A Station-Level Ridership Model for the Metro Network in Montreal City

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Source: www.trekearth.com
Introduction

Why do ridership demand forecasting?
- Justify investments in public transit and transit-oriented development (TOD)
- Identify factors that influence transit ridership

What factors are considered?
- Built environment, socioeconomics, transit service, etc.

How to relate factors with ridership?
- Simple and classical method: linear regression model
A direct ridership model:
• estimates potential demand
• in the initial stages, not long-term
• approximate figures

External factors have greater influence than internal factors (i.e. relating to transit service)

Density and land use have the biggest impact on transit use
1. To develop a ridership model based on the Montreal metro network for the AM peak period using boarding and alighting data from 1998 and 2003

2. To determine the most significant factors that affect transit use by evaluating direct elasticities from the model
16 studies

5 countries: US, China, Taiwan, Colombia and Canada

All transit modes: bus, bus rapid transit (BRT), light rail transit (LRT), commuter rail, heavy rail

Regression: ordinary least squares (OLS), two-stage least squares (2SLS), Poisson, negative binomial (NB), geographically weighted (GWR)

100+ factors affecting transit ridership
Factors Affecting Transit Ridership

Demographics
• Age
• Population
• Car ownership
• Ethnicity
• Income
• Gender
• Education

Station/Stop Features
• Parking facilities
• Terminal or transfer station
• Sidewalks
• Bike paths
• Traffic control

Neighbourhood Attributes
• Employment
• Households
• Land use (mix)
• Buildings
• Intersections
• Roads

Transit Service Attributes
• Fare prices
• Vehicle service miles/km
• Revenue vehicle hours
• Bus stops/lines
• Service frequency
• Distance to closest stop
• Connections

Perceptions and Others
• Cleanliness and safety
• Pedestrian friendliness
• Accidents
• Crimes
• Airport, university
• Weather
• Gas prices
Gaps in the Literature

- Metropolitan areas in Canada: Vancouver, Toronto, Montreal
- Subway systems
Montreal Metro Network

- 4 lines, 68 stations, 71 km of track
- 3 stations in Laval, built in 2007, omitted

Unique features:
- Entire network is underground
- Operates on rubber tires
**Data Description**

- Weekday AM peak (6:00-8:59 am) boarding and alighting for 1998 and 2003 for 65 stations, from Agence métropolitaine de transport (AMT)

![Trip Distribution in 1998](image1.png)

![Trip Distribution in 2003](image2.png)
Trip production (TP) = boardings
Trip attraction (TA) = alightings
Independent Variables

Socioeconomics

- Average household income ($1,000)
- Number of persons aged: 0-4; 5-14; 15-24; 25-44; 45-64; 65+ years old
- Average number of vehicles per household
- Average number of persons living in household
- Population (1,000s)
- Number of workers
Neighbourhood road and land use

- Total road length (m)
- Road length by classification: highways, arteries, collectors, local streets (m)
- Number of street segments
- Number of intersections
- Proportion of major roads
- Average street segment length (m)
Independent Variables

Neighbourhood road and land use (cont’d)

- Number of schools
- Number of commerce per km²
- Number of residences per km²
- Number of jobs per km²
- Land use mix index = \( \frac{\text{Commerce} \times \text{Residences} \times \text{Jobs}}{\text{Commerce} + \text{Residences} + \text{Jobs}} \)
- Areas by land use: commercial; government and institutional; residential; resource and industrial; open space; water; parks (1,000 m²)
Independent Variables

Transit
- Number of bus stops
- Number of bus routes
- Fare price of a single ticket ($)
- Distance by metro to Bonaventure station (km)
- Number of metros during the AM peak
- AM peak frequency $> 28$ ($0$=no; $1$=yes)
- Terminal station ($0$=no; $1$=yes)
- Transfer station ($0$=no; $1$=yes)

Other
- Year 2003 ($0$=no; $1$=yes)
Data Sources

- Census by Statistics Canada
- Desktop Mapping Technologies Inc. Spatial
- Société de transport de Montreal
- Origin-Destination Survey by Agence métropolitaine de transport
Geographic information system (GIS) was used to aggregate data within the buffer area and join them to corresponding metro station.

2 buffer sizes: 500 m and 1,000 m
Methodology

- Cote-Vertu station
- 500 m buffer
- 1,000 m buffer
  - Bus stops in 500 m buffer
  - Bus stops in 1,000 m buffer
- Street in 500 m buffer
- Street in 1,000 m buffer

**Land use**
- Commercial
- Government and Institutional
- Open Area
- Parks and Recreational
- Residential
- Resource and Industrial
Ridership = TP + TA

\[\ln (TP) = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \ldots + \alpha_n X_n + e_{1i}\]

\[\ln (TA) = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \ldots + \beta_n Z_n + e_{2i}\]

- OLS regression
- Systematic elimination of variables
  - P-value > 0.05 (insignificant)
  - Multicollinearity
  - Intuitive thinking
- Evaluate direct elasticities from model parameters
### Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Buffer Size (metre)</th>
<th>Model 1: Trip Production</th>
<th>Model 2: Trip Attraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>P-value</td>
<td>Elasticity</td>
</tr>
<tr>
<td><strong>INCOME</strong></td>
<td>1,000</td>
<td>-0.014</td>
<td>0.001</td>
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<tr>
<td><strong>POPULATION</strong></td>
<td>500</td>
<td>0.122</td>
<td>0</td>
</tr>
<tr>
<td><strong>COM_LU</strong></td>
<td>1,000</td>
<td></td>
<td></td>
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<tr>
<td><strong>G&amp;I_LU</strong></td>
<td>1,000</td>
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<tr>
<td><strong>BUS_STN</strong></td>
<td>500</td>
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<td></td>
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<tr>
<td><strong>BUS_LINE</strong></td>
<td>1,000</td>
<td>-0.005</td>
<td>0.112</td>
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<tr>
<td><strong>DIST_BONA</strong></td>
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<td>0</td>
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<tr>
<td><strong>HIGH_FREQ</strong></td>
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<td><strong>TERMINAL</strong></td>
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<tr>
<td><strong>TRANSFER</strong></td>
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<tr>
<td><strong>constant</strong></td>
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<td>1.708</td>
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<tr>
<td><strong>R-squared</strong></td>
<td></td>
<td>0.679</td>
<td>0.552</td>
</tr>
</tbody>
</table>
Discussion

TP model

- Population (500 m) and income (1,000 m)
- Transit variables play an important role
  - Connections to other transit modes (bus and train)
  - Distance from Bonaventure station in downtown
- Elasticities of income, terminal and transfer stations have same order of magnitude (80%)
Discussion

TA model

- Commercial and government & institutional land uses
- AM frequency, terminal and transfer stations
- Land use variables have highest elasticities (52-67%)
- Elasticities of terminal and transfer stations lower than TP model
Land use and transit-related factors are the most significant.

Ridership can be generated by:
- Increasing bus transit connectivity and metro service
- Promoting mixed land use zones

Future work and shortcomings:
- AM peak ridership only
- Relationship may not be purely cause-effect
- Model validation using longitudinal data (2008)
- Include other variables
- Ridership models for long-term prediction
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Questions?