Ridership Forecasting

1. Route ridership prediction needs and issues
2. Alternative approaches to route ridership prediction
   a. Professional judgment
   b. Survey-based methods
   c. Cross-sectional models
   d. Time-series models
3. Examples of route ridership prediction methods
   a. TTC elasticity method
   b. Direct Demand models
4. GIS-Based, Simultaneous-Equations, Route-Level Model
5. Network-Based Forecasting Methods
   a. MADITUC
   b. EMME/2
   c. TransCAD

We will focus on (short-run) route-level prediction methods.

Roles for Ridership/Revenue Prediction

1. Predicting ridership/revenue as a result of fare changes
   - system-wide prediction usually required
     - fare elasticity calculation
     - time-series econometric model
     - best methods use two-stage, market segment model
2. Predicting ridership/revenue for general agency planning and budgeting purposes
   - system-wide prediction required
     - trend projection
     - time-series econometric model
3. Predicting ridership/revenue as a result of service changes
   - route-level prediction usually required
   - service changes of interest include changes in
     - period(s) of operation
     - headway
     - route configuration
     - stop spacing
     - service type (e.g., local versus express)

Factors Affecting Transit Ridership

1. Exogenous (uncontrollable)
   a. auto ownership/availability & operating costs
   b. fuel prices & availability
   c. demographics (age, gender, etc.)
   d. activity system (population & employment distributions, etc.)

   Usually can be assumed to be "fixed" in the short-run.
2. Endogenous (controllable)
   a. fare
   b. headway (wait time)
   c. route structure (walk time; ride time)
   d. crowding*
   e. reliability*

   * usually not explicitly accounted for in ridership prediction methods.

Route Ridership Prediction

The traditional approach is reactive:

- exogenous change: monitor ridership change
- endogenous change: modify system accordingly
- does not attempt to anticipate impacts prior to the exogenous/endogenous change occurring

Current Practice

- Little attention is given to the problem in many agencies, except for fare changes and major capital projects.
- Traditional urban transport planning models are inappropriate and ineffective.
  - generally not detailed enough and too complex to run repeatedly
- Ad-hoc, judgmental methods dominate.

Approaches to Predicting Route Ridership

- Professional judgment
- Non-committal survey techniques
- Cross-sectional data models
- Time-series data models

Professional Judgment

- Widely used for a variety of changes
- Based on experience & local knowledge
- No evidence of accuracy of method or reproducibility of results
- Reflects:
  - lack of faith in formal models
  - lack of data and/or technical expertise to support the development of formal models
  - relative unimportance of topic to many agencies compared to impact of changes on existing passengers

Survey-Based Methods

Non-Committal Surveys

1. Survey potential riders to ask how they would respond to the new service (or service change)
2. Extrapolate to total population by applying survey responses at the market segment level.
3. Adjust for "non-committal bias" by multiplying by an appropriate adjustment factor (which can range in practice from 0.05 to 0.50).

Generally not recommended.

Survey-Based Methods

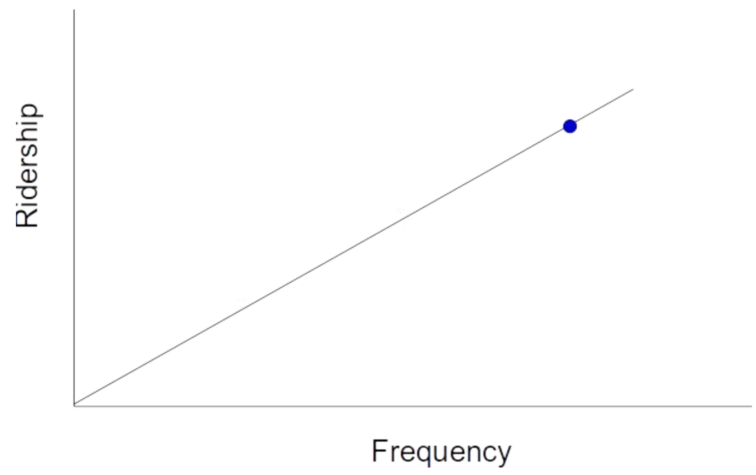
Stated Preference Surveys

- *Stated preference measurement* (conjoint analysis) is emerging as a viable statistical tool for assessing likely responses to proposed transportation system changes.
  - involves detailed, rigorous survey designs & data analyses
  - usually involves a series of tradeoffs that allows a planner to rank relative importance of different types of improvements
  - may be particularly useful for new services or new service areas

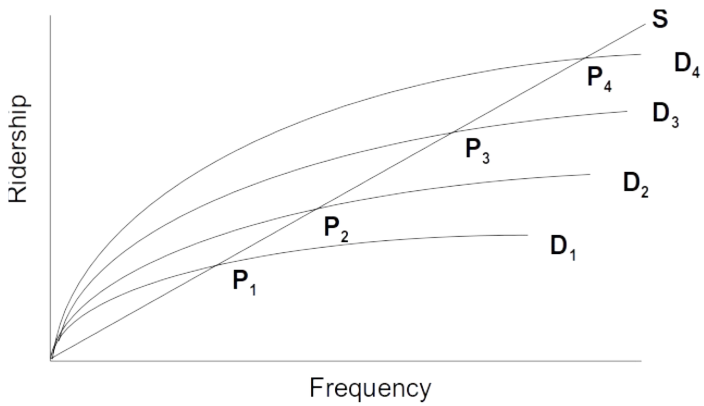
Cross-Sectional Models

- Use route & demographic data to explain route ridership
- Many methods, of varying complexity fall into this category. Four main approaches are:
  - rules of thumb
  - "similar routes" methods
  - multiple factor trip rate models
  - aggregate route regression models

Sample Regression Model



Transit Demand Curves and Scheduler's Rule



S = scheduler's decision rule
D_i = demand as a function of frequency for route i
P_i = observed ridership and frequency on route

Typical Transit Elasticities

Variable	Typical Value	Range
Fare	−0.3	−0.1 to −0.5
Headway	−0.4	−0.2 to −0.7
Total Travel Time	−1.0	N/A

Plus the following points:

- Small cities have larger fare elasticities than large cities.
- Bus travel is more elastic than commuter-rail and rapid-rail travel.
- Off-peak fare elasticities are double the size of peak-fare elasticities.
- Short-distance trips are more elastic than long-distance trips.
- Fare elasticities rise with income and fall with age.
- Of all trip purposes, the work trip is the most inelastic.
- Promotional fare elasticities are slightly larger than short-term fare elasticities following permanent fare revisions.

TTC Elasticity Method

- Compute total weighted travel time for before and after cases:
  - TWT = IVTT + 1.5 WAIT + 2.5 WALK + 10 NTRANS
  - TWT = Total weighted travel time (min.)
  - IVTT = In-vehicle travel time (min.)
  - WAIT = Total time spent waiting/transferring (min.)
  - WALK = Walk time to/from transit (min.)
  - NTRANS = Total number of transfers
- Compute after-change ridership using weighted travel time elasticities:
  - Peak-periods e = −1.5
  - Midday e = −2.0
  - Other off-peak e = −3.0

Direct Demand Route Regression Models

- Match census tract data to route service characteristics
- Difficult to implement without GIS tools
  - to apportion population and employment data among different routes
- Specification of good fit regression model leads to very large tract constants and other dummy variables being highly significant
- Does not recognize network interactions
- Supply/demand interaction not captured

Alternative Approaches to the Ridership Forecasting Problem

- GIS-based, simultaneous-equation, route-level models
  - capable of including competing/ complementary routes
  - able to address demand-supply interactions
  - logical next step beyond direct demand model
- Full network models
  - explicitly deal with competing/complementary routes
  - able to include trip distribution and mode split effects
  - logical next step beyond TTC-type model

- Both approaches require a computerized representation of the transit network and the service area.

GIS-based, Simultaneous Equations, Route-level Model (Portland Tri-Met Model)

Explicitly addresses demand-supply interactions

$R_{iz} = f(S_{iz}, X_{iz})$ [1]

$S_{iz} = g(R_{iz}, R_{i-1}, Z_{iz})$ [2]

where

R_{iz} = ridership on route *i* in segment *z*

R_{i-1} = ridership on route *i* in the previous time period

S_{iz} = level of service provided on route *i* in segment *z*

X_{iz} = other explanatory variables affecting ridership on route *i* in segment *z*

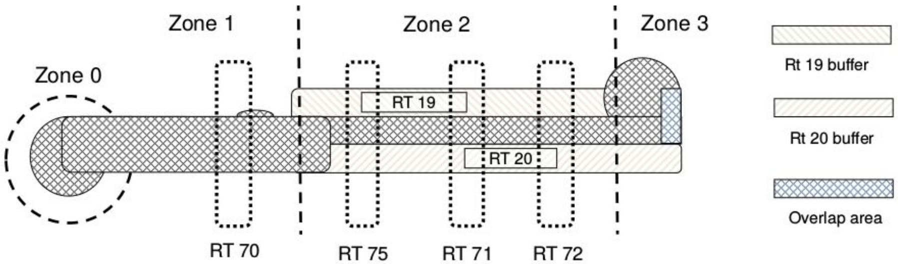
Z_{iz} = other explanatory variables affecting service provided on route *i* in segment *z*

Peng, et al. ("A Simultaneous Route-Level Transit Patronage Model: Demand, Supply, and Inter-Route Relationship", Transportation, Vol. 24, 1997, pp. 159-181).

Portland Tri-Met Model

Uses GIS to identify interactions between routes. Routes can be:

- independent
- complementary
- competing



$OVPOPPC_{ijz} = OVPOP_{ijz} / (POP_{iz} + POP_{jz})$
where i, j denotes competing routes

POP_{kz} = population in catchment area for route k ($k = i, j$) in zone z

$OVPOP_{ijz}$ = population in overlap area in zone z for routes i and j

Portland Tri-Met Model

To capture inter-route effects, modify equation [1] and add equation [3]:

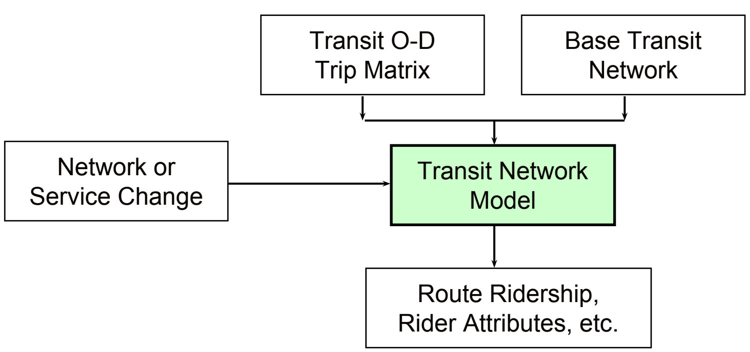
$$R_{iz} = f\,(S_{iz}, \Sigma_j R_{jz}, \Sigma_k R_{kz}, \Sigma_j OVPOPPC_{ijz}, X_{iz})\,[1]$$

where

$$\Sigma_j R_{jz} = h(S_{iz}, \Sigma_j OVPOP_{ijz}, POP_{jz}, Z_{jz}) \qquad [3]$$

R_k = alightings from complementary route k in zone z

Generalized Network-Based Modeling/Analysis Approach



Transit Origin-Destination Flow Matrix

Three levels of analysis:

1. Fixed transit flows
   - use observed current transit OD flows obtained from area-wide survey (e.g., telephone survey)
   - assumes demand for transit will not change as service changes (at least in the short run)
   - typical approach currently adopted
2. Variable modal split, fixed total demand
   - use observed current total (all modes) OD flows
   - apply a modal split model to determine transit flows
   - preferred approach for significant service changes
   - not generally operational
3. Variable total demand & modal split
   - requires full demand modeling capability (i.e., generation, distribution, modal split)
   - not generally necessary for transit service planning, since total OD flows are unlikely to change significantly during service planning period

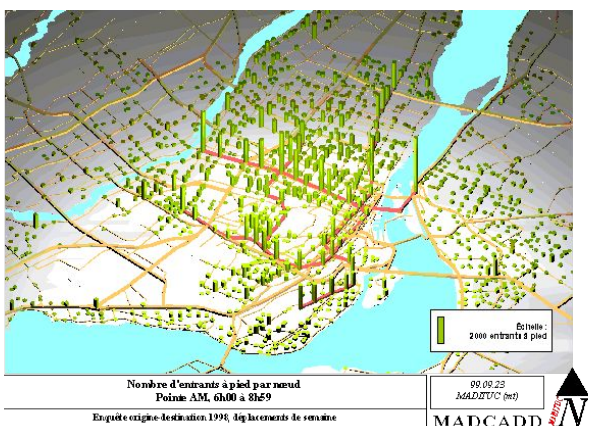
Examples of Transit Network Modeling and Analysis Packages

- MADITUC
- EMME/2
- TransCAD

MADITUC

- Modele d'Analyze Desagregee des Itineraires en Transport Urban Collectif
- Model for the Disaggregate Analysis of Itineraries on a Transit Network
- Developed at the Ecole Polytechnique, University of Montreal (Robert Chapleau)
- Requires "Montreal-style" OD survey data, including transit route choice information
- Does not have general demand modeling capabilities
- Designed specifically for transit service planning
- Is line-oriented rather than link/node-oriented
- Uses all-or-nothing assignment combined with detailed determination of network access/egress points
- Requires SAS for data analysis & graphics
- Used in 4 Canadian cities (Montreal, Quebec, Toronto, Winnipeg)

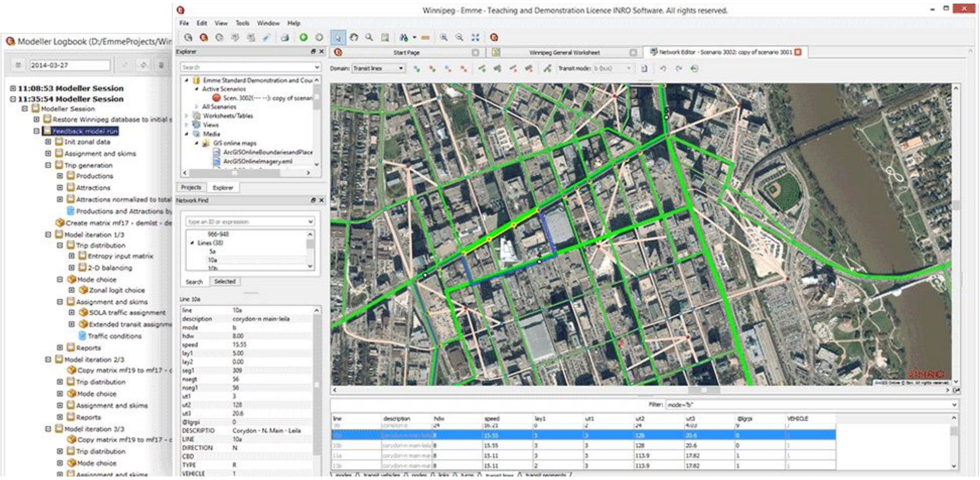
MADITUC



EMME/2

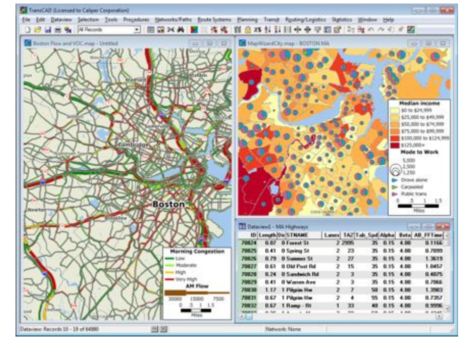
- Equilibre Multi-Modal
- Developed at the Centre for Transportation Research, University of Montreal (Michael Florian)
- Developed as a general regional transportation modeling package
- Can generate transit OD flows from a travel demand model
- Link/node oriented in its design
- Two types of transit assignment available
  - aggregate zone-to-zone flow multipath assignment procedure
    - generally not precise enough for transit route planning applications
  - disaggregate point-to-point trip assignment procedure
    - intended to be comparable to MADITUC
- Probabilistic (multipath) assignment
- Commercially available stand-alone package

EMME/2



TransCAD

- A GIS specifically designed for transportation modelling, developed by Caliper Corporation of Newton, MA
- Very good representation and tools to create and edit detailed transit networks
- API to add in your own mode-split models and assignment procedures to manipulate OD matrices
- Interactive computer graphics for network editing and display
- Network database management system
- Network assignment procedure
- Flexible display and output of results and base data



Transit Network Database

- Geocoded transit links & nodes
- Mapping of transit lines onto network links and nodes
- Transit line attributes
  - headways (by service period)
  - travel times (by service period)
  - mode of service (bus, subway, etc.)
- System attributes
  - operating cost data
  - energy consumption data
  - fares

Typical Package Outputs

- Link and line volumes
- Boardings by link, line, node
- OD travel times
  - in-vehicle
  - out-of-vehicle (walk, wait, transfer, etc.)
- Revenues, operating costs, energy consumption
  - by link or line
- Revenues, operating costs, rider characteristics
  - by origin or destination zone
- Outputs may be displayed in tables, reports, plots
  - network or zone based

Transit Route Assignment Procedures

- Assignment procedures assign origin-destination trips to specific paths through the transit network, thereby loading the specific transit routes with riders.
- Two major approaches to transit assignment exist
  - All-or-nothing assignment, in which all flow for a given origin-destination pair is assigned to a single path, with this path being the least-cost (travel time, etc.) path between the origin and the destination.
  - Multi-path assignment, in which several attractive paths between an origin and a destination are identified, and the flow is split probabilistically over these paths.
- For all-or-nothing to be plausible
  - simple and low-density transit network
  - little choice in access points
  - little choice in path on transit network

Transit Route Assignment Procedures

- Aggregate
  - assign total zone-to-zone flows on a centroid to-centroid basis
- Disaggregate
  - can assign individual trips from actual geocoded origin points to actual geocoded destination points
  - preferable for service planning purposes, if sufficiently disaggregate transit trip data are available

Logit Mode Choice Model

$$P_{it} = \frac{e^{v_{it}}}{\sum_{j=1}^{n} e^{v_{jt}}}$$

P_{it} = probability that individual *t* will choose alternative *i*

V_{it} = systematic utility of alternative *i* for individual *t*

= $\beta_1 X_{it,1} + \beta_2 X_{it,2} + \ldots + \beta_m X_{it,m}$

$X_{it,k}$ = k^{th} explanatory variable (travel time, etc.)

β_k = model coefficient for variable *k*

n = number of alternatives available

m = number of explanatory variables

Typical Variables In A Work Trip Mode Choice Model

- Modal characteristics
  - In-vehicle travel time
  - Out-of-vehicle travel time
  - Out-of-pocket travel cost
- Traveler characteristics
  - Income
  - Gender
  - Auto availability
  - Occupation