Background

Purpose

- Update and refine the 1998 ridership forecasting model
- Apply ridership forecasting model in multi-year budget and planning analysis
- Identify regional and system factors influencing ridership
  - Since June 2000, there have been changes that have impacted both ridership and revenue
    - system expansion
    - fare changes
    - socioeconomic development
    - gas prices

Background

Update Process

- Perform a backcasting exercise to assess how well the existing model would have predicted ridership and revenue from 2002 to 2008
- Review previous model and assess the feasibility, utility, and advisability of adding or removing variables
- Assess the feasibility of adding more submarkets (e.g., weekday versus weekend)
- Estimate revised model(s)
- Add an uncertainty analysis component to the revised model(s)
Presentation Outline

- Background
- Model Updates
- Findings
- Model Application
- Uncertainty Analysis

Model Updates
Peer Review

- TCRP Synthesis 66: 36 agencies surveyed, primarily use qualitative techniques relying on professional judgments

<table>
<thead>
<tr>
<th>Forecasting Technique</th>
<th>Number of Agencies Responding</th>
<th>Agencies Responding (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Judgment</td>
<td>29</td>
<td>83</td>
</tr>
<tr>
<td>Rules of Thumb/Similar Routes</td>
<td>28</td>
<td>80</td>
</tr>
<tr>
<td>Service Elasticities</td>
<td>22</td>
<td>63</td>
</tr>
<tr>
<td>Four-Step Travel Demand Model</td>
<td>18</td>
<td>51</td>
</tr>
<tr>
<td>Econometric Model</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Regression Analysis</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>20</td>
</tr>
</tbody>
</table>

Surveyed
- Bay Area Rapid Transit
- Chicago Transit Authority
- Los Angeles County MTA
- MTA New York City
Model Updates
Variables Tested

Several types of variables were considered as determinants of Metrorail and Metrobus

- Demographic
  - Population and Employment
- Tourism
  - Hotel Rooms Sold, Smithsonian Visitors
- Service Related
  - Fare, Service Hours, Parking Supply
- Special
  - Gas Price, Weather, Events
- Seasonal and Month

Model Updates
Model Estimation

Four monthly time-series regression models were developed

- Metrorail (Weekday)
- Metrorail (Weekend)
- Metrobus (Weekday)
- Metrobus (Weekend)

All models were developed by testing many of the variables in a variety of functional forms

Advanced statistical evaluation criteria and tests were used

The final specifications are simple linear regression models
Model Updates
Metrorail (Weekday)

Metrorail Weekday Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-9.104</td>
<td>-3.32</td>
</tr>
<tr>
<td>Natural Log of D.C. Employment</td>
<td>2.057</td>
<td>4.87</td>
</tr>
<tr>
<td>Natural Log of Hotel Rooms Sold</td>
<td>0.159</td>
<td>8.56</td>
</tr>
<tr>
<td>Natural Log of Gas Prices (lagged)</td>
<td>0.061</td>
<td>2.37</td>
</tr>
<tr>
<td>Natural Log of Metrorail Fare (lagged)</td>
<td>-0.117</td>
<td>-1.27</td>
</tr>
<tr>
<td>Severe Weather</td>
<td>-0.040</td>
<td>-3.37</td>
</tr>
<tr>
<td>July</td>
<td>0.046</td>
<td>4.70</td>
</tr>
<tr>
<td>June</td>
<td>0.048</td>
<td>5.23</td>
</tr>
<tr>
<td>December</td>
<td>-0.046</td>
<td>-4.45</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-Square</td>
<td>0.925</td>
<td></td>
</tr>
</tbody>
</table>

Number of Observations: 71
RMSE: 0.02
Adjusted R-Square: 0.925

Model Updates
Metrorail (Weekday)

Metrorail Weekday Observed vs. Estimated

Month

Metrorail Ridership (in Millions)
Model Updates
Metrorail (Weekend)

Metrorail Weekend Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-64.285</td>
<td>-12.95</td>
</tr>
<tr>
<td>Natural Log of D.C. Population</td>
<td>9.846</td>
<td>12.5</td>
</tr>
<tr>
<td>Natural Log of Hotel Rooms Sold</td>
<td>0.555</td>
<td>12.08</td>
</tr>
<tr>
<td>Weekend Snowstorm</td>
<td>-0.219</td>
<td>-4.36</td>
</tr>
<tr>
<td>July</td>
<td>0.106</td>
<td>4.77</td>
</tr>
<tr>
<td>October</td>
<td>0.059</td>
<td>2.57</td>
</tr>
<tr>
<td>January</td>
<td>-0.057</td>
<td>-2.42</td>
</tr>
<tr>
<td>April</td>
<td>0.112</td>
<td>4.91</td>
</tr>
<tr>
<td>June</td>
<td>0.075</td>
<td>3.27</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>0.048</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-Square</td>
<td>0.918</td>
<td></td>
</tr>
</tbody>
</table>

Model Updates
Metrorail (Weekend)

Metrorail Weekend Observed vs. Estimated

![Metrorail Ridership (in Millions)](chart)

- **Observed**
- **Estimated**

Month:
- Jul-02
- Oct-02
- Jan-03
- Apr-03
- Jul-03
- Oct-03
- Jan-04
- Apr-04
- Jul-04
- Oct-04
- Jan-05
- Apr-05
- Jul-05
- Oct-05
- Jan-06
- Apr-06
- Jul-06
- Oct-06
- Jan-07
- Apr-07
- Jul-07
- Oct-07
- Jan-08
- Apr-08
- Jul-08
- Oct-08
- Jan-09
- Apr-09

Ridership (in Millions):
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
Model Updates
Metrobus (Weekday)

Metrobus Weekday Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.262</td>
<td>0.13</td>
</tr>
<tr>
<td>Natural Log of D.C. Employment</td>
<td>0.893</td>
<td>2.99</td>
</tr>
<tr>
<td>September</td>
<td>0.036</td>
<td>3.03</td>
</tr>
<tr>
<td>October</td>
<td>0.036</td>
<td>3.1</td>
</tr>
<tr>
<td>December</td>
<td>-0.089</td>
<td>-7.65</td>
</tr>
<tr>
<td>January</td>
<td>-0.039</td>
<td>-3.38</td>
</tr>
<tr>
<td>February</td>
<td>-0.065</td>
<td>-5.63</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-Square</td>
<td>0.737</td>
<td></td>
</tr>
</tbody>
</table>

Model Updates
Metrobus (Weekday)

Metrobus Weekday Observed vs. Estimated

[Graph showing Metrobus Ridership (in Millions) over time, with observed and estimated data points.]
Model Updates
Metrobus (Weekend)

Metrobus Weekend Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-4.846</td>
<td>-1.39</td>
</tr>
<tr>
<td>Natural Log of Smithsonian Visitation</td>
<td>0.068</td>
<td>4.97</td>
</tr>
<tr>
<td>Natural Log of Metrobus Fare (lagged)</td>
<td>-0.241</td>
<td>-2.41</td>
</tr>
<tr>
<td>Natural Log of D.C. Population</td>
<td>2.572</td>
<td>2.9</td>
</tr>
<tr>
<td>Presidential Inauguration</td>
<td>-0.152</td>
<td>-5.34</td>
</tr>
<tr>
<td>July</td>
<td>0.031</td>
<td>1.66</td>
</tr>
<tr>
<td>August</td>
<td>0.042</td>
<td>2.48</td>
</tr>
<tr>
<td>September</td>
<td>0.088</td>
<td>5.45</td>
</tr>
<tr>
<td>October</td>
<td>0.068</td>
<td>4.86</td>
</tr>
<tr>
<td>May</td>
<td>0.042</td>
<td>2.66</td>
</tr>
<tr>
<td>June</td>
<td>0.050</td>
<td>3.23</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-Square</td>
<td>0.854</td>
<td></td>
</tr>
</tbody>
</table>

Model Updates
Metrobus (Weekend)

Metrobus Weekend Observed vs. Estimated

![Metrobus Ridership (in Millions)](image)

- Observed
- Estimated

Month

Number of Observations: 45
RMSE: 0.026
Adjusted R-Square: 0.854
Presentation Outline

- Background
- Model Updates
- Findings
- Model Application
- Uncertainty Analysis

Findings
Model Validity and Fit

- Model fit as measured by R-squared indicate:
  - Metrorail models have a high degree of fit
  - Metrobus models have an adequate degree of fit

- Mean absolute percentage error (MAPE) of the models (comparison of observed and model-predicted ridership for the model estimation periods) are in the same range as the previous modeling effort
  - Metrorail: 1.91% (previous model 1.46%)
  - Metrobus: 1.49% (previous model 1.95%)

- As noted in the previous model documentation, these ranges appear to be similar to other models, but not within the more-desirable 1.00%.
Findings
Key Factors Impacting Ridership

- **Employment and population** are the determinants of transit ridership
  - Employment drives weekday ridership
  - Population drives weekend ridership

- **Tourism** strongly influences ridership
  - Hotel Rooms Sold is a new variable influencing Metrorail ridership
  - Smithsonian Visitation remains a good indicator

- **Other variables**
  - Service Variables - Fare, Parking Supply
  - Special Variables - Gas Price, Weather, Events
  - Seasonal and Month

Findings
Impacts of Previous Fare Changes

- **Difficult to isolate the effects of fare changes from other independent variables in the models because:**
  - High level of correlation between fares and other variables
  - Very few fare changes in the estimation period

- **Model specifications that include fare variables indicate a reasonable range of fare elasticities (percent change in ridership due to a one percent change in fare):**
  - Metrorail fare elasticity: -0.12 to -0.18
  - Metrobus fare elasticity: -0.2 to -0.26

- **Recent similar modeling efforts in similar cities have had rail fare elasticities in the -0.10 to -0.20 range and bus fare elasticities in the -0.20 to -0.43 range**
Findings
Impacts of Gasoline Price Changes

- Gas price changes had a small effect on WMATA ridership during the model estimation period
- Weekday model specifications that include gas prices indicate a reasonable range of gas price elasticities (percent change in ridership due to a one percent change in gas price)
  - Metrorail weekday gas price elasticity: +0.04 to +0.07
  - Metrobus weekday gas price elasticity: +0.05 to +0.07
- Weekend ridership did not appear to be related to gas prices
- Recent similar modeling efforts in similar cities have had gas price elasticities in the +0.05 to +0.15 range

Presentation Outline

- Background
- Updates for this version
- Findings
  - Model Application
- Uncertainty Analysis
Model Application
Results Tab

Presentation Outline

- Background
- Model Updates
- Findings
- Model Application
- Uncertainty Analysis
Uncertainty Analysis

- Selected Oracle’s Crystal Ball Excel add-on
- Provides a way to test the reliability of model predictions and explore alternative scenarios
- Avoids single point estimates of future values of input variables; permits specification and selection of distributions for each input variable
- Useful for looking at range of possible forecasts where more than one input variable is involved
- Provides the probability of each outcome and the relative contribution of each input to that outcome
Uncertainty Analysis
Crystal Ball Inputs

Uncertainty Analysis
Crystal Ball Toolbar, Control Panel, and Forecast View
Uncertainty Analysis
Crystal Ball Report Output – Introduction Section

Uncertainty Analysis
Crystal Ball Report Output – Assumptions Section
Contact Info

- Wendy Jia, Project Manager
  wjia@wmata.com
  Washington Metropolitan Area Transit Authority

- Jay Evans, Kevin Tierney and Pramoda Gode
  jevans@camsys.com
  ktierney@camsys.com
  pgode@camsys.com
  Cambridge Systematics, Inc