Flexible Transit for Low-Density Communities

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Outline

1. Background

2. Methodological Approach
   - Semi-Flexible Service Design

3. Case Study Area
   - Service Performance

4. SP-RP Survey
   - Initial Findings
Public Transportation Provision in Low-Density Areas

Figure: Comparison of Street Connectivity in urban vs. suburban setting

- Vicious and virtuous cycles of regional transit allocation
- High-cost of demand-responsive transit, taxis
- Demographics: youth travel, silver tsunami, suburbanization of poverty
Semi-Flexible Systems: Types

Figure: Flexible Service Types (From Errico et al. [4])
Demand-Responsive Transit Services

- Typically door-to-door unless some structure in place (as in previous slide)
- Sometimes a deadline (2 hours before, evening before), particularly for paratransit
- Most research focuses on different service combinations, meaningful objective functions, varying input parameters (time windows, vehicle types)
Transportation Network Companies (TNCs) and other emerging options

- Uber, Lyft and Sidecar currently operate in Chicago - and all are testing shared services
- Curb and other apps for hailing/paying for cabs
- Bridj (Boston) serves origins and destinations that are otherwise not connected, or require many transfers
- Chariot, Leap and Loup (San Francisco) offer more “dynamic” transit routes, primarily for commuters, but are not dynamic in the sense of DRT
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Research Questions

- How much structure is needed at what level of demand?
- What level of structure offers benefits to both users and operators, as compared to DRT or fixed-route?
Conceptual Framework

- Demand Distribution
  - Expected Demand
  - Probabilities
- Selection of Compulsory Stops
- Clustering
- Sequencing
- Topographic Service Design
  - Time window definition
- Service Requests
- Operations Simulator
  - User Performance Measures: On-time performance, Travel time, Value, Overall Satisfaction
  - Operator Performance Measures: Productivity (pax/veh mile), Actual on-time performance, Cost/veh revenue hour
- Design Parameters
  - Objective weights
  - TW width and confidence
Simplified Concept

- Travel Demand
- Service Design
- Level of Service
Semi-Flexible Service Design

Existing Method: Single-Line DAS

- Crainic et al. - single line, single vehicle on networks with crow-fly distance
- Some interesting practical examples exist, e.g. Flexlinjen in Sweden and Kutsuplus in Finland, but little knowledge of supply-demand interactions
- Contribution: simulate on a real network with multiple vehicles and actual travel demand data

![Master Scheduling Problem](image)

- Visiting compulsory stops only
- Visiting compulsory and active optional stops

- Compulsory stops with time windows [earliest departure, latest arrival]
- Optional stops (some activated)

Errico et al. 2011a, 2011b; Crainic et al. 2010
Census Fact Finder 2012 Estimates:
- Population: 42,000
- Current trip requests: ~5-10 per hour (off-peak/peak)
- Service Area: 16 square miles
- Median income: $57,330
- Employment:
  - 33,000 over age 16
  - ~22,000 in labor force
  - 7.4% unemployment
  - Lockheed Martin employs 14,000
Applied to Existing Service Area

Figure: South Jefferson County Call-and-Ride Area
Clustering and Network Analysis

Figure: K-means Clustering with Clusters of highest degree labeled
Bird’s Eye View of Location 6/7

Figure: Bird’s Eye View of Kipling Ave. & W Chatfield Ave.
Simulate service without time windows (i.e. earliest arrival and latest departure from a “checkpoint”), but with compulsory stops, to determine ideal time for visiting.

Then add time windows to simulation to assess performance.
## Example: Joliet IL, 3 vehicles

<table>
<thead>
<tr>
<th>Compulsory Stops</th>
<th>Stop</th>
<th>Mean Arrival</th>
<th>SD Arrival</th>
<th>75 %ile</th>
<th>90th %ile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1: Joliet Metra Station</td>
<td>6.07</td>
<td>9.99</td>
<td>12.27</td>
<td>18.70</td>
</tr>
<tr>
<td>2</td>
<td>1: Joliet Metra Station</td>
<td>11.27</td>
<td>11.31</td>
<td>14.97</td>
<td>25.66</td>
</tr>
<tr>
<td>2</td>
<td>2: Twin Oaks Shopping Place</td>
<td>14.42</td>
<td>12.37</td>
<td>22.98</td>
<td>27.31</td>
</tr>
<tr>
<td>3</td>
<td>1: Joliet Metra Station</td>
<td>8.62</td>
<td>11.99</td>
<td>15.53</td>
<td>25.80</td>
</tr>
<tr>
<td>3</td>
<td>2: Twin Oaks Shopping Place</td>
<td>15.69</td>
<td>12.66</td>
<td>23.93</td>
<td>32.03</td>
</tr>
<tr>
<td>3</td>
<td>3: Larkin Village Apartments</td>
<td>6.86</td>
<td>9.26</td>
<td>15.05</td>
<td>15.05</td>
</tr>
<tr>
<td>4</td>
<td>1: Joliet Metra Station</td>
<td>13.49</td>
<td>13.49</td>
<td>22.59</td>
<td>29.99</td>
</tr>
<tr>
<td>4</td>
<td>2: Twin Oaks Shopping Place</td>
<td>7.34</td>
<td>12.13</td>
<td>10.93</td>
<td>27.31</td>
</tr>
<tr>
<td>4</td>
<td>3: Larkin Village Apartments</td>
<td>6.58</td>
<td>8.29</td>
<td>15.05</td>
<td>15.05</td>
</tr>
<tr>
<td>4</td>
<td>4: Joliet Mall and Shopping Center</td>
<td>12.65</td>
<td>13.77</td>
<td>22.35</td>
<td>25.90</td>
</tr>
</tbody>
</table>
Service Objectives

- Typical DRT service objective function is to maximize slack time in the schedule.
- Here, minimize sum of operator and user cost and impose a large penalty for time window violations
- User travel time vs. operating time
  - Simple test showed including user costs does not increase operator cost much, but an objective minimizing only operator costs resulted in much high user costs.
  - Sensitivity analysis regarding weights for users, operators and violations
Candidates tested: 1, 2, 4 and 6

Figure: K-means Clustering with Clusters of highest degree labeled
Assessment of Appropriate Candidate “Checkpoints”

Figure: South Jefferson County, Colorado: Potential Last mile connector, 3 compulsory stops, 2 vehicles
User Travel Time vs. Operating Time for Fleet Size = 3
Improved Reliability (for some cases)

- As you add vehicles and compulsory stops, arrival times at any point in service area are more predictable.
- For 3 vehicles, 3 compulsory stops: 1.5 minute reduction in standard deviation of arrival time, 0-1.2 minute increase in average travel time.
Survey Design

- Convenience sample of Chicago area commuters, 120 responses in September 2014:
  - CMAP newsletter
  - NUTC Facebook and Twitter accounts
  - Personal Facebook and Twitter accounts
- Short-, medium- and long-commute markets to generate different attribute levels for efficient design
  - Maximizes information obtained from each respondent, and choices presented are more realistic
  - Gathered information about actual commute and revealed preference to classify respondents
- Will conduct a winter panel, Feb 1-28
  - 35 respondents from summer offered to take follow-up survey.
**Stated Choice Survey**

**Scenario 1:**

<table>
<thead>
<tr>
<th></th>
<th><strong>Transit</strong></th>
<th><strong>Car</strong></th>
<th><strong>Flexible Transit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>In-Vehicle Travel Time</td>
<td>13 min</td>
<td>46 min</td>
<td>66 min</td>
</tr>
<tr>
<td>Travel Costs</td>
<td>4 USD</td>
<td>14.57 USD**</td>
<td>1 USD</td>
</tr>
<tr>
<td>Walk Time</td>
<td>18 min</td>
<td>3 min</td>
<td>3 min</td>
</tr>
<tr>
<td>Wait Time</td>
<td>***</td>
<td>***</td>
<td>7 min</td>
</tr>
<tr>
<td>Frequency (Headway)</td>
<td>every 12 minutes</td>
<td>every 20 minutes</td>
<td></td>
</tr>
<tr>
<td>Number of Transfers</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

**Notes:**
- **Travel cost for car is a combination of fuel costs and parking costs at work**
- **Transit wait time is dependent on a number of things including: service reliability, frequency and when you decide to leave your house**

Choose one of the following answers:

- Transit
- Car
- Flexible Transit
- None

**Figure:** Sample Scenario from Stated Choice Survey
Reliability of current travel mode

Survey captured current reliability by asking the user to report their actual travel time (ATT) for transit and/or auto, compared to Google API generated result, and rate how confident they were in on-time arrival given their reported allowed time:

Planning time index = Allowed/ Free flow; Buffer time index = (Allowed - Reported)/Reported
Preliminary results for flexible mode choice

- Value of...
  - Travel Time: $19/hour
  - Reliability: $10/hour
  - Wait Time: $27 ± 11/hour
  - Access Time: $29 ± 4 /hour

- Age ranged from 22 to 57 years old; 52% males in sample
- 57 of the 120 (48%) respondents have used a TNC such as Uber, Lyft, Sidecar:
  - These respondents were less likely to choose traditional transit in choice scenarios, all else equal, but neither more nor less likely to choose flexible transit over car
Initial Findings

Preliminary results for flexible mode choice (continued)

- Other notable items
  - Divvy significant, car-sharing was not → Early-adopters, low VOT, active travelers?
  - Whether a passenger conducts activities on-board (leisure reading, working on a laptop, relaxing) increased probability of choosing transit modes

- Respondents’ revealed preference tended toward transit use, simple inertia parameter does not explain much variation

- Stated Choice: 31% Car, 13% flexible transit, 56% traditional transit

1 60% transit, 26% car, 11% walk, 3% bike in sample, versus 45/55 transit/auto split for trips to CBD for all Chicago commuters
Initial Findings

Key Takeaways and Expected Findings

- Extract performance measures from user and operator objectives to determine appropriate service.
- Adding structure to a demand-responsive service may reduce (perceived) barriers to entry for people accustomed to a traditional transit service
  - Current transit users seem to prefer a timetable, had some wariness of (hypothetical) flexible mode
  - Structure can enhance reliability, but some flexibility will mean less walking in sparse areas
- Expect to identify thresholds for acceptable frequency of service in low-density areas
- **On-going** sensitivity analysis related to:
  - fleet size and capacity
  - objective function defined by user cost - trade-offs for operator and impact on demand
  - demand fluctuation: how robust is service design?


A Comment on Emerging and Existing Flexible Modes

- How will cities and agencies work with these platforms to improve service, potentially with their existing rolling stock?
- Will these services be low-cost enough to serve current captive markets?
- What is the role of car-sharing (and autonomous shared vehicles) in filling this gap?
User Travel Time vs. Operator Cost for Fleet Size 2 & 3

(Where user travel time has same penalty as operating time in objective function)
User Travel Time vs. Operator Cost for Fleet Size = 3
Watch out for hop-ons
Passenger Delay when Random Demand is Introduced

Figure: Difference in Boarding and Alighting times after Additional Demand at Compulsory Stops with Time Windows

(a) Absolute Difference in Boarding Times

(b) Absolute Difference in Alighting Times
Assessment of Appropriate Candidate “Checkpoints” - Another example

Figure: Potential Community Circulation, 3 compulsory stops, 2 vehicles
Flexible Technique: St. Charles, Illinois, USA (Chicago metro area)

Figure: Clustering and Network Analysis of Case Study Area in St. Charles & Geneva, Illinois
Flexible Technique: Joliet, Illinois, USA (Chicago metro area)