RIDERSHIP PREDICTION

Outline

1. Introduction: route ridership prediction needs and issues.

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

3. Examples of route ridership prediction methods:
   - TTC elasticity method
   - Stopher model
   - TTC methods

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

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

2. **Predicting ridership/revenue for general agency planning and budgeting purposes:**
   - **systemwide 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)

---> 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.)**

---> Usually can be assumed to be "fixed" in the short-run.

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
Endogenous Change } **Monitor Ridership Change** → **Modify System Accordingly**

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

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 & ineffective**
- **Ad-hoc, judgmental methods dominate**

Approaches to Predicting Route Ridership

1. Professional judgment
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

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.

B. Stated Preference Surveys

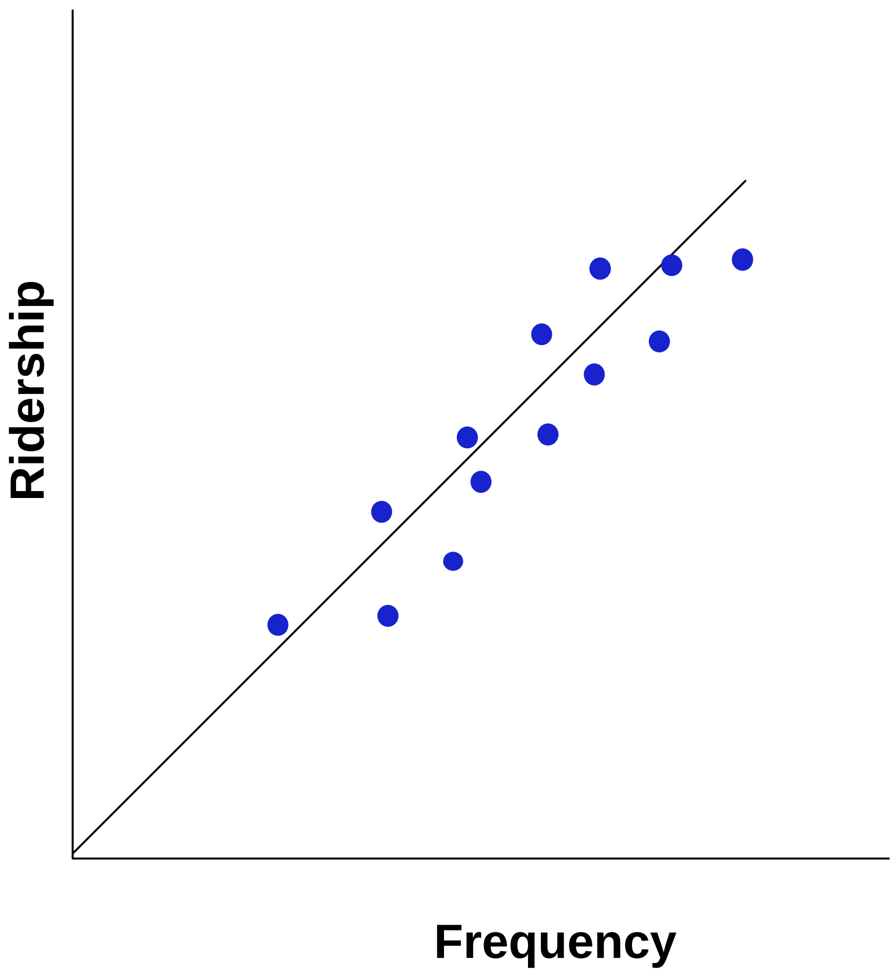
- "Stated preference measurement" (conjoint analysis) is emerging as a viable statistical tool for assessing likely responses to proposed transportation system changes
  - involves detailed, rigorous survey designs & data analyses
  - may be particularly useful for new services or new service areas

Cross-Sectional Models

- These models use route & demographic data to "explain" route ridership.

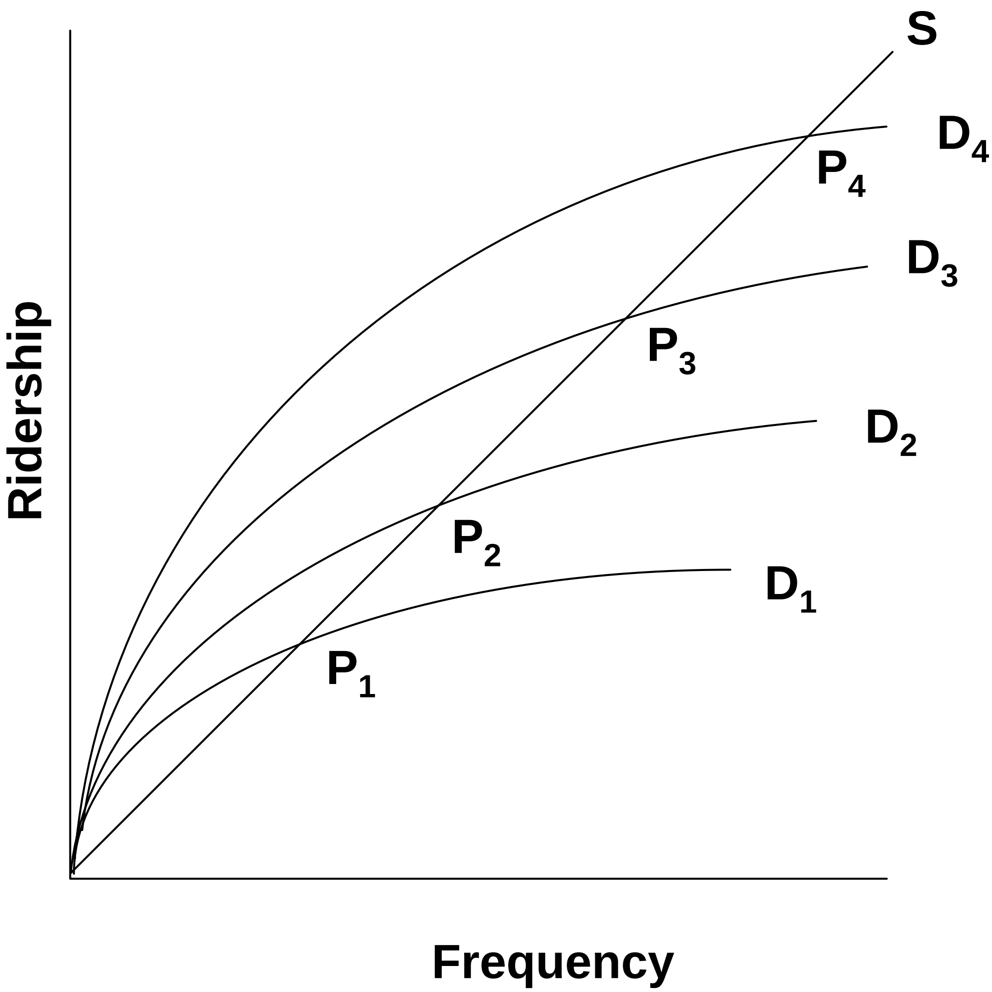
- Many methods, of varying complexity fall into this category. Four main approaches are:
  - "rules of thumb”
  - "similar routes" methods
  - multiple factor trip rate models
  - aggregate route regression models

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

Time Series Data Models

1 Elasticity Methods

Typical form:

$$R_1 = R_0 * \{1 + \Sigma_x e_x (x_1 - x_0)/x_0\}$$

where:

R_1 (R_0)	=	ridership after (before) change
x_1 (x_0)	=	value of service variable x after (before) change
e_x	=	elasticity with respect to service variable x

Typically uses average elasticity values

2. Time Series Regression

Relatively rare: data-hungry; technically demanding; performance improvement relative to simpler techniques not proven

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)

	Number of Methods				
Operators	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)

	Forecasting Method			
Operators	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%
	Forecasting Method			
Operators	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**

Stopher's Route Ridership Prediction Method
(Developed for Portland Tri-met)

- **Route segment level model forecasting boardings and alightings in peak and off-peak periods**
- **Cross-sectional regression equations developed for peak-period weekday day and weekday night service periods**
- **Equations include route service characteristics and Census socio-economic data re route service areas**
- **Three main files:**
  - **bus route file;**
  - **conversion file relating bus routes to census tracts; and**
  - **census tract data file**

Reference: Stopher, P.R. "Development of a Route Level Patronage Forecasting Method", presented at the Third National Conference on Transportation Planning Methods Applications, Dallas, April 22-26, 1991.

Stopher's Method:
Peak Period Model

Variable	Boardings	Alightings
CBD	844.621 (4.79)	1683.211 (9.50)
POP	-0.0476 (1.61)	-0.0872 (2.93)
TERM	15322.23 (41.65)	16047.75 (43.45)
EMP_RET	0.1725 (4.38)	0.1620 (4.10)
BUSES_HR	17.905 (4.65)	16.621 (4.21)
TRIPTIME	-0.5429 (1.63)	-0.2356 (0.71)
AGES25_34	0.0810 (0.88)	0.1753 (1.91)
REV_MILE	-0.0900 (1.61)	-0.1078 (1.92)
TOT_HOUS	-0.705 (2.83)	-0.7601 (3.04)
HH	0.859 (3.17)	0.968 (3.56)
F Statistic	527.13***	620.31***
R^2	0.955	0.962

***** Indicates significance at 99.9% or better**

TTC Route Ridership Prediction

- **Combination of rules of thumb (based on experience + survey data) and judgement**
- **Two methods used, depending on type of service change:**
  - **additional period(s) of operation; or**
  - **new route/route extension/major re-routing.**

Reference: Toronto Transit Commission, <u>Service Standards Process Technical Background Papers</u>, No. 1, "Ridership Forecasting Methods", January, 1991, pp. 1-11 (see Supplementary Readings)

Route Ridership
Prediction Method 1

SYSTEM-WIDE AVERAGE OPERATING PERIOD RIDERSHIP PROPORTIONS FOR ADDITIONAL PERIODS OF OPERATION

	RIDERSHIP IN ADDED PERIOD (% of Base Period)		
Added Period/ Base Period	Core Route Section (2)	Suburban Route Section (2)	Industrial Route Section (3)
(a) Day Normal/ AM Peak	75%	63%	66%
(b) Evening/ AM Peak	54%	41%	35%
(c) Total Saturday/ Total Weekday	53%	38%	28%
(d) Total Sunday/ Total Weekday	39%	26%	10%

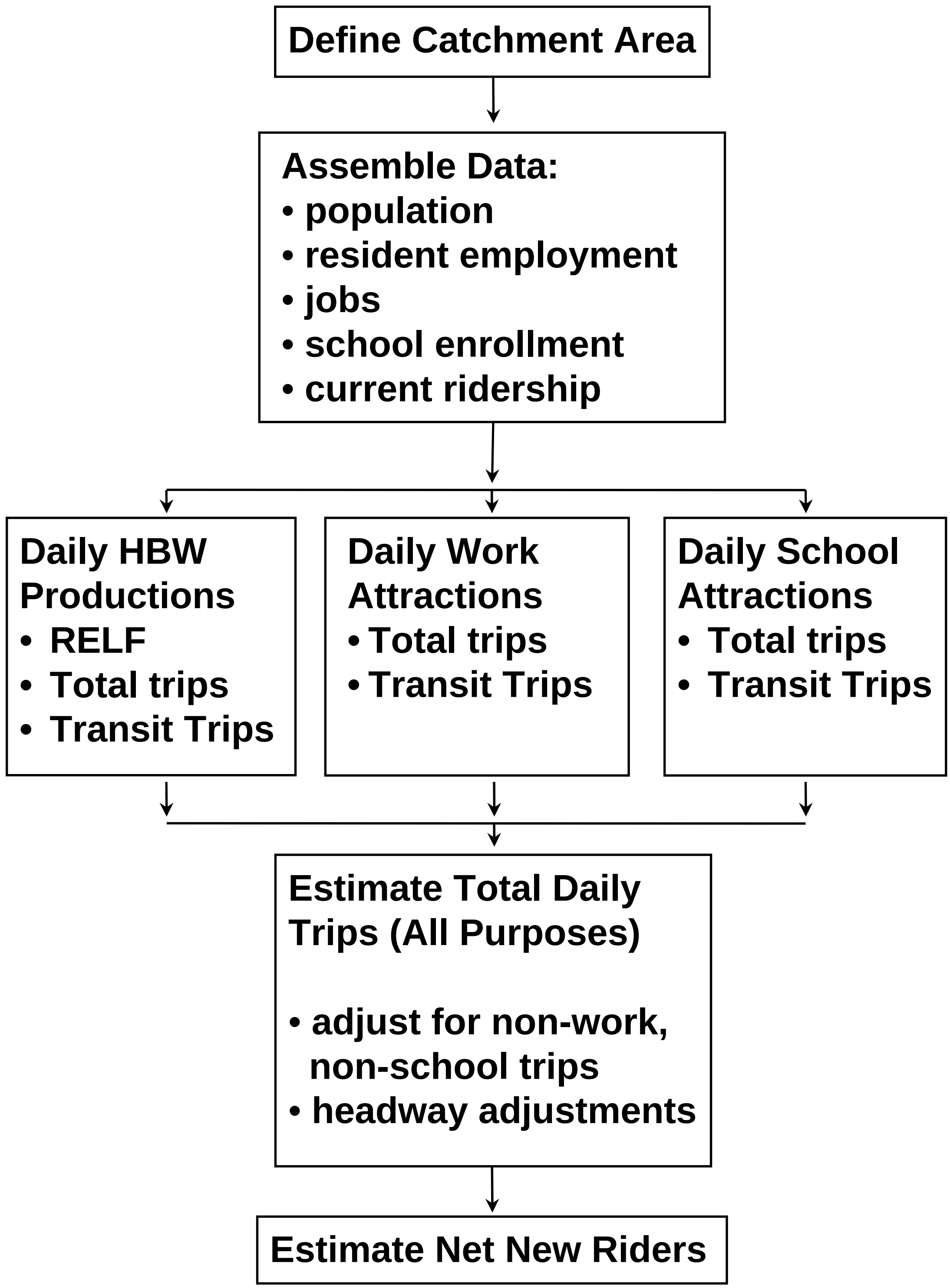
(1) Proportions are based on analysis of actual ridership counts on all routes in system. They are used to estimate ridership in proposed additional periods of operation on existing routes.

(2) Suburban route sections are those which serve non-industrial areas in the cities of Etobicoke, North York, and Scarborough. Core route sections serve non-industrial areas in the Cities of Toronto, York, and East York. Suburban and core categories were separated because of the significant variation in the operating period ridership proportions across the system.

(3) Industrial route sections are those which serve primarily industrial areas in Metro. These route sections were examined separately because their ridership is characterized by more home-to-work trips which are concentrated in the peak periods, with fewer trips occurring in the off-peak periods, than is the case for route sections serving residential or commercial areas

Route Ridership

Prediction Method 2



Route Ridership Prediction
Method 2, Mode Split Factors

- Based on existing average mode splits by:
  - zone of origin and destination
  - separately for work trip productions and attractions

- Example: for extreme Northeast zone:
  - transit mode split of 50% for work trip productions leading to CBD
  - transit mode split of 19% for all other work trip productions
  - transit mode split of 18% for all work trip attractions

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:

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

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

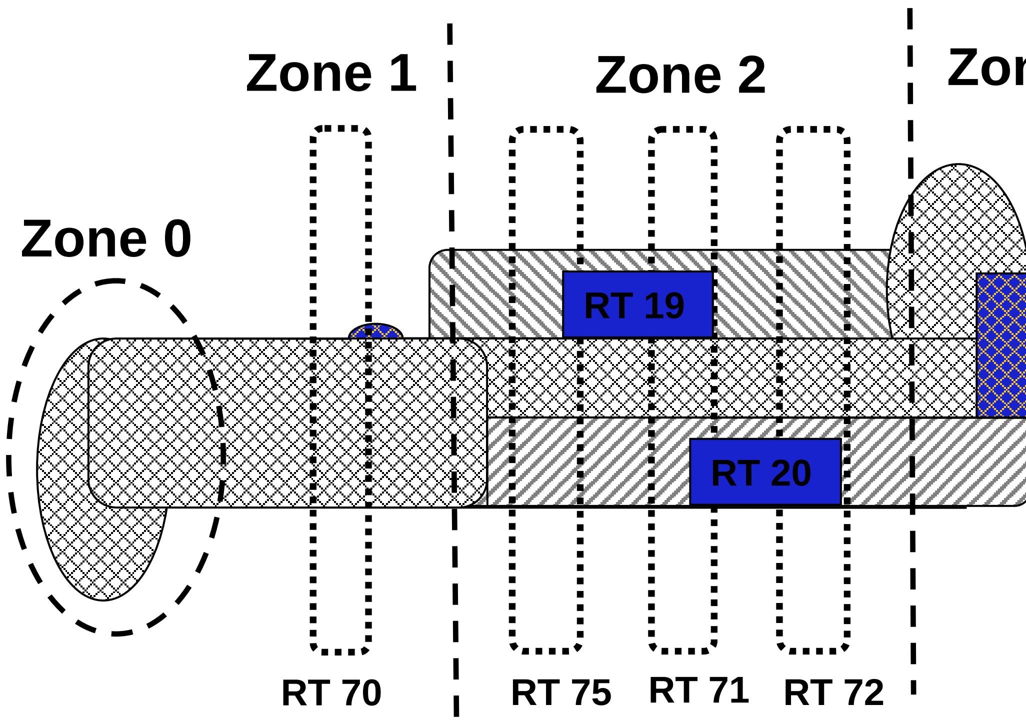
Z_{iz} = **other explanatory variables affecting service provided on route *i* in segment *z***

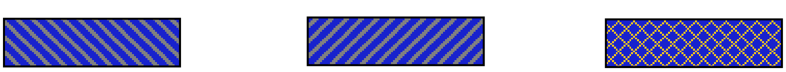
Peng, *et al.* ("A Simultaneous Route-Level Transit Patronage Model: Demand, Supply, and Inter-Route Relationship", *Transportation*, Vol. 24, 1997, pp. 159-181).

Portland Tri-Met Model (cont'd)

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

- independent
- complementary
- competing





Rt 19 buffer   Rt 20 buffer   Overlap area

$OVPOPPC_{ijz}$ = $OVPOP_{ijz}/(POP_{iz} + POP_{jz})$
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 (cont'd)

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

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

where

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

R_{kz} = **alightings from complementary route *k* in zone *z***