A Positive Model of Departure Time Choice

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Background and Objectives

Existing departure time choice studies

- Rational behavior and random utility theory
- Generating a large choice set
- Assuming complete information and maximize utility

Objective: A Positive/Descriptive Approach

- Developing descriptive departure time choice model
- Modeling how travelers actually behave
- Demonstrating the capability of the integration of this model and traffic simulation/DTA models
Positive Modeling Framework

Information
Experience
Other sources

Learning
Update knowledge

Knowledge
Cognitive map
Subjective beliefs

Perceived search cost
Subjective search gain

Search?

Yes

Search Rules
Find an alternative departure time

Decision Rules
Choose new departure time or no behavior change

No

Travel time,
Travel cost,
Schedule delay,
Etc.

Repetitive behavior

Travel Experience
RP-SP-Recall Data Collection

- Distributed 4,000 flyers during two weeks
- 7.6% response rate
- 151 is the final effective sample size

![Sample Distribution over Age](image1)

![Sample Distribution over Income](image2)
Questionnaire Structure

**Revealed Preference**
- Socio-economic information
- Most recent trip information

**Memory-recall questions**
- Recall the order of alternative departure times they tried
- Corresponding travel conditions

**Stated Preference**
- Travel time and Travel time range
- Fuel cost and toll cost
Knowledge and Learning

Knowledge Representation

- Experiences are stored in $I$ discrete categories
- Knowledge on the Day $m$: $K_m (n_1, \ldots, n_i, \ldots, n_I)$
- Corresponding utility: $U (u^1, \ldots, u^i, \ldots, u^I)$

Learning

- If observing $u^i$ on the Day $m+1$
- Bayes rule implies equal weights of past experience
- Updated knowledge: $K_{m+1} (n_1, \ldots, n_i + 1, \ldots, n_I)$
Subjective Search Gain

Subjective Beliefs

- \( K_m(n_1, \ldots, n_i, \ldots, n_I) \rightarrow P(p_1, \ldots, p_i, \ldots, p_I) \)
- Prior beliefs follow a Dirichlet distribution
- The posterior beliefs will also be a Dirichlet
- \( p_i = n_i / (\sum n_i) \)

Subjective search gain

- \( u \): the utility of the current departure time
- Expected utility improvement from an additional search
- \( g = \sum_{i\{u\geq u\}} p_i (u_i - u) \)
Perceived Search Cost

\[ c_{LOW} = g_n = \frac{u^* - u_{max,n}}{n + 1} \]

\[ c_{HIGH} = g_{n-1} = \frac{u^* - u_{max,n-1}}{n} \]

\[ c = \frac{1}{2}(c_{LOW} + c_{HIGH}) \]
Search Rules

Search 60+ min earlier, if
\[ ASDL > 70 \]  \hspace{1cm} \text{Rule 1}

Search 30-60 min earlier, if
\[ 45 < ASDL \leq 70 \]  \hspace{1cm} \text{Rule 2}

Search 0-30 min earlier, if
\[ ASDL > 0 \text{ AND } Delay > 0 \]  \hspace{1cm} \text{Rule 3}

Search 0-30 min later, if
\[ 0 < ASDL \leq 30 \text{ AND } Delay > 40\% \]  \hspace{1cm} \text{Rule 4}
\[ \text{OR}[ASDL \leq 10 \text{ AND } ASDE \leq 40 \text{ AND } Delay \leq 50\% \text{ AND } TT \leq 65] \]  \hspace{1cm} \text{Rule 5}

Search 30-60 min later, if
\[ ASDL = 0 \]  \hspace{1cm} \text{Rule 6}

Search 60+ min later, if
\[ ASDE > 75 \]  \hspace{1cm} \text{Rule 7}
\[ \text{OR}[ASDE > 45 \text{ AND } Delay > 10\%] (6.0/1.0) \]  \hspace{1cm} \text{Rule 8}

Otherwise, search 0-30 min earlier.  \hspace{1cm} \text{Rule 9}
Switch to the alternative departure time, if

\[ \Delta TIME \leq -35\% \text{ and } \Delta FC \leq -8\% \]  
\[ \Delta TC \leq 2.5 \text{ and } \Delta ASDL \leq -48\% \]  
\[ \Delta TC \leq 2.4 \text{ and } INCOME \geq \$150K \text{ and } \Delta ASDL \leq -31\% \]  
\[ \text{none-peak} = 1 \text{ and } PURPOSE = \text{Other and } \Delta TIME \leq -8\% \text{ and } \Delta ASDL \leq 53\% \]  
\[ \Delta ASDE \leq -20\% \text{ and } \Delta TC \leq 0.7 \]  

Otherwise, continue to use the current departure time.
Validation of the Search Rules

Overall Predictive Accuracy
- 93.3% correctly classified instances

Aggregate Shares of Alternatives

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<th>Share</th>
<th>60+ min earlier</th>
<th>30-60 min earlier</th>
<th>0-30 min earlier</th>
<th>0-30 min later</th>
<th>30-60 min later</th>
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<tbody>
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<td></td>
<td>Observed</td>
<td>Predicted</td>
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<td>30%</td>
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<td>0%</td>
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Numerical Example

Scenario Setup
- Link capacity: 1600 vehicles/hour
- Assumed initial temporal demand profile
- BPR function for travel time calculation
- Estimate peak spreading effects after 30% demand increase
Peak Spreading

![Graph showing peak spreading with different demand scenarios](image-url)
Day-to-Day Behavior Dynamics

Graph showing delay (minutes) vs. departure time from 4:00 to 12:00, with different iterations and scenarios represented by various lines.

- Original
- Scenario
- 2nd iteration
- 3rd iteration
- 4th iteration
- 8th iteration
- 12th iteration
**Model Application: ICC Impact**

**ICC Toll Facilities**

Variable price (peak, off-peak, over-night)

Section I (I-370 to MD-97) is now opened

**Drivers’ Value of Time**

- Refine the departure time choice model
- Consider travel time uncertainty
- Obtain reasonable subjective value of time

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<th>II</th>
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<th>IV</th>
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<td>Peak</td>
<td>$1.45</td>
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<td>$0.50</td>
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<td>Overnight</td>
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<td>$0.40</td>
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</table>
Impact of Time-of-Day Toll

![Chart showing impact of time-of-day toll before and after peak spreading]

- Before Peak Spreading
- After Peak Spreading

Volume vs. Time

Time:
- 15:00 to 21:00

Volume:
- 0 to 3000

Legend:
- Gray line: Before Peak Spreading
- Black line: After Peak Spreading
Conclusion and Discussion

Positive learning, searching, and decision-making

- Focusing on modeling the actual behavior
- Avoiding assumptions of perfect rationality and perfect information
- Can be implemented with activity-based, dynamic traffic assignment, and microsimulation models
- Aggregate peak-spreading sensitivities may be applied to improve 4-step models
Ongoing Research

Applications and scenario analysis
- Evaluating impact of new dynamically priced facilities
- Peak spreading due to increased congestion
- Land development project evaluation

Refining the model via new data collection
- GPS (before and after the construction of a new toll road) and smart-phone (2-year continuous) surveys in Maryland

Multi-dimensional travel decision-making
- Mode, destination, route, and en-route diversion choices
- Infer decision hierarchy, which may be person-specific, from empirical longitudinal behavior data
Thank You!

Questions, Comments, and Suggestions are Welcome. Please Contact:

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