Dynamic Public Transit Accessibility: Comparing the Effects of Infrastructure (Dis)investments Over Time

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Background
Background

- Accessibility – the ease of reaching destinations

- What about transit accessibility?
  - The ease of reaching transit
  - The ease of reaching destinations by transit
Background

- Reaching destinations by transit
  - Whether transit provides convenient travel experiences and reasonable travel times to jobs, services, leisure activities
  - How easily does transit allow people to participate in the daily activities that constitute a normal life?

- To do this, we must have tools that allow us to measure origin-to-destination (OD) transit travel times
Background

- Transit travel times are variable
Background

- Measures of transit accessibility need to account for variability in OD travel times

- Dynamic measures of accessibility:
  - Temporal variability in jobs-accessibility impacts the mode choice decision (Owen and Levinson)
  - Temporal variability in OD travel times means that most trips demanded in a region are not provided with adequate transit coverage (Polzin et al; Ritter & Farber)
  - Temporal variability in transit coverage can lead to precarious food accessibility with racial disparities (Farber et al)
Research Objectives

- Develop a new method for computing public transit travel times
- Develop methods for analyzing time-of-day variations in transit travel times
- Apply these methods in a series of practical case studies to demonstrate their usefulness
Method
Public Transit Travel Time Cube

\[ T = \{t_{i,j,m}\} \]

\(T\) is a 3D matrix of public transit travel times from origins, \(i\), to destinations, \(j\), at times, \(m\).
Computing the Cube

- GTFS Package(s)
- Pedestrian Network File

Add GTFS to Network Dataset

Transit Network Dataset

For Each $m$

Compute OD Cost Matrix

Block Group Centroids $(i, j)$ locations

Transit Evaluator

Public Transit Travel Time Cube
Querying the Cube

The Atomic Elements

$T_{i,:,m}$ -- a map of travel times from location $i$ to all other locations, with a departure time of $m$.

$T_{:,j,m}$ -- a map of travel times to location $j$ from all other locations, with a departure time of $m$.

$T_{i,:,j}$ -- a vector of travel times from $i$ to $j$ across all times of day.
Summarizing the Cube

Overall Average Travel Time: \( \left( \frac{\sum_{i,j,m} T_{i,j,m}}{N^2 M} \right) \)

Time Dependent Average Travel Time: \( \left( \frac{\sum_{i,j} T_{i,j,m}}{N^2}, \forall m \right) \)
Summarizing the Cube

Average Travel Time from an Origin: \( \left( \frac{\sum_{j,m} T_{i,j,m}}{NM}, \forall i \right) \)

Average Travel Time to a Destination: \( \left( \frac{\sum_{i,m} T_{i,j,m}}{NM}, \forall i \right) \)

Standard Deviation of Travel for an OD Pair: \( \sqrt{\frac{\sum_m (T_{i,j,m} - \bar{T}_{i,j})^2}{m}} \)
Fourier Transform to Retrieve Frequency

C) | Average Travel Time (Mins.) | SD of Travel Time | Dominant Frequency (Mins.) |
---|-----------------------------|-------------------|---------------------------|
OD Case A | 76.9 | 30.5 | 60.0 |
OD Case B | 77.5 | 30.4 | 60.0, 30.0 |
Case Study 1: Comparison of Transit Travel Times over Time
Case Study One

- Use travel time cubes to assess how travel times have changed in a region due to:
  - network modifications (e.g. new routes, deletion of routes, modification of routes)
  - Level of service modifications (e.g. operating hours, headways)

- Study Area 1: Wasatch Front 2011-2014
- Study Area 2: Portland 2009-2013
UTA
- Addition of new heavy rail line
- Addition of several commuter rail lines
- Removal of bus routes

Trimet
- Budget cuts lead to reduction in bus services

Visual Comparison
- Very difficult to assess the impact of these changes on travel times using network maps
## Changes in Route KMs Travelled

<table>
<thead>
<tr>
<th></th>
<th>Wasatch Front</th>
<th></th>
<th>TriMet</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bus</td>
<td>Light Rail</td>
<td>Commuter Rail</td>
<td>Bus</td>
</tr>
<tr>
<td>Time 1</td>
<td>96,072</td>
<td>5,683</td>
<td>3,594</td>
<td>108,921</td>
</tr>
<tr>
<td>Time 2</td>
<td>85,497</td>
<td>13,893</td>
<td>7,311</td>
<td>97,547</td>
</tr>
<tr>
<td>Change</td>
<td>-10,575</td>
<td>8,210</td>
<td>3,717</td>
<td>-11,374</td>
</tr>
<tr>
<td>Percentage Change</td>
<td>-11%</td>
<td>144%</td>
<td>103%</td>
<td>-10%</td>
</tr>
</tbody>
</table>
Aggregate Changes in Travel Times

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Average Travel Time (Mins.)</th>
<th>Time 1</th>
<th>Time 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wasatch Front</td>
<td></td>
<td>204.46</td>
<td>194.93</td>
</tr>
<tr>
<td>Portland</td>
<td></td>
<td>187.64</td>
<td>191.17</td>
</tr>
</tbody>
</table>

Utah improvements highest in AM Peak and in extended evening hours

Trimet declines consistently across all times of day
Two-Way Changes in Travel Times

Times to/from the southern areas were largely improved.

Eastern benches and West Valley area became harder to reach.

Portland experienced even declines throughout.
Changes in Travel Time Frequency

Improved (i.e. shortened) along rail expansions.

Inner city have decreases in service frequency.

Increased travel time cycles are linear along several routes.

Large swathes of the city to the west and south of the center that has experienced decreases in cycle lengths.
Case Study 2: Access to Jobs via Transit
Access to Jobs

\[ A_i = \frac{\sum_{j,m} f(T_{i,j,m}) E_j}{M} \]

where:

\( A_i \) is the jobs accessibility score for zone \( i \)
\( E_j \) is the employment at location \( j \) (from LEHD data)
\( M \) is the minutes in the 2hr period (7am-9am)
\( f(T_{i,j,m}) = \begin{cases} 1 & \text{if } T_{i,j,m} \leq 60 \\ 0 & \text{Otherwise} \end{cases} \)
Changes in Jobs Accessibility

**Wasatch Front**

35,700 to 33,200 population weighted jobs accessibility.

No changes along the heavy rail corridors.

Big exchanges between new light rail and deleted bus routes.

**Portland**

23,410 to 21,666 population weighted jobs accessibility.

Overall experienced reductions in the center and along some routes leaving the city.
Case Study 3:
The Effects of Bicycle use on the Last Mile Problem
The Last Mile Problem

- Distances from transit to final destinations can be too long to be accommodated by walking

- Joint cycling/transit integration is being adopted as a solution

- But how much travel time and reliability is achieved through cycling/transit trip integration?

→ Create a cycling/transit travel time cube and compare it with the walking/transit travel time cube.
Travel time improvements are highest in the off-peak hours, and in more peripheral locations.
Rush Hour Travel Time and SD from Central Station (7am-9am)

“Downtown” Salt Lake City – 9% of population and 18% of the region’s jobs

Cycling results in 32% reduction in travel times and 47% reduction in standard deviation of travel time.

Improvements increase with distance, but modified by network sparsity.
Conclusions
Discussion

- These tools make the $MILs spent on GTFS useful for transit planners and researchers

- Novelty comes from the pre-computation of the entire travel time cube and its ensuing analysis

- Large potential for future research:
  - Historical real-time vehicle location data
  - More accurate cost/benefit analysis
  - More use of time variability in mode-choice modelling
Sneak Peak at a Viz Tool

Realtime viz environment that makes exploring the data much faster and more intuitive

Matrix, map and graph Views

Linking and brushing enabled
Acknowledgements

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  - Melinda Morang, Esri
  - Utah Transit Authority
  - TriMet

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