Surface Transportation Optimization and Bus Priority Measures
Future of MBTA Bus Operations

Thursday, May 29, 2014
Executive Summary

• Bus transit is a critical component of the MBTA services and will be for the foreseeable future
• Corridor study demonstrated ability to increase reliability for multiple routes
• Some fleet replacement and maintenance facility issues coming to a head
• Opportunities exist to cost-effectively reduce MBTA’s carbon footprint through fleet and infrastructure investments
Agenda

• Why Bus Transportation Important
• Operational Reliability through Bus Priority Measures
• Alternative Propulsion for a Sustainable Future
• Bringing it all together: Pilot Opportunities
Why is Bus Transportation Important

• Large percentage of MBTA ridership (~30%)
  o Still Growing...11% growth in unlinked passenger trips from Jan 2007 to Mar 2012

• Environmental justice

<table>
<thead>
<tr>
<th></th>
<th>Minority</th>
<th>Low Income</th>
<th>English Proficiency*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>37%</td>
<td>21%</td>
<td>0.63%</td>
</tr>
<tr>
<td>Rapid Transit</td>
<td>27%</td>
<td>13%</td>
<td>0.14%</td>
</tr>
<tr>
<td>Commuter Rail</td>
<td>11%</td>
<td>2%</td>
<td>0.02%</td>
</tr>
</tbody>
</table>
Why is Bus Transportation Important

• Mobility
  o 34% of bus users have no household vehicle

• Service availability (Coverage)
  o % of street miles covered by transit market

<table>
<thead>
<tr>
<th></th>
<th>Bus</th>
<th>Subway</th>
<th>Commuter Rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>73%</td>
<td>7%</td>
<td>3%</td>
</tr>
</tbody>
</table>

• Lower capital cost to implement bus improvements vs. rail
• Public transportation’s role in global warming
Project Methodology

- Researched bus priority best practices
- Researched alternative propulsion systems
- Fact finding mission – London, UK
- Developed corridor selection criteria/methodology
- Developed conceptual design for corridor and modeled improvements
# Order of Magnitude Cost-Benefit Comparison

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low</td>
<td>Queue Jump</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium</td>
<td>Curb Extension</td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>Exclusive Bus Lane</td>
</tr>
</tbody>
</table>

## Cost-Effectiveness Matrix

- **High Cost, High Effectiveness:** Stop Consolidation
- **High Cost, Medium Effectiveness:** Restricted Bus Lane
- **High Cost, Low Effectiveness:** Exclusive Bus Lane Proof of Payment (PoP)
- **Medium Cost, High Effectiveness:** Center-to-Center Transit Signal Priority
- **Medium Cost, Medium Effectiveness:** Two-Door Boarding
- **Medium Cost, Low Effectiveness:** Stop Placement (near-side vs far-side)
- **Low Cost, High Effectiveness:** Queue Jump
- **Low Cost, Medium Effectiveness:** Curb Extension
WBC Corridor
(Washington St/Belgrade Ave/Centre St)

• 9 Bus routes on Washington Street Trunk
  o 30, 34, 34E, 35, 36, 37, 40, 50, and 51
• Does not include Key Bus Route
• Over 20,000 Weekday Daily Riders
• Mixed residential and neighborhood retail
• Passes through Environmental Justice area

ABC
A BETTER CITY
### Washington Street Corridor

**Key**
- Existing Signal
- Existing Signal (CC)
- Existing Bus Stop
- New/Relocated Stop
- Bus Stop Eliminated
- TSP Application
- Queue Jump Application
- TSP and Queue Jump Application

<table>
<thead>
<tr>
<th># Stops</th>
<th>IB</th>
<th>OB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Change</td>
<td>-3</td>
<td>-2</td>
</tr>
<tr>
<td>Net</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intersection Applications</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSP</td>
<td>4</td>
</tr>
<tr>
<td>Queue Jump</td>
<td>2</td>
</tr>
<tr>
<td>Bus Advance Signal</td>
<td>0</td>
</tr>
<tr>
<td>Net</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Curb Extension</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>0</td>
</tr>
<tr>
<td>Enhanced</td>
<td>0</td>
</tr>
<tr>
<td>Net</td>
<td>0</td>
</tr>
</tbody>
</table>
Centre Street Corridor

Key
- Existing Signal
- Existing Signal (CC
- Existing Bus Stop
- New/Relocated Stop
- Bus Stop Eliminated
- TSP Application
- Queue Jump Application
- Bus Advance Signal
- New Curb Extension
- Enhanced Curb Extension

<table>
<thead>
<tr>
<th># Stops</th>
<th>IB</th>
<th>OB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Change</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Net</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intersection Applications</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSP</td>
<td>0</td>
</tr>
<tr>
<td>Queue Jump</td>
<td>0</td>
</tr>
<tr>
<td>Bus Advance Signal</td>
<td>1</td>
</tr>
<tr>
<td>Net</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Curb Extension</th>
<th>#</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>2</td>
</tr>
<tr>
<td>Enhanced</td>
<td>3</td>
</tr>
<tr>
<td>Net</td>
<td>5</td>
</tr>
</tbody>
</table>
Improvement Packages

• **Low:**
  o Require minimal capital improvements
  o Implemented with minimal cost and delay

• **Medium:**
  o Require some capital improvements
  o Implemented in a short-medium time-frame.
  o Include all of the changes in the “low” category, as well as queue jumps and curb extensions.

• **High:**
  o Relatively high capital cost
  o May require some policy alterations or additional inter-agency coordination
  o Includes all bus priority treatments.
## Running Times - Inbound

<table>
<thead>
<tr>
<th>Location</th>
<th>Existing</th>
<th>No-Build</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagrange Street and Park Street</td>
<td>00:54</td>
<td>00:57</td>
<td>00:52</td>
<td>00:36</td>
<td>00:36</td>
</tr>
<tr>
<td>Belgrade Ave and Centre Street</td>
<td>01:49</td>
<td>01:55</td>
<td>01:55</td>
<td>02:42</td>
<td>02:42</td>
</tr>
<tr>
<td>Aldrich Street and Centre Street</td>
<td>02:55</td>
<td>03:04</td>
<td>02:59</td>
<td>02:47</td>
<td>02:47</td>
</tr>
<tr>
<td>Corinth Street and Washington Street</td>
<td>03:07</td>
<td>03:17</td>
<td>03:07</td>
<td>04:11</td>
<td>04:11</td>
</tr>
<tr>
<td>Granfield Avenue and Washington Street</td>
<td>04:23</td>
<td>04:36</td>
<td>04:31</td>
<td>02:09</td>
<td>02:09</td>
</tr>
<tr>
<td>Forest Hills</td>
<td>02:27</td>
<td>02:34</td>
<td>02:29</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Travel Time**

<table>
<thead>
<tr>
<th></th>
<th>Existing</th>
<th>No-Build</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
</table>

(Percent below No Build)

“No-Build” assumes 1% increase in travel time per year for five years

Travel times for Low, Medium and High represent the high range of travel times.
Time Savings – Inbound (AM Peak)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Total Time Savings per Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>01:30</td>
</tr>
<tr>
<td>Medium</td>
<td>00:27</td>
</tr>
<tr>
<td>High</td>
<td>00:30</td>
</tr>
</tbody>
</table>

- **Total Time Savings per Trip**: 1:30
- **Total Time Savings per Trip**: 3:03

Legend:
- Bus Stop Elim
- TSP
- Queue Jump
- Bus Advance
- Curb Extension
- Other (Bus Reroute, FH Off-board fare payment)
Running Times - Outbound

<table>
<thead>
<tr>
<th>Location</th>
<th>Existing</th>
<th>No-Build</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Hills</td>
<td>03:46</td>
<td>03:58</td>
<td>03:48</td>
<td>03:18</td>
<td>02:48</td>
</tr>
<tr>
<td>Mosgrove Avenue</td>
<td>04:30</td>
<td>04:44</td>
<td>04:44</td>
<td>04:34</td>
<td>04:34</td>
</tr>
<tr>
<td>Roslindale Village</td>
<td>02:22</td>
<td>02:29</td>
<td>02:24</td>
<td>02:14</td>
<td>02:14</td>
</tr>
<tr>
<td>Aldrich Street and Belgrade Avenue</td>
<td>02:30</td>
<td>02:38</td>
<td>02:36</td>
<td>02:32</td>
<td>02:32</td>
</tr>
<tr>
<td>Belgrade Avenue and Centre Street</td>
<td>02:21</td>
<td>02:28</td>
<td>02:28</td>
<td>02:28</td>
<td>01:58</td>
</tr>
<tr>
<td>Richwood and Centre Street</td>
<td>01:25</td>
<td>01:29</td>
<td>01:29</td>
<td>01:14</td>
<td>01:14</td>
</tr>
<tr>
<td>Centre Street and Lagrange Street</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Travel Time (Percent below No Build)

- Existing: 16:54
- No-Build: 17:46 (2%)
- Low: 17:29 (8%)
- Medium: 16:20 (15%)
- High: 15:20

“No-Build” assumes 1% increase in travel time per year for five years.

Travel times for Low, Medium and High represent the high range of travel times.
Time Savings – Outbound (PM Peak)

Total Time Savings per Trip = 2:17
Total Time Savings per Trip = 1:26
Total Time Savings per Trip = 0:51

Low
Medium
High

00:51
00:51
00:51

00:20
00:20
00:20

01:00
01:00
01:00

01:00
01:00
01:00

00:15
00:15
00:15

00:20
00:20
00:20

00:30
00:30
00:30

01:00
01:00
01:00

Bus Stop Elim  TSP  Queue Jump  Bus Advance  Curb Extension  Other (Bus Reroute, FH Off-board fare payment)
Bus Priority Measure Potential Impacts

Source: TCRP Report 26
## Passenger Hour Savings

Total Daily Travel Time Savings for Passengers on Routes 35, 36, 37

<table>
<thead>
<tr>
<th>Level</th>
<th>Inbound</th>
<th>Outbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>44 hours</td>
<td>28 hours</td>
</tr>
<tr>
<td>Medium</td>
<td>45 hours</td>
<td>84 hours</td>
</tr>
<tr>
<td>High</td>
<td>75 hours</td>
<td>84 hours</td>
</tr>
</tbody>
</table>

|= Day|
## Cost-Effectiveness Calculation

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Capital Cost</td>
<td>$690,000</td>
<td>$435,000</td>
</tr>
<tr>
<td>B</td>
<td>Daily PAX-hr Saved</td>
<td>160 hours</td>
<td>129 hours</td>
</tr>
<tr>
<td>C</td>
<td>Annualization Factor</td>
<td>252 day/year</td>
<td>252 day/year</td>
</tr>
<tr>
<td>D</td>
<td>Annual PAX-hr Saved</td>
<td>40,068 hours</td>
<td>32,508 hours</td>
</tr>
<tr>
<td>E</td>
<td>Cost per hour saved (E=A/D)</td>
<td>$17.22</td>
<td>$13.38</td>
</tr>
</tbody>
</table>

**Rule of Thumb…**

anything under $20 cost per hour saved is good
Bus Priority Work Conclusion

• Work reinforces MBTA Key Bus Route project
• Corridor (vs. route) level evaluation and implementation of bus priority measures has potential to improve travel time on several routes
• Addition of bus priority measures in the WBC corridor is cost-effective
• Time savings along corridor during the peak period will provide passenger time savings and improve reliability
Pilot Opportunity to Demonstrate Bus Priority Measure Potential

- Washington-Belgrade-Centre Corridor
  - Combined daily ridership of over 20,000 weekday daily riders
  - Environmental justice area
  - Increased reliability for several routes
  - Through several diverse, land-use corridors
  - Opportunity to improve urban landscape
  - Additional corridors considered
    - Brookline Avenue (Longwood Medical Area)
    - E Broadway (South Boston)
MBTA’s Carbon Footprint

• As a Producer...
  o MBTA Emissions – 13th Largest Source in Massachusetts

• As a Reducer...
  o Mode Shifts
    o Higher Occupancy Mode
    o 0.85 lbs per transit passenger trip vs. 16.3 lbs per car trip
  o Congestion Relief
    o Fewer vehicles on the road
  o Land Use
    o Support dense urban living
Alternative Propulsion Research

- Review current state of the MBTA fleet
- Review current state of the industry propulsion systems
  - Diesel
  - CNG
  - Hybrid-Electric
  - Battery-Electric
  - Hydrogen Fuel Cell
- Lifecycle cost comparison and cost-effectiveness comparison to reduce GHG emissions (relative to diesel)
Alternative Propulsion: State of the Fleet

- MBTA procured 40 New Flyer diesel-electric hybrid buses (May 2014)
- Critical to procure replacement of existing dual-mode articulated Silver Line buses
- Evaluation of current bus maintenance facility is required to understand existing and future capacity to support alternative propulsion system
State of the Industry: Propulsion System Summary

• DIESEL
  o Pros
    o Mature and reliable technology
    o Good range and fuel efficiency
    o MBTA has current infrastructure to support system
  o Cons
    o Generally non-domestic fuel source
    o Increasing fuel cost
    o Comparably louder than some other propulsion systems
    o Releases more particulate matter and nitrogen oxide pollutants than other systems

• NATURAL GAS
  o Pros
    o Mature and reliable technology
    o Relatively low fuel cost
    o MBTA familiarity with propulsion system
    o Low emissions and no particulate matter
    o Domestically produced fuel
    o As reliable as diesel propulsion
  o Cons
    o Slightly higher per bus cost than diesel
    o May require additional maintenance facility infrastructure to support additional buses
State of the Industry: Propulsion System Summary

• HYBRID-ELECTRIC TECHNOLOGY
  - Pros
    - Lower tailpipe emissions than standard diesel bus
    - Good range and better fuel efficiency than standard diesel
    - Can be used in combination with any type of combustion engine
    - MBTA has familiarity with propulsion system
  - Cons
    - Reports of less reliability than diesel and CNG
    - Increasing fuel cost; generally non-domestic fuel source
    - Higher vehicle costs
    - Technology is maturing

• BATTERY ELECTRIC
  - Pros
    - Zero emissions at point of use
    - Higher on-board customer satisfaction due to smoother and quieter ride
    - Fuel (electricity) prices generally stable
    - Not dependent on fossil fuel /electricity can be generated from renewable sources
  - Cons
    - Low range
    - High capital cost of buses and supporting infrastructure
    - Not significant presence in domestic fleets
    - Weight of battery packs decreases efficiency
    - Durability and long-term performance is unknown
State of the Industry: Propulsion System Summary

- HYDROGEN FUEL CELL
  
  **Pros**
  - Zero tailpipe emissions (besides water vapor).
  - Quiet operation
  - Hydrogen can be produced domestically and using renewable sources but currently at a high price
  - Shows a significant amount of promise but currently in demonstration phase

  **Cons**
  - VERY high cost of entry
  - Buses are currently prototypes and not domestically produced
  - Long term maintenance costs and reliability unknown
Propulsion System Lifecycle Cost Comparison

Key Assumptions
Lifecycle = 12 years
Annual Mileage/bus = 40,000
50 buses
## Cost Effectiveness in Reducing GHG Comparison

<table>
<thead>
<tr>
<th></th>
<th>Clean Diesel</th>
<th>CNG</th>
<th>Diesel-Electric Hybrid</th>
<th>Battery Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifecycle Emissions (Tons CO2)</td>
<td>4,174,000</td>
<td>3,933,000</td>
<td>3,339,000</td>
<td>1,339,000</td>
</tr>
<tr>
<td>GHG Reduction (compared to diesel)</td>
<td>241,000</td>
<td>835,000</td>
<td>2,835,000</td>
<td></td>
</tr>
<tr>
<td>Lifecycle Cost ($)</td>
<td>$41,540,000</td>
<td>$38,804,000</td>
<td>$47,632,000</td>
<td>$68,012,000</td>
</tr>
<tr>
<td>Cost Difference (compared to diesel)</td>
<td>-$2,736,000</td>
<td>$6,092,000</td>
<td>$26,472,000</td>
<td></td>
</tr>
<tr>
<td>$/Ton GHG reduced</td>
<td>-$11.35*</td>
<td>$7.30</td>
<td>$9.34</td>
<td></td>
</tr>
</tbody>
</table>

* Negative value shows a cost savings
Alternative Propulsion Precedence

• Compressed Natural Gas
  o 40 Agencies use CNG

• Hybrids
  o NYC MTA – 1,600 Hybrids in fleet by 2011...28% of fleet
  o SEPTA – 700+ by 2015...50% of fleet
  o WMATA – 548 Hybrids in fleet by 2011...37% of fleet

• Electric
  o King County Metro - $5 M federal grant for electric demonstration
  o Worcester Regional Transit Authority – 6 Proterra Electric Buses

• Hydrogen Fuel Cell (All Pilots)
  o AC Transit (Oakland) – 12 Hydrogen Fuel Cell
  o Connecticut Transit – 5 Hydrogen Fuel Cell
  o London – 8 Hydrogen Fuel Cell
  o Vancouver – 20 Hydrogen Fuel Cell
  o Several cities in Europe (through CHIC program)
Alternative Propulsion Conclusions

• CNG has the lowest lifecycle cost and is the most cost-effective in reducing GHG emissions
• Battery-electric buses show a great deal of promise
• Hydrogen-fuel cell technology may be a long term propulsion solution for all transportation, transit and otherwise; however, not a near-term solution
• Turnover 80-100 bus/year to continue to reduce average fleet age and turnover to new propulsion system
Pilot Opportunities to Demonstrate Alternative Propulsion and Bus Priority Measure Potential

- South Boston Waterfront
  - Hot bed of political and community interest and activity
  - Significant public and private development occurring (infrastructure funding)
  - “Innovation District” branding = Innovative execution
  - Address Silver Line Dual Mode Articulated fleet replacement
  - Alternative propulsion (zero tailpipe emissions) requirement
  - Silver Line Surface Route (SL2) and Bus Routes 4 and 7 = opportunities for bus priority measures
  - “T under D” construction management plan requires surface + bus priority solution
  - Articulated buses = multi-door boarding/rear-door validator
Pilot Opportunities to Demonstrate Alternative Propulsion and Bus Priority Measure Potential

- Replacement of Trackless-Trolley (Routes 71, 72, 73, 77)
  - Opportunity to pilot battery electric vehicles
  - Remove overhead catenaries for electric trolley buses
  - Placemaking opportunity while maintaining community interest (zero-ground level emissions)
  - Requires major infrastructure investment (recharging stations)
    - Opportunity to incorporate bus priority measures
  - 28 Neoplan Trackless Trolleys are 10 years old
# Federal Funding Opportunities

<table>
<thead>
<tr>
<th>Program</th>
<th>FY 14 Authorized ($ in millions)</th>
<th>Relevant Eligible Expenses and Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus and bus facilities formula grants, §5339</td>
<td>$428</td>
<td>Capital projects to replace, rehabilitate and purchase buses, vans, and related equipment, and to construct bus-related facilities</td>
</tr>
<tr>
<td>Fixed guideway capital investment grants, “New/Small Starts”</td>
<td>$1,907</td>
<td>New fixed guideway systems or extensions to fixed guideway systems; bus rapid transit; projects that improve capacity on an existing fixed guideway system</td>
</tr>
<tr>
<td>Congestion Mitigation and Air Quality Improvement Program (CMAQ)</td>
<td>$2,230</td>
<td>Projects likely to reduce congestion or contribute to the attainment or maintenance of a national ambient air quality standard; transit capital and operating costs</td>
</tr>
<tr>
<td>Surface Transportation Program</td>
<td>$10,100</td>
<td>Capital costs for transit projects eligible for FTA grant funding, including vehicles and facilities</td>
</tr>
<tr>
<td>Transportation Investment Generating Economic Recovery (TIGER)</td>
<td>$600</td>
<td>Capital and/or planning costs; safety, economic competitiveness, state of good repair, livability and environmental sustainability...expected contributions to economic recovery, as well as their ability to facilitate innovation and new partnerships</td>
</tr>
</tbody>
</table>
Next Steps

• Potential to implement improvement suggestions for WBC corridor
• Adoption of corridor level bus priority evaluation
• Meet with city and local representatives to build consensus and support
• Develop forum for future bus innovation in Boston
THANK YOU