Estimating Ridership of Rural Public Demand-Response Transit

Wednesday, November 16, 2016
Jeremy Mattson

• Associate Research Fellow, Small Urban and Rural Transit Center, Upper Great Plains Transportation Institute, North Dakota State University

• B.A. Economics and Business Management; M.S. Agricultural Economics; pursuing Transportation and Logistics Ph.D.

• Recent Research Activities:
  – Rural Transit Fact Book
  – Rural Intercity Transportation Demand
  – Aging and Mobility
  – Mobility Management and Human Service Transportation Coordination
  – Alternative Fuels and Hybrid Buses
  – Transit, Technology, and Public Participation
  – Marginal Cost Pricing and Subsidy of Transit
  – Transportation and Access to Health Care
1. What best describes your agency/organization/company?
   - Rural, small urban, or tribal transit provider
   - County or regional planning organization
   - State agency
   - Consultant
   - Other

2. What best describes your position at your agency/organization/company?
   - Transit Manager
   - Planner
   - State Program or RTAP Manager
   - Researcher
   - Other
Estimating Ridership of Rural Demand-Response Transit Services for the General Public

National RTAP Webinar
November 16, 2016

Jeremy Mattson
Small Urban and Rural Transit Center
Upper Great Plains Transportation Institute
North Dakota State University
Objective

Develop a model for estimating demand for rural demand-response transit services for the general public
Specific objectives

Estimate impacts of service characteristics
- Span of service
- Service coverage
- Fares
- Reservation requirements

Estimate impacts of service area characteristics
- Population
- Demographics
Previous Demand Models

**TCRP Report 161: Methods for Forecasting Demand and Quantifying Need for Rural Passenger Transportation**

- General public rural passenger transportation
- Passenger transportation specifically related to social services or other programs
- Fixed-route transit in micropolitan areas
- Commuter services from rural counties to urban centers

**ADA Paratransit Research**

TCRP Report 161: Demand for rural general public, non-program-related service

• Two methods
  – Peer data
    • Passenger trips per capita, passenger trips per vehicle mile, passenger trips per vehicle hour
    • Calculate mean, median, and ranges for systems in similar settings
  – Demand function developed based on 2009 rural NTD data
    • Based on the assumption that older adults, people with mobility limitations, and people without access to a vehicle represent the main users of these services

\[
\text{Non-program Demand (trips per year)} = (2.20 \times \text{Population Age 60+}) + (5.21 \times \text{Mobility Limited Population Age 18-64}) + (1.52 \times \text{Residents of Household Having No Vehicle})
\]
Demand for program trips

= 
Number of Program Participants
×
Program Events per Week
×
the Proportion of Program Participants who attend the Program on an Average Day
×
the Proportion of Program Participants that are Transit Dependent or Likely to Use the Transit Service provided/funded by the Agency
×
the Number of Weeks per Year the Program is Offered
×
2 (trips per participant per event)
TCRP Report 161: Demand for small-city fixed-route service

Unlinked passenger-trips = 5.77 × Revenue-hours of Service + 1.07 × Population + 7.12 × College/University Enrollment

Conditions of application: Population of urban center < 50,000. Does not include community college enrollment.
Commuter trips by transit from County to Urban Center per Day = 
Proportion Using Transit for Commuter Trips from Rural County to Urban Place × Number of Commuters × 2

Proportion Using Transit for Commuter Trips from Rural County to Urban Place = 0.024 + (0.0000056 × Workers Commuting from Rural County to Urban Place) - (0.00029 × Distance in Miles from Rural County to Urban Place) + 0.015 (if the Urban Place is a state capital)
ADA Paratransit Demand

• TCRP 119 provides a tool based on the following variables
  – Service area population
  – Base fare
  – Percentage of applicants for found conditionally eligible
  – Whether or not trip-by-trip eligibility determination based on conditions of eligibility is used
  – Percentage of service area population with household incomes below poverty line
  – Effective window used to determine on-time performance
• TCRP 158: More advanced regional planning model
• Goodwill and Joslin
  – Forecasted demand for transportation-disadvantaged services
  – Method used trip rates from the 2009 NHTS
Factors Affecting Ridership

• Demand for the service
  – Population
  – Demographics

• Level of service provided/Service characteristics
  – Days per week
  – Hours per day
  – Advance reservation requirements
  – Both demand-response and fixed-route?
  – Overlap in service area?
  – Regional or cultural differences, tribal transit?

• Cost of the service
Population and Demand-Response Transit Ridership
Models

• Two models
• Data sources
  – Model #1
    • Rural National Transit Database, 2013
    • American Community Survey (ACS) 2009-2013 5-year estimates
  – Model #2
    • Survey of rural transit agencies
Model #1

- Ridership is determined by:
  - Demand factors
    - Service area population
    - Demographic characteristics of service area
      - Percentage older adult (65 or older)
      - Percentage of households without vehicle
      - Percentage with a disability
  - Service characteristics
    - Operates both fixed-route and demand-response
    - Service area overlaps
    - Serves only a municipality
  - Fare level
  - Other
    - Tribal transit
    - Region
- Data for 731 agencies for 2013
Model #1

\[ \ln R_i = a_1 \ln POP_i + a_2 PELD_i + a_3 PNV_i + a_4 PDIS_i + a_5 FIXRT_i + a_6 POVR_i + a_7 MUNI_i + a_8 TRIBE_i + a_9 \ln FARE_i + a_{10} R1_i + a_{11} R2_i + a_{12} R3_i + a_{13} R4_i + a_{14} R5_i + a_{15} R6_i + a_{16} R7_i + a_{17} R8_i + a_{18} R9_i + e_i \]

where

\( R_i \) = demand-response ridership for transit agency \( i \)

\( POP_i \) = service area population for agency \( i \)

\( PELD_i \) = percentage of service area population for agency \( i \) that is elderly, defined as aged 65 or older

\( PNV_i \) = percentage of service area households for agency \( i \) without access to a vehicle

\( PDIS_i \) = percentage of service area population for agency \( i \) with a disability

\( FIXRT_i \) = a dummy variable equal to 1 if agency \( i \) also operates fixed-route service, 0 otherwise

\( POVR_i \) = percentage of service area population for agency \( i \) that also has access to another demand-response provider

\( MUNI_i \) = a dummy variable equal to 1 if agency \( i \) strictly serves a municipality, 0 if agency serves larger geographic area

\( TRIBE_i \) = a dummy variable equal to 1 if agency \( i \) is a tribal transit operator, 0 otherwise

\( FARE_i \) = fare level for agency \( i \)

\( R1_i \ldots R9_i \) = dummy variables for FTA regions 1 through 9
### Summary Statistics for Model #1 Variables

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger trips</td>
<td>26,344</td>
<td>14,976</td>
<td>31,758</td>
<td>180</td>
<td>180,983</td>
</tr>
<tr>
<td>Population</td>
<td>30,448</td>
<td>24,609</td>
<td>24,619</td>
<td>204</td>
<td>100,000</td>
</tr>
<tr>
<td>Percentage elderly</td>
<td>0.17</td>
<td>0.16</td>
<td>0.04</td>
<td>0.06</td>
<td>0.30</td>
</tr>
<tr>
<td>Percentage no vehicle</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0</td>
<td>0.11</td>
</tr>
<tr>
<td>Percentage disability</td>
<td>0.15</td>
<td>0.14</td>
<td>0.04</td>
<td>0.04</td>
<td>0.32</td>
</tr>
<tr>
<td>Fixed route</td>
<td>0.20</td>
<td>0</td>
<td>0.40</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Percentage overlap</td>
<td>0.23</td>
<td>0</td>
<td>0.41</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Municipality</td>
<td>0.16</td>
<td>0</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Tribal</td>
<td>0.01</td>
<td>0</td>
<td>0.12</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fare</td>
<td>1.24</td>
<td>0.90</td>
<td>2.41</td>
<td>0</td>
<td>25.89</td>
</tr>
</tbody>
</table>
Limitations of Rural NTD Data

• Incomplete and imprecise service area information
• No data:
  – Hours per day
  – Days per week
  – Advance reservation requirements
  – Type of service provided
Survey of Transit Agencies

- Previous study conducted in North Dakota and Florida
Survey of Transit Agencies

• Collected detailed information
  – Geographic service area
  – Span of service
  – Advance reservation requirements
  – Service eligibility and type
• Additional surveys conducted nationwide
• Data collected for 68 rural demand-response transit agencies
Model #2

- Ridership is determined by:
  - Service area population
  - Hours of service per day
  - Days of service per week
  - Advance reservation time
  - Operates both fixed-route and demand response
  - Fare level
Model #2

\[ \ln R_i = b_1 \ln POP_i + b_2 PctDays6_i + b_3 PctDays5_i + b_4 PctHrs12_i + b_5 PctHrs5_i + b_6 RES1_i + b_7 RES2_i + b_8 FIXRT_i + b_9 \ln FARE_i + e_i \]

where

\( R_i \) = demand-response ridership for transit agency \( i \)

\( POP_i \) = service area population for agency \( i \)

\( PctDays6_i \) = percentage of service area population for agency \( i \) that receives service 6 or 7 days per week

\( PctDays5_i \) = percentage of service area population for agency \( i \) that receives service 5 days per week

\( PctHrs12_i \) = percentage of service area population for agency \( i \) that receives service 12 or more hours per service day

\( PctHrs5_i \) = percentage of service area population for agency \( i \) that receives service less than 5 hours per service day

\( RES1_i \) = a dummy variable equal to 1 if agency \( i \) allows users to reserve same-day rides

\( RES1_i \) = a dummy variable equal to 1 if agency \( i \) requires users to reserve rides at least one-day in advance

\( FIXRT_i \) = a dummy variable equal to 1 if agency \( i \) also operates fixed-route service, 0 otherwise

\( FARE_i \) = fare level for agency \( i \)
## Summary Statistics for Model #2 Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger trips</td>
<td>31,103</td>
<td>19,490</td>
<td>45,351</td>
<td>63</td>
<td>343,937</td>
</tr>
<tr>
<td>Population</td>
<td>41,302</td>
<td>24,666</td>
<td>48,245</td>
<td>1,119</td>
<td>177,453</td>
</tr>
<tr>
<td>Percentage with 6 or 7 days</td>
<td>0.29</td>
<td>0</td>
<td>0.43</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Percentage with 5 days</td>
<td>0.62</td>
<td>1.00</td>
<td>0.45</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Percentage with 12 or more hours</td>
<td>0.34</td>
<td>0</td>
<td>0.45</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Percentage with less than 5 hours</td>
<td>0.03</td>
<td>0</td>
<td>0.14</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Same-day reservation</td>
<td>0.43</td>
<td>0</td>
<td>0.50</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Prior-day reservation</td>
<td>0.49</td>
<td>0</td>
<td>0.50</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Fixed-route</td>
<td>0.25</td>
<td>0</td>
<td>0.47</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>Fare</td>
<td>1.54</td>
<td>1.19</td>
<td>1.27</td>
<td>0</td>
<td>6.46</td>
</tr>
</tbody>
</table>
## Results: Model #1

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Estimated coefficient</th>
<th>Standard error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(Population)</td>
<td>0.83</td>
<td>0.02</td>
<td>0.000</td>
</tr>
<tr>
<td>Percentage elderly</td>
<td>7.99</td>
<td>0.99</td>
<td>0.000</td>
</tr>
<tr>
<td>Percentage with no vehicle</td>
<td>21.15</td>
<td>5.65</td>
<td>0.000</td>
</tr>
<tr>
<td>Percentage with disability</td>
<td>-0.46</td>
<td>1.20</td>
<td>0.703</td>
</tr>
<tr>
<td>Fixed-route</td>
<td>-0.65</td>
<td>0.11</td>
<td>0.000</td>
</tr>
<tr>
<td>Percentage overlap</td>
<td>-0.41</td>
<td>0.10</td>
<td>0.000</td>
</tr>
<tr>
<td>Municipality</td>
<td>0.77</td>
<td>0.10</td>
<td>0.000</td>
</tr>
<tr>
<td>Tribal</td>
<td>0.30</td>
<td>0.31</td>
<td>0.333</td>
</tr>
<tr>
<td>Ln(Fare)</td>
<td>-0.24</td>
<td>0.04</td>
<td>0.000</td>
</tr>
<tr>
<td>Region 1</td>
<td>-0.60</td>
<td>0.33</td>
<td>0.071</td>
</tr>
<tr>
<td>Region 2</td>
<td>-0.57</td>
<td>0.42</td>
<td>0.170</td>
</tr>
<tr>
<td>Region 3</td>
<td>-0.56</td>
<td>0.25</td>
<td>0.027</td>
</tr>
<tr>
<td>Region 4</td>
<td>-0.81</td>
<td>0.19</td>
<td>0.000</td>
</tr>
<tr>
<td>Region 5</td>
<td>0.50</td>
<td>0.20</td>
<td>0.012</td>
</tr>
<tr>
<td>Region 6</td>
<td>-0.15</td>
<td>0.22</td>
<td>0.480</td>
</tr>
<tr>
<td>Region 7</td>
<td>-0.36</td>
<td>0.19</td>
<td>0.057</td>
</tr>
<tr>
<td>Region 8</td>
<td>0.09</td>
<td>0.19</td>
<td>0.628</td>
</tr>
<tr>
<td>Region 9</td>
<td>0.16</td>
<td>0.25</td>
<td>0.523</td>
</tr>
</tbody>
</table>
Results: Model #1

• **Population** has a positive effect on ridership.
  – A 1% increase in population leads to a 0.83% increase in ridership.

• **Demographics** impact ridership.
  – Areas with a higher percentage of older adults or households without access to a vehicle have higher levels of ridership.
  – If the percentage of the population that is aged 65 or older increases by one percentage point, ridership increases by 8%.
  – If the percentage of the population that lives in a household without a vehicle increases by one percentage point, ridership increases by 21%.
Results: Model #1

• Agencies that provide both fixed-route and demand-response service have lower levels of demand-response ridership than agencies that provide just demand-response service, after accounting for all other variables.

• Agencies that serve areas where more than one transit provider is available have lower levels of ridership.

• Demand-response providers that strictly serve a municipality have higher levels of ridership than those serving a larger geographic area, after accounting for population and other factors.
Results: Model #1

- **Fares** have a negative impact on ridership. A 1% increase in fares leads to a 0.24% reduction in ridership.
- There are some **regional differences** in ridership not accounted for by these variables. Notably, region 5 agencies have higher levels of ridership, and agencies in regions 3 and 4 have lower levels.
Out-of-Sample Validation

- Results from the model were used to predict ridership for 2014
- Predicted ridership was compared to actual ridership

<table>
<thead>
<tr>
<th>Population under 100,000 (n=688)</th>
<th>Model #1</th>
<th>TCRP 161 Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>55,579</td>
<td>73,941</td>
</tr>
<tr>
<td>MAE</td>
<td>23,506</td>
<td>28,669</td>
</tr>
<tr>
<td>Population under 50,000 (n=544)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMSE</td>
<td>48,231</td>
<td>71,439</td>
</tr>
<tr>
<td>MAE</td>
<td>19,536</td>
<td>26,027</td>
</tr>
</tbody>
</table>
## Results: Model #2

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Estimated coefficient</th>
<th>Standard error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(Population)</td>
<td>0.69</td>
<td>0.07</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Percentage population with 6 or 7 days</td>
<td>1.65</td>
<td>0.80</td>
<td>0.0439</td>
</tr>
<tr>
<td>Percentage population with 5 days</td>
<td>1.41</td>
<td>0.69</td>
<td>0.046</td>
</tr>
<tr>
<td>Percentage population with 12 or more hours</td>
<td>0.50</td>
<td>0.43</td>
<td>0.2545</td>
</tr>
<tr>
<td>Percentage population with less than 5 hours</td>
<td>-0.40</td>
<td>1.20</td>
<td>0.7397</td>
</tr>
<tr>
<td>Same-day reservation</td>
<td>2.01</td>
<td>0.55</td>
<td>0.0006</td>
</tr>
<tr>
<td>Prior-day reservation</td>
<td>1.24</td>
<td>0.56</td>
<td>0.0321</td>
</tr>
<tr>
<td>Fixed-route</td>
<td>-0.65</td>
<td>0.39</td>
<td>0.1013</td>
</tr>
<tr>
<td>Ln(Fare)</td>
<td>-0.12</td>
<td>0.07</td>
<td>0.0843</td>
</tr>
</tbody>
</table>
Results: Model #2

- **Population** has a positive effect on ridership.
  - A 1% increase in population leads to a 0.69% increase in ridership.

- **Ridership is impacted by the number of days that service is available.**
  - As the percentage of service area population with service 5 days per week increases by one percentage point, ridership increases 1.41%.
  - Ridership increases 1.65% as the percentage of service area population with service 6 or 7 days per week increases by one percentage point.
Results: Model #2

• **Advance reservation time** has a negative impact on ridership.
  – Compared to agencies that require reservation two or more days in advance, ridership is 124% higher for providers that require reservation one day in advance and 201% higher for agencies that allow same-day service.

• Agencies that provide both fixed-route and demand-response service have lower levels of demand-response ridership than agencies that provide just demand-response service, after accounting for all other variables.

• **Fares** have a negative impact on ridership.
  – A 1% increase in fares leads to a 0.12% reduction in ridership.
Applications

• Forecast demand for new service
• Estimate the impact of service changes
  – Geographic coverage
  – Span of service
  – Fares
  – Reservation requirements
• Project future ridership based on population and demographic changes
Applying Model #1: The Formula

Natural log of ridership =
0.83 × natural log of population
+ 7.99 × percentage of population aged 65 or older
+ 21.15 × percentage of population without access to a vehicle
- 0.65 if the agency also operates a fixed-route service
- 0.41 × percentage of population that has access to other demand-response service
+ 0.77 if the agency operates strictly within a municipality
- 0.24 × natural log of the fare
- 0.56 if agency operates in FTA region 3
- 0.81 if agency operates in FTA region 4
+ 0.50 if agency operates in FTA region 5
Applying Model #1: The Data

- Demographic data from the ACS
- U.S. Census Bureau’s American Fact Finder: [www.factfinder.census.gov](http://www.factfinder.census.gov)

<table>
<thead>
<tr>
<th>Variable</th>
<th>ACS Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>B01001</td>
</tr>
<tr>
<td>Population aged 65 or older</td>
<td>B01001</td>
</tr>
<tr>
<td>Population without access to a vehicle</td>
<td>B08014</td>
</tr>
<tr>
<td>Population with a disability</td>
<td>B18101</td>
</tr>
</tbody>
</table>
Applying Model #1: Calculations

• Natural log of population and fares
• A number can be converted to its natural log in Excel using the following formula:
  \[ =\text{LN(number)} \]
• Percentages of populations of older adults and households without vehicles must be calculated and represented as decimal numbers ranging from 0-1
• The resulting calculation is the estimate for the natural log of ridership
  – The natural log of ridership can be converted to actual ridership using the following formula in Excel:
  \[ =\text{EXP(number)} \]
Applying Model #2: The Formula

Natural log of ridership =
0.69 × natural log of population
+ 1.65 × percentage of population with service 6 or 7 days per week
+ 1.41 × percentage of population with service 5 days per week
+ 2.01 if agency allows same-day reservations
+ 1.24 if agency requires reservations made one day in advance
- 0.65 if agency operates fixed-route service
- 0.12 × natural log of fare
Applying Model #2: The Data and Calculations

• Population data from the American Fact Finder
  – Counties, county subdivisions, cities, census tracts, block groups
• Need to estimate percentages of service area population receiving service 6+ days per week and 5 days per week
• Resulting calculation is an estimate of the natural log of ridership
Conclusions

• Existing demand models have a limited set of variables
• Two models developed
  – 2013 rural NTD data
  – Detailed service data collected by survey of agencies
• A number of factors affect ridership
• Improvement over previous models
Conclusions

• **Demographic characteristics** are important
  – Older adults
  – People without access to a vehicle

• **Geographic characteristics** of service are important

• **Fare elasticity** estimated at -0.12 to -0.24

• **Availability of service/quality of service** impacts ridership
  – Agencies providing more days of service had higher levels of service
  – Advance reservation time is important
Conclusions

• Two new tools for estimating ridership
• Identify high-productivity systems
• A greater number of variables and more specific service information improves the performance
• Limited by data availability
• Many factors specific to each agency and community not captured by the model
Thank you!

Questions?

jeremy.w.mattson@ndsu.edu

www.surtc.org
Thank you!

National RTAP
888-589-6821
info@nationalrtap.org
nationalrtap.org
facebook.com/nationalrtap

Recording will be available at nationalrtap.org/webinars; transcripts available upon request

Liz Taylor
Senior Project Manager
etaylor@nationalrtap.org

3rd National RTAP Technical Assistance Conference
Oct 29-Nov 1, 2017
Omaha, Nebraska
nationalrtap.org/conference2017