MODELLING USAGE RATE OF DRT SERVICE:
DISCRETE CHOICE MODEL WITH LATENT VARIABLES

Presentation prepared for TDM Symposium 2008, Vienna

John D Nelson
Professor of Transport Studies,
Centre for Transport Research,
School of Geosciences, University of Aberdeen

Structure

- Motivation
- Background and Case Study
- Assumptions and Hypothesis
- Modelling System
- Interpretation of Results
Motivation

- Many existing DRT services
  - Important role to improve social inclusion and accessibility
  - Still not performing to their true potential
  - Could not be viable as commercial services
- Key suggestion from previous research
  - Need to understand the passenger requirements further

Demand Responsive Transport (DRT)

- DRT is an intermediate form, somewhere between bus and taxi.
- Four composite case types (INTERMODE - Enoch et al., 2004)
  1. Interchange DRT
  2. Network DRT
  3. Destination-specific DRT
  4. Substitute DRT
UCall and LinkUp Service in Tyne and Wear

- Extended operation area
- More flexibility
  - Semi-fixed route with fixed timing point
  - Predefined area with fixed timing point
- More complexity
- Managing and dispatching

LinkUp Service Area

Interchange DRT
Network DRT
**UCall and LinkUp Vehicles**

UCall (Optare Alero on average 14 seats)

LinkUp (Optare Solo on average 24 seats)

Photos by NEXUS

---

**LinkUp Travel Dispatch Centre (TDC)**

Photo by NEXUS
Assumption and Hypothesis

- Each passenger has an underlying utility for using LinkUp.
- The utility is influenced by a passenger’s
  - Characteristics (PC)
  - Attitudes and perceptions towards the LinkUp (three latent variables, 3LV)
- Usage rate model is represented by the utility: $U = f(\text{PC}, 3\text{LV})$

Modelling Framework

- Characteristics of LinkUp Passenger, $X$
- Observed Choice: Usage Rate of LinkUp service, $d$
- Utility, $U$
- Indicators of Awareness, $I_A$
- Indicators of Satisfaction, $I_S$
- Indicators of Relative Advantage, $I_R$
- Latent Variable Models (MIMIC models)

Discrete Choice Model (Ordered Probit Model)
**Indicators of Awareness**

- All the places where the service runs
- What to do to use the service
- Where people are picked up and dropped off
- The days and times that the service operates
- Overall, how to use the service

*Don’t know at all* .......................................................... *Know very well*

1  2  3  4  5

**Indicators of Satisfaction**

- Walking distance (to and from the service)
- Vehicle time keeping at the pick up and drop off points
- Journey time
- Overall, making a booking
- Overall satisfaction with the service

*Extremely dissatisfied* ...................................................... *Extremely satisfied*

1  2  3  4  5
**Indicators of Relative Advantage**

- Places served by the service (matching your needs/destinations)
- Walking distance (to and from the service)
- Waiting time for the service
- Quality of vehicle
- Overall opinion of the service

Options:
- *Much worse* ................. *No different* ...................... *Much better than bus*

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

**Choice Indicators**

- Observed choice (usage rate, \( d \))
  \[
  d = \begin{cases} 
  1, & \text{if less than 1 trip per week} \\
  2, & \text{if 1 to 2 trips per week} \\
  3, & \text{if more than 3 trips per week} 
  \end{cases}
  \]

- The choice indicators are ordinal categorical
  - Ordered probit model
## Variable Definition

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dummy variable equal to one for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emp_Edu</td>
<td>Employed or education/ training respondents</td>
</tr>
<tr>
<td>Total_Car</td>
<td>Households which have at least one car</td>
</tr>
<tr>
<td>UCall_User</td>
<td>Respondents who used the previous UCall service</td>
</tr>
<tr>
<td>First_Trip</td>
<td>Respondents who made the first trip on LinkUp more than 3 months previously</td>
</tr>
<tr>
<td>Con_Pass</td>
<td>Respondents who have a concessionary travel pass</td>
</tr>
<tr>
<td>DtoD</td>
<td>Respondents who use the door-to-door service all or most of the time</td>
</tr>
</tbody>
</table>

## Results of Individual Latent Variables and Utility Function

\[
\eta_n = \gamma_{11} \text{Emp}_\text{Edu}_n + \gamma_{12} \text{Total}_\text{Car}_n + \gamma_{13} \text{UCall}_\text{User}_n + \gamma_{14} \text{First}_\text{Trip}_n + \gamma_{15} \text{Con}_\text{Pass}_n + \gamma_{16} \text{DtoD}_n + \zeta_n
\]

\[l = \text{Latent Awareness, Satisfaction, Relative Advantage}\]

\[
U_n = \beta_1 \text{Emp}_\text{Edu}_n + \beta_2 \text{Total}_\text{Car}_n + \beta_3 \text{UCall}_\text{User}_n + \beta_4 \text{First}_\text{Trip}_n + \beta_5 \text{Con}_\text{Pass}_n + \beta_6 \text{DtoD}_n + \beta_7 \eta_A + \beta_8 \eta_S + \beta_9 \eta_R + \varepsilon_n
\]
Interpretation of Results

- Three months could be critical time to establish user base
- Being a previous UCall user prompts negative attitudes
- Provision of door-to-door service is important
- Users in employment or education are potential customers but have negative attitudes

Interpretation of Results

- Relative advantage of DRT over buses is important
- Awareness of the service is critically important
- Vehicle size and misunderstanding of the operating concept lead to negative attitude
Questions

Thank you

j.d.nelson@abdn.ac.uk

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>79.17</td>
</tr>
<tr>
<td>Age (16 - 18 years)</td>
<td>12.58</td>
</tr>
<tr>
<td>Age (40 - 59 years)</td>
<td>27.61</td>
</tr>
<tr>
<td>Age (60+ years)</td>
<td>59.82</td>
</tr>
<tr>
<td>Employed or education/ training</td>
<td>28.53</td>
</tr>
<tr>
<td>Long term sick or disable</td>
<td>16.26</td>
</tr>
<tr>
<td>Household income (under £10,000 per year)</td>
<td>49.08</td>
</tr>
<tr>
<td>Household income (£10,000 - £19,999 per year)</td>
<td>24.23</td>
</tr>
<tr>
<td>Having at least one car in household</td>
<td>26.77</td>
</tr>
<tr>
<td>Having at least two LinkUp users in household</td>
<td>30.67</td>
</tr>
<tr>
<td>Previous UCall user</td>
<td>22.46</td>
</tr>
<tr>
<td>Single or return ticket</td>
<td>24.85</td>
</tr>
</tbody>
</table>
### Descriptive Statistics of The Sample (326 Respondents) (contd.)

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Concessionary travel passes</th>
<th>First trip on LinkUp (within 1 month)</th>
<th>First trip on LinkUp (1 - 2 months)</th>
<th>First trip on LinkUp (2 - 3 months)</th>
<th>First trip on LinkUp (3+ months)</th>
<th>Using door-to-door service (all or most of the time)</th>
<th>Using door-to-door service (never)</th>
<th>Using door-to-door service (not aware of the service)</th>
<th>Usage rate of LinkUp (less than 1 trip per week)*</th>
<th>Usage rate of LinkUp (1 - 2 trips per week)*</th>
<th>Usage rate of LinkUp (3+ trips per week)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>69.63</td>
<td>22.70</td>
<td>16.26</td>
<td>20.55</td>
<td>40.49</td>
<td>30.37</td>
<td>27.91</td>
<td>9.20</td>
<td>41.10</td>
<td>39.57</td>
<td>19.33</td>
</tr>
</tbody>
</table>

* 1 trip equal to outward and return

---

### Result of MIC Part for Latent Awareness

| Explanatory Variables | Estimate | p-value (Pr > |Z|) | Standardised Estimate |
|-----------------------|----------|----------------|-----------------------|
| Emp_Edu               | 0.352    | 0.265          | 0.071                 |
| Total_Car             | -0.169   | 0.348          | -0.046                |
| UCall_User            | -0.168   | 0.337          | -0.048                |
| First_Trip            | 0.515    | < 0.001        | 0.197                 |
| Con_Pass              | 0.081    | 0.672          | 0.022                 |
| DtoD                  | 0.652    | < 0.001        | 0.237                 |
### Result of MIC Part for Latent Satisfaction

| Explanatory Variables | Estimate | p-value (Pr > |Z|) | Standardised Estimate |
|-----------------------|----------|------------------|-----------------------|
| Emp_Edu              | -1.117   | < 0.001          | -0.304                |
| Total_Car            | -0.152   | 0.202            | -0.062                |
| UCall_User           | -0.543   | < 0.001          | -0.225                |
| First_Trip           | 0.159    | 0.039            | 0.088                 |
| Con_Pass             | 1.015    | < 0.001          | 0.324                 |
| DtoD                 | 0.313    | < 0.001          | 0.164                 |

### Result of MIC Part for Latent Relative Advantage

| Explanatory Variables | Estimate | p-value (Pr > |Z|) | Standardised Estimate |
|-----------------------|----------|----------------|-----------------------|
| Emp_Edu              | -0.522   | 0.054          | -0.158                |
| Total_Car            | -0.080   | 0.543          | -0.032                |
| UCall_User           | -0.407   | 0.010          | -0.167                |
| First_Trip           | 0.226    | 0.011          | 0.122                 |
| Con_Pass             | 0.391    | 0.015          | 0.152                 |
| DtoD                 | 0.291    | < 0.001        | 0.152                 |
Results of Ordered Probit

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Estimate</th>
<th>p-value (Pr &gt; ChiSq)</th>
<th>Standardised Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut Point 1</td>
<td>1.6493</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>Cut Point 2</td>
<td>2.9337</td>
<td>&lt;.0001</td>
<td></td>
</tr>
<tr>
<td>Emp_Edu</td>
<td>0.5742</td>
<td>0.0143</td>
<td>0.2580</td>
</tr>
<tr>
<td>Total_Car</td>
<td>-0.5205</td>
<td>0.0015</td>
<td>-0.2306</td>
</tr>
<tr>
<td>UCall_User</td>
<td>0.0480</td>
<td>0.7693</td>
<td>0.0200</td>
</tr>
<tr>
<td>First_Trip</td>
<td>0.3238</td>
<td>0.0180</td>
<td>0.1592</td>
</tr>
<tr>
<td>Con_Pass</td>
<td>0.0240</td>
<td>0.9132</td>
<td>0.0111</td>
</tr>
<tr>
<td>DtoD</td>
<td>0.7594</td>
<td>&lt;.0001</td>
<td>0.3497</td>
</tr>
<tr>
<td>Aware</td>
<td>0.1147</td>
<td>0.1003</td>
<td>0.1204</td>
</tr>
<tr>
<td>Sat</td>
<td>-0.1121</td>
<td>0.3232</td>
<td>-0.1048</td>
</tr>
<tr>
<td>Relat</td>
<td>0.3770</td>
<td>0.0010</td>
<td>0.3411</td>
</tr>
</tbody>
</table>

Equations of the Usage Rate Model

- **Structural equations**
  \[ U_n = V_n + \varepsilon_n = \beta_1 X + \beta_2 \eta + \varepsilon_n \]  
  and  
  \[ \eta = \Gamma X + \zeta \]

- **Measurement equations**
  \[ d = t \text{, if } \tau_{t-1} < U \leq \tau_t, \quad t = 1, 2, 3 \]  
  and  
  \[ y = \Lambda \eta + v \]
**Equations and Framework**

\[ \eta = \Gamma X + \zeta \]

**Characteristics of LinkUp Passenger,** \( X \)

**Awareness,** \( \eta_A \)

**Satisfaction,** \( \eta_S \)

**Relative Advantage,** \( \eta_R \)

\[ U_n = V_n + \varepsilon_n = \beta_1 X + \beta_2 \eta + \varepsilon_n \]

**Utility,** \( U \)

**Observed Choice:**
Usage Rate of LinkUp service, \( d \)

\[ d = t, \text{ if } \tau_{t-1} < U \leq \tau_t \quad t = 1, 2, 3 \]

**Indicators of Awareness,** \( I_A \)

**Indicators of Satisfaction,** \( I_S \)

**Indicators of Relative Advantage,** \( I_R \)

**Latent Variable Models (MIMIC models)**

**Latent Variables**

**Observed Variables**

**Structural Equations**

**Measurement Equations**

**Observed Variable**

**Observed variables** are the observations (it might be variables or measured scores) that we can observe or measure. The observations may include, for example, self-report responses to an attitudinal scale, coded responses to interview questions, scores on an achievement test, ranking with ordinal scale, and the like (Byrne, B.M., 2001).
Latent Variable

Latent variables (unobserved variables, or factors) are the variables that cannot be measured or observed directly. So, latent variables must be measured by linking to measured scores (observed or manifest variables) (Byrne, B.M., 2001).