Trip distribution

CEE 5240/6240

Urban and Regional Transportation Planning

30 January 2019

Civil & Environmental ENGINEERING

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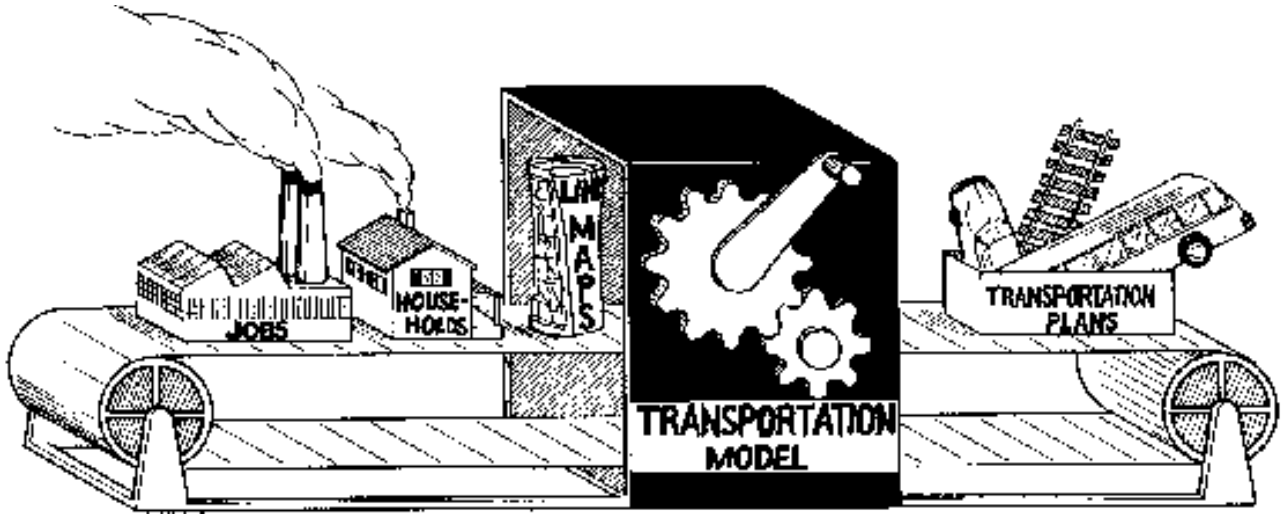
Outline

- Trip generation review
- Trip distribution overview
- Trip distribution methods
  - Growth factor model
  - Gravity model
  - Destination choice model
- Homework 5

Trip distribution

Trip-based models

1. Generation
2. Distribution
3. Mode choice
4. Assignment



Source: Beimborn (1995), A Transportation Modeling Primer
https://www4.uwm.edu/cuts/primer.htm

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Trip generation outputs

- Transportation analysis zones (TAZs)
- Trip productions vs. trip attractions
- Trip purposes
  - Home-based …
  - Non-home based…
- Methods: cross-classification, linear regression, etc.

	Trip productions			*Trip attractions*		
TAZ	**HBW**	**HBO**	**NHB**	**HBW**	**HBO**	**NHB**
1	50	75	25	5	10	25
2	87	34	112	0	0	65
3	41	42	49	35	56	53
4	0	0	236	187	134	201
5	62	57	38	14	16	54
…						

Trip distribution

- Linking trip productions & attractions
  - Productions ←→ Attractions
- Creating a matrix of trip productions & attractions
  - → PA trip matrix
- Converting to a matrix of trip origins & destinations
  - → OD trip matrix

	HBW trips				
TAZ (P\A)	**1**	**2**	**3**	**…**	**Total**
1	1	0	11		50
2	2	0	18		87
3	0	0	6		41
…					
Total	5	0	35		

Trip distribution

- Notation
  - Production zones i
  - Attraction zones j
  - Total trips P_i produced in zone i and attracted to all zones
  - Total trips A_j attracted to zone j and produced in all zones
  - Trips T_{ij} produced in zone i and attracted to zone j

	HBW trips				
TAZ (P\A)	**$j = 1$**	**$j = 2$**	**$j = 3$**	**…**	**Total**
$i = 1$	T_{11}	T_{12}	T_{13}		P_1
$i = 2$	T_{21}	T_{22}	T_{23}		P_2
$i = 3$	T_{31}	T_{32}	T_{33}		P_3
…					
Total	A_1	A_2	A_3		

Trip distribution

- Constraints
  - Row sums should equal trip productions
    - $\sum_j T_{ij} = P_i$
  - Column sums should equal trip attractions
    - $\sum_i T_{ij} = A_j$

	HBW trips				
TAZ (P\A)	$j = 1$	$j = 2$	$j = 3$	…	**Total**
$i = 1$	T_{11}	T_{12}	T_{13}		P_1
$i = 2$	T_{21}	T_{22}	T_{23}		P_2
$i = 3$	T_{31}	T_{32}	T_{33}		P_3
…					
Total	A_1	A_2	A_3		

- *Singly constrained*: if only one of these conditions (usually P_i) holds
- *Doubly constrained*: if both of these conditions hold

What factors affect trip distribution?

- What do you consider when you choose a destination?

- Impedance / level-of-service (LOS)
  - Travel time or (generalized) cost

- Attractiveness
  - # trip attractions
  - Employment by type

Trip distribution methods

- Growth factor model
  - Fratar/Furness method
  - Iterative fitting of growth factors
- Gravity model
  - Calibration → Friction factors
  - Application
- Destination choice model
  - Disaggregate approach
  - Multinomial logit modeling

Growth factor model

- Given a base-year PA or OD trip matrix, and limited information about future trips, apply growth factor(s) to base-year trip matrix to create future-year trip matrix.

- Rarely used in practice anymore
  - Cannot account for changes in impedance

Base Year

P \ A	z1	z2	z3	Total
z1	5	50	95	150
z2	45	5	100	150
z3	50	95	5	150
Total	100	150	200	450

Forecast Year

P \ A	z1	z2	z3	Total
z1	?	?	?	??
z2	?	?	?	??
z3	?	?	?	??
Total	??	??	??	???

Growth factor model – Simple

- Given:
  - Base-year PA trip matrix from survey data
  - Uniform area-wide growth of 20% ($\tau = 1.20$)

$$T'_{ij} = \tau \times T_{ij}$$

Base Year

P \ A	z1	z2	z3	Total
z1	5	50	95	150
z2	45	5	100	150
z3	50	95	5	150
Total	100	150	200	450

Forecast Year

P \ A	z1	z2	z3	Total
z1	6	60	120	186
z2	60	6	120	186
z3	60	120	6	186
Total	126	186	246	558

Growth factor model – Singly constrained

- Given:
  - Base-year PA trip matrix from survey data
  - Future-year production zone-specific growth factors (or productions)

$$T'_{ij} = \tau_i \times T_{ij}$$

Base Year

P \ A	z1	z2	z3	Total	τ_i
z1	5	50	95	150	??
z2	45	5	100	150	??
z3	50	95	5	150	??
Total	100	150	200	450	--

Forecast Year

P \ A	z1	z2	z3	Goal
z1	?	?	?	180
z2	?	?	?	165
z3	?	?	?	255
Total	??	??	??	600

Growth factor model – Doubly constrained

- Given:
  - Base-year PA trip matrix from survey data
  - Future-year production & attraction zone-specific growth factors

$$T'_{ij} = \tau_i \times T_{ij}$$

$$\neq$$

$$T'_{ij} = \tau_j \times T_{ij}$$

Base Year

P \ A	z1	z2	z3	Total	τ_i
z1	5	50	95	150	??
z2	45	5	100	150	??
z3	50	95	5	150	??
Total	100	150	200	450	--
τ_j	??	??	??	--	--

Forecast Year

P \ A	z1	z2	z3	Goal
z1	?	?	?	180
z2	?	?	?	165
z3	?	?	?	255
Goal	195	165	240	600

???

Fratar/Furness method

- Iteratively calculate growth factors τ_i and τ_j until they approach 1.
  - Step 1: $\tau_i = P^G_i \div P^B_i \longrightarrow T^1_{ij} = \tau_i \times T^B_{ij} \longrightarrow A^1_j$

Base Year (B)

P \ A	z1	z2	z3	Total	Goal	τ_i
z1	5	50	95	150	180	1.20
z2	45	5	100	150	165	1.10
z3	50	95	5	150	255	1.70
Total	100	150	200	450	--	--
Goal	195	165	240	--	600	--

Forecast Year (1)

P \ A	z1	z2	z3	Total
z1	6.0	60.0	114.0	180
z2	49.5	5.5	110.0	165
z3	85.0	161.5	8.5	255
Total	140.5	227.0	232.5	600

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Fratar/Furness method

- Iteratively calculate growth factors τ_i and τ_j until they approach 1.
  - Step 2:

$$\tau_j = A^G{}_j \div A^1{}_j \longrightarrow T^2{}_{ij} = \tau_j \times T^1{}_{ij} \longrightarrow P^2{}_i$$

Forecast Year (1)

P \ A	z1	z2	z3	Total	Goal
z1	6	60	114	180	180
z2	49.5	5.5	110	165	165
z3	85	161.5	8.5	255	255
Total	140.5	227	232.5	600	--
Goal	195	165	240	--	600
τ_j	1.39	0.73	1.03	--	--

Forecast Year (2)

P \ A	z1	z2	z3	Total
z1	8.3	43.6	117.7	169.6
z2	68.7	4.0	113.5	186.3
z3	118.0	117.4	8.8	244.1
Total	195	165	240	600

Fratar/Furness method

- Iteratively calculate growth factors τ_i and τ_j until they approach 1.
  - Step 1:

$$\tau_i = P^G{}_i \div P^2{}_i \longrightarrow T^3{}_{ij} = \tau_i \times T^2{}_{ij} \longrightarrow A^3{}_j$$

Forecast Year (2)

P \ A	z1	z2	z3	Total	Goal	τ_i
z1	8.3	43.6	117.7	169.6	180	1.06
z2	68.7	4.0	113.5	186.3	165	0.89
z3	118.0	117.4	8.8	244.1	255	1.04
Total	195	165	240	600	--	--
Goal	195	165	240	--	600	--

Forecast Year (3)

P \ A	z1	z2	z3	Total
z1	8.8	46.3	124.9	180
z2	60.9	3.5	100.6	165
z3	123.2	122.6	9.2	255
Total	192.9	172.4	234.6	600

Fratar/Furness method

- Iteratively calculate growth factors τ_i and τ_j until they approach 1.
  - Step 2:

$$\tau_j = A^G{}_j \div A^3{}_j \longrightarrow T^4{}_{ij} = \tau_j \times T^3{}_{ij} \longrightarrow P^4{}_i$$

Forecast Year (3)

P \ A	z1	z2	z3	Total	Goal
z1	8.8	46.3	124.9	180	180
z2	60.9	3.5	100.6	165	165
z3	123.2	122.6	9.2	255	255
Total	192.9	172.4	234.6	600	--
Goal	195	165	240	--	600
τ_j	1.01	0.96	1.02	--	--

Forecast Year (4)

P \ A	z1	z2	z3	Total
z1	8.9	44.3	127.7	181.0
z2	61.5	3.4	102.9	167.8
z3	124.5	117.3	9.4	251.2
Total	195	165	240	600

Fratar/Furness method

- Iteratively calculate growth factors τ_i and τ_j until they approach 1.
  - Step 1:

$$\tau_i = P^G_i \div P^4_i \longrightarrow T^5_{ij} = \tau_i \times T^4_{ij} \longrightarrow A^5_j$$

Forecast Year (4)

P \ A	z1	z2	z3	Total	Goal	τ_i
z1	8.9	44.3	127.7	181.0	180	0.99
z2	61.5	3.4	102.9	167.8	165	0.96
z3	124.5	117.3	9.4	251.2	255	1.01
Total	195	165	240	600	--	--
Goal	195	165	240	--	600	--

Forecast Year (5)

P \ A	z1	z2	z3	Total
z1	8.9	44.1	127.1	180
z2	60.5	3.3	101.2	165
z3	126.4	119.1	9.5	255
Total	195.8	166.5	237.8	600

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Fratar/Furness method

- Iteratively calculate growth factors τ_i and τ_j until they approach 1.
  - Step 2: $\tau_j = A^G{}_j \div A^5{}_j \longrightarrow |\tau_j - 1| < 0.01$ or 0.001

Forecast Year (5)

P \ A	z1	z2	z3	Total	Goal
z1	8.9	44.1	127.1	180	180
z2	60.5	3.3	101.2	165	165
z3	126.4	119.1	9.5	255	255
Total	195.8	166.5	237.8	600	--
Goal	195	165	240	--	600
τ_j	1.00	0.99	1.01	--	--

Done!?

Growth factor model

- Advantages?
  - Simple
  - No impedance/LOS information needed

- Disadvantages?
  - No volumes to and from new zones
  - Not good for looking at policy effects
  - Ignores congestion (and any LOS)

Gravity model

- Given
  - a base-year PA or OD trip matrix
  - information about future trip productions & attractions, and
  - information on zone-to-zone impedance
- Iteratively develop/apply friction factors to create future-year trip matrix
- Still commonly used in practice
  - Practice heading toward destination choice models

Base Year

P \ A	z1	z2	z3	Total
z1	5	50	95	150
z2	45	5	100	150
z3	50	95	5	150
Total	100	150	200	450

Forecast Year

P \ A	z1	z2	z3	Goal
z1	?	?	?	180
z2	?	?	?	165
z3	?	?	?	255
Goal	195	165	240	600

Gravity model

- Analogous to Newton's law of gravity:
  - $T_{ij} = \alpha \times P_i \times A_j \div (d_{ij})^2$

- Directly proportional to…
  - Trips P_i produced in zone i
  - Trips A_j attracted to zone j

- Inversely proportional to…
  - Impedance d_{ij} between zones i and j

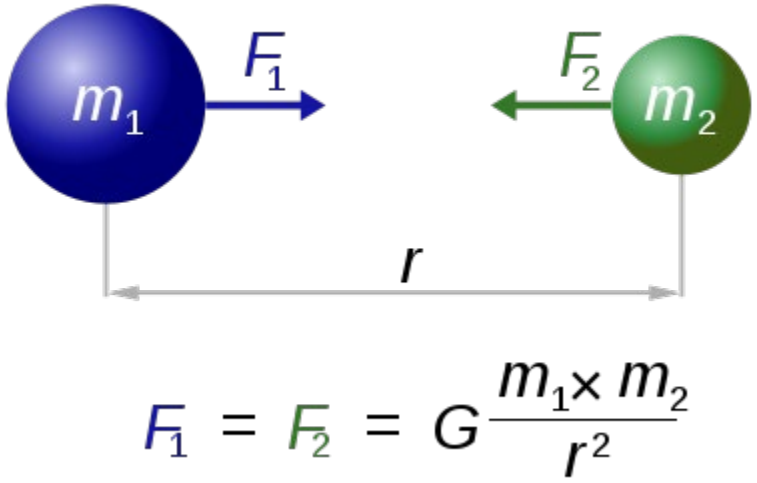


Image: https://en.wikipedia.org/wiki/Newton%27s_law_of_universal_gravitation#/media/File:NewtonsLawOfUniversalGravitation.svg

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Gravity model

- Generalization

$$T_{ij} = \alpha \times P_i \times A_j \div (d_{ij})^2$$

$$T_{ij} = \alpha_{ij} \times P_i \times A_j \times f(c_{ij})$$

$$T_{ij} = (M_i \times N_j) \times P_i \times A_j \times f(c_{ij})$$

- Directly proportional to…
  - Trips P_i produced in zone i
  - Trips A_j attracted to zone j

$$T_{ij} = (M_i \times P_i) \times (N_j \times A_j) \times f(c_{ij})$$

$$T_{ij} = m_i \times n_j \times f(c_{ij})$$

- Inversely proportional to…
  - Generalized cost function $f(c_{ij})$ between zones i and j

Gravity model

$$T_{ij} = (M_i \times P_i) \times (N_j \times A_j) \times f(c_{ij})$$

- Singly constrained

$$M_i = 1 \div \sum_j (A_j \times f(c_{ij})) \qquad N_j = 1$$

- Doubly constrained

$$M_i = 1 \div \sum_j (N_j \times A_j \times f(c_{ij}))$$

$$N_j = 1 \div \sum_i (M_i \times P_i \times f(c_{ij}))$$

Friction factors

$$f(c_{ij}) = F_{ij}$$

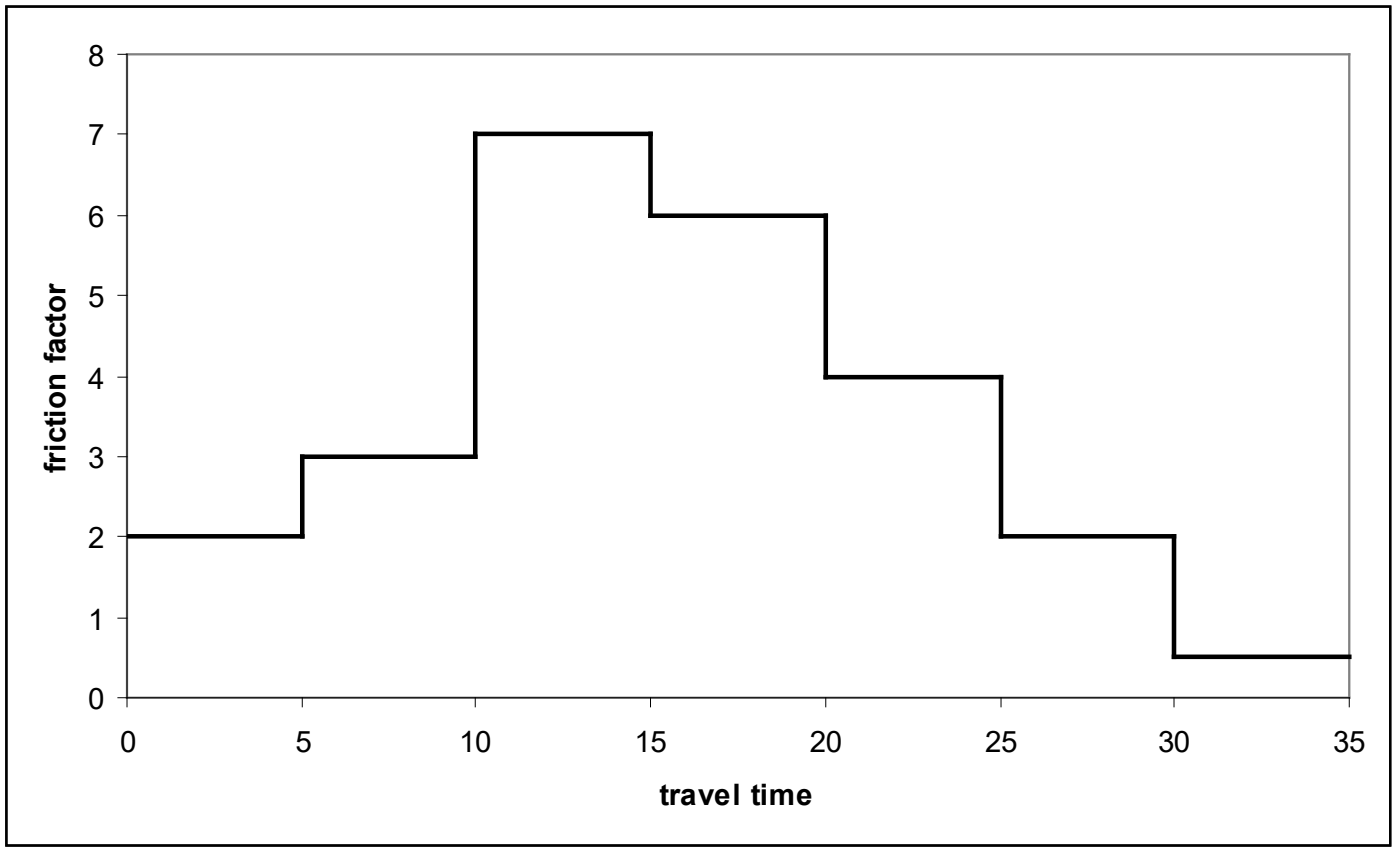
- Parametric (mathematical equation)
  - Power $$f(c_{ij}) = F_{ij} = (c_{ij})^{y}$$
  - Exponential $$f(c_{ij}) = F_{ij} = \exp(z \times c_{ij})$$
  - Gamma $$f(c_{ij}) = F_{ij} = x \times (c_{ij})^{y} \times \exp(z \times c_{ij})$$

$$y < 0 \qquad z < 0$$

Friction factors

$$f(c_{ij}) = F_{ij}$$

- Non-parametric (look-up table)

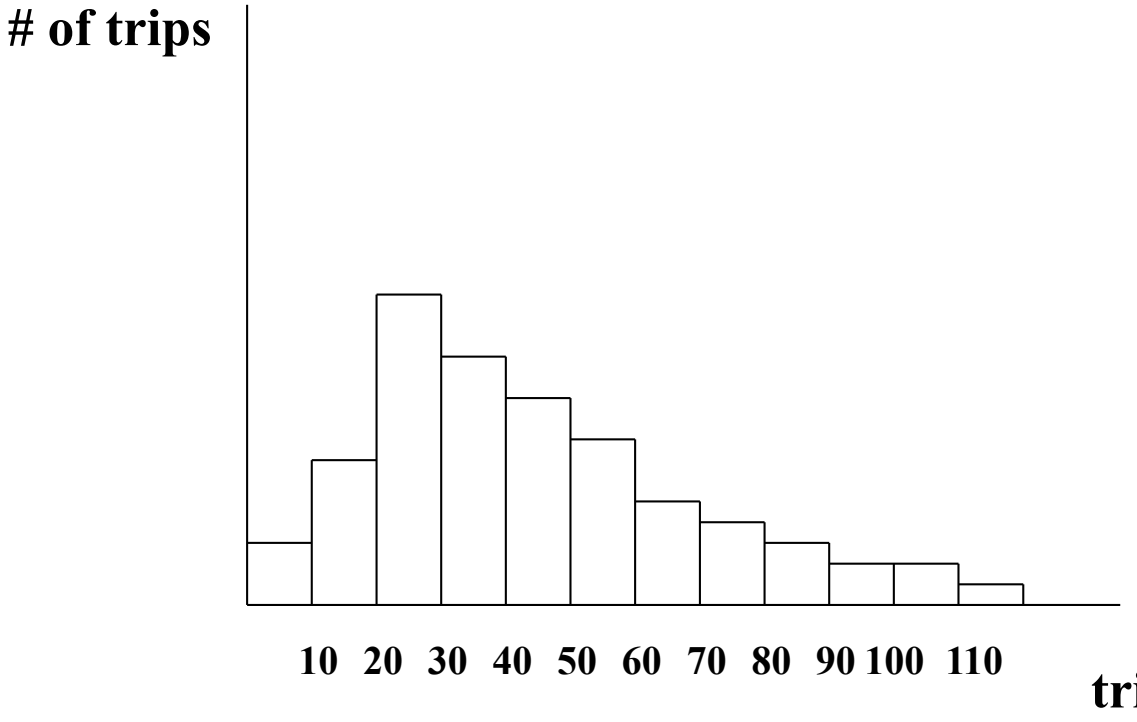


$$F_{ij} = \begin{cases} F_1 & \text{if } 0 \le t_{ij} \le 5 \\ F_2 & \text{if } 5 \le t_{ij} \le 10 \\ & \\ F_7 & \text{if } 30 \le t_{ij} \le 35 \end{cases}$$

Friction factors

$$f(c_{ij}) = F_{ij}$$

- Used to match observed trip length distribution



Time Bin	Predicted	Observed	FF
1	799.9964	800	0.798501
2	2639.926	2640	1.512652
3	1520.033	1520	1.083482
4	905.0445	905	0.476607
Total	**5865**	**5865**	

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Gravity model calibration

- Given
  - Initial PA trip matrix T_{ij}, P_i, A_j
  - Generalized cost (or impedance) matrix
  - Gravity model form
  - Friction factor functional form

Base Year

P \ A	z1	z2	z3	Total
z1	5	50	95	150
z2	45	5	100	150
z3	50	95	5	150
Total	100	150	200	450

Impedance

TT	z1	z2	z3
z1	5	16	13
z2	16	7	20
z3	13	20	2

$$T_{ij} = P_i \times A_j \times F_{ij} \div \sum_j (A_j \times F_{ij})$$

F_{ij} = lookup table

Gravity model calibration

- Determine the friction factors (F_{ij})
  - 0. Assume initial friction factors $F_{ij} = 1$
  - 1. Create friction factor matrix
  - 2. Calculate denominator sum $\sum_j (A_j \times F_{ij})$
  - 3. Apply formula to calculate $T_{ij} = P_i \times A_j \times F_{ij} \div \sum_j (A_j \times F_{ij})$

Impedance

TT	z1	z2	z3
z1	5	16	13
z2	16	7	20
z3	13	20	2

FF matrix (1)

TT	z1	z2	z3
z1	1.00	1.00	1.00
z2	1.00	1.00	1.00
z3	1.00	1.00	1.00

1

Base Year (1)

P \ A	z1	z2	z3	Total	$\sum_j$
z1	33.3	50.0	66.7	150	450.0
z2	33.3	50.0	66.7	150	450.0
z3	33.3	50.0	66.7	150	450.0
Total	100.0	150.0	200.0	450	--

2

3

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Gravity model calibration

- Determine the friction factors (F_{ij})
  - 4. Calculate estimated trip length distribution
  - 5. Update friction factors $FF_{new} = FF_{old} \times (\text{Obs} \div \text{Est})$
  - Repeat steps 1. through 5. until FFs don't change

Friction Factors (2)

TT	Est.	Obs.	FF
1-10	150	15	0.10
11-15	100	145	1.45
16-20	200	290	1.45

4

5

FF matrix (2)

TT	z1	z2	z3
z1	0.10	1.45	1.45
z2	1.45	0.10	1.45
z3	1.45	1.45	0.10

1

Base Year (2)

P \ A	z1	z2	z3	Total	$\sum_j$
z1	2.9	63.0	84.1	150	517.5
z2	48.3	5.0	96.7	150	450.0
z3	56.9	85.3	7.8	150	382.5
Total	108.1	153.3	188.6	450	--

2

3

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Gravity model calibration

- Determine the friction factors (F_{ij})
  - Repeat steps 1. through 5. until FFs don't change

Friction Factors (3)

TT	Est.	Obs.	FF
1-10	15.7	15	0.10
11-15	140.9	145	1.49
16-20	293.3	290	1.43

4

5

FF matrix (3)

TT	z1	z2	z3
z1	0.10	1.43	1.49
z2	1.43	0.10	1.43
z3	1.49	1.43	0.10

1

Base Year (3)

P \ A	z1	z2	z3	Total	$\sum_j$
z1	2.7	61.7	85.6	150	522.9
z2	48.4	4.8	96.8	150	444.3
z3	58.4	84.2	7.5	150	383.3
Total	109.5	150.7	189.8	450	--

2

3

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Gravity model calibration

- Determine the friction factors (F_{ij})
  - Repeat steps 1. through 5. until FFs don't change

Friction Factors (4)

TT	Est.	Obs.	FF
1-10	15.0	15	0.10
11-15	144.0	145	1.50
16-20	291.0	290	1.43

4

5

FF matrix (4)

TT	z1	z2	z3
z1	0.10	1.43	1.50
z2	1.43	0.10	1.43
z3	1.50	1.43	0.10

1

Base Year (4)

P \ A	z1	z2	z3	Total	$\sum_j$
z1	2.7	61.3	86.0	150	524.3
z2	48.4	4.8	96.8	150	442.8
z3	58.8	83.8	7.4	150	383.6
Total	109.9	149.9	190.2	450	--

2

3

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Gravity model calibration

- Determine the friction factors (F_{ij})
  - Repeat steps 1. through 5. until FFs don't change

$$| FF_{new} - FF_{old} | < 0.01 \text{ or } 0.001$$

Done!?

Friction Factors (4)

TT	Est.	Obs.	FF
1-10	15.0	15	0.10
11-15	144.0	145	1.50
16-20	291.0	290	1.43

Friction Factors (5)

TT	Est.	Obs.	FF
1-10	15.0	15	0.10
11-15	144.7	145	1.51
16-20	290.3	290	1.43

4

5

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Gravity model calibration

- A few notes and warnings
  - Things that are slightly different from the Fratar/Furness method

- 1. When calculating trips using $T_{ij} = P_i \times A_j \times F_{ij} \div \sum_j (A_j \times F_{ij})$ …
  - Always use the original P_i and A_j values, NOT the new totals

- 2. When updating the friction factors using $FF_{new} = FF_{old} \times (\text{Obs} \div \text{Est})$
  - Always multiply by the old FF values, DON'T just divide observed by estimated

Gravity model application

- Given
  - Future trip productions & attractions P_i , A_j
  - Future generalized cost / impedance matrix
  - Calibrated friction factors F_{ij}
- Calculate future $T_{ij} = P_i \times A_j \times F_{ij} \div \sum_j (A_j \times F_{ij})$

Impedance

TT	z1	z2	z3
z1	7	18	16
z2	18	11	20
z3	16	20	5

Friction Factors

TT	Est.	Obs.	FF
1-10	15	15	0.10
11-15	145	145	1.51
16-20	290	290	1.43

Forecast Year

P \ A	z1	z2	z3	Goal
z1	?	?	?	180
z2	?	?	?	165
z3	?	?	?	255
Goal	195	165	240	600

Gravity model application

- Apply calibrated model $T_{ij} = P_i \times A_j \times F_{ij} \div \sum_j (A_j \times F_{ij})$
  - 1. Create friction factor matrix
  - 2. Calculate denominator sum $\sum_j (A_j \times F_{ij})$
  - 3. Apply formula to calculate T_{ij}

Impedance

TT	z1	z2	z3
z1	7	18	16
z2	18	11	20
z3	16	20	5

Forecast Year

P \ A	z1	z2	z3	Total	$\sum_j$
z1	6.0	70.9	103.1	180	598.7
z2	52.6	47.7	64.7	165	871.2
z3	131.8	111.6	11.6	255	538.8
Total	190.4	230.2	179.4	600	--

Friction Factors

TT	z1	z2	z3
z1	0.10	1.43	1.43
z2	1.43	1.51	1.43
z3	1.43	1.43	0.10

1 2 3

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Gravity model

- Advantages?
  - Takes into account impedance/LOS information
  - Can accommodate new zones

- Disadvantages?
  - Requires restrictive assumptions (FFs)
  - Not fully behaviorally consistent

Destination choice model

- Based in microeconomic (& psychological) consumer behavior theories
  - Discrete choice model

- People choose an alternative (destination) in order to maximize utility
  - Destination choice utility = f(impedance, destination attractiveness)

$$U_{ij} = (\beta_{TT} \times TT_{ij}) + \beta_{Emp} \times \ln(\sum_s \beta_s \times Emp_{js}) + \varepsilon_{ij}$$

Destination choice model

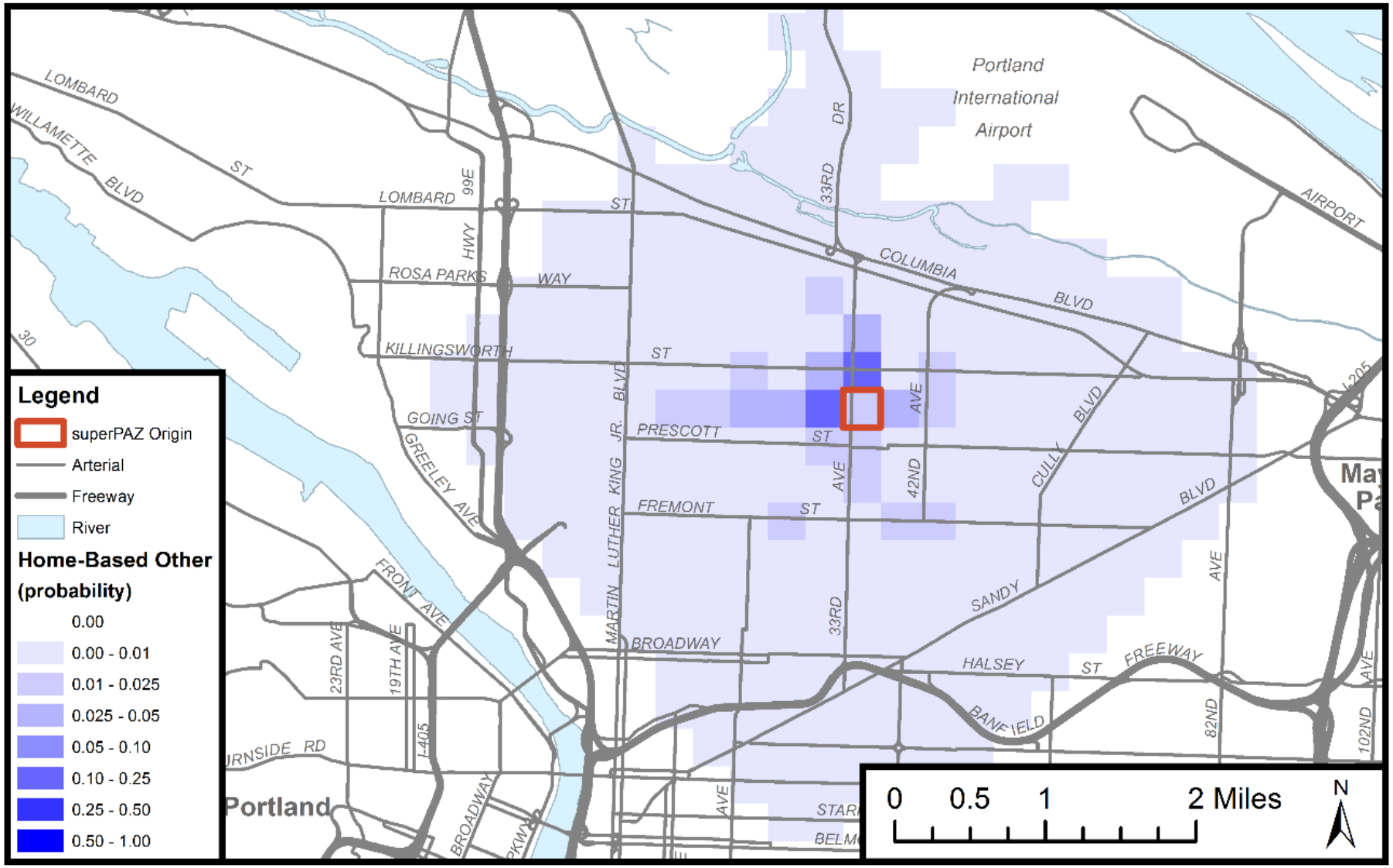
- Multinomial logit model
  - Assumes error terms are independently & identically distributed Gumbel (an approximation of the normal distribution)

  - Probability of choosing destination zone j

$$P(j \mid i) = \exp(U_{ij}) \div \sum_k \exp(U_{ik})$$

$$U_{ij} = (\beta_{TT} \times TT_{ij}) + \beta_{Emp} \times \ln(\sum_s \beta_s \times Emp_{js}) + \varepsilon_{ij}$$

Destination choice model



Destination choice model

- Advantages?
  - Takes into account impedance/LOS information
  - Can account for specific attraction information
  - More consistent with behavioral theory

- Disadvantages?
  - More complex to understand (probabilities)
  - More involved to estimate and apply
  - Only singly constrained (productions)

WFRC trip distribution

Exhibit 39: Doubly- Constrained Gravity Model Equations

$$T_{ij} = P_i * \frac{A_j * f(d_{ij})}{\sum_{all\ zones\ z} A_z * f(d_{iz})}$$

Where:

T_{ij}	=	the forecast flow produced by zone *i* and attracted to zone *j*
P_i	=	the forecast number of trips produced by zone *i*
A_j	=	the forecast number of trips attracted to zone *j*
d_{ij}	=	the impedance between zone *i* and zone *j*
$f(d_{ij})$	=	the friction factor between zone *i* and zone *j*

7.1.2 Friction Factors

The distribution model uses the generalized costs to look up the trip impedance between zones. These trip impedance look up vales are called friction factors. The distribution model's friction factors for HBW, HBSch, HBShp, HB0th, NHBW, NHBNW, IX and XI trip purposes were calibrated to match trip-length frequencies from the 2012 HH travel survey.

Friction factors for the SH_LT, SH_MD and SH_HV truck purposes were based on a gamma function, exhibiting the following functional form:

$$A \cdot x^B \cdot e^{Cx}$$

Where:

e = the exponential function

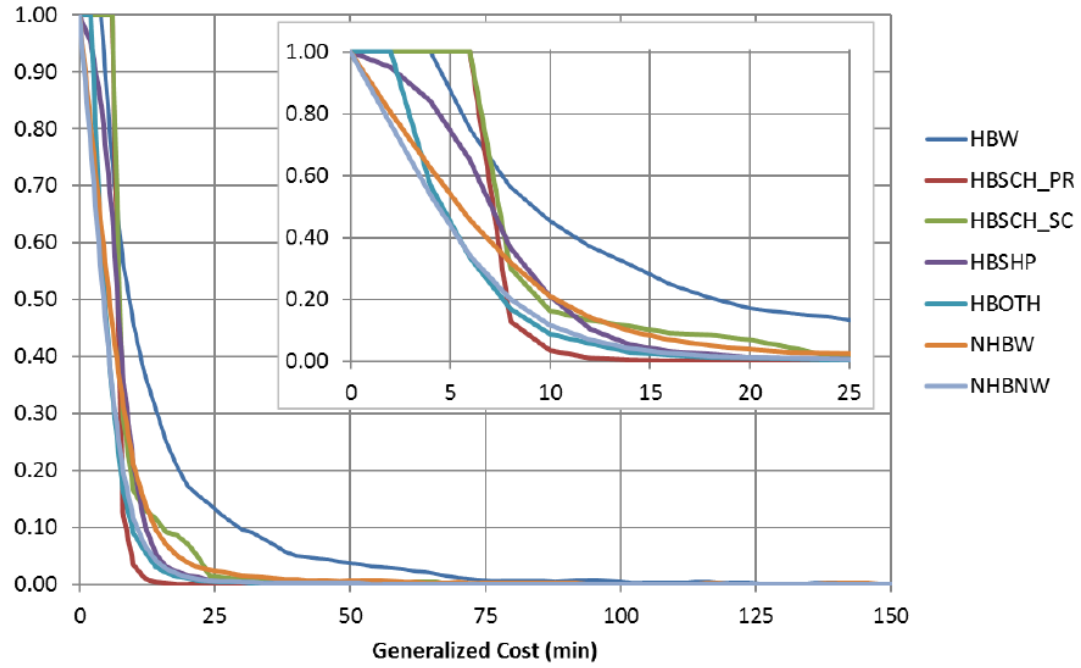
x = generalized cost (expressed in minutes)

A, B & C = purpose specific parameters

The purpose specific parameters were set to the following:

	A	B	C
SH_LT	1.0	-0.20	-0.080
SH_MD	1.0	-0.18	-0.050
SH_HV	1.0	-0.18	-0.035

Exhibit 40. Friction Factors – Person Trips



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WFRC HBW destination choice

Exhibit 44. Logit Model Formulation

$$P_i(k) = \frac{\exp(U_{k|i})}{\sum_{j \in D} \exp(U_{j|i})}$$

where:

$P_i(k)$ is the probability of selecting attraction , given production zone

$j \in D$ are the unique alternatives (attractions) in the sample set

U_j is the utility of selecting an attraction zone, given production zone

Exhibit 45: Utility of Each Destination

$$U_{j|i} = \beta_0 \times \beta_1 \times accessibility_{j|i} + \beta_2 \times quality_{j|i} + \ln(\beta_3 \times quantity_{j|i})$$

7.2.1 Destination Choice Model Estimation

In version 8 of the model, the destination choice model was not updated based on the most recent data. The data used for model estimation come from two sources, a 1992 home interview survey and a 2002 transit onboard. Both surveys were expanded to represent the 2002 population in the region. The estimation data set used auto and non-motorized trips from the home interview survey and transit trips from the onboard. Estimation weights were computed by purpose, mode, and household auto ownership level (0, 1, 2+). Illogical observations, e.g. drive alone trips in a 0 auto household, and observations not connected in the path builder were dropped. The estimation file contains 7,024 usable records, 5,111 are from the home interview survey, and 1,913 are from the onboard survey.

The data were grouped into two income categories, low and high household income. Low income was defined as those earning less than $25,000 in 2002 dollars. This definition corresponds to the lowest three income categories in the onboard survey. The income categories for the 1992 home interview survey were inflated into 2002 dollars using the consumer price index. After inflation, the low income definition included the two lowest income categories.

The primary accessibility variable in the destination choice model is the mode choice logsum variable. This variable is the primary separation measure.

Exhibit 43: Model Flow Diagram with Destination Choice

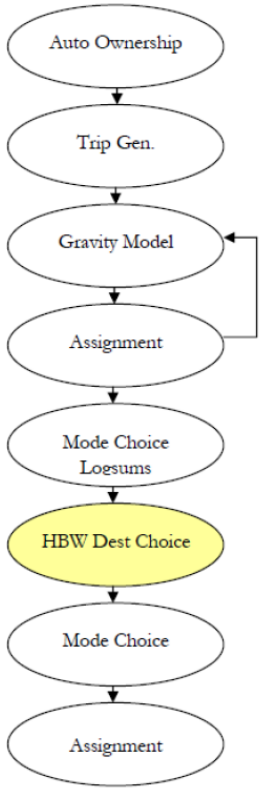


Exhibit 46. HBW Destination Choice Model Estimation Results

Variable	Coefficient
Logsum - 0 Auto	0.311
Logsum - 1 Auto, Low Income	0.212
Logsum - 1 Auto, High Income	0.212
Logsum - 2 Auto, Low Income	0.399
Logsum - 2 Auto, High Income	0.428
Highway Distance	-0.089
Retail Ratio - 0 Auto	0.458
Retail Ratio - 1 Auto, High Income	-0.524
Retail Ratio - 2 Auto, High Income	-0.718
Industrial Ratio - 1 Auto, Low Income	-1.269
Industrial Ratio - 1 Auto, High Income	-0.921
Industrial Ratio - 2 Auto, High Income	-0.459

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Questions?

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Homework 5

- Gain experience estimating and applying trip generation models.
  - Apply a doubly-constrained growth factor model
  - Calibrate a singly-constrained gravity model
  - Apply a singly-constrained gravity model
  - Describe advantages/disadvantages of trip distribution methods and factors/variables included in trip distribution models