GTFS-enabled Spatiotemporal Analysis of Transit Services

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Transit Accessibility

- How easy it is for an individual to reach a desired destination using public transit?

- Public transit feasibility as a travel choice is affected by
  1. spatial coverage
  2. temporal coverage of transit services

- Applications
  1. Evaluation of the existing services
  2. Travel demand forecasts
  3. Decision making related to transportation investments and land use development
Transit Accessibility Measures

- **Travel Time Discretionary:**
  1. Local Index Of Accessibility (LITA)
  2. Transit Capacity and Quality of Service Manual (TCQSM)
  3. Time of Day

- **Travel Time Dependent:**
  1. Cumulative Measures (Vickerman, 1974)
  2. Gravity (weighted) Measures (Hansen, 1959)
  3. Utility-Based Measures
  4. Constraints-Based Measure (Wu & Miller, 2002)
  4. Composite Measures (Harvey Miller, 1999)
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Cumulative Accessibility Measures

- Counts the number of potential opportunities that can be reached within a predetermined travel time window (or distance):

$$A_i = \sum_{j=1}^{J} B_j \times a_j$$

$A_i$ - Cumulative Accessibility Measure at point $i$ to potential activity zones $J$

$B_j$ - A binary value equals to 1 if zone $j$ is within the predetermined threshold and 0 otherwise

$a_j$ - Opportunities in zone $j$
Cumulative Accessibility Measures

- Number of jobs within 10 minutes of travel time by automobile during the morning peak in 2000

Adopted from El-Geneidy & Levinson, 2006.
Gravity Accessibility Measures

- Weights the number of potential opportunities that can be reached based on impedance or cost function (e.g. time, distance):

\[ A_i = \sum_{j=1}^{J} O_j \times f(C_{ij}) \]

- \( A_i \): Gravity Accessibility at point \( i \) to potential activity at point \( j \)
- \( O_j \): The opportunities at point \( j \)
- \( f(C_{ij}) \): The impedance or cost function to travel between \( i \) and \( j \)
Gravity Accessibility Measures

- Gravity-based accessibility to jobs by automobile during the morning peak in 2000 using the $\frac{1}{tt_{ij}}$ as impedance function

Adopted from El-Geneidy & Levinson, 2006.
Weighted Average Travel Time
Potential Accessibility

- Weighted Average Travel Time (WATT)
  \[ WATT_i = \frac{\sum_{j=1}^{J} O_j \times t_{ij}}{\sum_{j=1}^{J} O_j} \]

  \( WATT_i \)- WATT for station \( i \)
  \( t_{ij} \)- Travel Time between station \( i \) and station \( j \) using public transit

- Potential Accessibility (PA)
  \[ PA_i = \sum_{j=1}^{J} \frac{O_j}{t_{ij}} \]

  \( PA_i \)- PA for station \( i \)
Limitations

Previous studies do not consider:

- Temporal changes in transit service throughout the day and day of week
  1. Neglect the transit-dependent population
  2. Neglect the daily fluctuation in transit services

- Unclear Visualization

- Hard for agencies to implement the method
  1. Computation extensive with ARCGIS (60 days for Salt Lake City transit)
  2. Challenging to find transit service data
  3. Importing the raw data is challenging
Our Contribution

- Develop a user-friendly efficient tool to calculate PA and WATT for every minute of the week and provide a clear visualization of results
  - Use open source databases (GTFS and Census data)
  - Develop a travel time calculation algorithm from GTFS data
  - Use C++ to improve the computational efficiency
  - Filtering the results based on socioeconomic characteristic of station coverage area
GTFS

- General Transit Feed Specification (GTFS) was created in 2005 by Google and TriMet to represent agencies’ schedule, trip, route, stop data, etc.
- Zip file consists of several plain text files which have been formatted as Comma-separated Values (CSV).
- Potential applications:
  1. Transit Operation performance measures
  2. Ridership performance measures (combined with APC)
  3. Transit Accessibility Measures
GTFS in C++
Stops, Routes, Trips
ST. George Transit Map
SUNTRAN

- 6 bus routes
- 134 transit stops
- Fixed Headway of:
  1. 40 mins
  2. 80 mins
- City Population: 76,817
St. George Stations WATT
Run Time = 4 mins

Average WATT for St. George Stations (population in 700 meter radius of stations)
ST. George Transit Map

TAUCAHN Station

- Recreational Station
- Route 5 is the only passing route
- Headway: 80 mins
- Population around the station is about 20 people
Tuacahn Station’s WATT

Average WATT for St. George Stations (population in 700 meter radius of stations)
ST. George Transit Map
Sunset Corner Station

- Close to shopping Centers

- Routes 3, 4, 5, and 6 are passing this station

- Population around the station is about 1600 people
Sunset Corner Station’s WATT

Average WATT for St. George Stations (population in 700 meter radius of stations)

Station ID

Average WATT (min)
TAUCAHN Station WATT

WATT For Sunset Corner Station

36 mins
Conceptual Framework

- Using GTFS the travel time between all stations for each time-of-day is calculated

- From census data, station attractiveness is calculated (number of jobs)

- Using the results of previous steps, WATT for each station and time-of-day is calculated
DATA Visualization

Visualizing stations WATT on map
Data Visualization

Filter Stations by disadvantaged population density and low accessibility

Below 10th percentile of all stations WATT
APC and AFC Study

- Using Genetic Algorithm to prepare the APC/AFC dataset (noise cancelation)

\[ GA: \text{minimize } (\text{abs}(DT_{\text{estimated}} - DT_{\text{actual}})) \]

- Combining Linear Regression with GA to analyze the fare payment structure of bus routes

\[ GA: \text{min} \{\text{abs}((\beta_{B_{CTVM}} \cdot B_{CTVM_i} + \varepsilon_i) - (\alpha_{B_{Cash_i}} \cdot B_{Cash_i} + \alpha_{B_{TVM_i}} \cdot B_{TVM_i}))\} \]

| Coefficient | Std. Error | t     | P>|t| |
|-------------|------------|-------|------|
| DT          |            |       |      |
| Weekend *   | 1.087      | 0.173 | 6.30 | 0.000 |
| B-EFC *     | 5.279      | 0.081 | 65.57| 0.000 |
| B-TVM *     | 1.803      | 0.025 | 73.03| 0.000 |
| B-Cash *    | 6.917      | 0.033 | 211.6| 0.000 |
| A-EFC *     | 2.020      | 0.206 | 9.79 | 0.000 |
| A-CTVM *    | 1.611      | 0.037 | 43.40| 0.000 |
| Door-Cycle *| 1.509      | 0.097 | 15.60| 0.000 |
| Fair-Mall stop indicator (Magna dir.) * | 2.116 | 0.192 | 11.00 | 0.000 |
| 3575 W stop indicator * | -2.588 | 0.259 | -9.98 | 0.000 |
| 3955 W stop indicator * | 1.617 | 0.204 | 7.92 | 0.000 |
| Fair-Mall stop indicator (TRAX dir.) * | 3.432 | 0.277 | 12.40 | 0.000 |
| 1685 W stop indicator * | 2.287 | 0.225 | 10.15 | 0.000 |
| Constant*   | 2.026      | 0.143 | 14.15| 0.000 |
Future Work: WATT and APC/AFC data

Modeling the joint impact of WATT on ridership (APC) and fare payment (AFC) can help answer these questions:

- Dwell Time Analysis to improve GTFS travel time
- Transit service (fare, service coverage, etc.) vs. social equity
- Does higher accessibility encourage higher ridership?
- If yes? How?
- What are the externalities affecting ridership?
THANK YOU!

REFERENCES:


