RIDERSHIP PREDICTION

Outline

1. Introduction: route ridership prediction needs and issues.

2. Alternative approaches to route ridership prediction.
   - Professional judgement
   - Survey-based methods
   - Cross-sectional models
   - Time-series models

3. Examples of route ridership prediction methods:
   - TTC elasticity method
   - "Direct Demand" models

4. GIS-Based, Simultaneous-Equations, Route-Level Model

5. Network-Based Forecasting Methods
   - TransCAD
   - EMME/2

Roles for Ridership/Revenue Prediction

1. **Predicting ridership/revenue as a result of fare changes**

    - **systemwide 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:**

    - **systemwide prediction required**
        - -- trend projection
        - -- time-series econometric model

Roles for Ridership/Revenue Prediction

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)

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

Factors Affecting Transit Ridership

1. **EXOGENOUS (uncontrollable):**

   - Auto ownership/availability & operating costs

   - Fuel prices & availability

   - Demographics (age, gender, etc.)

   - Activity system (population & employment distributions, etc.)

   $\longrightarrow$ *Usually can be assumed to be "fixed" in the short-run.*

Factors Affecting Transit Ridership

2. ENDOGENOUS (controllable):

- Fare

- Headway (wait time)

- Route structure (walk time; ride time)

- Crowding*

- Reliability*

Usually not explicitly accounted for in ridership prediction methods.

Route Ridership Prediction

Traditional Approach:

Exogenous Change: monitor ridership change

Endogenous Change: modify system accordingly

Reactive -- does not attempt to anticipate impacts prior to the exogenous/endogenous change occurring.

Route Ridership Prediction

Current Practice:

- Little attention given to the problem in many agencies, except for fare changes and major capital projects

- Traditional urban transport planning models inappropriate and ineffective (generally not detailed enough and too complex to run repeatedly)

- Ad-hoc, judgemental methods dominate

Approaches to Predicting Route Ridership

1. Professional judgement

2. Non-committal survey techniques

3. Cross-sectional data models

4. Time-series data models

Professional Judgement

- 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 properties (compared to impact of changes on existing passengers)

Survey-Based Methods

A. 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).

---> NOT generally recommended.

Survey-Based Methods

## B. 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

- These 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
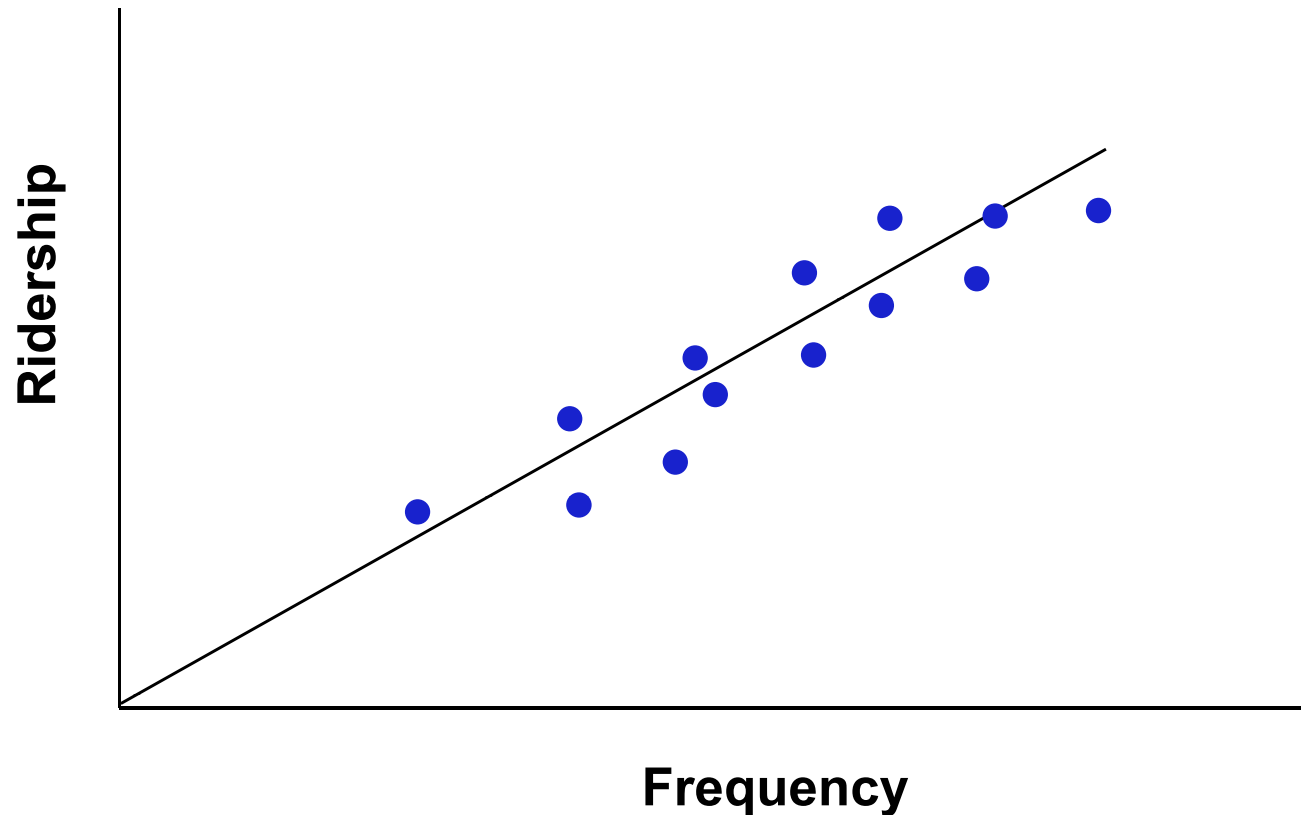
- **Ridership/frequency combination for a route**

Transit Demand Curves and Scheduler's Rule
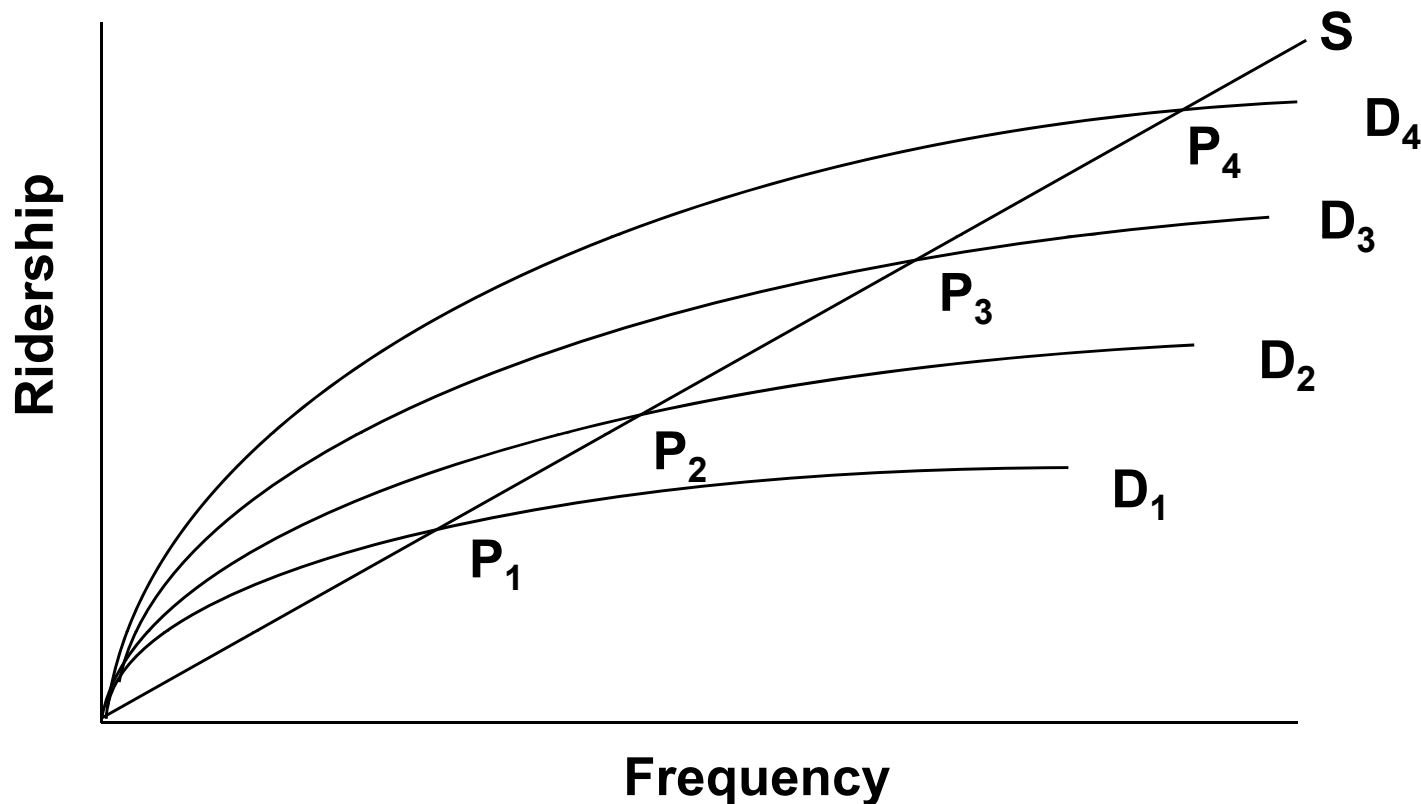
S = scheduler's decision rule

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- 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.

Usage of Route Ridership Prediction Methods

Number of ridership estimation methods used by operators (1990 survey)

Operators	Number of Methods				
	One	Two	Three	Four	Total
Count	18	15	5	1	39
Percent	46%	38%	13%	3%	100%

Number of operators reporting use of each type of ridership forecasting method (1990 survey)

Operators	Forecasting Method			
	Judgement	Non-committal Survey	Similar Routes	Rules of Thumb
Count	17	4	10	10
Percent	44%	10%	26%	26%
Change from 1982	23%	-5%	3%	-10%

Operators	Forecasting Method			
	Linear Regression	Elasticity	Non-Forecasting	Other
Count	5	12	7	4
Percent	13%	31%	18%	10%
Change from 1982	8%	21%	-3%	-8%

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

- Example: Peter Stopher's model in your readings

- Attempts to 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 Stopher-type 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.*

This is usually achieved through some form of Geographic Information System (GIS).

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

Explicitly addresses demand-supply interactions:

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

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

where

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

R_{-1i} = 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
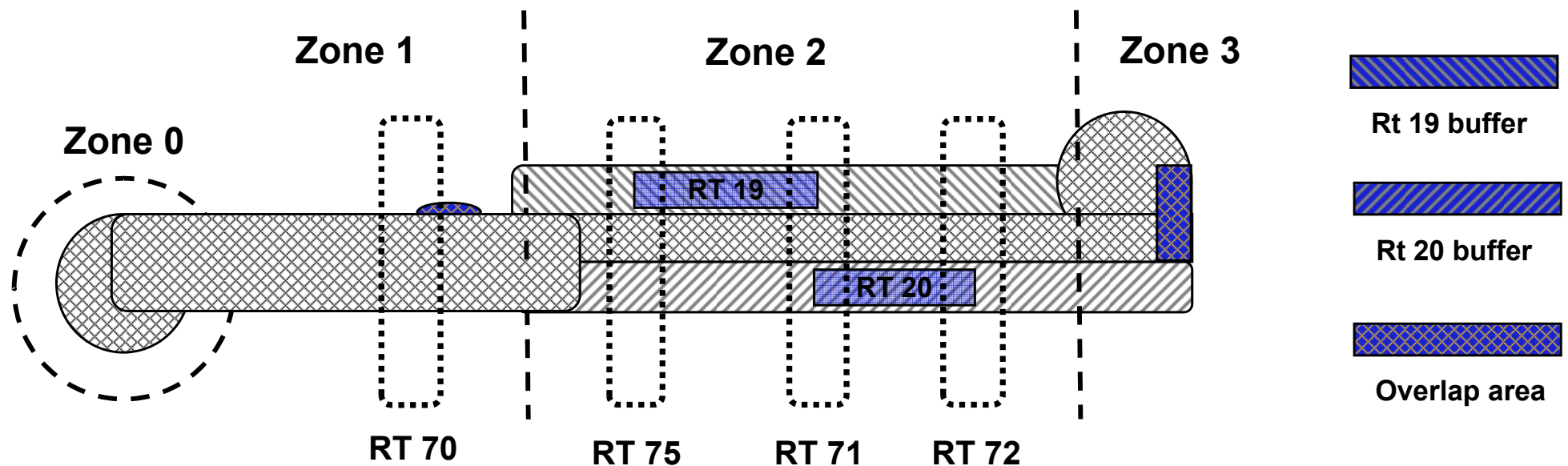
Z_{iz} = other explanatory variables affecting service provided on route i in segment z

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 (cont'd)

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

- independent
- complementary
- competing

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

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

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

Portland Tri-Met Model (cont'd)

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

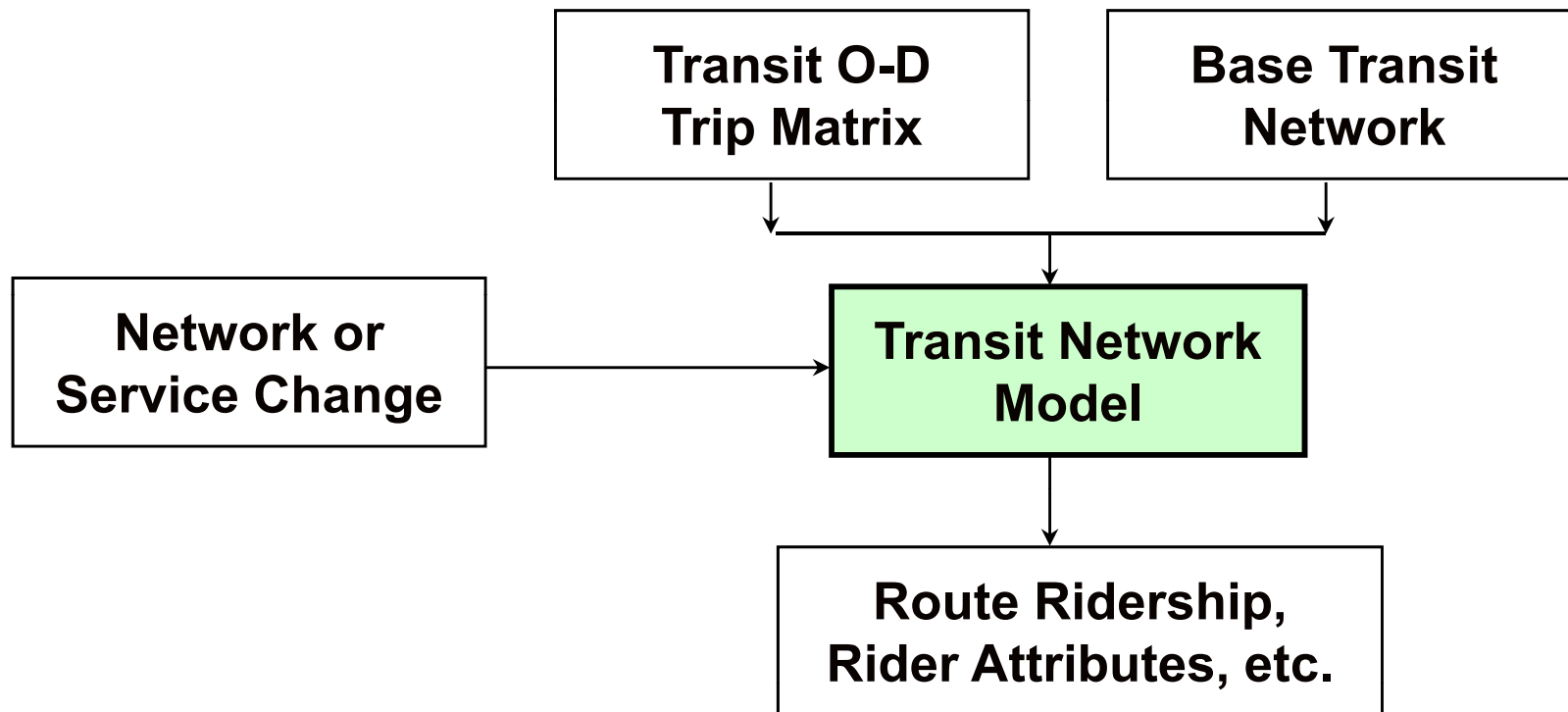$$R_{iz} = f(S_{iz}, \Sigma_j R_{jz}, \Sigma_k R_{kz}, \Sigma_j OVPOPPC_{ijz}, X_{iz}) \quad\quad [1]$$

where

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

$$R_k = \text{alightings from complementary route } k \text{ in zone } z$$

Generalized Network-Based Modeling/Analysis Approach

```
┌─────────────────┐        ┌─────────────────┐
│  Transit O-D    │        │  Base Transit   │
│  Trip Matrix    │        │  Network        │
└─────────────────┘        └─────────────────┘
         │                          │
         └──────────┬───────────────┘
                    ▼
┌─────────────────┐   ┌─────────────────┐
│  Network or     │──▶│  Transit Network│
│  Service Change │   │  Model          │
└─────────────────┘   └─────────────────┘
                             │
                             ▼
                    ┌─────────────────┐
                    │  Route Ridership,│
                    │  Rider Attributes, etc.│
                    └─────────────────┘
```

Transit Origin-Destination Flow Matrix

Three Levels of Analysis

1. **Fixed Transit Flows**

   - use observed current transit o-d 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

Transit Origin-Destination Flow Matrix

Three Levels of Analysis (cont'd)

2. **Variable Modal Split, Fixed Total Demand**

    - use observed current total (all modes) o-d flows

    - apply a modal split model to determine transit flows

    - preferred approach for significant service changes

    - not, however, 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 o-d flows are unlikely to change significantly during service planning period

Examples Of Transit Network Modeling & Analysis Packages

1. **EMME/2, MADITUC**

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

Examples Of Transit Network Modeling and Analysis Packages

1. **MADITUC**

Modele d'Analyze Desagregee des Itineraires en Transport Urban Collectif

or

Model for the Disaggregate Analysis of Itineraries on a Transit Network

- **Developed at the Ecole Polytechnique, University of Montreal (Robert Chapleau)**

- **Requires "Montreal-style" O-D survey data, including transit route choice information**
  - **does <u>not</u> have general demand modeling capabilities**

- **Designed specifically for transit service planning**

- **Is "line-oriented" rather than "link/node- oriented" in design**

- **Uses "all-or-nothing" assignment combined with detailed determination of network access/egress points**

- **Runs on mainframe/minicomputer & PCs**

- **Requires SAS for data analysis & graphics**

- **Used in 4 Canadian cities (Montreal, Quebec, Toronto, Winnipeg)**

Examples of Transit Network Modeling and Analysis Packages, cont'd

2. EMME/2

Equilibre Multi-Modal, Multi-Modal Equilibrium/2

- Developed at the Centre for Transportation Research, University of Montreal (Michael Florian)

- Developed as a general regional transportation modeling package
  - can be used to generate transit O-D flows from a travel demand model
  - or, can input observed transit O-D matrix
  - link/node oriented in its design

- Two types of transit assignment available
  1. "Aggregate" zone-to-zone flow multipath assignment procedure
     - generally not precise enough for transit route planning applications
  2. "Disaggregate" point-to-point trip assignment procedure
     - intended to be comparable to MADITUC
     - probabilistic (multipath) assignment

- Commercially available package

- Runs on mainframes, minicomputers, microcomputers

- "Stand-alone" package

TransCAD Network Model Capabilities

- **Interactive computer graphics for network editing and display**

- **Network database management system**

- **Network assignment procedure**

- **Flexible display & output of results & base data**

  - **plots & reports**

  - **screen displays, printer & plotter hard copies**

Transit Network Database

- **Geocoded transit links & nodes**

- **"Mapping" of transit lines onto network links & 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**

- **O-D 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:

1. **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.**

2. **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, need:

- **simple and low-density transit network**
- **little choice in access points**
- **little choice in path on transit network**

Transit Route Assignment Procedures

- Assignment procedures can also be either:

    1. Aggregate, in that they assign total zone-to-zone flows on a centroid to-centroid basis.

    2. Disaggregate, in that they can assign individual trips from "actual" geocoded origin points to "actual" geocoded destination points.

    --> Disaggregate assignment methods clearly preferable for service planning purposes, providing 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 No. k

n = No. of Alternatives Available

m = No. 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

- **Traveller characteristics:**

  - Income

  - Gender

  - Auto availability

  - Occupation

1.258J / 11.541J / ESD.226J Public Transportation Systems

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