Bus Rapid Transit (BRT) System

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Structure

- Good Transportation System
- BRTS and components
- BRTS in Megacities
- BRTS in India- Indore, Mumbai and Delhi
What do we want from an City’s Transportation System?
Efficiency

Congestion in Bangalore costs the city approximately Rs. 7,600 Crore per Year in lost economic output and excessive fuel use.

This is ~5% of the city’s GDP.

Sources:
Efficiency

GDP

Mexico City
Sao Paulo
Buenos Aires
Bangkok
Santiago
Dakar

Safety

- 120,000 people die due to road traffic accidents annually (highest in the world)

- Nearly 50% of these are pedestrians and other non-motorised transport users in million-plus cities

- Traffic accidents are the #1 cause of death amongst males aged 18-35

Sources:
WHO (2012) “Global status on Road Safety”
NCRBI Annual Accident Database
Safety

Road Fatalities per million population (major Indian cities)

Sources:
Various – CDPs, CMPs, NCRBI Annual Accident Database
## Accessibility

<table>
<thead>
<tr>
<th>City</th>
<th>Distance to Public Transport Stop (Avg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhubaneshwar</td>
<td>0.78 km</td>
</tr>
<tr>
<td>Hubli-Dharwad</td>
<td>1.03 km</td>
</tr>
<tr>
<td>Bhopal</td>
<td>1.05 km</td>
</tr>
<tr>
<td>Kanpur</td>
<td>1.4 km</td>
</tr>
<tr>
<td>Nagpur</td>
<td>0.94 km</td>
</tr>
<tr>
<td>Hyderabad</td>
<td>0.6 km</td>
</tr>
<tr>
<td>Bangalore</td>
<td>0.99 km</td>
</tr>
<tr>
<td>Mumbai</td>
<td>0.74 km</td>
</tr>
</tbody>
</table>

Sources: Ministry of Urban Development, (2011), Traffic and Transportation Policies and Strategies in Urban India
Affordability

In Lower Income Groups, transportation costs are approximately 15-20% of monthly average income.

With the growth of the city and increasing land prices in the inner core areas, lower income groups are being shifted to the periphery, resulting in longer trip lengths, higher transport expenditure, and longer time spent in commute.

Sources:
Mobility for Development (2008), Bangalore Case Study
High Quality of Service

- Comfortable
- Reliable
- Frequent
Environmental Sustainability

Estimated Growth in Emissions from Urban Transport – 2000 to 2030

+7.05% per year

Sources: Schipper et al (2008)
Contributes to desired urban form

Sources: CEPT University

10 Million 2030

INR 2000 Crores/yr
Density - 150 persons/ha
Area - 666 sqkm

INR 3000 Crores/yr
Density - 125 persons/ha
Area - 800 sqkm

INR 4500 Crores/yr
Density - 100 persons/ha
Area - 1000 sqkm

INR 6075 Crores/yr
Density - 75 persons/ha
Area - 1333 sqkm

How much area would we like to urbanise?
A good urban transport system should be

- Efficient
- Safe
- Accessible
- Affordable
- Provide a high quality of service
- Be Environmentally Sustainable and
- Contribute to the desired Urban Form of the city
Bus Rapid Transit System
BRT and busway systems in the world

evolution of the # of cities and km per decade

- Before 1990 (16 cities) - 507 km
- 1991 - 2000 (19 cities) - 1025 km
- 2001 - 2010 (103 cities) - 3707 km
- Since 2011 (18 cities) - 4071 km

source: BRTdata.org, May 2013
Bus priority systems in the world

Growth of bus priority systems since 1970

- 1972/2010*: Lima
- 1974/1991*: Curitiba
- 2000: Bogotá (TransMilenio)
- 2010: Guangzhou

Year BRT/busway commenced

Cumulative Number of Cities

New Cities

Source: BRTdata.org, July 2014
<table>
<thead>
<tr>
<th>#</th>
<th>Cities</th>
<th>Population in Million</th>
<th>Passengers/day</th>
<th># of Corridors</th>
<th>Kms</th>
<th>BRTS Lanes</th>
<th>General Traffic Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rio De Janeiro</td>
<td>6.4 (12.4)</td>
<td>1,659,100</td>
<td>8</td>
<td>67</td>
<td>2, 4</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>2</td>
<td>Mexico-City</td>
<td>8.9 (21.2)</td>
<td>755,000</td>
<td>4</td>
<td>95</td>
<td>2</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>3</td>
<td>Guangzhou</td>
<td>12.8</td>
<td>800,000</td>
<td>1</td>
<td>23</td>
<td>4</td>
<td>8, 10</td>
</tr>
<tr>
<td>4</td>
<td>Istanbul</td>
<td>13.9</td>
<td>750,000</td>
<td>1</td>
<td>52</td>
<td>2</td>
<td>6, 8, 10</td>
</tr>
<tr>
<td>5</td>
<td>Bogota</td>
<td>7.6</td>
<td>1,980,000</td>
<td>8</td>
<td>106</td>
<td>2, 4</td>
<td>4, 6, 8, 10</td>
</tr>
<tr>
<td>6</td>
<td>Sao-Paulo</td>
<td>11.4 (19.9)</td>
<td>2,109,000</td>
<td>10</td>
<td>122</td>
<td>2, 4</td>
<td>4, 6, 8</td>
</tr>
<tr>
<td>7</td>
<td>Ahmedabad</td>
<td>6.3</td>
<td>150,000</td>
<td>18</td>
<td>68 (130)</td>
<td>2</td>
<td>4, 6, 8</td>
</tr>
</tbody>
</table>
Key BRT Components

- Distinctive Image
- Segregated Busways
- Stations with prepayment and level boarding
- Buses with multiple doors
- Centralized Control
- IT

Centralized Control

IT

Stations with prepayment and level boarding

Segregated Busways
BRT in Megacities:

Istanbul    Seoul    Sao Paulo

México City    Rio de Janeiro    Bogotá
Istanbul

135 lakh population
3 Metro Lines, Tram, Ferries
45 Km BRT, 10 Km in construction, 25+ Km Proposed
Istanbul

45 Km Median Lanes on Expressway
7,50,000 passengers per day
22,000 pphpd, 40 km/h
México City
20 lakh population (ZMVM)
207 km Metro
+ 13 km Light Rail +
Trolleybuses +
27 km Suburban Rail

BRT Metrobús
6 years. 95 km

http://www.metrobus.df.gob.mx/mapa.html
Corredor Insurgentes, Ciudad de Mexico (2005)
Includes Bi-articuladed Buses
Stations Metrobus
Mexico
Tepalcates Terminal
Rio de Janeiro
143 lakh population, 43 km metro
BRT 150 km planned 2012-2016
## Transoeste Ligerão

### Currently in operation
- May 2012
- 40 km of which 32 km segregated median busways
- 29 stations, 2 terminals
- 65 articulated buses
- 55,000 pax/day
- R$ 2.75 (USD 1.36) per trip

### Project
- 56 km of which 48 km segregated median busways
- 55 stations, 3 terminals
- 91 articulated buses
- 110,000 pax/day by the end of 2012
- 220,000 pax/day when connected to Metro in 2016
- 31 feeder routes, 147 feeder buses
- Capital investment R$ 1,6 bilion (USD 800 million)
Photo: EMBARQ Brasil
Transoeste Ligerão

- Work in progress (71%)
- 20 min time savings
- High occupancy
- Jaywaking – Run overs
TransMilenio, Bogotá
80 lakh population
104 km, 2 million pax/day (Dec 2012)
Fase III TransMilenio, Bogotá
20 km, 520,000 pax/day (Dec 2012)

Fase III TransMilenio, Bogotá
20 km, 520,000 pax/day (Dec 2012)

Eldorado Trunkway
- 12.2 km
- 1 Terminal Station
- 1 Integration Station
- 12 intermediate Stations
- 1 depot
- Pedestrian overpass access, 1 pedestrian tunnels

Carrera 10ª Trunkway
- 7.7 km
- 1 Terminal Station
- 2 Integration Stations
- 8 Intermediate Stations
- 1 depot
- 2 pedestrian tunnels
- At grade pedestrian access

Portal Eldorado Troncal Calle 26 Terminal
Central Station Urban Renewal Project (under construction)

http://www.uru.gov.co/conenido/articulo/247-estacion-central
Portal del 20 de Julio Terminal Station
Troncal Carrera 10a
Calle 6 Intersection and Intermediate Terminal
(under construction)
Guangzhou
128 lakh population
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
- 8,000,000 passengers per day
BRT in Megacities

- Integral part of multimodal transport
- Developed as networks, not isolated corridors
- Started with meaningful pilot projects, and rapidly expanded into extensive networks
- Relatively low cost, rapid implementation, high impact
  - Travel time: e.g. 50% reduction Istanbul
  - Road Safety: e.g. 48% less fatalities, Bogota
  - Air pollutant emissions: e.g. 40% less PM, Mexico
  - Land Use: high development along corridor e.g. Curitiba
BRTS in Indian Cities
Defining BRTS Capacity

BRTS Capacity = (Vehicle Capacity) x (Designed Load Factor) x (Platforms per Station) x (Bus Throughput per Platform)

Bus Capacity

Regular Bus- 60
Articulated- 160
Bi-articulated- 250
Key Challenges in Implementation

- Political Will
- Leadership
- Technical
- Media
- Public Perception
- Internal Capacity
Overcoming Challenges in Implementing BRT
Indore City

- Population: 2.2 million (3.4% annual growth rate)
- Financial hub of Madhya Pradesh
- Rapid industrial development in past decade
- Termed as ‘Mini Mumbai’
- Motor vehicles doubled in 10 years (8% AGR)
- 220 fatal accidents in 2011
Traffic Situation in Indore..
Indore City Bus Statistics

- Started :: 2006
- Number of routes :: 15
- Average route length :: 18 km
- Number of bus stops :: 210
- Fleet Size :: 110 bus
- Operating frequency :: 8 – 26 minutes
- Avg. daily ridership :: 100,000 pax
- Ridership per bus :: 910 pax/bus/day
Benefits of the System: Mode Shift

Safety & Quality has helped attract trips from private travel modes.

- IPT: 54%
- New Travellers: 20%
- Private Vehicle: 16%
- Walk: 4%
- Bicycle: 6%
Lives Saved, Emissions Reduced

- Lives saved due to Indore City Bus: 6.25/year
- Hundreds of accidents avoided
- CO2 Reduced: ~5.5 ton/day

<table>
<thead>
<tr>
<th>Mode of Transport</th>
<th>Modal Split (Trips)</th>
<th>Number of Trips</th>
<th>Average Trip Length (Km)</th>
<th>Passenger Km Travelled</th>
<th>Fatalities Caused (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Vehicles</td>
<td>57.0 %</td>
<td>1.46 million</td>
<td>6.44 Km.</td>
<td>9.40 million</td>
<td>80</td>
</tr>
<tr>
<td>PT – City Bus</td>
<td>3.92 %</td>
<td>0.10 million</td>
<td>8.00 Km.</td>
<td>0.80 million</td>
<td>0</td>
</tr>
<tr>
<td>PT – IPT</td>
<td>9.13 %</td>
<td>0.23 million</td>
<td>5.70 Km.</td>
<td>1.31 million</td>
<td>12</td>
</tr>
<tr>
<td>Bicycle + Walk</td>
<td>25.8 %</td>
<td>0.68 million</td>
<td>4.27 Km.</td>
<td>2.91 million</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>4.15 %</td>
<td>0.11 million</td>
<td>6.44 Km.</td>
<td>0.72 million</td>
<td>128</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100 %</td>
<td>2.56 million</td>
<td>5.84 Km.</td>
<td>14.98 mill.</td>
<td>220</td>
</tr>
</tbody>
</table>
Traffic Situation in Indore.. Forecast

![Graph showing traffic situation in Indore over time with projected forecast for 2021.]
Hence, Indore decided to develop BRTS
## Project Basics

<table>
<thead>
<tr>
<th>Initiated</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of route</td>
<td>11.46 km</td>
</tr>
<tr>
<td>Road section</td>
<td>31.6m ROW: 4.8 km 60m ROW: 6.65 km</td>
</tr>
<tr>
<td>System type</td>
<td>Closed, with Median stations</td>
</tr>
<tr>
<td>Stations</td>
<td>21</td>
</tr>
<tr>
<td>Number of buses</td>
<td>50</td>
</tr>
<tr>
<td>Type of bus</td>
<td>12 m long with AC 900 mm Floor 245 hp, BS III engine</td>
</tr>
<tr>
<td>Completion</td>
<td>April 2013</td>
</tr>
</tbody>
</table>
Corridor
Stations
Fleet
BRT’s Impact on Urbanisation in Indore

- New Malls, Hotels, Hospitals, Corporate Offices etc. have developed since project inception
- BRT catalyzed the Urban renewal process for Indore
- Premium on FAR in commercial buildings presents significant funding generation
Transforming Indore...

Arts and Commerce College
Transforming Indore...
Challenges faced in Indore
Challenges: Project Financing

- Initial cost estimate as per DPR: INR 173 Cr
- Cost approved under JnNURM: INR 98.45 Cr
  - Included cost of civil works of corridor only
- Cost ‘EXTRAs’ that got left out
  - Land acquisition
  - ITS (AVLS + AFCS + Signalling)
  - Stations
  - Depot
  - Operational deficit
- EXTRA Costs amounting to **INR 350 Cr**
## Indore approach: Project Financing

<table>
<thead>
<tr>
<th>S.No</th>
<th>Challenge</th>
<th>Approach adopted</th>
</tr>
</thead>
</table>
| 1    | Land acquisition | • All land acquisition done using Transfer of Develop Rights (TDR) model  
• Savings to the tune of **INR 270 Cr** |
| 2    | ITS (AVLS + AFCS + Signalling) (INR 40 Cr) | • Floated ITS contract on Annuity model; Not successful  
• Capital expenditure – part GEF, part awaiting JnNURM approval |
| 3    | Stations (INR 20 Cr) | • Municipal Corporation approved construction in anticipation of JnNURM funds |
## Indore approach: Project Financing

<table>
<thead>
<tr>
<th>S.No</th>
<th>Challenge</th>
<th>Approach adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Depot construction (INR 7 Cr)</td>
<td>- 80% cost borne by State government; rest by City</td>
</tr>
<tr>
<td>5</td>
<td>Operational deficit</td>
<td>- Advertisement rights along corridor passed to AICTSL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- DUTF being constituted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Tax on new vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Tax on FAR permissions etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Parking and congestion fees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 80% deficit for first 2 years to be borne by state; rest by City</td>
</tr>
</tbody>
</table>
Challenges: Coordination

- Project development split among multiple agencies
  IMC – Stations construction
  IDA – Corridor construction
  AICTSL – Bus procurement and Operations
  RTO – Issuing of Permits and Existing routes reorganization
  Traffic Police – Enforcement and Management

- Lack of coordination between agencies
- Agencies not completely aware of concept of BRT
- Lack of overall ownership of the project
Indore Approach: Coordination

- Since 2012, regular coordination and project review meetings, chaired by Collector - weekly
- Monthly progress monitored by political and administrative heads of the State and city
- Study tours of all stakeholder agencies to other successful BRT systems – IDA, IMC, Traffic Police
  Ahmedabad
  Bogota
Challenges: Technical

- Started BRT implementation with most congested corridor
  Indore approach: Administration’s persistence, and Indore citizens contributions

- In view of success of Janmarg, Indore decided to switch from staggered to median stations
  Since corridor was already constructed, road camber was not as per changed station location
  Indore approach: Surface treatment near BRT stations to match bus and station level
Challenges: Internal Capacity

AICTSL before BRT:
Mandate was planning and monitoring of city bus services
Had only administrative expenditures – Revenues always greater than Expenses
Challenges: Internal Capacity

Since BRT development started
- Started engaging consultant – Preparation of DPRs
- Procurement of buses (earlier done by operator) started to be undertaken by AICTSL
- Involvement in infrastructure design process
- Branding and public outreach

Post BRT implementation
- AICTSL will have to manage substantial assets
- AICTSL took on financial risk, in order to improve service quality
Indore Approach: Internal Capacity

» Strategic partnerships with domain experts
  EMBARQ India
  CEPT University

» This helped in:
  Project management support
  Operations planning
  Infrastructure design
  Development of bus specifications
  Development of model contracts
  Financial projections
  Developing ITS requirements
  Audit of consultants’ work
Challenges: Public Outreach

बहुत रुलाने वाला ट्रैफिक सिस्टम का गुद्दा

फिर जाम का जंगल

[कलेक्टर ने माना] हर रोज 80 हजार यात्रियों के गुलाम पर भी संशय

बीआरटीएस की डिजाइन में कमी
Challenges: Public Outreach

- Lot of negative publicity received from press and media. BRTS blamed for ‘any’ and ‘every’ traffic incident along BRT corridor by media and experts.
- Limited awareness among people and media presents great challenges for BRTS.
- Extended construction time because of parallel projects.
Indore Approach: Public Outreach

- Public presentations made
  - Educational institutes
  - Media
  - General public
- Informative video film prepared
  - Broadcast on television and theatres
- Information material – leaflets
- Linking project updates to social media network – www.facebook.com/IndoreBRT
- Study tour for Media personnel to Ahmedabad BRT
Public presentations
iBus is Indore’s new DRT system that is scheduled to launch trial runs in April 2013.
Other Broader Challenges

» Limited capacity of bus manufacturer to deliver buses in time

  Being faced by most manufacturers in view of increased demand owing to JnNURM funding
Technological advancements

- Traffic signal system: State-of-the-art, solar powered, wireless, vehicle actuated system, with push button pedestrian crossings
  - Reduced delays
  - Reduced maintenance
- Integrated ticketing for BRT and existing city buses
  - Passenger convenience
- Fully air conditioned fleet of monocoque buses
  - Safety and comfort
Wi-Trac Traffic Signals
Lessons from the Indore Experience
Fundamental Need: Leadership

➢ To lead from the front – provide a vision
  Do not promote contradicting strategies
  Ex: Promoting parking & Public Transport at same time

➢ Build consensus – keep the flock together
  Handle project delays

➢ Choose the right options
  Learn from the lessons/mistakes of others
  Ex: Design changes after success of Janmarg

➢ Walk the talk – tough decision making
  Taxation, Regulation, Enforcement
CONNECT with the project – OWN it!
CONNECT project to the people – public outreach and acceptance
CONNECT with the media – share and highlight information
CONNECT with multiple stakeholder agencies – increase / facilitate team working
CONNECT with strategic knowledge partners – bridge knowledge gaps, keep abreast with technological advancements
Atal Indore City Transport Services Ltd.
Plot. No. 30, Residency Area, A.B. Road,
Opp. M.G.M. Medical College, INDORE 452001
Ph. : +91-731-2499888 | E-mail - info@citybusindore.com

www.facebook.com/IndoreBRT
BRTS CORRIDOR AND NETWORK VISION FOR MUMBAI
BRTS Network - Connecting the Suburbs

Line 1: WEH
Line 2: JVLR
Line 3: EEH
Line 4: SCLR
Line 5: CMLR
Line 6: LBS Marg
Line 7: Ghodbunder Road
Line 8: Bandra-Sion
Overall Network: 116 km
## Lane Configuration Mumbai

<table>
<thead>
<tr>
<th>Road</th>
<th>Lane Configuration (Lanes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEH</td>
<td>10</td>
</tr>
<tr>
<td>JVLR</td>
<td>8, 10</td>
</tr>
<tr>
<td>EEH</td>
<td>10</td>
</tr>
<tr>
<td>SCLR</td>
<td>6, 8</td>
</tr>
<tr>
<td>CMLR</td>
<td>8, 10</td>
</tr>
<tr>
<td>LBS Marg</td>
<td>6, 8</td>
</tr>
<tr>
<td>Ghodbunder Road</td>
<td>4, 6</td>
</tr>
<tr>
<td>Bandra-Sion</td>
<td>6</td>
</tr>
</tbody>
</table>
WEH Context

Western Express Highway BRT Corridor
WEH BRTS Corridor

- 17 flyovers
- Entire WEH Length: 24.3km (50% flyover, 50% at-grade road)
- People Served- 450,000 people everyday
- Average Travel Time -
  - Peak Hour- 70 mins
  - Off-Peak Hour- 40 mins
Data Analysis

- OD (Sample Size: 1300-Buses, 8000-Autos, 4000-Two-Wheelers, 13,500-Cars)
- Bus Occupancy (6 Stops/16 hours)
- Boarding and Alighting Survey (6 routes and 6 Bus Stops)
- Passenger Survey (Sample Size-1000)
- Junction Counts (9 Major Junctions)
- 52 Bus Routes Data and ETM Data along WEH from BEST
Demand Estimation – Peak Hour

- Existing Bus Passengers = 9,000
- Other Buses = 3,000
- Auto and 2-Wheeler Commuters = 3,000
- Taxis = 500
- Cars = 500
- Attracted Users = 5,000

- Potential Demand Estimated = 21,000 pphpd
BRTS Components for 21,000 pphpd

- Centralized Control
- IT
- Segregated Busways
- Large Stations with prepayment and level boarding
- Distinctive Image
- Buses with multiple doors
- Overtaking Lanes
Vehicles and Passengers Carried - Western Express Highway

- Cars: 30% Mode, 16% Passengers
- 2Ws: 26% Mode, 13% Passengers
- Autos: 18% Mode, 10% Passengers
- BEST Buses: 1% Mode, 35% Passengers
- Taxis: 8% Mode, 5% Passengers
- Others: 17% Mode, 21% Passengers

EMBARQ India
Technical Challenges

- Varying Cross Section of the WEH
- Operational Plan
- Lane Shift
- Weaving Analysis
- Feeder Service Integration
- Construction Considerations
- Design for Long Flyovers and station access
- Impact on General Traffic lanes, narrow sections
OD Patterns

- WEH: 48%
- Outside: 26%
- WEH: 20%
- Outside: 7%
Operational Plan - Alternative #1

BRTS with Trunk and feeder system
Alternative #1

PROS
- High frequency of Trunk service
- Reduced waiting times with lower fleet
- Complete control over the operation of BRT system
- Highly reliable service
- Streamline operations along WEH

CONS
- Introduces additional transfers (up to two transfers) for some passengers
- Integration of feeder buses to ensure ease of transfer
- Will need large fleet for feeder services
- Will need transfer hubs for further connectivity
Alternative #2

Bus Priority on WEH with existing long and short distance routes and few feeder and direct systems
Alternative #2

**PROS**
- Shorter routes with higher frequency
- Few Direct services- serving as feeders
- Reduced waiting times with lower fleet
- Higher degree of control over the operation of BRT system
- Provide reliable service
- Increased economic productivity

**CONS**
- Introduces additional transfers for few passengers
- Need to have transfer hubs
- Integration of feeder services
## Lane Shift

<table>
<thead>
<tr>
<th>Speed (kmph)</th>
<th>Speed (mph)</th>
<th>DDOT Formula for Taper length</th>
<th>Lane Shift requirement (General Traffic)</th>
<th>Taper Length Estimation for lane shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>40.39</td>
<td>$V \times W$</td>
<td>9.5 (metres) 31.16 (feet)</td>
<td>1259 (feet) 384 (metres)</td>
</tr>
<tr>
<td>60</td>
<td>37.28</td>
<td>$V^2 \times W/60$</td>
<td>9.5 (metres) 31.16 (feet)</td>
<td>722 (feet) 220 (metres)</td>
</tr>
<tr>
<td>55</td>
<td>34.18</td>
<td>$V^2 \times W/60$</td>
<td>9.5 (metres) 31.16 (feet)</td>
<td>607 (feet) 185 (metres)</td>
</tr>
<tr>
<td>50</td>
<td>31.07</td>
<td>$V^2 \times W/60$</td>
<td>9.5 (metres) 31.16 (feet)</td>
<td>501 (feet) 153 (metres)</td>
</tr>
<tr>
<td>45</td>
<td>27.96</td>
<td>$V^2 \times W/60$</td>
<td>9.5 (metres) 31.16 (feet)</td>
<td>406 (feet) 124 (metres)</td>
</tr>
<tr>
<td>40</td>
<td>24.86</td>
<td>$V^2 \times W/60$</td>
<td>9.5 (metres) 31.16 (feet)</td>
<td>321 (feet) 98 (metres)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed (kmph)</th>
<th>Speed (mph)</th>
<th>DDOT Formula for Taper length</th>
<th>Lane Shift requirement (BRTS)</th>
<th>Taper Length Estimation for lane shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>40.39</td>
<td>$V \times W$</td>
<td>3 (metres) 9.84 (feet)</td>
<td>397 (feet) 121 (metres)</td>
</tr>
<tr>
<td>60</td>
<td>37.28</td>
<td>$V^2 \times W/60$</td>
<td>3 (metres) 9.84 (feet)</td>
<td>228 (feet) 69 (metres)</td>
</tr>
<tr>
<td>55</td>
<td>34.18</td>
<td>$V^2 \times W/60$</td>
<td>3 (metres) 9.84 (feet)</td>
<td>192 (feet) 58 (metres)</td>
</tr>
<tr>
<td>50</td>
<td>31.07</td>
<td>$V^2 \times W/60$</td>
<td>3 (metres) 9.84 (feet)</td>
<td>158 (feet) 48 (metres)</td>
</tr>
<tr>
<td>45</td>
<td>27.96</td>
<td>$V^2 \times W/60$</td>
<td>3 (metres) 9.84 (feet)</td>
<td>128 (feet) 39 (metres)</td>
</tr>
<tr>
<td>40</td>
<td>24.86</td>
<td>$V^2 \times W/60$</td>
<td>3 (metres) 9.84 (feet)</td>
<td>101 (feet) 31 (metres)</td>
</tr>
</tbody>
</table>
Weaving Challenge
Feeder Service Integration

Skywalk Access connecting BRT to Feeder Service located on Service Lanes

BRT Lane 7m

Carriage way 14m

Service Lanes with Feeder Service 6m

BRT Station 7m

Feeder Buses operate on Service Road, with Skywalk access to median BRT station
Construction Challenge
Travel Time Conditions on WEH

![Travel Time Graph]  

- **Existing Travel Time**  
- **Travel Time with BRTS**

<table>
<thead>
<tr>
<th>Year</th>
<th>Existing Travel Time</th>
<th>Travel Time with BRTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
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<tr>
<td>2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td>47</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Passengers on WEH - Peak Hour

Motor Vehicles

Existing BEST Buses

Future with BRTS

BRTS Key to increase capacity
BRTS Station Area Design

- BRT Station
- Level Boarding
- Long Platforms
- Special BRTS Buses
BRTS Station Area Design

Passing lane at station for express services and to ensure low travel and waiting time for commuters
A BRTS network is an important and quick complement to Mumbai’s Mobility Pilot Corridor for WEH can be completed in 2 years with an investment of Rs 500-600 Crores Possible Impact of BRTS along WEH and network

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Savings</th>
<th>Quantity (WEH)</th>
<th>Quantity (BRTS Network)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy use</td>
<td>16.4 %</td>
<td>17 Million litres of Fuel</td>
<td>68 Million litres of Fuel</td>
</tr>
<tr>
<td>Emissions</td>
<td>16.3 %</td>
<td>49,000 tons of CO\textsubscript{2} /yr</td>
<td>200,000 tons of CO\textsubscript{2}/yr</td>
</tr>
<tr>
<td>Travel Time</td>
<td>27 %</td>
<td>18 mins/peak trip</td>
<td>12 mins/peak trip</td>
</tr>
<tr>
<td>Road Safety</td>
<td>33 %</td>
<td>Reduction of 78 serious injuries and 15 fatalities/year</td>
<td>Reduction of 300 serious injuries and 60 fatalities/year</td>
</tr>
</tbody>
</table>
## Delhi Bus Corridor - Facts

### Quick Facts

<table>
<thead>
<tr>
<th><strong>Delhi Bus Corridor</strong></th>
<th><strong>April 20, 2008</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date of launch</strong></td>
<td>5.6 kilometers</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>Number of stations</strong></td>
<td>57</td>
</tr>
<tr>
<td><strong>Number of different routes</strong></td>
<td>6,500 passengers per hour (In each direction)</td>
</tr>
<tr>
<td><strong>Peak ridership</strong></td>
<td>120 buses per hour</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>18 km per hour (during peak hours)</td>
</tr>
<tr>
<td><strong>Average commercial speed</strong></td>
<td>Rs. 14 crores per km</td>
</tr>
<tr>
<td><strong>Total infrastructure investment</strong></td>
<td>Rs. 1 to Rs. 4 per passenger citywide</td>
</tr>
</tbody>
</table>

Source: Delhi Integrated Multimodal Transit System Ltd., February 2009
Case Study- Delhi

- Bus breakdowns in bus lanes
- Pedestrian “jaywalking”
- Encroachment of bus lanes by motor vehicles
- High bus occupancy levels during peak hours
- Unreliable bus operations
## Comparison of Delhi System to international systems

<table>
<thead>
<tr>
<th>DESIGN</th>
<th>PERFORMANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEATURE</strong></td>
<td><strong>CHARACTERISTIC</strong></td>
</tr>
<tr>
<td><strong>Bus Lanes</strong></td>
<td>✓ Buses physically segregated from car traffic ✓ Median bus lanes ✓ Clear signage for bus corridor</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Traffic Management Planning</strong></td>
<td>✓ Improved road design ✓ Short traffic signal cycles for buses and pedestrians ✓ Advanced traffic signal technology ✓ Management of bus turning</td>
</tr>
<tr>
<td><strong>Stations</strong></td>
<td>× Protected bus stations × Level boarding for buses at stations × Prepayment system at station × Stations comfortably accommodate all passengers × Handicap accessible</td>
</tr>
<tr>
<td><strong>Vehicles</strong></td>
<td>✓ Easy boarding/alighting low floor buses* ✓ Low-emissions buses (compressed natural gas) ✓ Buses use emissions post-treatment to reduce air pollution × Multi-door buses for easy boarding</td>
</tr>
<tr>
<td><strong>Service</strong></td>
<td>× Express routes × Short service routes × Bus supply matches passenger demand</td>
</tr>
<tr>
<td><strong>Information Technology</strong></td>
<td>× Electronic fare collection systems ✓ Automatic vehicle location (GPS)** ✓ Real-time user information systems × Real-time control and dispatch of buses</td>
</tr>
</tbody>
</table>

*Envolta
**Globetrotter

EMBARQ India
Elements for successful implementation

Based on the learning from various BRT systems worldwide the following criteria are essential for successful implementation of BRT:

- Do one corridor | Do it well | At least 60-70% Origin-Destination trips along the corridor should be served
- Demand assessment and operational plan should be in place before starting design
- Stations should be high quality
- Level Boarding Essential to achieve desired productivity
- Special buses prevent operational control from being compromised (Cannot allow any buses)
- Branding, Communication and Marketing for the new system
Elements to create CHANGE

- Right priorities for a city
- Political Will
- Leadership
- Public Participation
- Media Engagement and Support
Thank You!

26 June, 2013