CEE 123 Transport Systems 3: Planning & Forecasting

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Homework #6 -- Trip Distribution Modeling [S O L U T I O N S]

The following problems deal with a hypothetical, 4-zone region (this data will be used in a subsequent trip assignment homework). Table 1 summarizes surveyed activity system and trip generation data (productions and attractions) for 2020 and estimates of activity system variables for 2030.

Table 1. Base and Future HBW Trips and Demographic Data Summary

Zone	HBW P(i) '20	HBW A(j) '20	HH(i) Households '20	HH(i) Households '30	C(i) Cars '20	C(i) Cars '30	W(i) Workers '20	W(i) Workers '30	E(j) Empl. '20	E(j) Empl. '30	I(i) Inc. both
1	825	710	321	330	447	460	390	395	300	300	Low
2	775	800	402	470	360	420	345	480	360	450	Med
3	910	970	330	300	396	375	582	570	600	690	High
4	865	895	375	420	450	465	399	450	456	455	Med
Tot	3375	3375	1428	1520	1653	1720	1716	1895	1716	1895	N/A

Problem 1. Trip Generation [10 points]
Household **HBW** trip production and attraction models for the region as a whole have been estimated and found to be significant.

$P_i = 34.8 + 0.59\ HH_i + 0.80\ C_i + 0.63\ W_i$

$A_j = 485.1 + 0.84\ E_j$

a. Using the **base data**, apply the models and estimate a goodness-of-fit measure for each model. For example, compute the root mean square error, RMSE=sqrt[(1/n)Σ(est-obs)^2]. Comment on the fit.
b. Use the demographic **forecasts** provided to predict and tabulate future trip ends for the production and attraction models. These estimates will be used in the trip distribution forecast.

Solution:
Analysis is best accomplished via a spreadsheet.

a. *Validation is summarized below. RMS Error provides a suitable Goodness-of-Fit measure supplement the percent or relative errors which are tabulated under "Deviations [100*(est-obs)/obs]". These errors are very small. Computed RMSE for productions and attractions are 2.6 trips and 22.2 trips, respectively.*

b. *Forecasts are computed using the production and attraction models provided and are summarized below. Forecasted attractions A(j)* are normalized to forecasted productions. Final forecasts are rounded to the nearest trip. These forecasts will be used in Problem 3.*

	HBW Trip Ends		Households		Cars		Workers		Employment		Income
	P(i)	A(j)	HH(i)		C(i)		W(i)		E(j)		I(i)
TAZ	2010	2010	2010	2020	2010	2020	2010	2020	2010	2020	Both
1	825	710	321	330	447	460	390	395	300	300	Low
2	775	800	402	470	360	420	345	480	360	450	Med
3	910	970	330	300	396	375	582	570	600	690	High
4	865	895	375	420	450	465	399	450	456	455	Med
Total	3375	3375	1428	1520	1653	1720	1716	1895	1716	1895	

	HBW Trip Ends		Estimated (2010)		Deviations	(E-O)/O	Forecast (2020)			Final	
	P(i)	A(j)	P(i)	A(j)	P(i) Error	A(j) Error	P(i)	A(j)	norm aA(j)	Prod	Attr
TAZ	2010	2010	2010	2010	2010	2010	2020	2020	2020	2020	2020
1	825	710	827.5	737.1	0.30	3.82	846.4	737.1	752.5	846	752
2	775	800	777.3	787.5	0.30	-1.56	950.5	863.1	881.1	951	881
3	910	970	913.0	989.1	0.33	1.97	870.9	1064.7	1086.9	871	1087
4	865	895	867.4	868.1	0.28	-3.00	938.1	867.3	885.4	938	885
Total	3375	3375	3385.2	3381.8	0.30	0.20	3605.9	3532.2	3605.85	3606	3606
	p(i) = 34.8 + 0.59HH(i) + 0.80C(i) + 0.63W(i)						a(j) = 485.1+0.84*E(j)				

Problem 2. Trip Distribution: Calibration (20 pts)

By hand, calibrate a singly-constrained trip distribution model for the base year data. Show ALL calculations for three iterations. Does the model converge? Use 5-minute time categories and Attraction Factoring.

Table 2. Base Travel Time and Trip Distribution Matrix (2020)

BASE From\To	Travel Times 1	2	3	4	BASE From\To	Trip Interchanges 1	2	3	4	P(i)
1	5	16	13	18	1	250	125	375	75	825
2	16	7	20	12	2	100	400	50	225	775
3	13	20	2	9	3	205	60	225	420	910
4	18	12	9	3	4	155	215	320	175	865
					A(j)	710	800	970	895	3375

Solution: *The FHWA production-constrained gravity model is calibrated via the standard friction factor method. Table 2a below summarizes only the results of the estimated trip length frequency distribution at each interation. Attraction Factoring was performed at each iteration. A minimum of 3 iterations was required and the model did converge within 5 percent in 3 iterations (within 1 percent by the 5th iteration).*

Table 2a. SCGM Friction Factor Calibration Iterations

k	Travel Time Interval	OD Pairs in Time Interval	Observed Trips	(%)	Fk	Iter # 1 (%)	Fk	Iter # 2 (%)	Fk	Iter # 3 (%)	Fk
1	0 - 5	11,33,44	650	19.3	1.00	19.7	0.98	19.1	0.99	19.7	0.96
2	6 - 10	22,34,43	1140	33.8	1.00	20.0	1.69	31.6	1.81	32.3	1.89
3	11 - 15	13,31,24,42	1020	30.2	1.00	24.9	1.22	31.3	1.17	30.5	1.16
4	16 - 20	12,21,14,41,23,32	565	16.7	1.00	35.5	0.47	17.9	0.44	17.6	0.42

Converged after 3 Iteration (all F-bins +/- 5%)

Table 2b. SCGM Calibration Iterations Trip Matrices and Adjusted Attractors

i\j	Iter 1: 1	2	3	4	i\j	Iter 2: 1	2	3	4	i/j	Iter 3: 1	2	3	4	Pi
1	174	195	237	219	1	215	116	364	130	1	268	118	323	116	825
2	163	184	223	205	2	80	324	110	261	2	90	363	91	231	775
3	191	216	261	242	3	212	93	233	372	3	246	91	208	365	910
4	182	205	249	229	4	76	220	371	198	4	88	228	361	188	865
Aj	710	800	970	895	Aj	583	753	1078	961	Aj	692	800	983	900	3375
Wj	710	800	970	895	Wj*	865	850	873	834	Wj*	888	850	861	829	

Problem 3. Trip Distribution: Application (10 points)
In response to identified problems in the base network and to anticipated traffic volumes from future growth, a network infrastructure project has been planned that would change base travel times between some zones. In general, infrastructure would be improved around Zone 1 (low income with little projected growth) while problems identified in Zone 4 would not be addressed.

Forecast the future total trip matrices using the trip generation forecast from Problem 1, the calibrated model from Problem 2, and the original (A0) and new (A1) skims given in Table 3. Utilize column/row factoring on the final trip table.

Table 3. Base and Future Transportation System Skims

BASE 2020 From\To	Travel Times 1	2	3	4	FUTURE 2030 From\To	Travel Times 1	2	3	4
1	5	16	13	18	1	6	14	11	14
2	16	7	20	12	2	14	8	17	15
3	13	20	2	9	3	11	17	3	11
4	18	12	9	3	4	14	15	11	5

Solution:
Forecasted P's and A's (balanced) are utilized, first, with existing skims (A0), and then with future skims (A1). Since travel times have changed for some zone pairs, associated friction factors will also change (e.g., trips from 1 to 2 used F4 in the base but F3 in the future). Forecast trip tables were Column & Row Factored. Note that column sums do not exactly match but are within one percent of the forecasted Trip Generation results. The spreadsheet output is provided for A0 and A1. Note the changes in the forecast P/A trip table for the two future scenarios.

A0. Future Ps and As with Base Skims

A0 Analysis

TAZ	Travel Time Skims 1	2	3	4
1	5	16	13	18
2	16	7	20	12
3	13	20	2	9
4	18	12	9	3

TAZ	Friction Factors 1	2	3	4
1	0.96	0.42	1.16	0.42
2	0.42	1.89	0.42	1.16
3	1.16	0.42	0.96	1.89
4	0.42	1.16	1.89	0.96

TAZ	HBW P-A Matrix 1	2	3	4	P(i)
1	224	115	392	115	846
2	87	457	125	282	951
3	192	81	230	368	871
4	70	226	454	188	938
A(j)	573	879	1201	953	3606
A(TG)	752	881	1087	885	
CF	1.3132	1.0018	0.9053	0.9285	

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
1	846	1	752	5	1	0.96	721.9	0.265	224
		2	881	16	4	0.42	370.0	0.136	115
		3	1087	13	3	1.16	1260.9	0.463	392
		4	885	18	4	0.42	371.7	0.136	115
			3605				2724.6	1.000	846

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
2	951	1	752	16	4	0.42	315.8	0.091	87
		2	881	7	2	1.89	1665.1	0.481	457
		3	1087	20	4	0.42	456.5	0.132	125
		4	885	12	3	1.16	1026.6	0.296	282
			3605				3464.1	1.000	951

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
3	871	1	752	13	3	1.16	872.3	0.220	192
		2	881	20	4	0.42	370.0	0.093	81
		3	1087	2	1	0.96	1043.5	0.264	230
		4	885	9	2	1.89	1672.7	0.423	368
			3605				3958.5	1.000	871

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
4	938	1	752	18	4	0.42	315.8	0.074	70
		2	881	12	3	1.16	1022.0	0.241	226
		3	1087	9	2	1.89	2054.4	0.484	454
		4	885	3	1	0.96	849.6	0.200	188
			3605				4241.8	1.000	938

TAZ	HBW P-A Matrix: Column Factored 1	2	3	4	P(i)	RF
1	294	115	354	107	871	0.971
2	114	458	113	262	946.95	1.004
3	252	82	208	342	883.19	0.986
4	92	226	411	174	903.8	1.038
A(j)	752	881	1087	885	3605	

TAZ	HBW P-A Matrix: Row Factored 1	2	3	4	P(i)	RF
1	286	112	344	104	846	1
2	114	460	114	263	951	1
3	249	80	205	337	871	1
4	95	235	427	181	938	1
A(j)	744	887	1090	885	3606	
CF	1.0107	0.993	0.997	1.000		
Dev(%)	-1.063	0.6911	0.2742	-0.009		<5%

A1. Future Ps and As with Future Skims

A1 Analysis

TAZ	Travel Time Skims 1	2	3	4
1	6	14	11	14
2	14	8	17	15
3	11	17	3	11
4	14	15	11	5

TAZ	Friction Factors 1	2	3	4
1	1.89	1.16	1.16	1.16
2	1.16	1.89	0.42	1.16
3	1.16	0.42	0.96	1.16
4	1.16	1.16	1.16	0.96

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
1	846	1	752	6	2	1.89	1421.3	0.300	254
		2	881	14	3	1.16	1022.0	0.216	183
		3	1087	11	3	1.16	1260.9	0.267	225
		4	885	14	3	1.16	1026.6	0.217	184
			3605				4730.8	1.000	846

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
2	951	1	752	14	3	1.16	872.3	0.217	206
		2	881	8	2	1.89	1665.1	0.414	394
		3	1087	17	4	0.42	456.5	0.114	108
		4	885	15	3	1.16	1026.6	0.255	243
			3605				4020.6	1.000	951

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
3	871	1	752	11	3	1.16	872.3	0.263	229
		2	881	17	4	0.42	370.0	0.112	97
		3	1087	3	1	0.96	1043.5	0.315	274
		4	885	11	3	1.16	1026.6	0.310	270
			3605				3312.5	1.000	871

i	P(i)	j	A(j)	t(ij)	k	F(ij)	A*F	Share	T(ij)
4	938	1	752	14	3	1.16	872.3	0.218	204
		2	881	15	3	1.16	1022.0	0.255	239
		3	1087	11	3	1.16	1260.9	0.315	295
		4	885	5	1	0.96	849.6	0.212	199
			3605				4004.8	1.000	938

TAZ	HBW P-A Matrix 1	2	3	4	P(i)
1	254	183	225	184	846
2	206	394	108	243	951
3	229	97	274	270	871
4	204	239	295	199	938
A(j)	894	913	903	895	3606
A(TG)	752	881	1087	885	
CF	0.841	0.9647	1.2035	0.9884	

	HBW P-A Matrix: Column Factored					
TAZ	1	2	3	4	P(i)	RF
1	214	176	271	181	843	1.004
2	174	380	130	240	923.44	1.030
3	193	94	330	267	883.81	0.986
4	172	231	355	197	954.85	0.982
A(j)	752	881	1087	885	3605	

	HBW P-A Matrix: Row Factored					
TAZ	1	2	3	4	P(i)	RF
1	215	177	272	182	846	1
2	179	391	134	247	951	1
3	190	92	325	263	871	1
4	169	227	349	193	938	1
A(j)	752	888	1081	885	3606	
CF	0.9998	0.993	1.006	0.999		
Dev(%)	0.0183	0.7436	-0.569	0.0556		<5%

Comments: What changes can you notice? WHile it's easier to look for link volume changes after trip assignment is completed, you can notice differences in the two trip tables (for A0 and A1). From the skims, travel times to and from TAZ 1 have been reduced, while most times to and from TAZ 4 have deteriorated. The resulting A1 volumes, compared to A0 volumes, show decreases in intrazonal trips in TAZ 1 and 2, and increases in trips between TAZs 1 and 4. Demographic changes also come into play. What changes do you think multiply the impacts of travel time? A full analysis would \ compare both A0 and A1 to the base year, as well as A1 to A0.

Problem 4. Trip Distribution: Performance (10 points)
Summary statistics help describe the overall flow pattern at the end of trip distribution. Using skim tree times for the base and future networks, and the base and estimated future trip distribution matrices, compute the average trip travel times for 2020 and 2030. Tabulate total trips, total time, and average travel times for each year.

Solution:
Calculation Results: *results. Summary results are provided in Table 4. In A0, average travel times increase, particularly for interzonal trips. In A1, the increase is somewhat less for interzonal but greater for intrazonal. The results vary geographically (see below).*

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Table 4. Summary Statistics for Base and Future Trips
-----------------------------------------------------------
 Performance           BASE           A0          A1
   Measure          (observed)      (est.)      (est.)
-----------------------------------------------------------
 Total Trips           3375          3606        3606
 - Interzonal          2325          2474        2482
 - Intrazonal          1050 (31%)    1132 (31%)  1124
 Total Travel Time    34445         37249       39030
 - Interzonal         29420         31647       32670
 - Intrazonal          5025          5602        6360
 Average Travel Time     10.21         10.33       10.82
 - Interzonal            12.65         12.79       13.17
 - Intrazonal             4.79          4.95        5.66
-----------------------------------------------------------
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Problem 5. Travel Surveys (20 points)
The spreadsheet provides 2020 household socio-economic and travel diary data for a sub-sample of Miasma Beach households. Use **households 4 through 6**.

1. **Calculate** the trip travel time, activity duration, and trip purpose classification (HBW, HBO, or NHB) for each trip and append to the table. **Compute** the mean travel time by mode and mean activity duration by purpose. Submit a hardcopy (e-copy optional) of the updated spreadsheet.

   SOLUTION: *Calculation results.*

   Note: All times expressed as hours:minutes. Mean travel time was 12 minutes (9 min for 7 walk trips (19%); 10 min for 6 bike trips (16%); 25 minutes for 4 bus trips (11%); and 11 min for 20 car trips (54%)). Mean activity duration was 2:50, with 6:36 for work/school activities and 0:41 for non-work activities (durations not computed for return home trips). Note activity types do not follow the trip type classification (e.g., the first two work activities are actually at the end of, first, an HBW trip and, second, a NHB trip).

2. **Plot** the travel patterns on a Miasma Beach network map. Label each trip end as a production (P) or attraction (A) and label the trip type (HBW, HBO, NHB). Use color and/or line types to distinguish individuals and/or trip types. You may need to plot households on separate maps.

   Solution Map not shown in this solution key. Trips can be drawn as straight lines between the origin and destination centroids, and should be color-coded by trip type (e.g., HBW).

3. **Calculate** the associated OD trip table and the PA trip table.

   Solution S'2025 (All trip types)

PA Table	1	2	3	4	5	6	Pi
1	4	4	3	0	0	1	12
2	0	2	4	0	0	0	6
3	1	0	1	0	0	0	2
4	0	0	0	0	0	0	0
5	1	0	0	0	4	3	8
6	0	0	0	0	0	0	0
Aj	6	6	8	0	4	4	28

OD Table	1	2	3	4	5	6	Oi
1	4	2	2	0	0	1	9
2	2	2	2	0	0	0	6
3	2	2	1	0	0	0	5
4	0	0	0	0	0	0	0
5	1	0	0	0	4	1	6
6	0	0	0	0	2	0	2
Dj	9	6	5	0	6	2	28

   If you've correctly plotted the Os and Ds in part (c), the total Os and Ds in each zone should match. Try to code each trip by Ps and As and you'll see that this will match the PA trip table.

Problem 6. Trip Distribution: Calibration Algorithm (5 points)
Provide the numbered algorithm steps (or flowchart) for calibrating a Single Constrained Gravity Model.

Last Updated: 6 June 2025