11.943J/ESD.935
Urban Transportation, Land Use, and the Environment in Latin America: A Case Study Approach

14 February, 2002

Lecture 3:
Transportation Strategies, Options, Examples
Paths of Intervention

Institutions

Visions, Strategies

Plans

Investments

Operations

Laws/Regs.

Supply

Land Use

Demand
“Supply-Side” Interventions

Roadway Infrastructure
- Challenge: multi-agency responsibility
  - local, regional, national
  - maintenance,
  - management
  - expansion
- provision (public) vs. operation (generally private)
- Challenge: Prices charged do not reflect costs
  - [Finance issues detailed in future class]
Roadway Maintenance

- Roadway systems already constitute massive public investments
  - Typically poorly maintained
  - Maintenance investments typically exhibit very high rates of return
  - Institutional challenges:
    - responsibilities allocated according to traffic (local, regional, national);
    - revenue raising capabilities not necessarily matched with institutional responsibilities nor user impact (i.e., distance and weight related registration fees).
Roadway Maintenance

- Need for a “maintenance culture” and maintenance management systems
  - to plan and budget for required maintenance on a systematic basis
  - Implementing surveys of road condition, distinguishing routine, periodic maintenance, and rehabilitation/reconstruction

- Impacts:
  - Traffic flow (congestion)
  - roadway safety
  - vehicle maintenance and performance
Traffic Management

Maximize efficiency of existing infrastructure
- Focus on moving goods and persons (not vehicles, per se)
- Defer capital expenditures for expansion (‘buy time’)
- Immediate impacts, often with minimal adverse side effects and at relatively low cost

Improve safety and environmental performance

Challenges
- Virtually impossible to satisfy needs of all users (i.e., pedestrians vs. motor vehicles, bus priority vs. auto, etc.)
- Often “low profile” – little political visibility
- Implies a continuous process – not a “one shot” solution
Traffic Management - Measures

- Traffic circulation design
  - one way streets,
  - vehicle bans during certain hours and/or in certain areas
  - traffic calming and other measures to improve non-motorized transport conditions

- Traffic signal management (computerized, synchronized, specific user priority – i.e., buses, pedestrians, cyclists)
  - Linked to advances in telecommunications and intelligent transportation systems (ITS)
  - Technology “leapfrog” opportunity?

- On-street parking policies

- Enforcement
Traffic Management – Bus Priority

- **Bus lanes**: typically re-allocating general roadspace to bus-only use; normally not physically separated
- **Busways**: segregated, higher capacity, often requires new right of way.
- Latin America, particularly Brazil, has been a pioneer
  - Curitiba, Recife, Porto Alegre, Sao Paulo, Belo Horizonte, Quito, Bogota, Lima, Santiago
- **Signal priority**: much less common (non-existent?) in developing countries
  - complex to design and manage, difficult to organize with multiple operators (on-vehicle hardware requirements)
Bus Priority - Challenges

- **Operational**
  - difficult to enforce bus lanes (i.e., encroaching traffic)
  - with high “informal” sector presence and/or many small vehicles, and/or exceptionally high bus flow - limited effectiveness

- **Engineering**
  - integration with other road traffic
  - protecting passengers coming/go ing from stops

- **Political**
  - opposition to space re-allocation
  - desire for high-tech solutions (i.e., metros)
Optimal transport network size?
- U.S. cities, avg. 35% of urban area for transport infrastructure; European cities, 20-25%; Asian cities, 10-12%…

Key is hierarchical network appropriately scaled to urban fabric and adequately fit according to need and use
## Roadway Hierarchy

<table>
<thead>
<tr>
<th>Type</th>
<th>Function</th>
<th>NMT Facilities</th>
<th>Design speed</th>
<th>Direct Land Access</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidewalks, paths</td>
<td>Pedestrian flow</td>
<td>Yes</td>
<td></td>
<td>Unrestricted</td>
<td>Essential for access</td>
</tr>
<tr>
<td>Cycle paths</td>
<td>Bike flow</td>
<td>Yes</td>
<td></td>
<td>Unrestricted</td>
<td>Continuous system preferable</td>
</tr>
<tr>
<td>Local Streets</td>
<td>Property Access</td>
<td>Sidewalks</td>
<td>30-40 Km/hr</td>
<td>Unrestricted</td>
<td>Discourage through traffic</td>
</tr>
<tr>
<td>Collector Streets</td>
<td>Links local street to arterials</td>
<td>Sidewalks; bike lanes possible</td>
<td>40-50 Km/hr</td>
<td>Generally Unrestricted</td>
<td>Discourage through traffic</td>
</tr>
<tr>
<td>Arterials</td>
<td>Intra-city travel</td>
<td>Sidewalks; bicycle lanes w/ demand</td>
<td>50-75 Km/hr</td>
<td>Only to major traffic generators</td>
<td>“Backbone” of urban street system</td>
</tr>
<tr>
<td>Express-ways</td>
<td>Inter and Intra-city travel</td>
<td>None</td>
<td>&gt;75 Km/hr</td>
<td>No direct land access</td>
<td>Grade separated inter-sections</td>
</tr>
</tbody>
</table>

When to Expand Capacity?

- Typically requires system-wide analysis
  - Avoid “shifting bottlenecks”
  - Full comparison to alternatives (traffic management and demand management)
  - Impacts on non-motorized transport
  - Comparison of full costs and benefits is necessary, but not sufficient
    - Valuation of environmental externalities,
    - Better understanding of impacts on urban form
    - Distributional effects of investments
  - Must take into account induced demand
Capacity Expansion & Induced Demand

- Theory: Increases in roadway capacity attracts increases in traffic
  - Reduced travel costs (time) produces increases in demand

- Implications
  - Underestimated social costs from generated traffic (over-estimated benefits of reduced congestion);
  - Additional benefits of greater overall mobility

- Empirical estimates: Elasticities of Vehicle Distances Traveled with respect to lane miles
  - Short run: 0.5 (Noland, US State Level)
  - Long run: 0.8 (Noland); 0.9 (Hansen & Huang, CA); 1.0 (SACTRA)
Induced Demand - Graphically

**Induced Travel**

- Travel Price
- Travel Quantity

- P1
- P2
- Q1
- Q2

**Induced Travel w/ Growth in Underlying Demand**

- Induced Demand
- Q2-Q1:
- Q3-Q2:
- Exogenous Growth

- P1
- P3
- Q1
- Q2
- Q3

- S1
- S2
- D1
- D2
- D3
Induced Demand - Effects

- Short Run
  - Changes in travel departure times, route switches, mode switches, longer trips, and some increase in trip generation.

- Long Run
  - Changes in land use patterns and spatial location of activities
Induced Demand - Implications

- Need to differentiate between induced demand and demand growth due to demographic factors (income, population, etc.)
  - Noland’s models for US estimate over 5 year period approximately 25% (21%-29%) of VMT growth due to induced demand
    - Implies 43 million additional tonnes of CO2 emissions

- Need to balance induced demand’s benefits (increased mobility/accessibility) with its social costs

- Road construction cannot solve congestion
Does Induced Demand Exist for Other Modes?

- Busways, Rail, NMT facilities – an attempt, in part, to induce demand to these modes
  - Improving travel times, improving travel comfort, security, safety
- Noland (1995) shows that increased cyclist perception of safety produces a greater than proportional increase in bicycle use
- Ortuzar et al (2000) estimate that cycle network construction in Santiago (3.2 km per km² would produce a 350% increase in bike mode share (from 1.6% to 5.8% of trips)
## Infrastructure Expansion – Mass Transit

<table>
<thead>
<tr>
<th>Item</th>
<th>Caracas</th>
<th>Bangkok</th>
<th>Mexico</th>
<th>Kuala Lumpur</th>
<th>Tunis</th>
<th>Quito</th>
<th>Bogota</th>
<th>Porto Alegre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Metro</td>
<td>Metro</td>
<td>Metro</td>
<td>Light Rail</td>
<td>Light Rail</td>
<td>Trolley-busway</td>
<td>Busway</td>
<td>Buway</td>
</tr>
<tr>
<td><strong>Layout</strong></td>
<td>100% tunnel</td>
<td>100% elevated</td>
<td>20% E 55% G 25% T</td>
<td>100% elevated</td>
<td>At grade</td>
<td>At grade</td>
<td>At grade</td>
<td>At grade</td>
</tr>
<tr>
<td><strong>Capital Cost/km ($mns)</strong></td>
<td>90 70 w/o veh.</td>
<td>74 29 w/o veh.</td>
<td>41 23 w/o veh.</td>
<td>50</td>
<td>13 9 w/o Veh.</td>
<td>10 1.8 w/o veh.</td>
<td>5.2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Max. capacity (p/h/d)</strong></td>
<td>32,400</td>
<td>50,000</td>
<td>39,300</td>
<td>30,000</td>
<td>12,000</td>
<td>15,000</td>
<td>35,000</td>
<td>20,000</td>
</tr>
</tbody>
</table>

Source: World Bank, 2001, p. 120.
Mass Transit Infrastructure – Major Issues

- **Busways**
  - as discussed earlier (slide 9)
  - rapid to deploy
  - ability to integrate with urban form? (Curitiba)

- **Rail**
  - typically viewed as far too expensive for developing cities
  - Clearly play a role in dense travel corridors
  - As income grows, justification can grow – investments become relatively more affordable; value of time savings increases
  - How to better integrate with urban form (both existing and new infrastructure); value capture, station development, etc.
  - What should pricing policy be?
Example of Roles in “Loose” Regulation

<table>
<thead>
<tr>
<th>City</th>
<th>Authority(ies)</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogota</td>
<td>Issues licenses (route, hours, capacity); basic fares; poor overall regulation</td>
<td>Vehicle Owners pay “entry fee” to licensed company; premium fare</td>
</tr>
<tr>
<td>Buenos Aires</td>
<td>Issues concession licenses; Ministry of Economy sets fares; Transport Authority</td>
<td>Vehicles are “share” in company (association); operators set vehicle type; company influences sched.</td>
</tr>
<tr>
<td>Mexico City</td>
<td>Issues route-based licenses for buses and minibuses; sets fares and routes</td>
<td>Operators determine vehicle type and schedule</td>
</tr>
</tbody>
</table>

**Example of Roles in “Strong” Regulation**

<table>
<thead>
<tr>
<th>City</th>
<th>Authority(ies)</th>
<th>Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curitiba</td>
<td>Gross cost contracts on area basis; reimburses operators based on per kms; fares, vehicle type, schedule, route, # buses specified.</td>
<td>10 “Formal” Companies.</td>
</tr>
<tr>
<td>Rio</td>
<td>Licenses specify level of service and fares, routes and vehicle types.</td>
<td>33 licensed companies.</td>
</tr>
<tr>
<td>Santiago</td>
<td>Contract specifies route and frequency; fare and vehicle type established in bidding.</td>
<td>~250 companies set fares and vehicle type via bidding.</td>
</tr>
<tr>
<td>São Paulo</td>
<td>Contract – based on standardized cost schedule – specifies route, frequency and vehicle type; payment on per km basis.</td>
<td>50 private operators; contract does not allow for much innovation.</td>
</tr>
</tbody>
</table>

Public Transport Management

Obstacles and Challenges
- Ensuring competitive route bidding
- Service and Fare Integration
- Adequate enforcement of service conditions (frequencies, fares, etc.)
- “Formalization” of Companies
- Reducing “incumbents’ advantage”
- Long-Term profitability
- Institutional capacity and political influence
Transport Supply – Vehicle Owners

- Private Vehicle Characteristics and influence
  - Size, Weight – price based
    - potential influence via tax policy, registration fees
  - Emissions, Safety – regulation based, possibly price based
    - New vehicle standards, in-use vehicle standards, I/M programs,
    - Potential to link to pricing mechanisms (fuel prices, registration prices, purchase prices).

- Public Vehicle Characteristics and influence
  - Via the management/regulatory regimes
Transport Demand Management

- Prices, Fares, Subsidies
  - Fuel charges, road pricing charges, insurance charges
- Blunt instruments
  - Driving bans ("Hoy no Circula")
- The Role of Traffic Management and Supply Management
## Land Use: Supply-Demand Interaction

### Hypotheses of The “Three D’s”

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Vehicle Trip Rates</th>
<th>Choice of non-private vehicle for:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Non-Work Trips</td>
</tr>
<tr>
<td>Density</td>
<td>Reduce</td>
<td>Increase</td>
</tr>
<tr>
<td>Diversity</td>
<td>Reduce</td>
<td>Increase</td>
</tr>
<tr>
<td>Design</td>
<td>Reduce</td>
<td>Increase</td>
</tr>
</tbody>
</table>
Land Use: Reality of the “Three D’s”

“Modest to moderate at best”
- Densities important for personal business
- Commercial activity accessibility important for HH VMT
- Retail activity accessibility important for work trip mode choice
- Design elements (Grid layout, limited on street parking) important for non work travel
- Need for co-existence of the Three D’s

In the developing world what can really be achieved??
- (see, for example, WBCSD, Table 4.10, p. 4-28)

Source: Cervero & Kockelman, 1997.
Solution Sets - Key

- Vision
- Strategy
- Tactics
- Integrated Approach
- Institutional Implications
The Curitiba “Story”
Curitiba: Background

Population (Thousands)

- Metro Region
- Curitiba

Source: Curitiba Prefeitura Municipal
Curitiba: Background

- City Size: 431 km$^2$, city proper
  ~800 km$^2$, metro region

- GDP per Capita: $5,150 (US$1994)
  - employment: 35% retail-commercial;
    19% manufacturing

- Private Autos: 270 per 1000 people
  (1993)
### Curitiba: Evolution of a Transport System

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>Linear Access Plan Conceived</td>
</tr>
<tr>
<td>1970</td>
<td>Jaime Lerner Elected Mayor</td>
</tr>
<tr>
<td>1972</td>
<td>Pedestrianization of Downtown Streets</td>
</tr>
<tr>
<td>1974</td>
<td>First Two Busways</td>
</tr>
<tr>
<td>1978</td>
<td>Additional Busway</td>
</tr>
<tr>
<td>1979</td>
<td>First Interdistrict Bus Line</td>
</tr>
<tr>
<td>1980</td>
<td>East-West Busway</td>
</tr>
<tr>
<td></td>
<td>Fare and Service Integration</td>
</tr>
<tr>
<td>1991</td>
<td>Express Bus with Tube Stops</td>
</tr>
<tr>
<td>1992</td>
<td>Bi-articulated Buses</td>
</tr>
</tbody>
</table>
Fundamental Principle I: Land Use-Transport Integration

A “Linear City”:

• Focusing urban expansion along structural axes
  – Centered on busways

• Promote densification of land uses on axes
  – Zoning, Regulations, Incentives
Fundamental Principle II: Public Transport Priority in Road Infrastructure

“Trinary” Road System

Busway

Local Collectors

High Capacity One-Way Streets