Marginal Cost Pricing and Subsidy of Transit in Small Urbanized Areas

Jeremy Mattson
David Ripplinger
Small Urban & Rural Transit Center

Transportation Research Board, 91st Annual Meeting
Washington, DC
January 23, 2012
Overview

• Survey of transit agencies
  ▪ Changes in fares, service levels, funding
• Rationale for subsidies
• Marginal cost pricing
• Cost model
• Estimates of economies of density, economies of scale, marginal cost, required subsidies
• Conclusions and other areas for research
Survey

• Transit agencies in small urbanized areas (50,000 to 200,000 population)
• Conducted Nov-Dec 2010
• Online survey sent to 305 transit agencies across the country
• Responses from 141 transit agencies (46% response rate)
Agencies that have made cuts in service since January 1, 2009, or are considering cuts (n=140)

- Made cuts: 30%
- Considering cuts: 9%
- No cuts: 61%
Cuts by transit agencies that have made service reductions (n=38)

- Reduction of service hours: 74%
- Elimination or reduction of weekend service: 34%
- Reduction in service frequency on existing routes: 53%
- Reduction in geographic coverage of service: 32%
- Other: 13%
Factors that motivated decisions to cut transit service (n=38)

- Decrease in funding: 82%
- Decrease in other revenues: 13%
- Increase in fuel costs: 16%
- Increase in other costs: 16%
- Decrease in service demand: 16%
- Other: 16%
Transit agencies that have added service since January 1, 2009, or are considering increases (n=138)

- No increases: 41%
- Made increases: 49%
-Considering increases: 10%
Types of services added by transit agencies that have made service increases (n=68)

- Increase in service hours: 41%
- Introduction or increase of weekend service: 22%
- Increase in service frequency on existing routes: 37%
- Increase in geographic coverage of service: 54%
Percentage of transit agencies that have increased fares since January 1, 2009, or are considering fare increases (n=134)

- Increased fares: 33%
- No fare increase: 55%
- Considering increase: 12%
Motivations for fare increases (n=44)

- Decrease in funding: 50%
- Decrease in other revenues: 18%
- Increase in fuel costs: 41%
- Increase in other costs: 36%

Percentage of transit agencies
### Other Actions Taken by Agencies that Have Cut Service or Increased Fares

<table>
<thead>
<tr>
<th>Other Actions</th>
<th>Agencies that have:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cut Service</td>
</tr>
<tr>
<td>Cut Service</td>
<td>45%</td>
</tr>
<tr>
<td>Increased Service</td>
<td>38%</td>
</tr>
<tr>
<td>Increased Fares</td>
<td>51%</td>
</tr>
<tr>
<td>Decreased Fares</td>
<td>5%</td>
</tr>
</tbody>
</table>
Demand for Service

• Two-thirds of transit agencies responding to this survey said that demand for transit service in their community is increasing; 28% answered that demand is staying about the same, while just 4% said that demand is decreasing.

• Of those who said that demand is increasing, most (94%) said their agency is facing limitations in its ability to add service to meet this demand.
Changes in operational funding over the last year (n=132)

- **Local/regional funding**:
  - Decreased: 36%
  - About the same: 48%
  - Increased: 16%

- **State funding**:
  - Decreased: 34%
  - About the same: 57%
  - Increased: 9%

- **Federal funding**:
  - Decreased: 11%
  - About the same: 76%
  - Increased: 13%
What Do Transit Systems View as the Rationale for Transit Subsidies?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>To enhance mobility for the underprivileged</td>
<td>119</td>
<td>91%</td>
</tr>
<tr>
<td>To offset social costs of automobile travel</td>
<td>100</td>
<td>76%</td>
</tr>
<tr>
<td>To take advantage of economies of scale</td>
<td>83</td>
<td>63%</td>
</tr>
</tbody>
</table>
Percentage of transit agencies that refer to any of the following consequences of automobile travel when trying to obtain funding (n=132)

- Air pollution: 60%
- Congestion: 55%
- Greenhouse gas emissions: 53%
- Dependence on foreign energy supplies: 31%
- None of the above: 30%
- Cost of supplying parking: 20%
- Automobile accidents: 10%
Rationale for Subsidies

• Special needs for transit by the underprivileged
• Existence of subsidies to other modes of travel
  ▪ Second-best pricing
• Economies of scale in transit
  ▪ Mohring Effect
• Positive externalities associated with transit
Marginal Cost Pricing

- Social welfare is maximized when prices equal marginal cost
- If there are increasing returns to scale
  - $MC < AC$
  - Subsidy is required
Long-Run Small Urban Transit Cost Model

- Translog function
- $TC = f(Y, N, P_i, Z)$
  - Where $TC = \text{total cost}$, $Y = \text{output}$, $N = \text{network size}$, $P_i = \text{input prices}$, $Z = \text{environmental variables}$
  - Vehicle revenue miles is used as the output
- Limited to agencies that directly operate fixed-route service, and
- Section 5307 agencies with population no greater than 200,000
- Used data from NTD for 2006-2009 for 168 agencies
## Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>St. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Revenue Miles</td>
<td>1,525,181</td>
<td>2,161,787</td>
</tr>
<tr>
<td>Total Cost</td>
<td>3,914,416</td>
<td>4,021,933</td>
</tr>
<tr>
<td>Labor share</td>
<td>72%</td>
<td></td>
</tr>
<tr>
<td>Fuel share</td>
<td>14%</td>
<td></td>
</tr>
<tr>
<td>Maintenance share</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Capital share</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Fleet size</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>Average age</td>
<td>8.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Seats/vehicle</td>
<td>27.8</td>
<td>8.9</td>
</tr>
</tbody>
</table>
## Data for Transit Agencies by Size

<table>
<thead>
<tr>
<th>Output Percentile</th>
<th>Vehicle Revenue Miles (’000 miles)</th>
<th>Fleet size</th>
<th>Wage rate</th>
<th>Labor share</th>
<th>Fuel share</th>
<th>Maint. share</th>
<th>Capital share</th>
<th>Average cost (per vehicle mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>232</td>
<td>11</td>
<td>22.08</td>
<td>68%</td>
<td>15%</td>
<td>6%</td>
<td>11%</td>
<td>4.59</td>
</tr>
<tr>
<td>11-30</td>
<td>459</td>
<td>19</td>
<td>22.79</td>
<td>70%</td>
<td>14%</td>
<td>7%</td>
<td>9%</td>
<td>4.02</td>
</tr>
<tr>
<td>31-50</td>
<td>726</td>
<td>25</td>
<td>22.16</td>
<td>71%</td>
<td>14%</td>
<td>7%</td>
<td>8%</td>
<td>3.96</td>
</tr>
<tr>
<td>51-70</td>
<td>1112</td>
<td>32</td>
<td>24.47</td>
<td>73%</td>
<td>14%</td>
<td>7%</td>
<td>7%</td>
<td>3.52</td>
</tr>
<tr>
<td>71-90</td>
<td>2077</td>
<td>43</td>
<td>24.80</td>
<td>74%</td>
<td>13%</td>
<td>6%</td>
<td>6%</td>
<td>3.02</td>
</tr>
<tr>
<td>&gt;90</td>
<td>6315</td>
<td>54</td>
<td>29.00</td>
<td>77%</td>
<td>11%</td>
<td>6%</td>
<td>5%</td>
<td>1.51</td>
</tr>
<tr>
<td>Variable</td>
<td>Parameter estimate</td>
<td>t-value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------</td>
<td>---------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.337</td>
<td>11.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wage</td>
<td>0.721</td>
<td>145.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel</td>
<td>0.137</td>
<td>40.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0.070</td>
<td>36.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital</td>
<td>0.073</td>
<td>11.86</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>0.908</td>
<td>33.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output*Output</td>
<td>0.160</td>
<td>6.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output*Wage</td>
<td>0.052</td>
<td>11.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output*Fuel</td>
<td>-0.009</td>
<td>-3.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output*Maintenance</td>
<td>-0.013</td>
<td>-8.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output*Capital</td>
<td>-0.027</td>
<td>-5.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>0.005</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area*Area</td>
<td>0.184</td>
<td>2.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area*Wage</td>
<td>-0.025</td>
<td>-3.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area*Fuel</td>
<td>0.016</td>
<td>3.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area*Maintenance</td>
<td>0.006</td>
<td>2.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area*Capital</td>
<td>0.002</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area*Output</td>
<td>-0.120</td>
<td>-3.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seats/Vehicle</td>
<td>0.006</td>
<td>8.51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Length Trip</td>
<td>-0.010</td>
<td>-3.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Estimates of returns to density, returns to scale, marginal cost, required subsidy at the sample mean

- **RTD** = \( \frac{1}{\varepsilon_Y} = \frac{1}{0.908} = 1.101 \)

- **RTS** = \( \frac{1}{\varepsilon_Y + \varepsilon_N} = \frac{1}{0.908 + 0.005} = 1.095 \)

- **MC** = \( \frac{\partial C}{\partial Y} = \frac{\partial \ln C}{\partial \ln Y} \cdot \frac{C}{Y} = \varepsilon_Y \cdot \frac{C}{Y} = 0.908 \times 2.57 = $2.33 \text{ per vehicle mile} \)

- Required subsidy = AC – MC = $0.24 \text{ per vehicle mile}
## Estimates for Transit Agencies Grouped by Size

<table>
<thead>
<tr>
<th>Output Percentile</th>
<th>Returns to Density</th>
<th>Average cost</th>
<th>Marginal cost</th>
<th>Required subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>1.65</td>
<td>4.59</td>
<td>2.78</td>
<td>1.80</td>
</tr>
<tr>
<td>11-30</td>
<td>1.40</td>
<td>4.02</td>
<td>2.88</td>
<td>1.14</td>
</tr>
<tr>
<td>31-50</td>
<td>1.27</td>
<td>3.96</td>
<td>3.12</td>
<td>0.83</td>
</tr>
<tr>
<td>51-70</td>
<td>1.17</td>
<td>3.52</td>
<td>3.02</td>
<td>0.50</td>
</tr>
<tr>
<td>71-90</td>
<td>1.04</td>
<td>3.02</td>
<td>2.89</td>
<td>0.13</td>
</tr>
<tr>
<td>&gt;90</td>
<td>0.88</td>
<td>1.51</td>
<td>1.71</td>
<td>-0.20</td>
</tr>
</tbody>
</table>
Full Cost Model

External costs (Litman 2009, http://www.vtpi.org/tca/)
- Pollution: $0.13 per vehicle mile
- Greenhouse gas emissions: $0.09 per vehicle mile
- Roadway facilities: $0.04 per vehicle mile
- Crash costs: $0.27 per vehicle mile
- Total: $0.53 per vehicle mile
Full Cost Model

Marginal external waiting benefit

- $MEWB = - \frac{\delta WT}{\delta Q} \times X \times VOWT$

- $WT \propto \frac{1}{Freq}$

- $Freq = \frac{Q}{NL}$

- $WT = 2.0 \text{ minutes} + 0.3 \times \text{headway}$
## Estimates for Example Systems

<table>
<thead>
<tr>
<th>Transit Agency</th>
<th>Route miles</th>
<th>Average headway (hours)</th>
<th>Vehicle miles (thousand)</th>
<th>Returns to Density</th>
<th>Avg. cost</th>
<th>Internal Marginal Cost</th>
<th>External marginal cost</th>
<th>Marginal external waiting benefit</th>
<th>Total social marginal cost</th>
<th>Required subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fond du Lac, WI</td>
<td>60</td>
<td>1.17</td>
<td>160</td>
<td>1.83</td>
<td>5.94</td>
<td>3.25</td>
<td>0.53</td>
<td>0.77</td>
<td>3.01</td>
<td>2.93</td>
</tr>
<tr>
<td>Middletown, OH</td>
<td>59</td>
<td>1.02</td>
<td>205</td>
<td>1.70</td>
<td>3.48</td>
<td>2.04</td>
<td>0.53</td>
<td>0.72</td>
<td>1.85</td>
<td>1.63</td>
</tr>
<tr>
<td>Cheyenne, WY</td>
<td>107</td>
<td>1.10</td>
<td>367</td>
<td>1.47</td>
<td>2.54</td>
<td>1.73</td>
<td>0.53</td>
<td>0.35</td>
<td>1.91</td>
<td>0.63</td>
</tr>
<tr>
<td>Grand Forks, ND</td>
<td>80</td>
<td>1.08</td>
<td>382</td>
<td>1.46</td>
<td>3.91</td>
<td>2.69</td>
<td>0.53</td>
<td>0.46</td>
<td>2.75</td>
<td>1.16</td>
</tr>
<tr>
<td>Rome, GA</td>
<td>328</td>
<td>2.28</td>
<td>451</td>
<td>1.40</td>
<td>5.11</td>
<td>3.64</td>
<td>0.53</td>
<td>0.82</td>
<td>3.36</td>
<td>1.75</td>
</tr>
<tr>
<td>Billings, MT</td>
<td>181</td>
<td>1.17</td>
<td>555</td>
<td>1.34</td>
<td>5.37</td>
<td>4.00</td>
<td>0.53</td>
<td>0.41</td>
<td>4.13</td>
<td>1.24</td>
</tr>
<tr>
<td>Waterloo, IA</td>
<td>118</td>
<td>0.81</td>
<td>580</td>
<td>1.33</td>
<td>3.90</td>
<td>2.94</td>
<td>0.53</td>
<td>0.22</td>
<td>3.25</td>
<td>0.65</td>
</tr>
<tr>
<td>Davis, CA</td>
<td>81</td>
<td>0.59</td>
<td>719</td>
<td>1.27</td>
<td>5.35</td>
<td>4.21</td>
<td>0.53</td>
<td>0.62</td>
<td>4.12</td>
<td>1.23</td>
</tr>
<tr>
<td>Sioux Falls, SD</td>
<td>195</td>
<td>1.24</td>
<td>719</td>
<td>1.27</td>
<td>4.64</td>
<td>3.66</td>
<td>0.53</td>
<td>0.41</td>
<td>3.78</td>
<td>0.87</td>
</tr>
<tr>
<td>Odessa, TX</td>
<td>203</td>
<td>1.13</td>
<td>721</td>
<td>1.27</td>
<td>2.95</td>
<td>2.33</td>
<td>0.53</td>
<td>0.16</td>
<td>2.70</td>
<td>0.26</td>
</tr>
<tr>
<td>Santa Fe, NM</td>
<td>124</td>
<td>0.73</td>
<td>942</td>
<td>1.20</td>
<td>4.01</td>
<td>3.33</td>
<td>0.53</td>
<td>0.13</td>
<td>3.73</td>
<td>0.28</td>
</tr>
<tr>
<td>Wilmington, NC</td>
<td>138</td>
<td>0.49</td>
<td>1,443</td>
<td>1.11</td>
<td>3.24</td>
<td>2.92</td>
<td>0.53</td>
<td>0.08</td>
<td>3.37</td>
<td>-0.12</td>
</tr>
<tr>
<td>58-system Average</td>
<td>117</td>
<td>1.05</td>
<td>490</td>
<td>1.45</td>
<td>4.39</td>
<td>3.11</td>
<td>0.53</td>
<td>0.63</td>
<td>3.01</td>
<td>1.39</td>
</tr>
</tbody>
</table>
Additional considerations

- External costs of automobile travel and second-best pricing
- Economic benefits of improving mobility
- Distortionary effects of subsidies
Conclusions

• Close to half of transit agencies in small urban areas have either reduced service or increased fares over the last two years.
• The main reason for these actions has been a decrease in funding.
• Economies of scale and economies of density are found to exist for small urban transit systems, providing rationale for subsidies.
QUESTIONS?