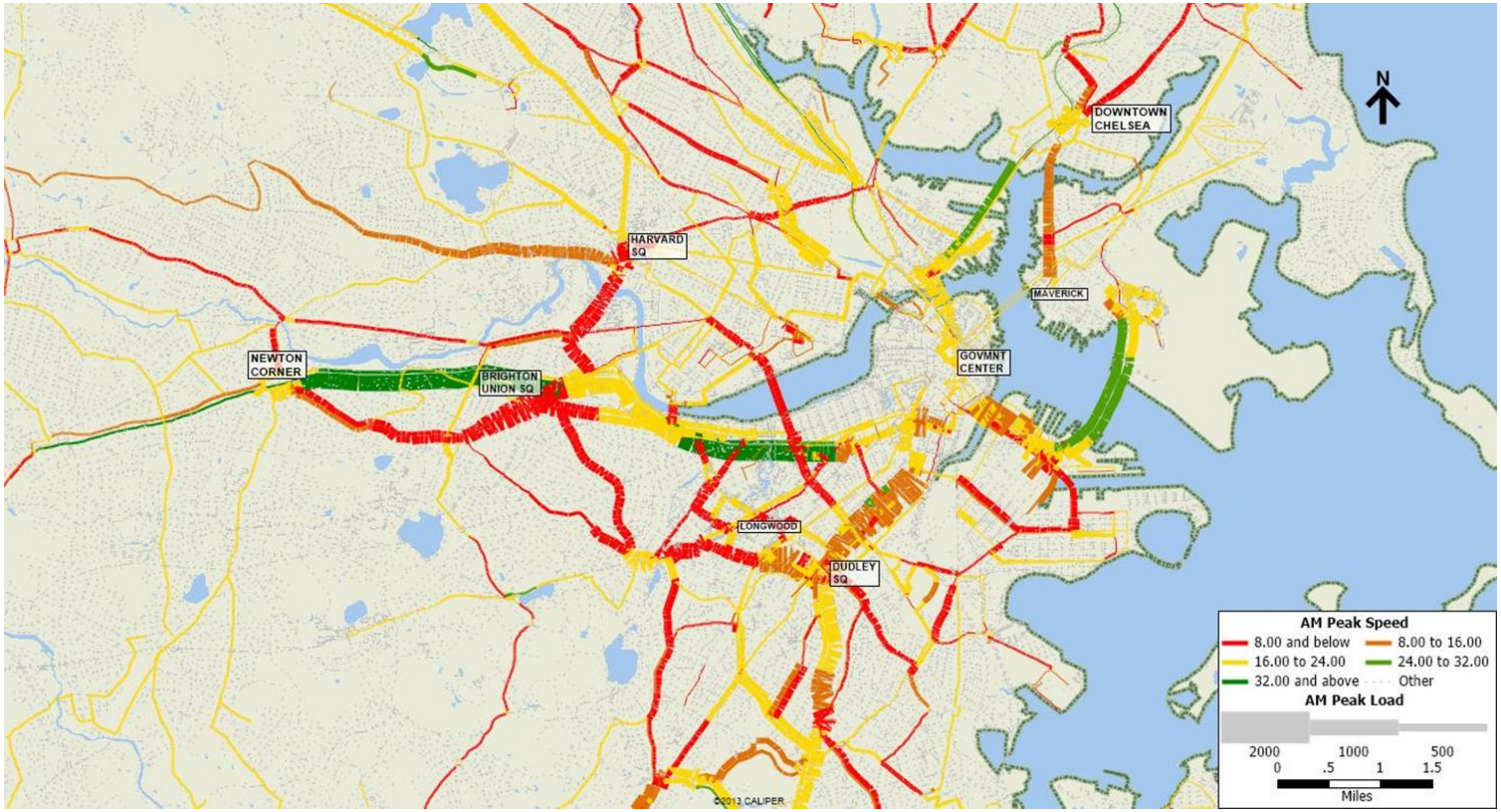
CH. 4 DEMAND MODELLING

- Shift away from household survey-based 4 step demand modeling
- Detailed explanation of faster and cheaper modeling methods based on detailed boarding and alighting and transfer data



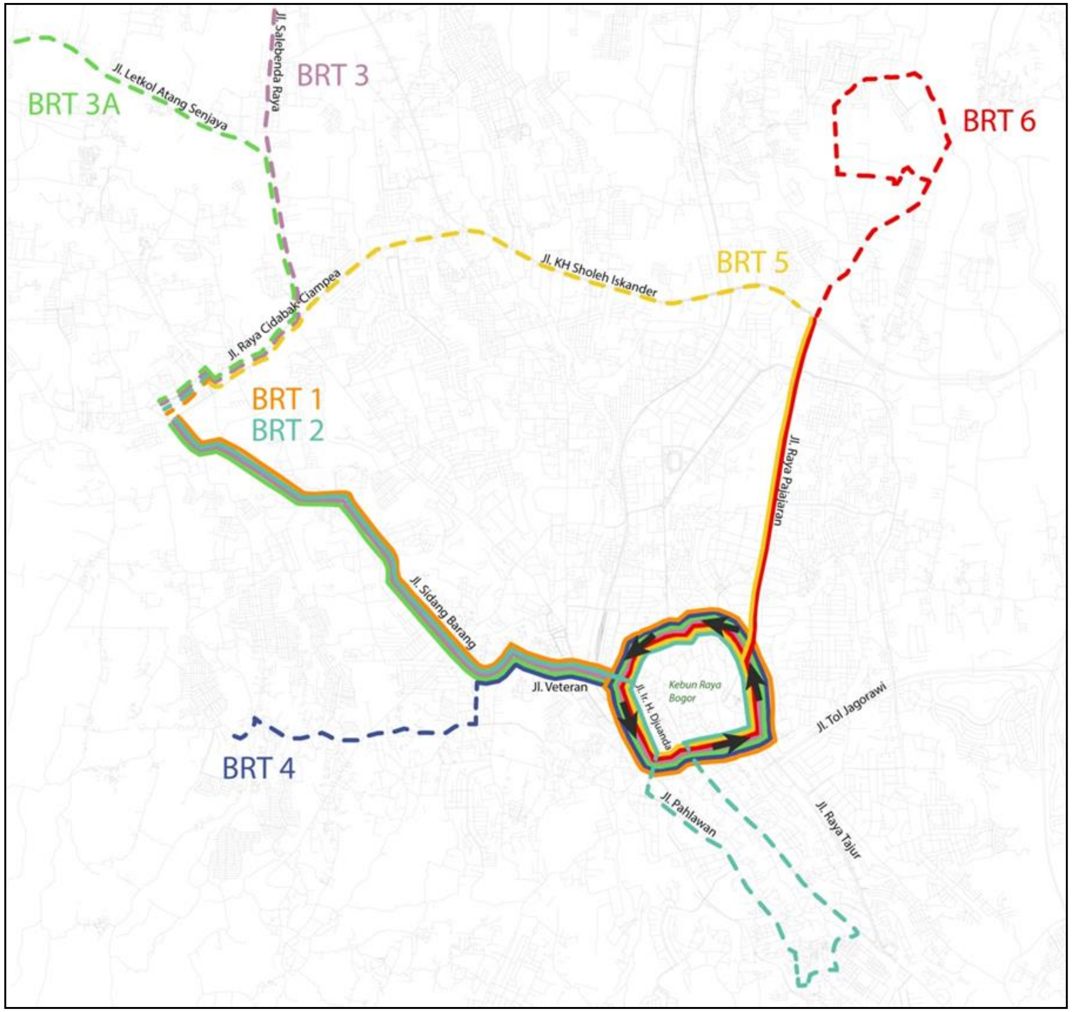
CH. 5: CORRIDOR SELECTION PROCESS

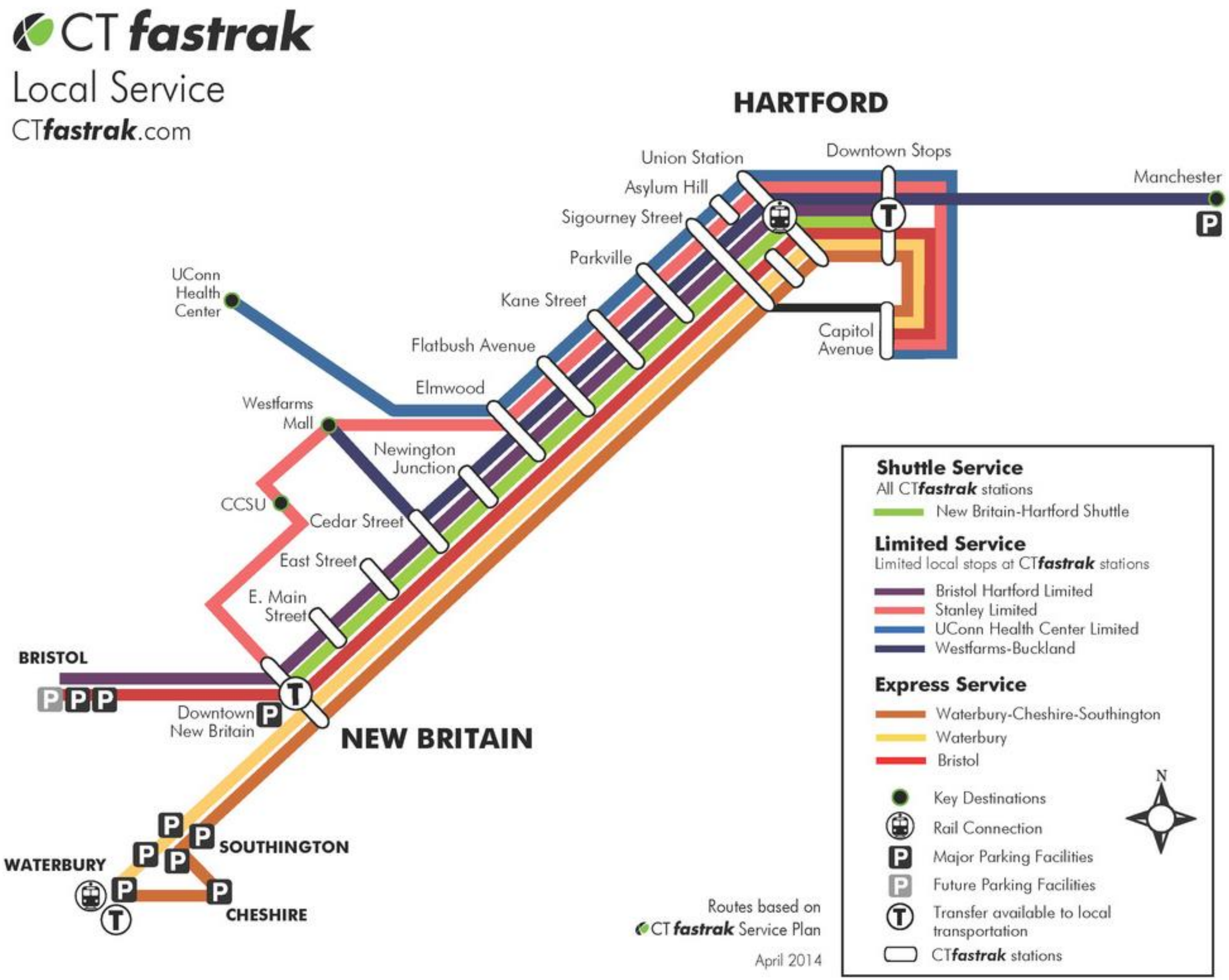
- Corridors rather than routes with the highest existing transit demand
- Corridors facing greatest speed delays
- Corridors with high projected future ridership growth
- Right of way considerations
- Cost considerations
- Political considerations



- Service/routing plan determines:
  - System’s demand
  - The needed fleet size
  - The existing routes affected
  - The speed and capacity of system
  - The needed sizing of the stations

Yet, most BRT infrastructure is designed without reference to a service plan, or service planning assumptions are hidden in the modeling assumptions.





Direct services model brings the highest ridership

New service planning questions answered

- Which existing routes should be incorporated into the BRT?
- When (if ever) should a direct service be spilt into a trunk route and a feeder route?
- Where should stops be placed?
- Limited stop services
  - When should limited stop service be introduced?
  - When should stops be skipped?

CH. 6: SERVICE PLANNING

Direct service systems avoid expensive, land-intensive transit centers.

Also avoid redirecting routes to reach the transit center.

Optimal distance between stations:

0.2 - 0.5 miles

However, needs to be site specific depending on

- demand at station
- in-vehicle time
- walking time

Bus Stop		Daily Demand		Elimination code
Code	Location	Boarding	Alighting	
6648	Western & Ogden	49	40	2
8245	Western & 14th Street	11	21	1
14531	Western & 16th Street	41	32	0
8249	Western & 18th Street	27	40	1
8250	Western & 19th Street	28	38	2
15059	Western Pink Line Station	278	221	0
14555	Western & Cermak	350	393	0
17058	Western & 23rd Street	38	57	1
8255	Western & 24th Street	88	56	0
8256	Western & 25th Street	19	14	1

When to add express routes

- When the removal of fixed dwell time (per stop) benefits more riders than the additional delay caused by lower frequency of service.
- This tends to occur when clusters of stops are skipped.
- When very high frequency causes bunching, it may help to have an express service.
    - On BRT corridor, dwell time becomes irregular and causes bunching at frequencies of greater than 30 per hour, with 22 per hour optimal.

Formula for Calculating BRT Corridor Capacity and Speed

$$Co = \frac{Nsp * 1{,}440}{\left[\frac{Td * (1 - Dir)}{Cb} + (Ren * T1)\right]}$$

Co = Corridor capacity (in terms of passengers per peak hour per direction or pphpd)

Nsp = Number of stopping bays

X = Saturation level

1,440 = Number of seconds in an hour a station can be occupied without saturating (.4 * 3600)

Td = Dwell time

Dir = Percentage of vehicles that are limited-stop or express vehicles

Cb = Capacity of the vehicle

Ren = Renovation rate

T1 = Average boarding and alighting time per passenger

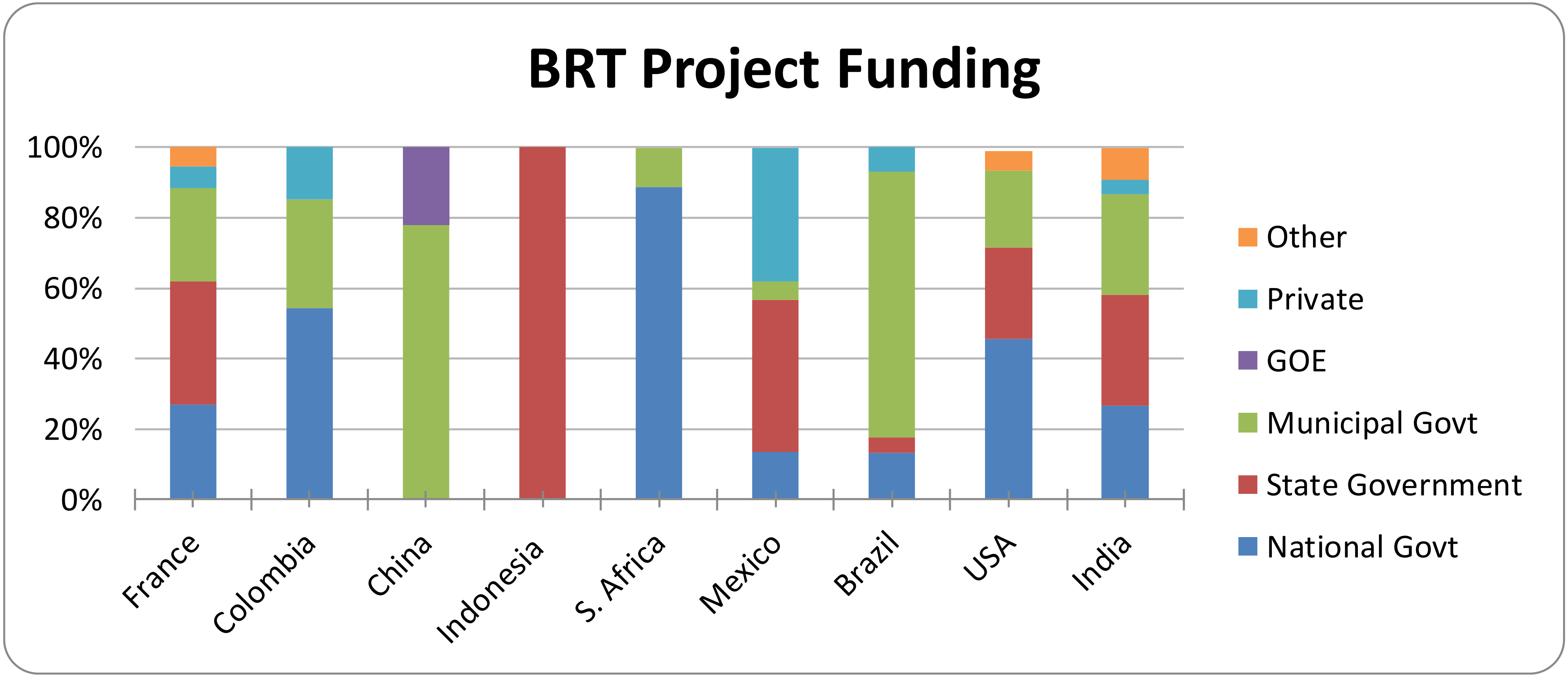
CONTRACTING OUT

BRT System	Bus Operations
Rouen, France (TransDev)	Private
Paris Mobilien, Ile de France (RATP)	Private
Brisbane, Australia (TransitLink)	Public
Amsterdam R-Net (Transdev)	Private
HealthLine, Cleveland (RTC)	Public
Cambridgeshire, England	Private
Nantes, France (Semitans)	Public
LA Metro (Orange Line)	Public
Las Vegas (RTCSV)	Private
Ottawa, Canada (OC Transpo)	Public
Pittsburgh MLK (Port Authority)	Public
Nagoya busway (City of Nagoya)	Public

BRT Operating Contract Types

BRT System	Contract Type
Rouen, France (TransDev)	Design-Build-Operate forms
Paris Mobilien, Ile de France (RATP)	Service contract (gross cost)
Cambridgeshire, England	Route contract (net cost)
Nantes, France (Semitans)	Service contract (gross cost)
Las Vegas (RTCSV)	Route contract (gross cost)
Amsterdam R-Net	Route contract (net cost)

REVIEW OF FUNDING APPROACHES



REVIEW OF FINANCING APPROACHES