Outline:

• Introduction
• Bus Stops
• Bus Lanes
• Signal Priority
• Bus Rapid Transit
It’s Time for Bus Priority

• Bus service will always be essential
  – Rail’s reach is limited / its cost, prohibitive

• Rail gets “ultimate” priority
  – Should bus have no priority at all

• Priority is a strong way to counter bus’s negative image
  – Priority indicates that society values bus
  – Priority makes bus service more competitive
## Bus Service Quality Is Too Often an Accident

<table>
<thead>
<tr>
<th>Without Protection:</th>
<th>With Protection:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Slow</td>
<td>• Fast</td>
</tr>
<tr>
<td>• Unreliable</td>
<td>• On time</td>
</tr>
<tr>
<td>• Bunched</td>
<td>• Regularly spaced</td>
</tr>
<tr>
<td>• Crowded</td>
<td>• Even loads</td>
</tr>
<tr>
<td></td>
<td>“Bus Rapid Transit”</td>
</tr>
</tbody>
</table>
Bus Stops Location and Policies

- **Far-side** (vs. Near-side)
  - less queue interference
  - easier pull-in
  - fewer ped conflicts
  - snowbank problem demands priority in maintenance

- **Curb extensions** benefit transit, peds, and traffic (0.9 min/mi speed increase)

- **Pull-out priority** (it’s the law in some states)

- **Reducing dwell time** (vehicle design, fare collection, fare policy)
Bus Priority Measures in Space
Bus Lane

The “traditional” priority measure

• Enforcement, especially vs. parking
• Turn restrictions

Political dilemma requires foresight

• If there’s little traffic: “Buses don’t need it”
• Traffic grows: “Buses can’t have it.”
Bus Priority in Space
Contraflow Bus Lane

Av. Ponce de Leon, Santurce, PR
Queue Jumper Lane

Common in the U.K.
Queue Jumper with Ramp Metering

**Metering Needed Due to Oversaturation**

Metered on-ramp, Seattle area freeway
Queue Jumper with Bottleneck Metering

Arterial entering inner part of Eindhoven, the Netherlands

10 sec. green per minute
Bypass on Saturated Arterial

• Frontage road provides local access, bus bypass
• Bus-activated gate for entry control
• Signal at bus entry meters traffic so entering bus won’t join a long queue
Priority in Time = Signal Priority
Passive Priority

Signal timing that helps transit without actively detecting a transit vehicle

• Short cycles (help peds, too!)

San Diego Trolley example (downtown, at grade)

• Signals are pretimed for trolley progression
• Through band for trolleys every 2 minutes
• Suitable for high frequency service with predictable running & dwell times
Active Priority at Signals

1. Detection

• Prefer *local* detection: transponder, smart loops, dedicated short-range radio

• Location: *predict* vs. *respond*
  – Near side dilemma (or not)

• Exit detector (stopline) to avoid waste

• Detectors on all approaches for queue management
Active Priority at Signals
2. Control Tactics

• Extend green (++)
• Early green
• Early red (to hurry the next green)
• Skip, insert, or resequence phases
• “Near-side flush:” (a) green to clear bus stop; (b) short red during dwell; (c) green
• Advanced prediction: adjust phase lengths so that transit arrives on green
• Recovery tactics: restore capacity, dissipate queues
“Interruptible” Traffic Signal Control

- For auto traffic, focus on capacity, not progression
  - lose progression: travel time increases a little
  - lose capacity: travel time increases a lot, jams the road
  - Overlaying priority on arterial progression is too limiting
- Resolve competition between priority calls
- Bus saves 12-15 s per intersection
- No significant capacity loss
- Auto travel time increases a little (justice?)
Conditional Priority as a Means of Operational Control

Eindhoven, the Netherlands

- On-board computer monitors location, schedule deviation
- Priority granted if bus is 20 s late
- Provides push / pull needed to keep bus on schedule
- Less traffic interruption
- Requires finely tuned schedule, which requires extensive data collection & analysis
Evaluations Based on Mean Values
Understate Benefits

- **Running time impact (Boston study)**
  - mean: reduced 10% (30 min to 27 min)
  - 95-percentile value: reduced 23% (38 to 29 min)

- **Crowding impact**
  - mean: no change (since headway is fixed)
  - 90-percentile value: reduced 12% (166 to 145)

- **Operating cost is usually tied to 90- or 95-percentile:**
  savings is 33%, not 10%

- **Passenger satisfaction:** also tied more to 90- or 95-percentile values
A Policy of Congestion Protection

- Cycle: slow buses ⇔ more cars
- Minimizing person-delay for fixed demand fails to account for demand effect
  - Transit benefits: amplified by new customers
  - Auto losses: diminished by rerouting
- Consistency with other efforts to influence mode choice
- Overcome interagency leadership vacuum
The BRT Challenge

As we move from current conventional bus service (CBS) towards a higher quality system Bus Rapid Transit (BRT).”

- What are the critical choices in system design?
- How do we model the system?
- How do we evaluate it?

Pilar Rodriguez, MST Thesis (MIT, 2002)
Key BRT Attributes

Physical
- Right-of-way priority
- Expedited boarding and alighting
- Stops
- Vehicles
- Fare Collection

System
- AVL system
- Signal system
- Passenger information system
Key BRT Attributes

Service
  Knowledge-based planning and operations
  High frequency
  High reliability

Control
  System
  Distinct image
  Connectivity
  Land use integration

Pilar Rodriguez, MST Thesis (MIT, 2002)
CBS Typical Travel Time Components

Sample route from CTA

- Cumulative Moving Time
- Cumulative Dwell Time
- Cumulative Signal Time
- Cumulative Total Time

Distance [mi]

Time [min]

Berwyn

95th St.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

0 10 20 30 40 50 60 70 80 90

Spring 2006, Lecture 24

Pilar Rodriguez, MST Thesis (MIT, 2002)
Trade-off: Stop Spacing vs. Access Time

Access Time and Coverage

\[ R = 500 \text{ m} \]

Access Time [min]

Area covered [%]

Stop Spacing [m]
Trade-off: Lane Exclusivity vs. Waiting Time

Lane exclusivity impact on passenger waiting time

- Mixed traffic
- Preferential lanes
- At-grade exclusive lanes
- Grade separated exclusive lanes

Waiting time [min]

Degree of lane exclusivity

Mixed traffic  Preferential lanes  At-grade exclusive lanes  Grade separated exclusive lanes

Pilar Rodriguez, MST Thesis (MIT, 2002)
Trade-off: Boarding/Alighting Time vs. Waiting Time

Impact of boarding/alighting time \( c \) on Passenger waiting time

Waiting Time [min]

On/off Time per passenger [secs/pass]

On-board payment  Off-vehicle
Cash  Contact card  Contactless

Pilar Rodriguez, MST Thesis (MIT, 2002)
Trade-off: Signal Priority vs. Waiting Time

Signal priority impact on passenger waiting time

- Passive priority
- Queue jumping
- Active unconditional priority
- Active conditional priority

Waiting time [min]

Degree of lane exclusivity

Pilar Rodriguez, MST Thesis (MIT, 2002)
Modeling

• **Two different scales:**
  • Corridor level:
    • Description of the transit experience
    • A building block for BRT
    • Focus on access and operational issues
  • System-wide level
    • The impacts on modal choice and ridership
    • Changing perceptions of choice riders
    • Appropriate network configurations incl. transfers
    • Competing with parallel improvements for the automobile driver
Evaluation Measures

- Primary objective is ridership
- Ridership gains come from LOS improvements
- Two challenges:
  - Forecasting of LOS gains
  - Forecasting of ridership as a result from LOS gains
## Typical Evaluation Measures
(Obviously conditioned by our own analytical approach!)

<table>
<thead>
<tr>
<th>Group</th>
<th>Category</th>
<th>Evaluation measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Users</td>
<td>Travel Time</td>
<td>Access Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waiting Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In-vehicle Time</td>
</tr>
<tr>
<td>Agency</td>
<td>Operation Costs</td>
<td>Running time</td>
</tr>
<tr>
<td></td>
<td>Capital costs</td>
<td>Infrastructure cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technology cost</td>
</tr>
</tbody>
</table>
## Impact Matrix Evaluation

<table>
<thead>
<tr>
<th>IMPACTS</th>
<th>CRITICAL VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lane exclusivity</td>
</tr>
<tr>
<td></td>
<td>Guidance</td>
</tr>
<tr>
<td></td>
<td>Spacing</td>
</tr>
<tr>
<td></td>
<td>Boarding level</td>
</tr>
<tr>
<td></td>
<td>Bus capacity</td>
</tr>
<tr>
<td></td>
<td>No. doors</td>
</tr>
<tr>
<td></td>
<td>Transaction location</td>
</tr>
<tr>
<td></td>
<td>Fare media</td>
</tr>
<tr>
<td></td>
<td>Priority method</td>
</tr>
<tr>
<td>Users Access time</td>
<td>X</td>
</tr>
<tr>
<td>Users Waiting time</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>Users In-vehicle time</td>
<td>X X X X X</td>
</tr>
<tr>
<td>Users Running time</td>
<td>X X X X X X X</td>
</tr>
<tr>
<td>Agency Infrastructure cost (road &amp; vehicles)</td>
<td>X X X X X X</td>
</tr>
<tr>
<td></td>
<td>Technology Cost</td>
</tr>
</tbody>
</table>
Usual Evaluation Elements

- Ridership gains
- Benefits = time savings as % of current time
- Infrastructure, technology, and operational cost
- Average cost to achieve one percent time reduction for each alternative

Choice of a prioritization criteria:
- Users: travel time cost-effectiveness
- Agency: running time cost effectiveness
- Both: travel + running time cost effectiveness
BRT Implementation Process

1. Understand transit system
2. Select BRT corridor
3. Assess corridor performance
4. Define implementation strategy
5. Evaluate components
6. Prioritize components
7. Design BRT system
8. Build infrastructure
9. Operate services

System goals
System constraints
Corridor goals
Components priority list
Infrastructure design
Service configuration
Service performance