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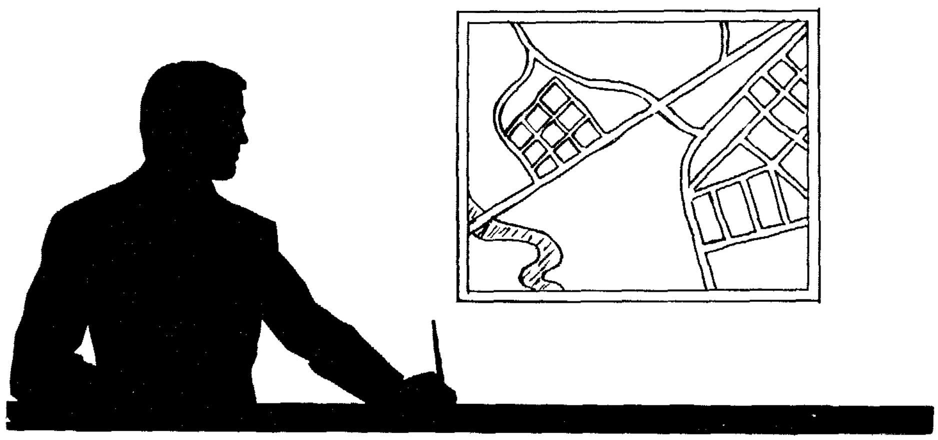
TRAFFIC PLANNING

PROGRAMING PROJECTS

SYSTEM PLANNING APPENDIX

TRANSIT PLANNING

MONITORING & FORECASTING



Transportation Planning for Your Community

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
1980

PREFACE

This publication is part of a series entitled Transportation Planning for Your Community and is designed to acquaint officials and planners with transportation planning for communities of from 25,000 to 200,000 population.

The series consists of two guides that explain the concepts of transportation planning and five technical manuals that describe techniques for carrying out transportation planning programs. The guides are: A Guide for the Decisionmaker and The Manager's Guide for Developing a Planning Program. The five technical manuals are titled:

Traffic Planning

Transit Planning

System Planning

Monitoring and Forecasting

Programing Projects

A Guide for the Decisionmaker describes the importance of urban transportation and the benefits of transportation planning. It includes a review of how transportation planning works, and the role of city, county and town officials in transportation planning.

The Manager's Guide for Developing a Planning Program describes the principles of transportation planning and is directed to those engineers, planners and administrators who are charged with the responsibility of organizing and administering the transportation planning program.

The individual technical manuals describe transportation planning techniques appropriate for small communities. The manuals also include references to other publications that describe appropriate planning techniques.

The Traffic Planning manual is a reference of basic traffic engineering techniques and their potential for improving traffic flow and traffic safety of urban arterial streets and highways. The manual identifies the traffic engineering measures appropriate for consideration in development of transportation improvement plans and programs.

The Transit Planning manual includes techniques for estimating transit patronage, service options, and operating requirements. Also included are procedures for evaluating the need for specialized services for the elderly and handicapped.

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The System Planning manual details the steps required for the functional classification of streets and highways, the estimation of future traffic, the estimation of the impacts of future traffic, and the estimation of street and highway system requirements. An Appendix includes alternative methods for forecasting traffic.

The Monitoring and Forecasting manual provides instructions for assembling inventories of transportation and land activity. It describes methods for monitoring the performance of the transportation system and general community development and methods for forecasting information needed in urban transportation planning.

The Programing Projects manual contains procedures for development of the transportation improvement program. Included are procedures for identification of candidate improvement projects, determination of the plan to fund candidate improvement projects, assignment of priorities to candidate improvement projects, budget allocation and project scheduling, and monitoring, adjusting and evaluating the programs.

This series was prepared by the COMSIS Corporation and the Highway Users Federation for Safety and Mobility under a grant from the Federal Highway Administration with the aid of a "steering committee" made up of the following officials:

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APPENDIX A

USEFUL DATA (DEFAULT VALUES) FOR MANUAL AND COMPUTER APPLICATIONS

TABLE A-1

DETAILED TRIP GENERATION CHARACTERISTICS[a]
URBANIZED AREA POPULATION: 25,000 - 50,000

Income Range 1970 $ (000's)	Avg Autos Per HH[d]	Average Daily Person Trips per HH[e]	% HH by Autos Owned[b]				Average Daily Person Trips Per HH by No. of Autos/HH[c]				% Average Daily Person Trips by Purpose[f]		
			0	1	2	3+	0	1	2	3+	HBW	HBNW	NHB
0-3	0.59	5.7	51	40	8	1	2.8	7.8	12.2	14.2	24	54	22
3-4	0.83	8.1	29	60	10	1	2.8	9.5	14.1	16.1	23	54	23
4-5	0.91	9.3	24	62	13	1	2.8	10.5	15.0	17.5	21	55	24
5-6	1.02	11.1	18	63	18	1	2.8	12.0	16.0	19.0	18	56	26
6-7	1.08	12.8	13	65	21	1	3.0	13.2	17.0	21.0	16	60	24
7-8	1.16	14.1	10	66	22	2	3.4	14.1	18.0	22.5	15	62	23
8-9	1.23	15.4	7	65	26	2	5.0	15.0	18.5	23.5	15	63	22
9-10	1.33	16.5	4	62	31	3	6.5	15.5	19.0	24.8	14	63	23
10-12.5	1.47	17.8	2	52	43	3	7.0	16.0	20.0	26.2	13	63	24
12.5-15	1.67	19.3	1	40	50	9	7.0	16.2	20.6	27.0	12	64	24
15-20	1.79	19.7	1	30	58	11	7.2	15.2	21.2	25.5	11	64	25
20-25	1.90	20.2	1	24	59	16	7.5	13.5	22.0	24.2	10	63	27
25+	1.98	20.4	1	22	55	22	8.0	13.2	22.0	24.1	10	63	27
Wt. Avg	1.53	14.4	14	50	30	6	5.3	13.8	18.3	22.8	14	62	24

FOOTNOTES:

a. Total of internal and external trips generated by area residents.
b. Source: 1970 Census
c. Source: Origin-Destination Surveys
d. Calculated (using b)
e. Calculated (using b and c)
f. Source: Future Highways and Urban Growth 1/ and Transportation and Traffic Engineering Handbook 2/

TABLE A-2

DETAILED TRIP GENERATION CHARACTERISTICS[a]

URBANIZED AREA POPULATION: 50,000-100,000

Income Range 1970 $ (000's)	Avg Autos Per HH[d]	Average Daily Person Trips Per HH[e]	% HH by Autos Owned[b]				Average Daily Person Trips Per HH by No. of Autos/HH[c]				% Average Daily Person Trips by Purpose[f]		
			0	1	2	3+	0	1	2	3+	HBW	HBNW	NHB
0-3	0.56	4.5	53	39	7	1	2.0	6.5	11.5	12.5	21	57	22
3-4	0.81	6.8	32	58	10	1	2.2	8.0	13.0	15.0	21	57	22
4-5	0.88	8.4	26	61	12	1	2.6	9.5	14.5	16.5	21	57	22
5-6	0.99	10.2	20	62	17	1	3.0	11.0	15.5	18.0	18	59	23
6-7	1.07	11.9	15	64	20	1	3.0	12.5	16.5	19.5	18	59	23
7-8	1.17	13.2	11	64	23	2	3.5	13.3	17.0	21.5	16	61	23
8-9	1.25	14.4	8	62	28	2	4.8	14.0	17.5	22.5	16	61	23
9-10	1.31	15.1	6	60	32	2	5.5	14.3	17.5	24.0	16	61	23
10-12.5	1.47	16.4	3	49	44	3	6.2	15.0	18.5	25.5	15	62	23
12.5-15	1.69	17.7	2	38	52	8	6.1	15.0	19.0	25.5	14	62	24
15-20	1.85	18.0	2	28	57	13	6.0	13.5	19.5	23.0	13	62	25
20-25	2.03	19.0	1	21	58	20	6.0	13.0	20.0	23.0	13	62	25
25+	2.07	19.2	1	19	59	21	6.0	12.5	20.0	23.0	13	62	25
Weighted Average	1.55	14.1	12	47	35	6	4.6	12.6	17.2	21.4	16	61	23

FOOTNOTES:

a. Total of internal and external trips generated by area residents.

b. Source: 1970 Census

c. Source: Origin-Destination Survey

d. Calculated (using b)

e. Calculated (using b and c)

f. Source: Future Highways and Urban Growth 1/ and Transportation and Traffic Engineering Handbook 2/

TABLE A-3

DETAILED TRIP GENERATION CHARACTERISTICS[a]
URBANIZED AREA POPULATION: 100,000- 200,000

Income Range 1970 $ (000's)	Avg Autos Per HH[d]	Average Daily Person Trips Per HH[e]	% HH by Autos Owned[b]				Average Daily Person Trips Per HH by No. of Autos/HH[c]				% Average Daily Person Trips by Purpose[f]		
			0	1	2	3+	0	1	2	3+	HBW	HBNW	NHB
0-3	0.49	4.0	57	37	6	0	1.0	7.5	10.5	13.8	20	63	17
3-4	0.72	6.8	36	56	8	0	1.7	9.2	13.3	16.4	22	60	18
4-5	0.81	8.4	29	61	10	0	2.5	10.2	14.5	17.6	22	58	20
5-6	0.94	10.2	21	65	13	1	3.5	11.4	14.5	19.0	22	58	20
6-7	1.01	11.7	17	66	16	1	4.5	12.5	15.6	20.5	20	58	22
7-8	1.14	13.6	12	65	21	2	5.4	13.8	17.0	22.2	20	57	23
8-9	1.25	15.3	9	61	28	2	5.8	15.0	17.5	23.0	20	57	23
9-10	1.34	16.2	6	58	33	3	6.3	15.8	18.0	23.5	19	57	24
10-12.5	1.50	17.3	4	50	40	6	6.8	16.0	19.0	24.5	19	57	24
12.5-15	1.65	18.7	2	40	51	7	7.0	16.0	20.4	25.0	19	56	25
15-20	1.85	19.6	2	28	57	13	7.2	15.0	21.0	25.5	18	56	26
20-25	2.01	20.4	1	20	61	18	7.5	15.0	21.0	25.5	18	55	27
25+	2.07	20.6	1	19	59	21	7.5	15.0	21.0	25.2	18	55	27
Wt. Avg.	1.55	14.5	14	48	33	6	5.4	13.7	18.4	22.4	20	57	23

FOOTNOTES:

a. Total of internal and external trips generated by area residents.
b. Source: 1970 Census
c. Source: Origin-Destination Surveys
d. Calculated (using b)
e. Calculated (using b and c)
f. Source: Future Highways and Urban Growth 1/ and Transportation and Traffic Engineering Handbook 2/

TABLE A-4

TRIP GENERATION PARAMETERS

PART A - TRIP PRODUCTION ESTIMATES

Urbanized Area Population	Average Daily Person Trips Per HH[a]	% Average Daily Person Trips by Mode[b]			% Average Daily Person Trips by Purpose[a]			Auto Person Trips as a % of Total Person Trips[c]			Auto Driver Trips as a % of Total Person Trips[d]		
		Public Transit	Auto Passenger	Auto Driver	HBW	HBNW	NHB	HBW	HBNW	NHB	HBW	HBNW	NHB
25,000- 50,000	16	2	44	54	14	62	24	98	99	99	71	54	69
50,000-100,000	14	2	40	58	16	61	23	96	99	98	70	54	69
100,000-200,000	14	6	30	64	20	57	23	88	97	94	64	54	66

FOOTNOTES:

a. From Table A-1-A-4
b. Source: Transportation and Traffic Engineering Handbook 2/
c. Source: Origin-Destination Surveys
d. Calculated using c and Table A-20

TABLE A-4(continued)

TRIP GENERATION PARAMETERS

PART B - USEFUL CHARACTERISTICS FOR TRIP ESTIMATION

Urbanized Area Population	External Travel Characteristics		Total Areawide Truck Trips as a % of Areawide Auto Driver Trips[b]
	% of Total External Trips Passing Through Area[a]	% of Total External Trips to the CBD[a]	
25,000- 50,000	28	26	30
50,000-100,000	21	22	27
100,000-200,000	15	22	17

FOOTNOTES:

Source: Transportation and Traffic Engineering Handbook 2/

Source: Traffic Approaching Cities 3/

TABLE A-4 (continued)

TRIP GENERATION PARAMETERS

PART C - TRIP ATTRACTION ESTIMATING RELATIONSHIPS[a]
(All Population Groupings for either Vehicle or Person Trips)

TO ESTIMATE TRIP ATTRACTIONS FOR AN ANALYSIS AREA, USE:

$$\text{HBW Trip Attractions} = F_1 \left[1.7 \text{ (Analysis Area Total Employment)} \right]$$

$$\text{HBNW Trip Attractions} = F_2 \left[10.0 \begin{pmatrix} \text{Analysis Area} \\ \text{Retail} \\ \text{Employment} \end{pmatrix} + 0.5 \begin{pmatrix} \text{Analysis Area} \\ \text{Non-Retail} \\ \text{Employment} \end{pmatrix} + 1.0 \begin{pmatrix} \text{Analysis Area} \\ \text{Dwelling} \\ \text{Units} \end{pmatrix} \right]$$

$$\text{NHB Trip Attractions} = F_3 \left[2.0 \begin{pmatrix} \text{Analysis Area} \\ \text{Retail} \\ \text{Employment} \end{pmatrix} + 2.5 \begin{pmatrix} \text{Analysis Area} \\ \text{Non-Retail} \\ \text{Employment} \end{pmatrix} + 0.5 \begin{pmatrix} \text{Analysis Area} \\ \text{Dwelling} \\ \text{Units} \end{pmatrix} \right]$$

Where: F_1, F_2 and F_3 are areawide control factors.

TO DEVELOP AREAWIDE CONTROL FACTORS, USE:

$$F_1 = \frac{\text{Areawide Productions for HBW Trips}}{1.7 \text{ (Areawide Total Employment)}}$$

$$F_2 = \frac{\text{Areawide Productions for HBNW Trips}}{\left[10.0 \begin{pmatrix} \text{Areawide} \\ \text{Retail} \\ \text{Employment} \end{pmatrix} + 0.5 \begin{pmatrix} \text{Areawide} \\ \text{Non-Retail} \\ \text{Employment} \end{pmatrix} + 1.0 \begin{pmatrix} \text{Areawide} \\ \text{Dwelling} \\ \text{Units} \end{pmatrix} \right]}$$

$$F_3 = \frac{\text{Areawide Productions for NHB Trips}}{\left[2.0 \begin{pmatrix} \text{Areawide} \\ \text{Retail} \\ \text{Employment} \end{pmatrix} + 2.5 \begin{pmatrix} \text{Areawide} \\ \text{Non-Retail} \\ \text{Employment} \end{pmatrix} + 0.5 \begin{pmatrix} \text{Areawide} \\ \text{Dwelling} \\ \text{Units} \end{pmatrix} \right]}$$

FOOTNOTES:

a. Source: Office of Planning Methodology and Technical Support, UMTA

TABLE A-5

ASSUMPTIONS USED IN DEVELOPING CONVERSION CHARTS

FOR URBANIZED AREAS WITH POPULATION 100,000 AND ABOVE:

	CBD	Central City	Suburb
Terminal time (mins.)	6	3	1
Local street distance (miles)	0.0625	0.1875	0.5000
Local street speed (mph)	11	15	25
Local street time (mins.)	0.34	0.75	1.20
Total terminal time[b] (terminal + local street time) (mins.)	6.34	3.75	2.20

FOR URBANIZED AREAS WITH POPULATION LESS THAN 100,000:

	CBD	Central City	Suburb
Terminal time (mins.)	4	2	1
Local street distance (miles)	0.0625	0.1875	0.5000
Local street speed (mph)	14	20	29
Local street time (mins.)	0.27	0.56	1.03
Total terminal time[b] (terminal + local street time) (mins.)	4.27	2.56	2.03

FOOTNOTE:

a. Source: Various urban transportation studies.

b. This time represents the total terminal time at either the origin end or the destination end of a trip. Therefore, to obtain the total O-D terminal time for a trip originating, say, in the CBD and terminating in the suburb, this time is 6.34 + 2.20 = 8.54 mins. (for an urbanized area population of 100,000 and above).

TABLE A-6

SPEED VALUES (MPH) BY FACILITY TYPE BY SUBREGION BY URBANIZED AREA POPULATION[a]

Urbanized Area Population	SUBREGION TYPE					
	CBD		Central City		Suburb	
	Arterial	Freeway	Arterial	Freeway	Arterial	Freeway
25,000- 100,000	17	38	35	52	38	55
100,000- 200,000	16	36	23	42	32	50

FOOTNOTE:

a. Source: Various urban transportation studies.

TABLE A-7

DISTRIBUTION FACTORS BY URBANIZED AREA POPULATION AND BY TRIP PURPOSE

	URBANIZED AREA POPULATION UNDER 100,000				URBANIZED AREA POPULATION OVER 100,000			
TRAVEL TIME (mins.)	HBW	HBNW	NHB	ALL	HBW	HBNW	NHB	ALL
1	30	70	33	51	15	75	50	57
2	20	40	20	30	10	50	25	35
3	15	22	15	18	8.0	30	15	22
4	10	15	10	12	6.0	20	10	15
5	8.0	9.6	7.5	8.7	5.0	12	8.0	10
6	5.6	8.0	6.0	6.9	4.0	9.0	6.0	7.3
7	4.5	5.2	4.5	4.9	3.2	6.0	4.2	5.0
8	3.5	3.8	3.4	3.6	2.8	4.3	3.3	3.7
9	2.8	2.7	2.8	2.7	2.2	3.2	2.6	2.9
10	2.2	2.0	2.2	2.1	2.1	2.5	2.2	2.4
11	1.8	1.8	1.8	1.8	1.8	1.9	1.7	1.8
12	1.5	1.4	1.5	1.4	1.6	1.6	1.5	1.6
13	1.3	1.0	1.2	1.1	1.3	1.2	1.2	1.2
14	1.1	0.85	1.0	0.94	1.1	0.90	1.0	1.0
15	0.9	0.80	0.8	0.81	1.0	0.78	0.80	0.82
16	0.74	0.60	0.70	0.66	0.80	0.61	0.67	0.66
17	0.62	0.52	0.60	0.56	0.70	0.50	0.58	0.56
18	0.55	0.45	0.50	0.48	0.63	0.42	0.52	0.48
19	0.50	0.40	0.42	0.42	0.57	0.38	0.45	0.43
20	0.44	0.34	0.36	0.36	0.50	0.33	0.40	0.38
21	0.38	0.30	0.31	0.32	0.45	0.29	0.32	0.33
22	0.35	0.26	0.27	0.28	0.40	0.25	0.29	0.29
23	0.32	0.24	0.25	0.26	0.36	0.23	0.25	0.26
24	0.29	0.21	0.22	0.23	0.33	0.20	0.22	0.23
25	0.28	0.18	0.19	0.20	0.28	0.18	0.18	0.20
26	0.25	0.16	0.16	0.18	0.26	0.17	0.16	0.19
27	0.24	0.15	0.16	0.17	0.23	0.15	0.15	0.17
28	0.23	0.13	0.14	0.15	0.21	0.14	0.13	0.15
29	0.22	0.13	0.13	0.15	0.19	0.13	0.12	0.13
30	0.20	0.12	0.13	0.14	0.18	0.12	0.10	0.13
31	0.19	0.10	0.10	0.11	0.16	0.13	0.09	0.13
32	0.18	0.09	0.10	0.10	0.15	0.12	0.09	0.12
33	0.17	0.08	0.09	0.10	0.14	0.09	0.08	0.09
34	0.17	0.07	0.09	0.09	0.13	0.08	0.07	0.09
35	0.16	0.07	0.08	0.09	0.12	0.08	0.06	0.08

TABLE A-8

AVERAGE DAILY AUTO OCCUPANCY RATES (1976) BY
URBANIZED AREA POPULATION AND TRIP PURPOSE[a]

URBANIZED AREA POPULATION	TRIP PURPOSE						
	HBW	HB Shop	HB Soc-Rec	HB Other	HBNW[b]	NHB	All Purposes[c]
25,000 - 100,000	1.38	1.57	2.31	1.52	1.82	1.43	1.50
100,000 - 200,000	1.37	1.57	2.31	1.52	1.81	1.43	1.50

FOOTNOTES:

a. Source: Nationwide Personal Transportation Study: Report No. 1 4/ and Nationwide Personal Transportation Study: Report No. 8 5/

b. Weighted average of auto occupancy rates for HB Shop, HB Social-Recreational and HB Other trip purposes.

c. Weighted average of auto occupancy rates for all trip purposes.

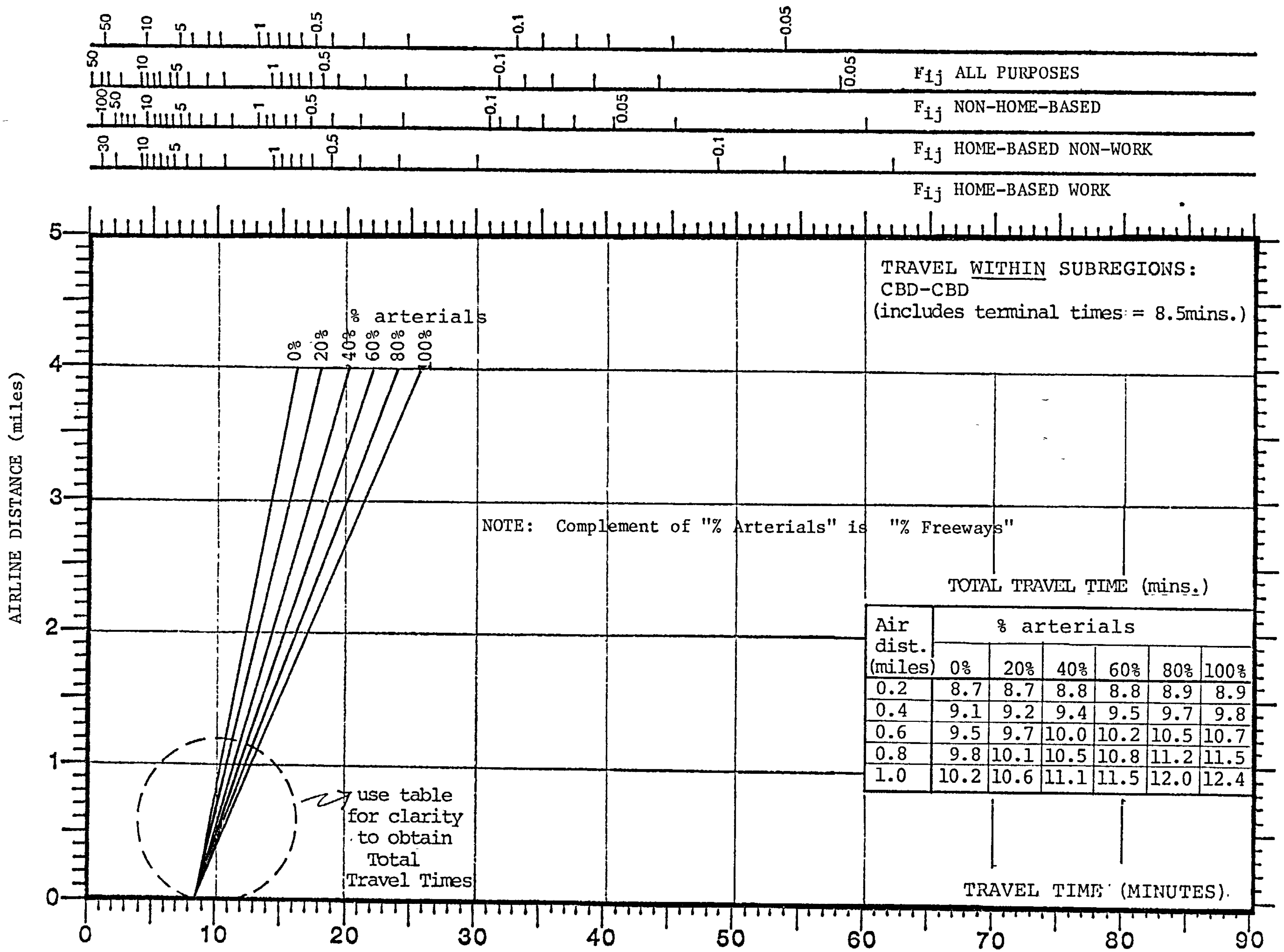
TABLE A-9

AVERAGE DAILY AUTO OCCUPANCY RATES (1976) BY
URBANIZED AREA POPULATION AND LAND-USE AT TRIP DESTINATION[a]

	LAND-USE AT TRIP DESTINATION					
URBANIZED AREA POPULATION	RESIDENTIAL	COMMERCIAL	MANU-FACTURING	TRANSPORTATION FACILITIES	PUBLIC BUILDINGS	OPEN SPACE
25,000 - 100,000	1.54	1.39	1.35	1.30	1.72	1.84
100,000 - 200,000	1.56	1.42	1.34	1.31	1.72	1.89

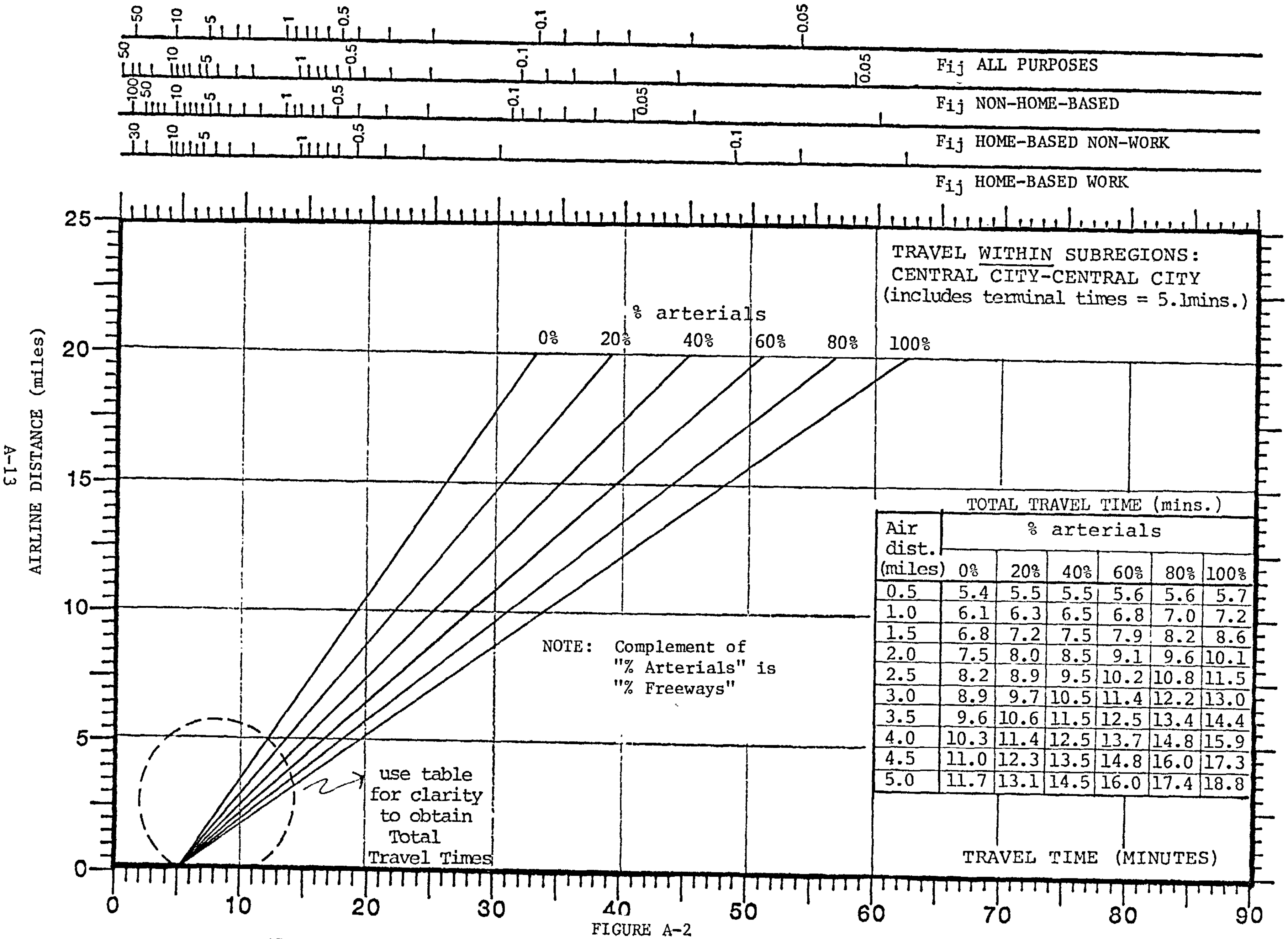
FOOTNOTE:

a. The auto occupancy rates may vary by the location of the land-use, i.e, in the CBD, central city or suburb, and therefore, by parking costs and employment densities. The rates may also vary by the level of service of transit provided and the existence of any ride-share programs.



Air dist. (miles)	% arterials					
	0%	20%	40%	60%	80%	100%
0.2	8.7	8.7	8.8	8.8	8.9	8.9
0.4	9.1	9.2	9.4	9.5	9.7	9.8
0.6	9.5	9.7	10.0	10.2	10.5	10.7
0.8	9.8	10.1	10.5	10.8	11.2	11.5
1.0	10.2	10.6	11.1	11.5	12.0	12.4

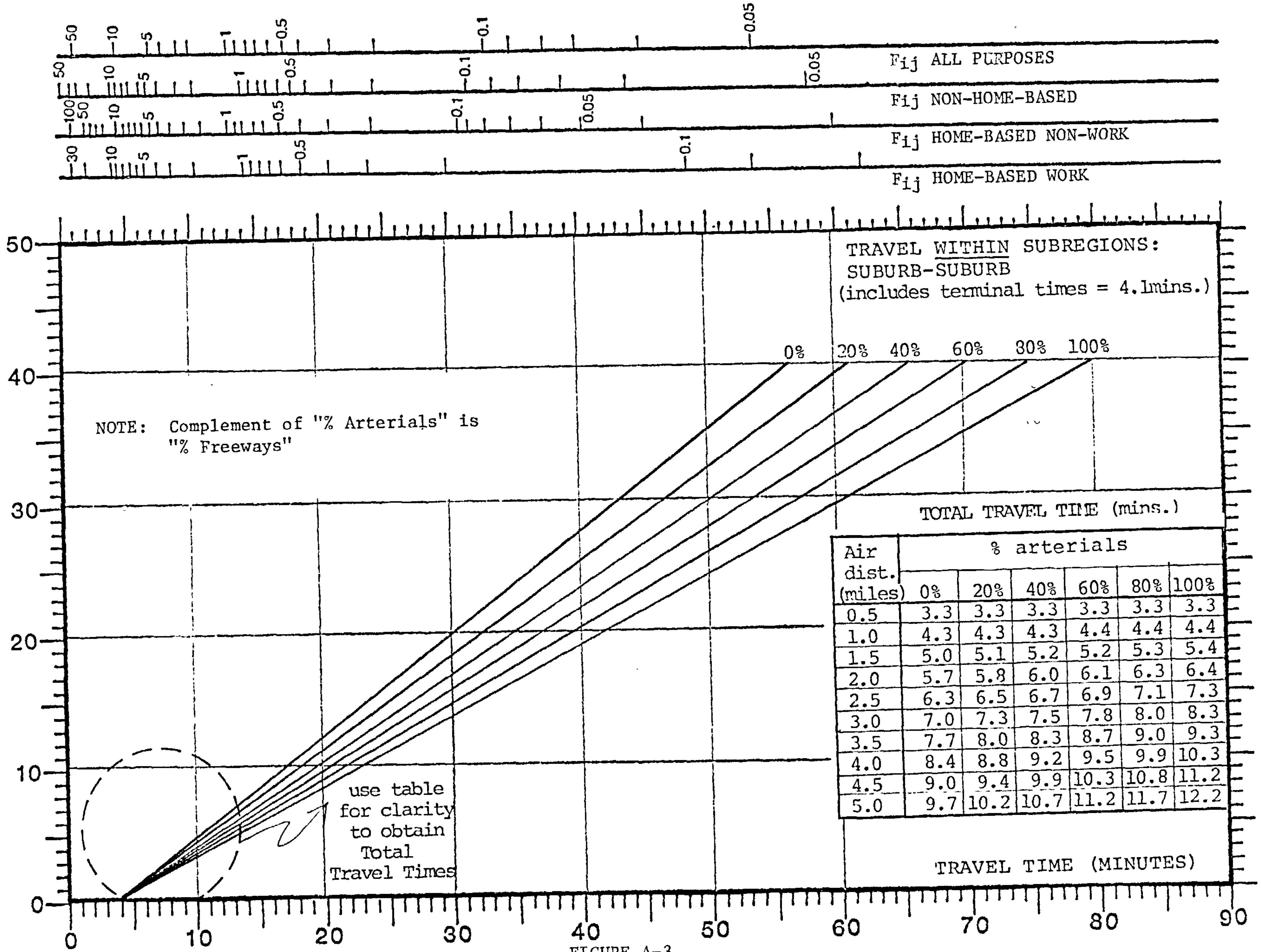
FIGURE A-1
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = UNDER 100,000



TOTAL TRAVEL TIME (mins.)

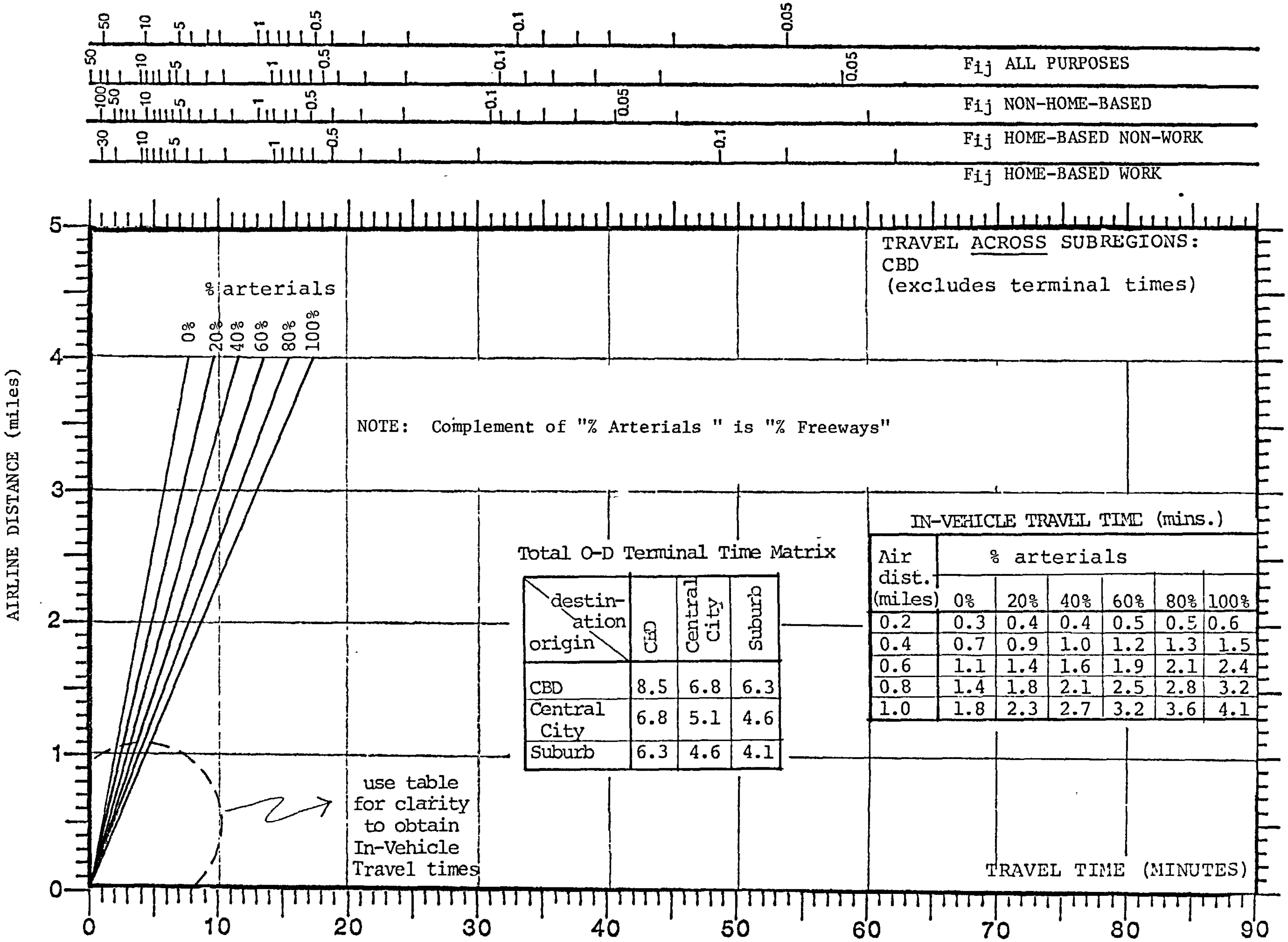
Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	5.4	5.5	5.5	5.6	5.6	5.7
1.0	6.1	6.3	6.5	6.8	7.0	7.2
1.5	6.8	7.2	7.5	7.9	8.2	8.6
2.0	7.5	8.0	8.5	9.1	9.6	10.1
2.5	8.2	8.9	9.5	10.2	10.8	11.5
3.0	8.9	9.7	10.5	11.4	12.2	13.0
3.5	9.6	10.6	11.5	12.5	13.4	14.4
4.0	10.3	11.4	12.5	13.7	14.8	15.9
4.5	11.0	12.3	13.5	14.8	16.0	17.3
5.0	11.7	13.1	14.5	16.0	17.4	18.8

FIGURE A-2
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = UNDER 100,000



Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	3.3	3.3	3.3	3.3	3.3	3.3
1.0	4.3	4.3	4.3	4.4	4.4	4.4
1.5	5.0	5.1	5.2	5.2	5.3	5.4
2.0	5.7	5.8	6.0	6.1	6.3	6.4
2.5	6.3	6.5	6.7	6.9	7.1	7.3
3.0	7.0	7.3	7.5	7.8	8.0	8.3
3.5	7.7	8.0	8.3	8.7	9.0	9.3
4.0	8.4	8.8	9.2	9.5	9.9	10.3
4.5	9.0	9.4	9.9	10.3	10.8	11.2
5.0	9.7	10.2	10.7	11.2	11.7	12.2

FIGURE A-3
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = UNDER 100,000



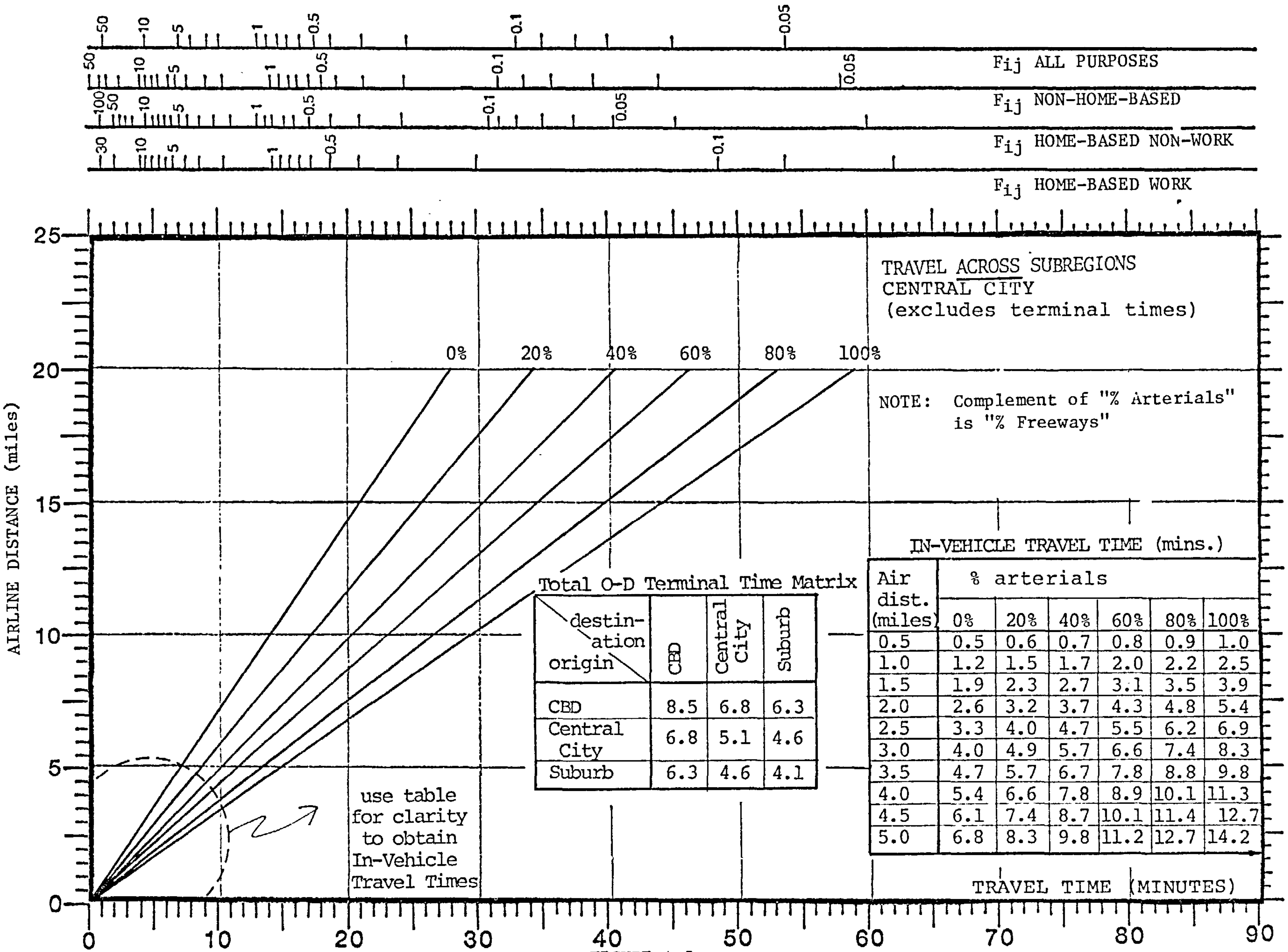
Total O-D Terminal Time Matrix

destination / origin	CBD	Central City	Suburb
CBD	8.5	6.8	6.3
Central City	6.8	5.1	4.6
Suburb	6.3	4.6	4.1

IN-VEHICLE TRAVEL TIME (mins.)

Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.2	0.3	0.4	0.4	0.5	0.5	0.6
0.4	0.7	0.9	1.0	1.2	1.3	1.5
0.6	1.1	1.4	1.6	1.9	2.1	2.4
0.8	1.4	1.8	2.1	2.5	2.8	3.2
1.0	1.8	2.3	2.7	3.2	3.6	4.1

FIGURE A-4
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = UNDER 100,000



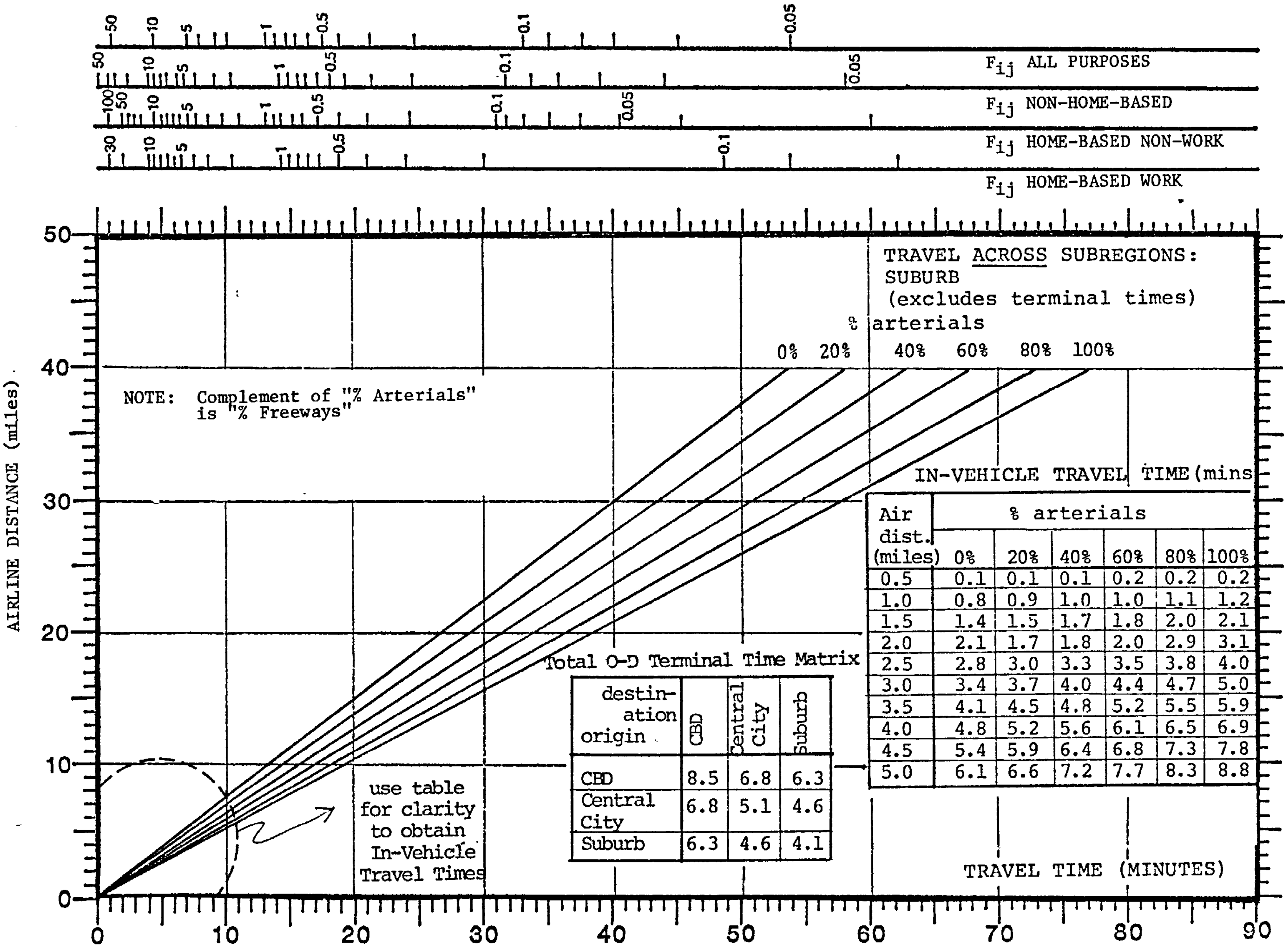
Total O-D Terminal Time Matrix

origin \ destination	CBD	Central City	Suburb
CBD	8.5	6.8	6.3
Central City	6.8	5.1	4.6
Suburb	6.3	4.6	4.1

IN-VEHICLE TRAVEL TIME (mins.)

Air dist. (miles)	% arterials					
	0%	20%	40%	60%	80%	100%
0.5	0.5	0.6	0.7	0.8	0.9	1.0
1.0	1.2	1.5	1.7	2.0	2.2	2.5
1.5	1.9	2.3	2.7	3.1	3.5	3.9
2.0	2.6	3.2	3.7	4.3	4.8	5.4
2.5	3.3	4.0	4.7	5.5	6.2	6.9
3.0	4.0	4.9	5.7	6.6	7.4	8.3
3.5	4.7	5.7	6.7	7.8	8.8	9.8
4.0	5.4	6.6	7.8	8.9	10.1	11.3
4.5	6.1	7.4	8.7	10.1	11.4	12.7
5.0	6.8	8.3	9.8	11.2	12.7	14.2

FIGURE A-5
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = UNDER 100,000



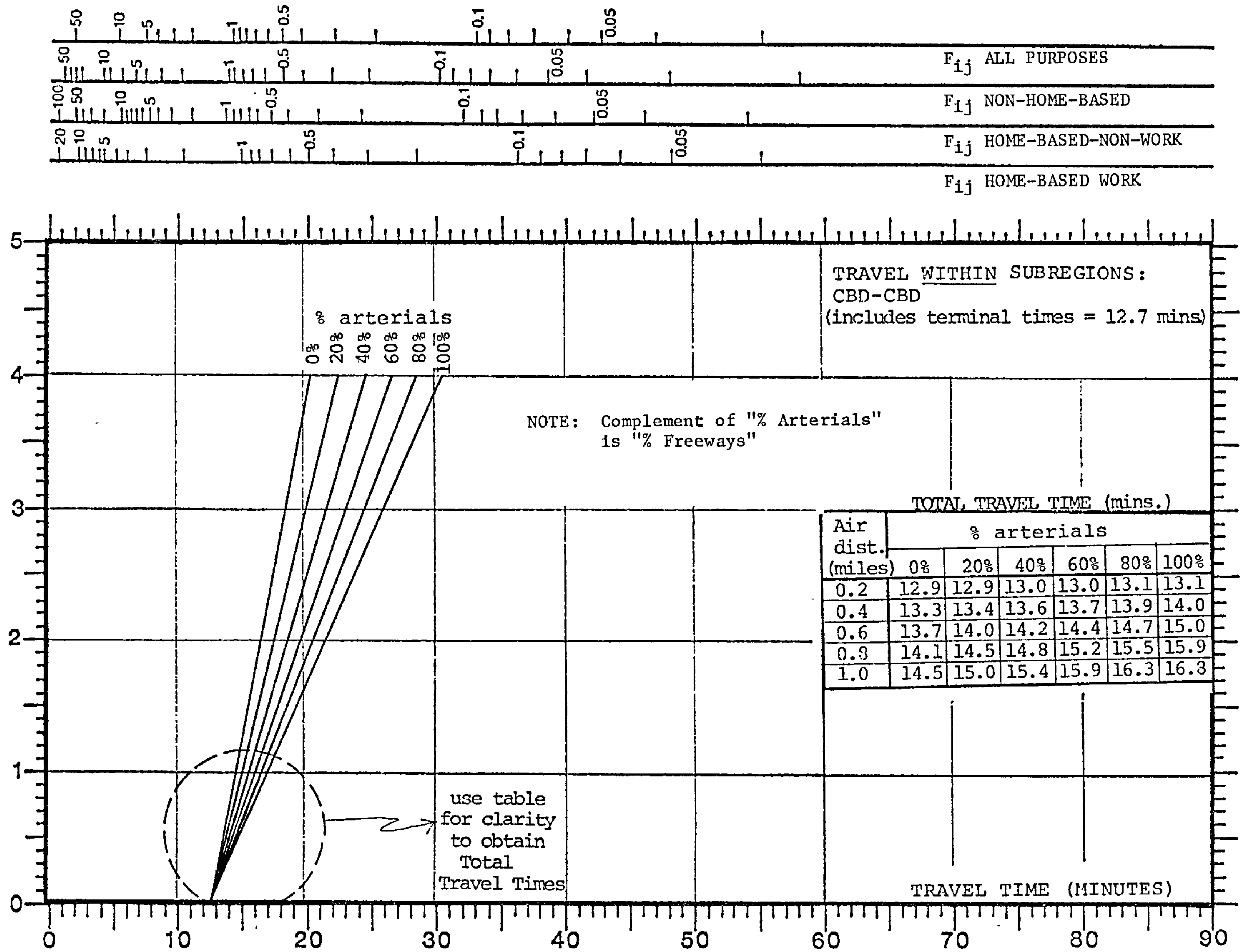
Total O-D Terminal Time Matrix

destination / origin	CBD	Central City	Suburb
CBD	8.5	6.8	6.3
Central City	6.8	5.1	4.6
Suburb	6.3	4.6	4.1

IN-VEHICLE TRAVEL TIME (mins

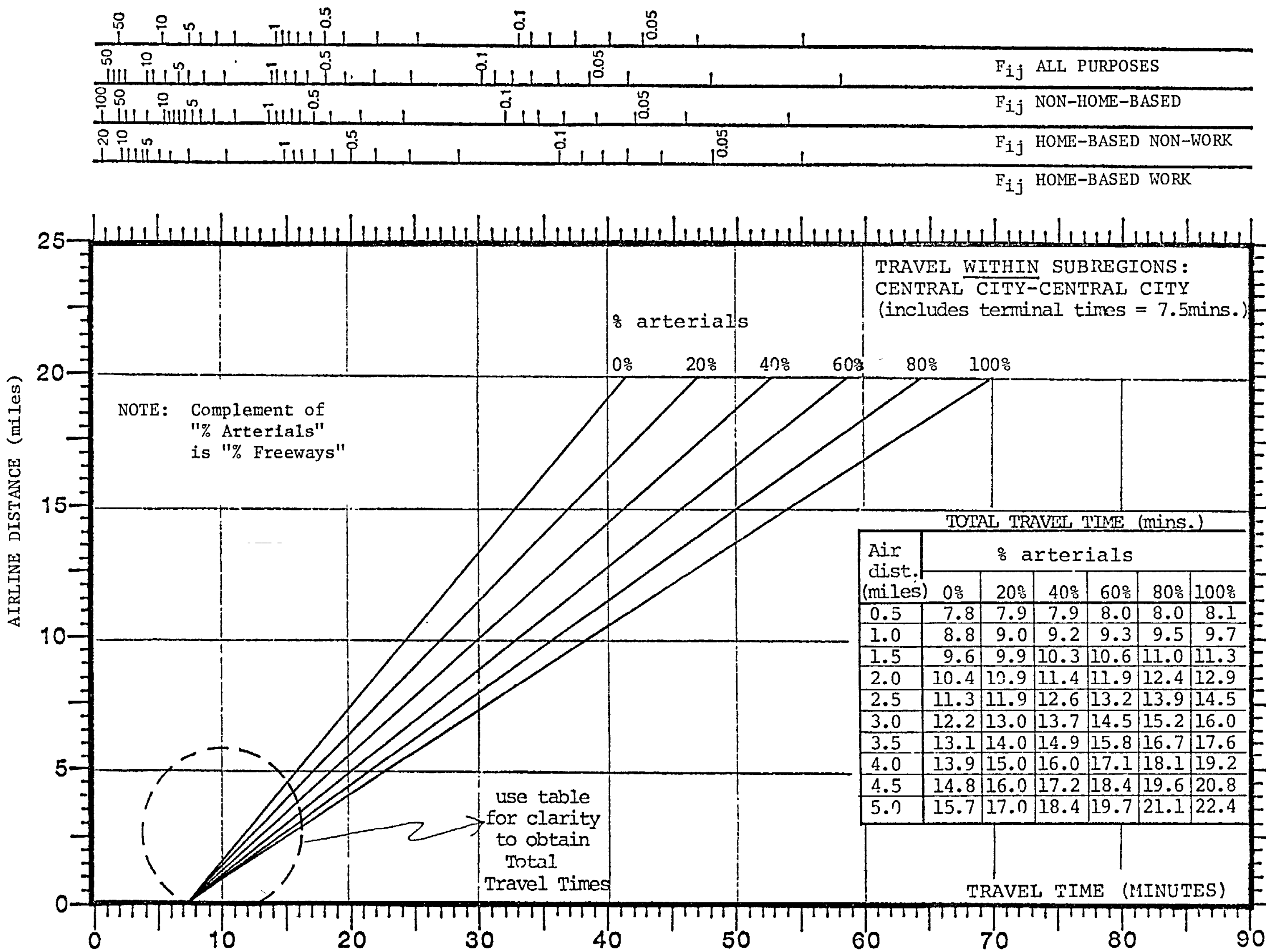
Air dist. (miles)	% arterials					
	0%	20%	40%	60%	80%	100%
0.5	0.1	0.1	0.1	0.2	0.2	0.2
1.0	0.8	0.9	1.0	1.0	1.1	1.2
1.5	1.4	1.5	1.7	1.8	2.0	2.1
2.0	2.1	1.7	1.8	2.0	2.9	3.1
2.5	2.8	3.0	3.3	3.5	3.8	4.0
3.0	3.4	3.7	4.0	4.4	4.7	5.0
3.5	4.1	4.5	4.8	5.2	5.5	5.9
4.0	4.8	5.2	5.6	6.1	6.5	6.9
4.5	5.4	5.9	6.4	6.8	7.3	7.8
5.0	6.1	6.6	7.2	7.7	8.3	8.8

FIGURE A-6
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = UNDER 100,000



Air dist. (miles)	% arterials					
	0%	20%	40%	60%	80%	100%
0.2	12.9	12.9	13.0	13.0	13.1	13.1
0.4	13.3	13.4	13.6	13.7	13.9	14.0
0.6	13.7	14.0	14.2	14.4	14.7	15.0
0.8	14.1	14.5	14.8	15.2	15.5	15.9
1.0	14.5	15.0	15.4	15.9	16.3	16.8

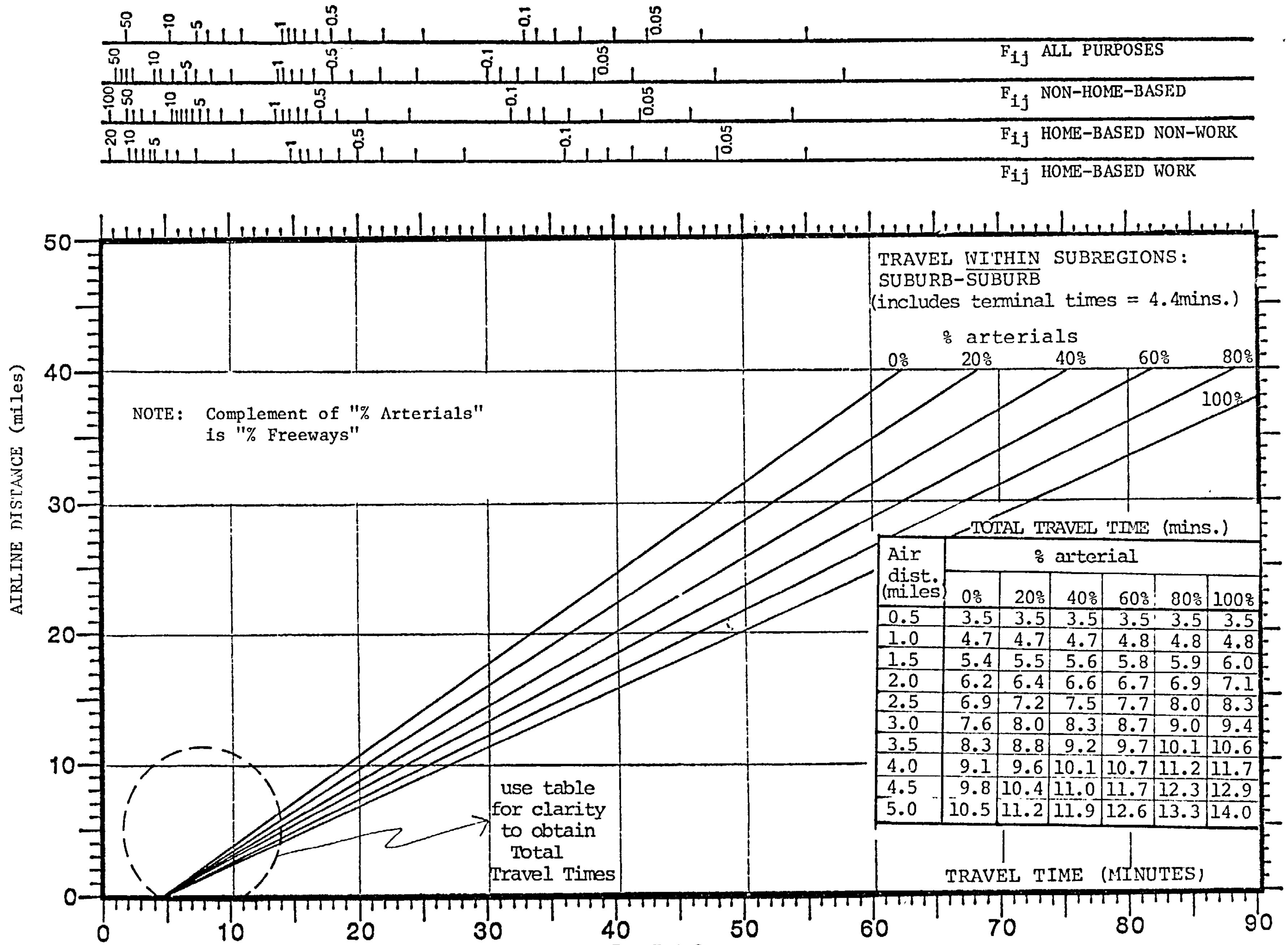
FIGURE A-7
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = OVER 100,000



TOTAL TRAVEL TIME (mins.)

Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	7.8	7.9	7.9	8.0	8.0	8.1
1.0	8.8	9.0	9.2	9.3	9.5	9.7
1.5	9.6	9.9	10.3	10.6	11.0	11.3
2.0	10.4	10.9	11.4	11.9	12.4	12.9
2.5	11.3	11.9	12.6	13.2	13.9	14.5
3.0	12.2	13.0	13.7	14.5	15.2	16.0
3.5	13.1	14.0	14.9	15.8	16.7	17.6
4.0	13.9	15.0	16.0	17.1	18.1	19.2
4.5	14.8	16.0	17.2	18.4	19.6	20.8
5.0	15.7	17.0	18.4	19.7	21.1	22.4

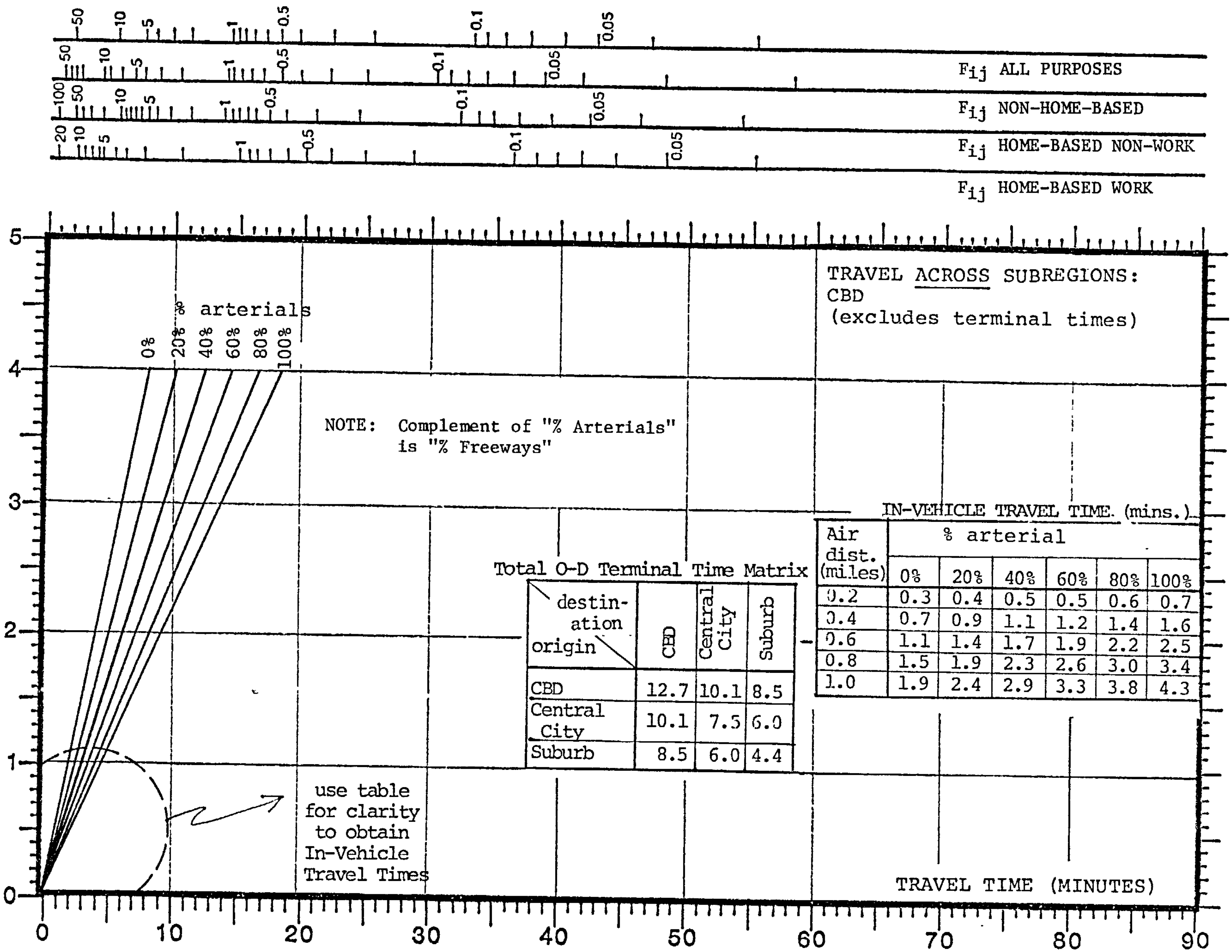
FIGURE A-8
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = OVER 100,000



Air dist. (miles)	% arterial					
	0%	20%	40%	60%	80%	100%
0.5	3.5	3.5	3.5	3.5	3.5	3.5
1.0	4.7	4.7	4.7	4.8	4.8	4.8
1.5	5.4	5.5	5.6	5.8	5.9	6.0
2.0	6.2	6.4	6.6	6.7	6.9	7.1
2.5	6.9	7.2	7.5	7.7	8.0	8.3
3.0	7.6	8.0	8.3	8.7	9.0	9.4
3.5	8.3	8.8	9.2	9.7	10.1	10.6
4.0	9.1	9.6	10.1	10.7	11.2	11.7
4.5	9.8	10.4	11.0	11.7	12.3	12.9
5.0	10.5	11.2	11.9	12.6	13.3	14.0

FIGURE A-9

AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = OVER 100,000



Total O-D Terminal Time Matrix

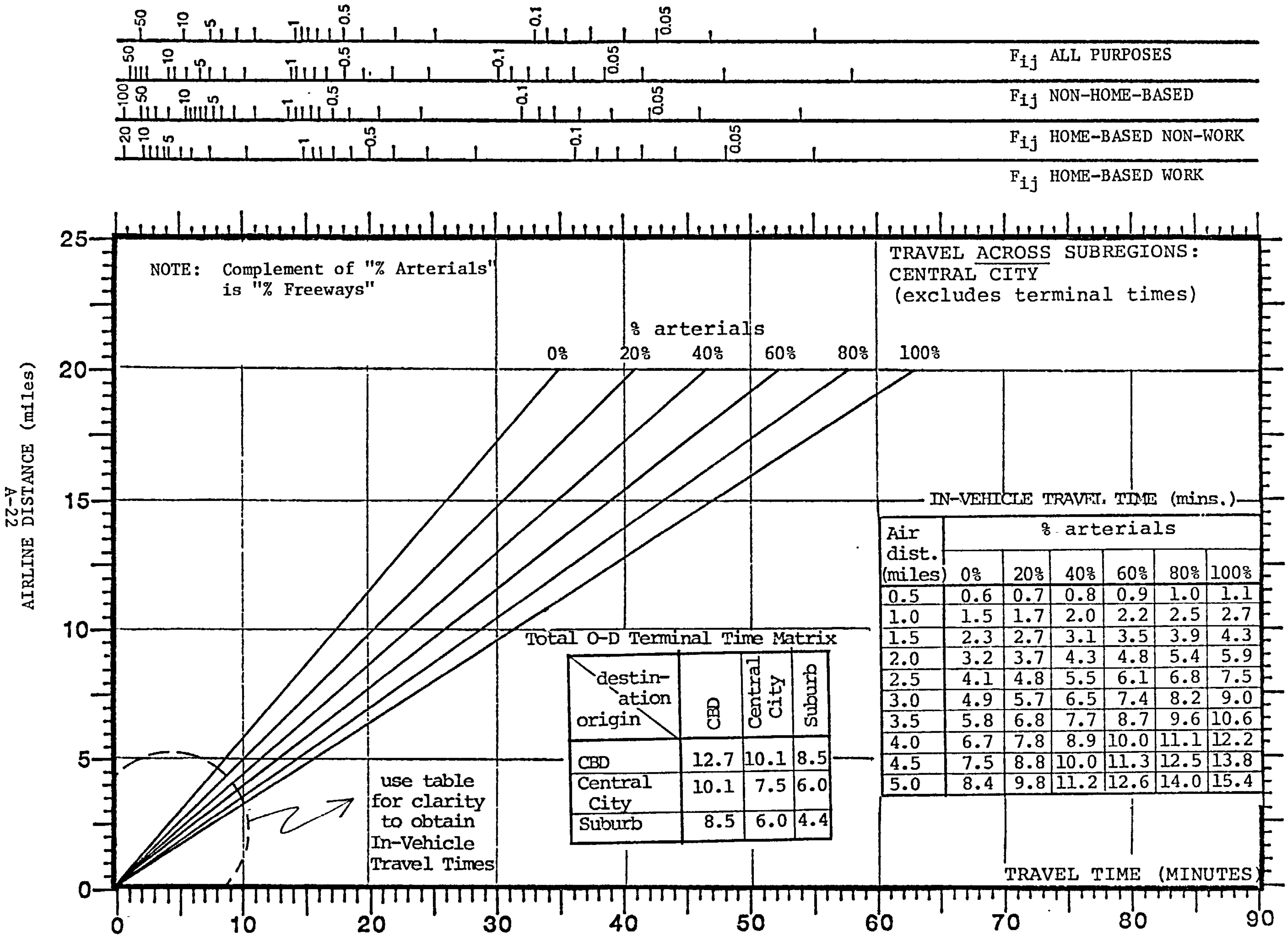
destination / origin	CBD	Central City	Suburb
CBD	12.7	10.1	8.5
Central City	10.1	7.5	6.0
Suburb	8.5	6.0	4.4

IN-VEHICLE TRAVEL TIME (mins.)

Air dist. (miles)	% arterial					
	0%	20%	40%	60%	80%	100%
0.2	0.3	0.4	0.5	0.5	0.6	0.7
0.4	0.7	0.9	1.1	1.2	1.4	1.6
0.6	1.1	1.4	1.7	1.9	2.2	2.5
0.8	1.5	1.9	2.3	2.6	3.0	3.4
1.0	1.9	2.4	2.9	3.3	3.8	4.3

FIGURE A-10

AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE:
URBANIZED AREA POPULATION = OVER 100,000



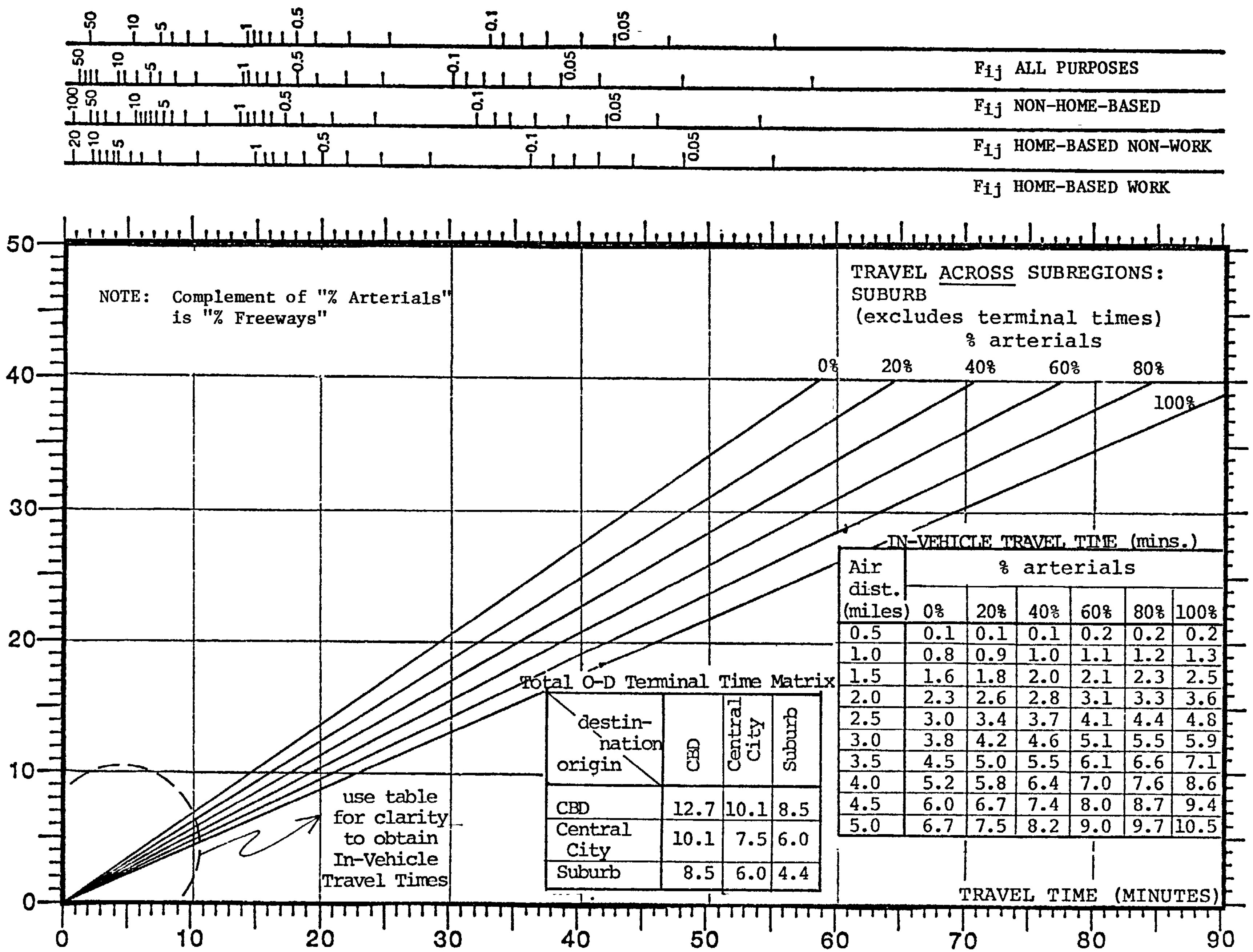
Total O-D Terminal Time Matrix

origin \ destination	CBD	Central City	Suburb
CBD	12.7	10.1	8.5
Central City	10.1	7.5	6.0
Suburb	8.5	6.0	4.4

IN-VEHICLE TRAVEL TIME (mins.)

Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	0.6	0.7	0.8	0.9	1.0	1.1
1.0	1.5	1.7	2.0	2.2	2.5	2.7
1.5	2.3	2.7	3.1	3.5	3.9	4.3
2.0	3.2	3.7	4.3	4.8	5.4	5.9
2.5	4.1	4.8	5.5	6.1	6.8	7.5
3.0	4.9	5.7	6.5	7.4	8.2	9.0
3.5	5.8	6.8	7.7	8.7	9.6	10.6
4.0	6.7	7.8	8.9	10.0	11.1	12.2
4.5	7.5	8.8	10.0	11.3	12.5	13.8
5.0	8.4	9.8	11.2	12.6	14.0	15.4

FIGURE A-11
AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE: URBANIZED AREA POPULATION = OVER 100,000



Total O-D Terminal Time Matrix

destination / origin	CBD	Central City	Suburb
CBD	12.7	10.1	8.5
Central City	10.1	7.5	6.0
Suburb	8.5	6.0	4.4

IN-VEHICLE TRAVEL TIME (mins.)

Air dist. (miles)	% arterials 0%	20%	40%	60%	80%	100%
0.5	0.1	0.1	0.1	0.2	0.2	0.2
1.0	0.8	0.9	1.0	1.1	1.2	1.3
1.5	1.6	1.8	2.0	2.1	2.3	2.5
2.0	2.3	2.6	2.8	3.1	3.3	3.6
2.5	3.0	3.4	3.7	4.1	4.4	4.8
3.0	3.8	4.2	4.6	5.1	5.5	5.9
3.5	4.5	5.0	5.5	6.1	6.6	7.1
4.0	5.2	5.8	6.4	7.0	7.6	8.6
4.5	6.0	6.7	7.4	8.0	8.7	9.4
5.0	6.7	7.5	8.2	9.0	9.7	10.5

FIGURE A-12

AIRLINE DISTANCE vs. TRAVEL TIME vs. DISTRIBUTION FACTORS BY TRIP PURPOSE: URBANIZED AREA POPULATION = OVER 100,000

APPENDIX B

APPLICATION OF THE MANUAL TRIP DISTRIBUTION PROCEDURE

Five districts in a hypothetical urban area of 60,000 population are to be analyzed for all purpose trips, i.e., HBW + HBNW + NHB trips. Productions and attractions for each district (and for all three purposes) are provided from the trip generation phase. The method proceeds in the following manner:

STEP 1: Map of Study Area. Lay out a map showing the five districts, district centroids and subregion boundaries (Figure B-1). A map showing major arterials and freeways is useful. A highway road map is usually suitable for this purpose.

STEP 2: Enter Production and Attraction Trip Ends - P_i, A_j. These trip end totals (for all purpose trips) are entered in the trip distribution worksheet along with other identification features such as headings, district numbers, etc. (Figure B-2). Thus, for example, district #2 produces 10,400 all purpose trips and attracts 11,600 trips. The total number of all purpose trips for the 5 districts amounts to 100,000 trips.

STEP 3: Enter District-to-District Travel Times and Distribution Factors - t_{ij}, F_{ij}. Although it is only the distribution factors that are to be used in the computation of trip interchanges, it is useful to enter and retain the travel times - these times will enable the user to better relate and perceive the spatial separation between the districts (Figure B-3).

Helpful Aids and Notes of Caution:

1. Since the construction of the travel time/distribution factor matrix entails repetitive steps, it is important that the user build up and maintain some kind of "mental rhythm" particularly when there are a large number of interchanges involved. This results in some time savings. One efficient approach is exemplified below:

	Steps	User Response
i.	Identification of origin-destination subregions	"2 to 5, central city to suburb."
ii.	Scaling of airline distance and reading off travel time from appropriate graphs.	"Figure A-5: 1.6 mile central city @ 20% arterial...in-vehicle travel time = 2.6 mins."
		"Figure A-6: 1.1 mile suburb @ 100% arterial...in-vehicle travel time = 1.4 mins."
iii.	Total O-D terminal times	"Central city to suburb = 6.0 mins."
iv.	Total travel time	"2.6 + 1.4 + 6.0 = 10.0 mins."
v.	Distribution factor (all purpose) @ 10 mins.	"1.70"

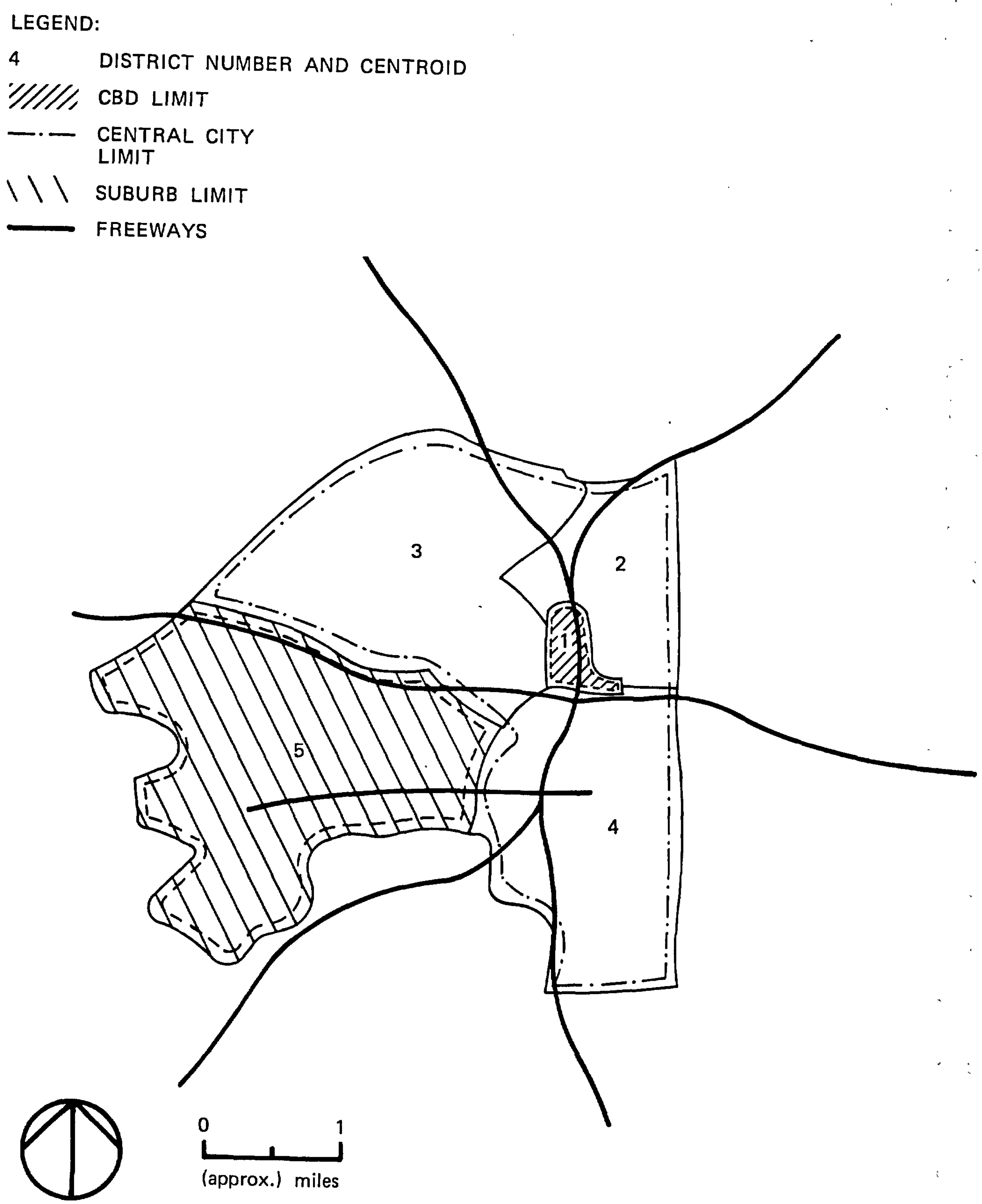


FIGURE B-1

MAP OF STUDY AREA:
HYPOTHETICAL CITY (STEP 1)

TRIP	AREA TYPE	AREA #	P_i \ A_j	ATTRACTION: CBD 1	CENTRAL CITY 2	CENTRAL CITY 3	CENTRAL CITY 4	SUBURB 5	ΣA_j		
				42,300	11,600	20,500	17,600	8,000	100,000		
PRODUCTION	CBD	1	5,900								
PRODUCTION	CENTRAL CITY	2	10,400								
PRODUCTION	CENTRAL CITY	3	27,100								
PRODUCTION	CENTRAL CITY	4	18,200								
PRODUCTION	SUBURB	5	38,400								
		ΣP_i	100,000								

FIGURE B-2

MANUAL TRIP DISTRIBUTION WORKSHEET:
ENTER PRODUCTION AND ATTRACTION TRIP ENDS (STEP 2)

TRIP	AREA TYPE	AREA #	P_i \ A_j	CBD 1: 42,300		CENTRAL CITY 2: 11,600		CENTRAL CITY 3: 20,500		CENTRAL CITY 4: 17,600		SUBURB 5: 8,000		ΣA_j 100,000
PRODUCTION	CBD	1	5,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20	
PRODUCTION	CENTRAL CITY	2	10,400	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17	
PRODUCTION	CENTRAL CITY	3	27,100	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28	
PRODUCTION	CENTRAL CITY	4	18,200	6	0.34	6	0.34	10	0.17	4	0.53	8	0.23	
PRODUCTION	SUBURB	5	38,400	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34	
		ΣP_i	100,000											

Tij=Travel time

Fij=All-purpose distribution factor

NOTE: Friction Factors for this example are *not* from Appendix A, but fabricated from example.

FIGURE B-3

ENTER DISTRICT-TO-DISTRICT TRAVEL TIMES AND DISTRIBUTION FACTORS (STEP 3)

And so on. This series of operations can be performed very easily on the desk calculator. A calculator with paper tape could prove handy in that travel time for the various portions of the trip interchange can be saved for later checking should the need arise. Note that in Figure B-3, the distribution factors are not from Appendix A, but have been fabricated for the example.

2. Although the time matrix is triangular, it is helpful to enter all the interchange cells with their respective travel time and distribution factors.

3. Caution should be exercised when making judgments on the freeway-arterial percentage mix for any interchange, since distances on a map can be visually deceptive especially when a small map scale is used.

STEP 4: Calculate Attraction Factors (A_jF_{ij}), Accessibility Index ($\sum A_jF_{ij}$) and Production Index (R_i) - Interation #1. Except for R_i, the terms A_jF_{ij} and $\sum A_jF_{ij}$ are calculated to the nearest 100 (Figure B-4). For example:

- o Attraction factor from district i=2 to district j=5 is:

$$A_jF_{ij} = 8,000 \times 0.17 = 1,400$$

- o Accessibility index for district i=2 is:

$$\sum_{j=1}^{5} A_jF_{ij} = 14,400 + 6,100 + 4,700 + 6,000 + 1,400$$
$$= 32,600$$

- o Production index for district i=2 is:

$$R_i = \frac{P_i}{\sum_{j=1}^{5} A_jF_{ij}} = 10,400/32,600 = 0.319018$$

And so on for all rows and columns.

Helpful Aids and Notes of Caution:

1. As a time saving measure, the attraction factors (A_jF_{ij}) can be computed by columns instead of rows. For instance, for column 5, the attraction (A_j=8,000) can be stored as a constant in the desk calculator; the attraction factors (A_jF_{ij}'s) from i=1 to 5 can be calculated by entering the respective F_{ij} in the calculator and obtaining the product.

STEP 5: Calculate Trip Interchanges (T_{ij}) - Iteration #1. The trip interchanges are calculated using $T_{ij} = R_iA_jF_{ij}$. The production and attraction totals at the end of iteration #1 are also obtained

TRIP	AREA TYPE	AREA #	P_i \ A_j	CBD 1 (42,300)		CENTRAL CITY 2 (11,600)		CENTRAL CITY 3 (20,500)		CENTRAL CITY 4 (17,600)		SUBURB 5 (8,000)		ΣA_j (100,000)	ACCESSIBILITY INDEX $\Sigma A_j F_{ij}$	PRODUCTION INDEX $R_i = \frac{P_i}{\Sigma A_j F_{ij}}$
PRODUCTION	CBD	1	5,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20			
				17,800		3,900		5,700		6,000		1,600			35,000	0.168571
				3,000		700		1,000		1,000		300		5,900		
	CENTRAL CITY	2	10,400	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17			
				14,400		6,100		4,700		6,000		1,400			32,600	0.319018
				4,600		2,000		1,500		1,900		400		10,400		
		3	27,100	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28			
				11,800		2,700		8,600		3,000		2,200			28,300	0.957597
				11,300		2,600		8,200		2,900		2,100		27,100		
		4	18,200	6	0.34	6	0.34	10	0.17	4	0.53	8	0.23			
				14,400		3,900		3,500		9,300		1,800			32,900	0.553191
				8,000		2,200		1,900		5,100		1,000		18,200		
	SUBURB	5	38,400	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34			
				8,500		2,000		5,700		4,000		2,700			22,900	1.676856
				14,300		3,400		9,600		6,700		4,500		38,400		
	ΣP_i		100,000	41,200		10,900		22,200		17,600		8,300		100,000	Attraction totals at the end of iteration #1	
				−3%		−6%		+8%		0%		+4%			% difference from true attractions	
				43,400		12,300		18,900		17,600		7,700			Adjusted attraction totals for iteration #2	

AjFij=Attraction factor—iteration #1

Tij=Trip interchange—iteration #1

NOTE: Friction Factors for this example are *not* from Appendix A but fabricated for this example.

FIGURE B-4

CALCULATE ATTRACTION FACTORS, ACCESSIBILITY INDEX AND PRODUCTION INDEX—ITERATION #1 (STEP 4)

CALCULATE TRIP INTERCHANGES—ITERATION #1 (STEP 5)

(Figure B-4). Thus:

- o Trip interchange for district i=2 and district j=5 is:

$$T_{ij} = R_i A_j F_{ij} = 0.319018 \times 1{,}400 = 400$$

- o Production total for district i=2 is:

$$P_i = \sum_{j=1}^{5} T_{ij} = 4{,}600 + 2{,}000 + 1{,}500 + 1{,}900 + 400$$

$$= 10{,}400 \text{ (which matches the desired } P_i\text{)}$$

- o Attraction total for district j=5 is:

$$A_j = \sum_{i=1}^{5} T_{ij} = 300 + 400 + 2{,}100 + 1{,}000 + 4{,}500$$

$$= 8{,}300$$

(Unbalanced: +4% difference from desired A_j)

At this point, due to the structure of the Gravity Model formulation which constrains the production values, the production total for each district will equal the true production trip ends. The attraction totals, however, will not necessarily match their input values. To refine the calculated interchanges, attraction totals are adjusted prior to application in iteration #2.

The adjustment is made as shown below:

- o Adjusted attraction total for district j=5 for use in iteration #2 is:

$$A_5^2 = A_5^1 \left(\frac{A_5}{C_5^1}\right) = 8{,}000 \times \frac{8{,}000}{8{,}300} = 7{,}700$$

where: C_5^1 = Column 5 total for iteration #1.

And so on for all columns (Figure B-4).

Helpful Aids and Notes of Caution:

1. A time saving can be realized by storing R_i as a constant in the calculator and then computing T_{ij} by entering $A_j F_{ij}$ for j=1 to 5.

2. There must be production balance; if not, an error may have been introduced in the preceding calculations. However, if the balance is off only slightly, it may be due to rounding errors which may be ignored.

3. It is wise to compute the percent differences between the attraction total at the end of iteration #1 and the desired attractions. This will indicate the magnitude of deviations.

4. It should be noted that the trip matrix is not triangular, i.e., trips from i to j $\neq$ trips from j to i; therefore, interchanges for all cells must be calculated.

STEP 6: Recalculate Terms as in Step 4 - Iteration #2. This step (Figure B-5) is a repetition of Step 4, but using the adjusted attraction totals out of iteration #1. Thus:

- Attraction factor from district i=2 to district j=5 is:

$$A_jF_{ij} = 7{,}700 \times 0.17 = 1{,}300$$

- Accessibility index for district i=3 is:

$$\sum_{j=1}^{5} A_jF_{ij} = 14{,}800 + 6{,}500 + 4{,}300 + 6{,}000 + 1{,}300$$
$$= 32{,}900$$

- Production index for district i=2 is:

$$R_i = \frac{P_i}{\sum_{j=1}^{5} A_jF_{ij}} = 10{,}400/32{,}900 = 0.316109$$

And so on for all rows and columns.

STEP 7: Recalculate Terms as in Step 5 - Iteration #2. This step is a repetition of Step 5, but using the new attraction factors (A_jF_{ij}) and the new production index (R_i) computed in Step 6. The production and attraction totals are also calculated by rows and columns respectively (Figure B-5). Thus:

- Trip interchange from district i=2 to district j=5 is:

$$T_{ij} = R_iA_jF_{ij} = 0.316109 \times 1{,}300 = 400$$

- Production total for district i=2 is:

$$P_i = \sum_{j=1}^{5} T_{ij} = 4{,}700 + 2{,}100 + 1{,}400 + 1{,}900 + 400$$
$$= 10{,}400 \text{ (which matches the desired } P_i\text{)}$$

AjFij=Attraction factor–iteration #2

Tij=Trip interchange–iteration #2

TRIP	AREA TYPE	AREA #	P_i \ A_j	CBD 1	CENTRAL CITY 2	CENTRAL CITY 3	CENTRAL CITY 4	SUBURB 5	ΣA_j	ΣA_jF_{ij}	$R_i = \frac{P_i}{\Sigma A_jF_{ij}}$
ATTRACTION				42,300	11,600	20,500	17,600	8,000	100,000		
PRODUCTION	CBD	1	5,900	5 | 0.42	6 | 0.34	7 | 0.28	6 | 0.34	9 | 0.20			
				17,800	3,900	5,700	6,000	1,600		35,000	0.168571
				3,000	700	1,000	1,000	300	5,900		
				18,200	4,200	5,300	6,000	1,500		35,200	0.167614
				3,100	700	900	1,000	300	5,900		
	CENTRAL CITY	2	10,400	6 | 0.34	4 | 0.53	8 | 0.23	6 | 0.34	10 | 0.17			
				14,400	6,100	4,700	6,000	1,400		32,600	0.319018
				4,600	2,000	1,500	1,900	400	10,400		
				14,800	6,500	4,300	6,000	1,300		32,900	0.316109
				4,700	2,100	1,400	1,900	400	10,400		
		3	27,100	7 | 0.28	8 | 0.23	5 | 0.42	10 | 0.17	7 | 0.28			
				11,800	2,700	8,600	3,000	2,200		28,300	0.957597
				11,300	2,600	8,200	2,900	2,100	27,100		
				12,200	2,800	7,900	3,000	2,200		28,100	0.964413
				11,800	2,700	7,600	2,900	2,100	27,100		
		4	18,200	6 | 0.34	6 | 0.34	10 | 0.17	4 | 0.53	8 | 0.23			
				14,400	3,900	3,500	9,300	1,800		32,900	0.553191
				8,000	2,200	1,900	5,100	1,000	18,200		
				14,800	4,200	3,200	9,300	1,800		33,300	0.546547
				8,100	2,300	1,700	5,100	1,000	18,200		
	SUBURB	5	38,400	9 | 0.20	10 | 0.17	7 | 0.28	8 | 0.23	6 | 0.34			
				8,500	2,000	5,700	4,000	2,700		22,900	1.676856
				14,300	3,400	9,600	6,700	4,500	38,400		
				8,700	2,100	5,300	4,000	2,600		22,700	1.691630
				14,700	3,600	9,000	6,800	4,400	38,400		
		ΣP_i	100,000	41,200	10,900	22,200	17,600	8,300	100,000	Attraction totals at the end of iteration #1	
				–3%	–6%	+8%	0%	+4%		% difference from true attractions	
				43,400	12,300	18,900	17,600	7,700		Adjusted attraction totals for iteration #2	
				42,400	11,400	20,600	17,700	8,200	100,000	Attraction totals at the end of iteration #2	
				0%	–.2%	0%	+1%	+3%		% difference from true attractions	
										Adjusted attraction totals for iteration #3, if required	

NOTE: Friction Factors are *not* from Appendix A, but fabricated for this example.

FIGURE B-5

RECALCULATE ATTRACTION FACTORS, ACCESSIBILITY INDEX, PRODUCTION INDEX–ITERATION #2 (STEP 6)

RECALCULATE TRIP INTERCHANGES–ITERATION #2 (STEP 7) o Attraction total for district j=5 is:

$$A_j = \sum_{j=1}^{5} T_{ij} = 300 + 400 + 2,100 + 1,000 + 4,400$$

$$= 8,200$$

(+3% difference from desired A_j)

At the end of this iteration, the new attraction totals should have converged very close to the desired attraction totals. If this is not the case and it is desired that trip interchanges be refined further through an additional iteration (#3), the adjusted attraction totals can be computed as follows:

o Adjusted attraction total for district j=5 for use in iteration #3 (if desired) is:

$$A_5^3 = A_5^2 \left(\frac{A_5}{C_5^2}\right) = 7,700 \times \frac{8,000}{8,200} = 7,500$$

And so on for all columns. Note that at the end of iteration #2, all of the attraction totals are within ±3% of the desired attraction totals which is sufficiently accurate in nearly all applications. Generally, a third iteration is not recommended.

Finally, the average trip time (ATT) of the all purpose trips can be calculated, if desired, quite simply by using:

$$ATT = \frac{\sum_{i=1}^{5} \sum_{j=1}^{5} T_{ij} \cdot t_{ij}}{\sum_{i=1}^{5} \sum_{j=1}^{5} T_{ij}}$$

Where:

T_{ij} = trip interchanges from area i to area j

t_{ij} = travel time for trip interchange ij

i.e.:

$$ATT = \frac{(3100 \times 5) + (700 \times 6) + \ldots + (6800 \times 8) + (4400 \times 6)}{100,000}$$

$$= 7.0 \text{ minutes}$$

At this juncture, it is advisable to conduct a systematic checking of the various calculations to confirm the validity of the figures. If no errors are detected, the 5 x 5 district trip distribution is then considered complete.

These interchanges represent the all purpose trips; if required, the HBW or HBNW or NHB trip interchanges can also be calculated in a similar fashion. Note, however, that for the HBW, HBNW and NHB trips, the district-to-district travel times remain the same as those calculated initially; only the distribution factors will be different.

In some cases where a quick and rough trip distribution matrix is to be developed, one need only perform the distribution computations for the HBW trips, and then factor these to arrive at the total (all purpose) trip distribution. Thus, the HBNW and NHB trip distributions could be avoided altogether. These "expansion" factors are provided in the Users Guide, (6), Chapter 6, "Time of Day Characteristics," and for more details refer to the Users Guide, (6), Chapter 10, "Scenario for Site Development Impact Analysis: Boise, Idaho."

The manual trip distribution procedure described above is summarized diagrammatically using the flowchart in Figure B-6.

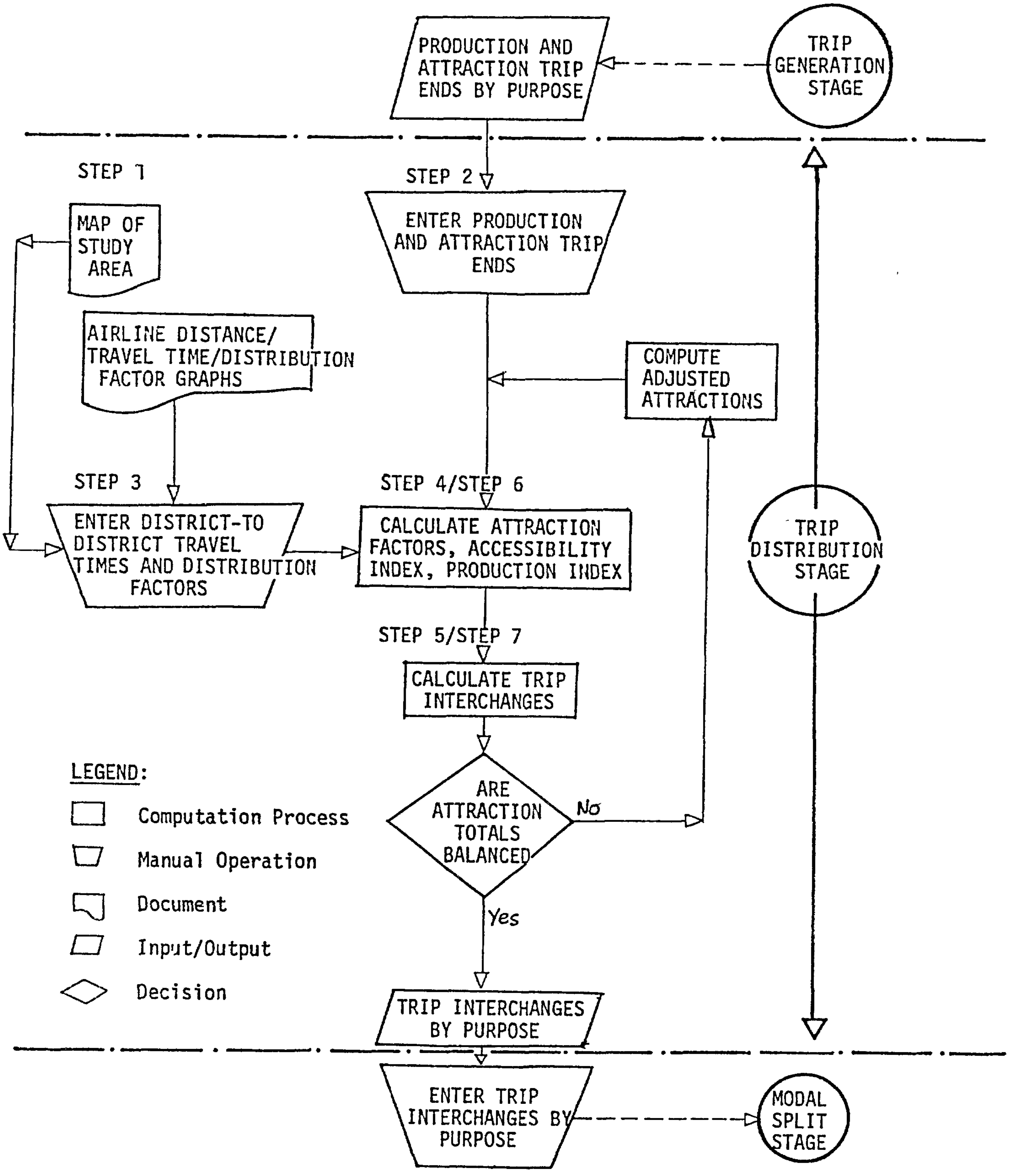


FIGURE B-6

SUMMARY FLOWCHART OF THE
MANUAL TRIP DISTRIBUTION PROCEDURE

APPENDIX C

TRIP INTERCHANGE MODAL SPLIT MODEL

Model Development

The Simplified Logit Model (SLM) was developed through an analysis of the UTPS UMODEL default modal split model and distribution factor curves for gravity type trip distribution models.

The mode choice model contained in the UTPS program UMODEL 7/ simultaneously performs the trip distribution and modal split functions. The mathematical form of the model is:

$$T_{m(i,j)} = P_i \cdot \frac{A_j \cdot e^{-\Theta I_{m(i,j)}}}{\sum_j \sum_m A_j \cdot e^{-\Theta I_{m(i,j)}}}$$

Where:

$T_{m(i,j)}$ = Trips from i to j by mode m

P_i = Productions at i (home end)

A_j = Attractions at j (destination end)

e = 2.71828

Θ = A calibrated constant that varies by trip purpose

$I_{n(i,j)}$ = A measure of impedance by mode m equal to:
(1.0 x in-vehicle time) +
(2.5 x excess time) + trip cost)/
(0.33 x income per minute)

Research indicates that it is possible to state the impedance variable in the same form as time is displayed in the Gravity Model equation. That is, $e^{-\Theta I}$ can be replaced with I^{-b} where I is equal to a measure of trip impedance and b is an exponent of the trip impedance, dependent on the trip purpose. Thus, substituting the expression for time, the equation becomes.

$$T_{m(i,j)} = P_i \cdot \frac{A_j \cdot I^{-b}_{m(i,j)}}{\sum_j \sum_m A_j \times I^{-b}_{m(i,j)}}$$

The form of the above equation is still such that distribtuion and modal split are accomplished simultaneously. The rate transformation was accomplished by dividing transit trips by auto trips and converting the ratio into an actual fractional market share quantity as follows:

$$r = \frac{T_{t(i,j)}}{T_{a(i,j)}}$$

where:

r = ratio of transit trips to auto trips

$$\therefore \quad ms_{t(i,j)} = \frac{r}{1 + r}$$

where:

$ms_{t(i,j)}$ = fractional market share of trips estimated to use the transit mode.

Thus, the SLM model is reduced to the following equation:

$$ms_{t(i,j)} = \frac{I^b_{a(i,j)}}{I^b_{a(i,j)} + I^b_{t(i,j)}}$$

In other words, the fractional market share for the transit mode is equal to the quotient of the auto impedance raised to a power of "b" and the sum of the transit impedance and auto impedance each raised to a power of "b."

It has been found that the calibration exponent, b, can be determined by calculating the slope of the distribution factor about the point of intersection with the average trip length. Default calibration exponents for small urban areas are shown in Table C-1. Nomographs for modal split were prepared using b values for cities in the greater than 100,000 population category (Figures C-9 through C-11).

The level of detail at which the mode choice procedure is applied is a function of time availability. One should not hesitate to apply the procedure to large analysis areas (e.g., districts) if time constraints are stringent.

There are two major outputs of the mode choice analysis:

- o Interchanges of transit person trips
- o Interchanges of auto person trips.

The transit person trips will probably be summarized by the user to show transit travel by either large analysis areas or corridors and may be input to other transit system analyses.

The auto person trips will most likely be subjected to an auto occupancy analysis to convert the person trips into auto driver trips as preparation for further analysis of the highway system.

TABLE C-1

SLM CALIBRATION EXPONENTS

TRIP PURPOSE	b values	
	POPULATION < 100,000	POPULATION > 100,000
HBW	2.15	1.99
HBNW	2.67	2.71
NHB	2.78	2.68

Data Required for Application

The data required for mode choice analysis vary depending upon previous work undertaken for the study area. It is recommended, where possible, that the user make every effort to take advantage of models and values that are specific to the study area. For those areas with a minimal history of transportation planning, default values have been incorporated into the modal choice procedures and can be used without further manipulation.

Table C-2 lists the data elements required for application of the mode choice procedures. The user can quickly distinguish between those input elements which must be supplied and those that are already available.

1. Highway Airline Distance. The highway airline distance can be obtained from several sources. If the analyst has used the trip distribution procedures described in the System Planning manual, the analysis area-to-analysis area airline distances might already have been developed.

2. Transit Airline Distance. For analysis area pairs that have direct transit service, the highway airline distance can be used to represent transit airline distance for estimating transit demand of radially oriented trips. For area pairs where transit service is indirect, the user must exercise great caution. In those cases, the transit patron will probably be required to travel in a radial direction to a transfer point, change direction and continue to the final destination. It is recommended that the transit airline distance for indirect trips be determined in components to account for indirect routing by: a) measuring from the production analysis area centroid to the transfer point, b) measuring the distance from the transfer point to the final destination area and, c) summing (a) and (b) as the transit airline distance. The user will need to invoke careful interpretation of airline distance in those instances.

Some area pairs may not be accessible by transit. Those areas without service can be quickly identified using a graphic representation of the transit system routes (data element 11) and can be immediately eliminated from any further mode choice analysis.

3. Transit Fare. The user will be required to supply area-to-area transit fare. If the user is studying an alternative with a flat fare system, this task becomes trivial in terms of the level of effort. On the other hand, an alternative that has an elaborate zone or graduated fare structure will require additional effort to organize the fare data between analysis areas.

4. Auto Operating Cost. The cost being considered is actually the out-of-pocket cost to the auto user. Over the years, modal split models have been calibrated with a wide range of assumed values for out-of-pocket operating costs. Currently, most modeling efforts are estimating these costs to be approximately five cents per mile in 1970 dollars. Other values of cost are available to the user in the mode choice procedures and the final responsibility for selecting a cost rests with the analyst. It should be observed that it is possible to assess mode choice under an assumption of varying auto operating costs. For example, the user may wish to analyze the magnitude of a shift to transit if auto operating costs were to double.

TABLE C-2

INPUT DATA ELEMENTS REQUIRED FOR MODE CHOICE ANALYSIS

INPUT DATA ELEMENT[a]	SOURCE	
	Default	User Supplied
1. Highway Airline Distance		X
2. Transit Airline Distance		X
3. Transit Fare		X
4. Auto Operating Cost		X
5. Attraction End Parking Cost		X
6. Average Highway Speed		X
7. Impedance Exponent (b) Values	X	
8. Median Income	X	
9. Access Time	X	
10. Person Trip Table		X
11. Graphical Display of Transit System		X

FOOTNOTE:

a. Input data elements 1,2,3,6 and 10 are by analysis area pairs (e.g., district-to-district).

Input data elements 5,8 and 9 are by the appropriate analysis area (e.g., data element 5 for the attraction district).

Input data elements 4 and 11 are by the study area.

Input data element 7 is by trip purpose (HBW, HBNW or NHB).

5. Attraction End Parking Cost. The user will be required to develop estimates of parking cost in order to use the highway impedance nomographs (exhibited later in this chapter). Parking costs will be necessary for each trip purpose since trip duration varies between the work and non-work purposes. As a guide, the user can assume a duration of nine hours for the HBW trip and two hours for the HBNW and NHB trip purposes. The parking costs shown in the highway impedance nomographs represent the full parking charge associated with a trip. For the purpose of demand analysis it is appropriate to consider one-half of the actual parking changes associated with a round trip. The curves contained in the highway impedance nomographs represent a consideration of one-half the mid-range parking costs as described by each highway impedance nomograph. In preparing the estimates of parking costs by analysis area, the analyst is cautioned to develop the cost based on all available parking (free and paid) for the particular trip purpose under consideration.

6. Average Highway Speed. Area-to-area average highway speed can be determined from previous efforts of the user or as a special exercise. To determine average auto operating speed using the manual trip distribution nomographs contained in the System Planning manual:

a. Locate the appropriate "Airline Distance vs. Travel Time vs. Distribution Factors" graph.

b. Determine the mix of highway facilities (i.e., between freeways and arterials) the trip will traverse.

c. Enter the appropriate graph (Figures A-1 through A-11) at the appropriate airline distance and read across to the facility mix desired and down to the travel time.

d. Substract from the travel time the terminal time (if included) shown for that graph and convert the new time to an operating speed using the nomograph shown in Figure C-1.

7. Impedance Exponent (b) Values. Impedance exponents for the general modal choice model are supplied for the user in the form of transit modal choice nomographs (Figures C-9, C-10 and C-11) for three trip purposes - HBW, HBNW and NHB. Those nomographs can be used if the analyst elects to employ the SLM in a manual mode. The "b" values shown in Table C-1 can be incorporated into a computerized application procedure. The results obtained for the manual and computerized applications will be comparable.

8. Median Income. The mode choice analysis procedures assume a median family income of $9,000/year for converting travel cost items into equivalent minutes. Median income (by each analysis area) is referenced since most land-use forecasting procedures produce the number of households within an income range. However, average household income values may be used if they are available. Income is applied to all impedance components dealing with trip costs to convert each to equivalent minutes. If the user wishes, the default impedance curves may be adjusted to take into account varying median income values.

EXAMPLE:

If the centroid-to-centroid airline distance between two analysis areas = 10 miles and the corresponding in-vehicle time = 30 minutes, then the average operating speed = 24 mph.

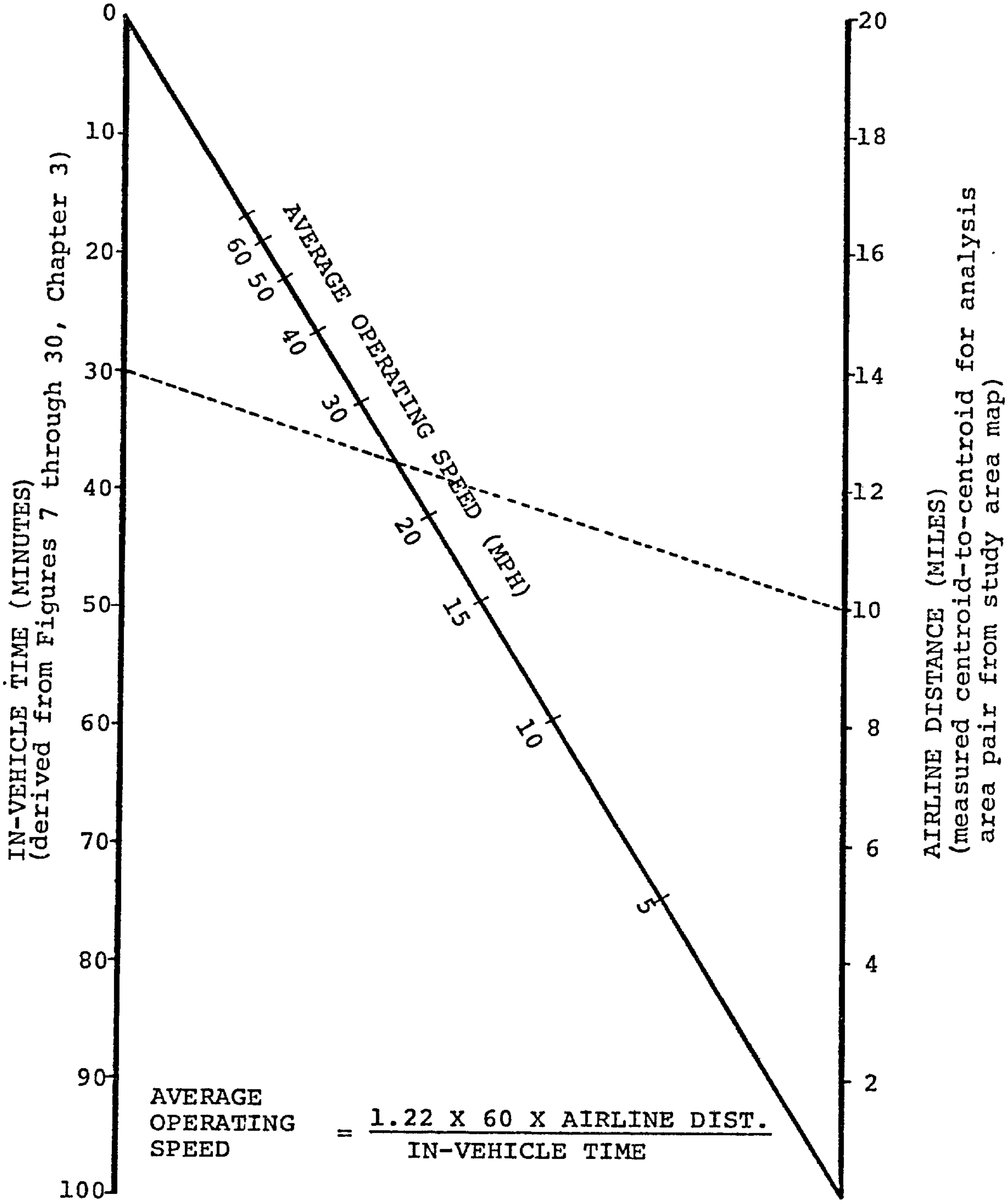


FIGURE C-1

NOMOGRAPH FOR
CONVERSION OF AIRLINE DISTANCE TO
AVERAGE OPERATING SPEED

9. Access Time. Access time is that quantity of time from leaving the origin point to getting into the vehicle (bus or auto) plus the time between exiting the vehicle and reaching the trip destination. For transit trips, it may also include time to transfer between transit vehicles. It is also referred to as out-of-vehicle time plus, if appropriate, in-vehicle time not associated with the line haul part of the trip. For calculating transit impedance, access time represents an important segment of the total impedance value. In the manual procedure, the transfer time is assumed to be zero. Trip interchanges which involve a transfer can have an impedance adjustment by adding 2.5 times the transfer time to the impedance read from the nomograph. Transfer time can be estimated as one-half the headway of the transit line being transferred to.

10. Person Trips. The user is required to supply area-to-area person trips for each trip purpose (maximum of three purposes - HBW, HBNW and NHB). Trips may be used as developed from the trip distribution procedure or, the user may elect to use a computer developed trip table if one is available. With regard to the separate application for each trip purpose, if the user desires, only modal choice analysis for the HBW trip purpose may be conducted and then the number of transit trips derived doubled to estimate Annual Average Weekday (AAWD) transit passenger movements. Also, see information relative to an all purpose model later in this Appendix.

11. Graphical Display of Transit System. The user will need a graphic representation of the existing or proposed transit system to overlay the analysis area boundaries for determining those interchanges with and without transit service. Movements without transit service may be eliminated from the modal choice analysis, and it can be assumed that all trips for those interchanges are made via auto (auto driver and auto passenger). The analyst can assume specific areas, use the transit system via Park-n-ride or Kiss-n-ride access. Care should be exercised, though, or an over-estimation of this type of trip will result. If transit service differs significantly between the peak and off-peak periods in the specific study area, separate peak and off-peak descriptions will be required. As a general rule, the peak system applies to the HBW trip purpose travel while the remaining two trip purposes (i.e., HBNW and NHB) should be associated with the off-peak system.

Application of the Manual Modal Choice Estimation Procedures

A generalized flowchart of the manual modal choice procedure is shown in Figure C-2. The procedure shown must be completed once for each trip purpose subjected to an analysis. There are three main steps required with application of the modal choice procedure as follows:

STEP 1. Determine Auto and Transit Impedances. The first and most difficult task confronting the user is determining area-to-area impedances. (NOTE: The user is directed to Figure C-3, "Modal Choice Analysis Work Sheet A" for application of the procedures.) To minimize the level of effort required, it is recommended that the user consider two-way trips; e.g., assume the travel characteristics between i and j equal j to i and sum the trips to get a total movement between i and j. This simplification should be fully satisfactory except in localized transit service areas

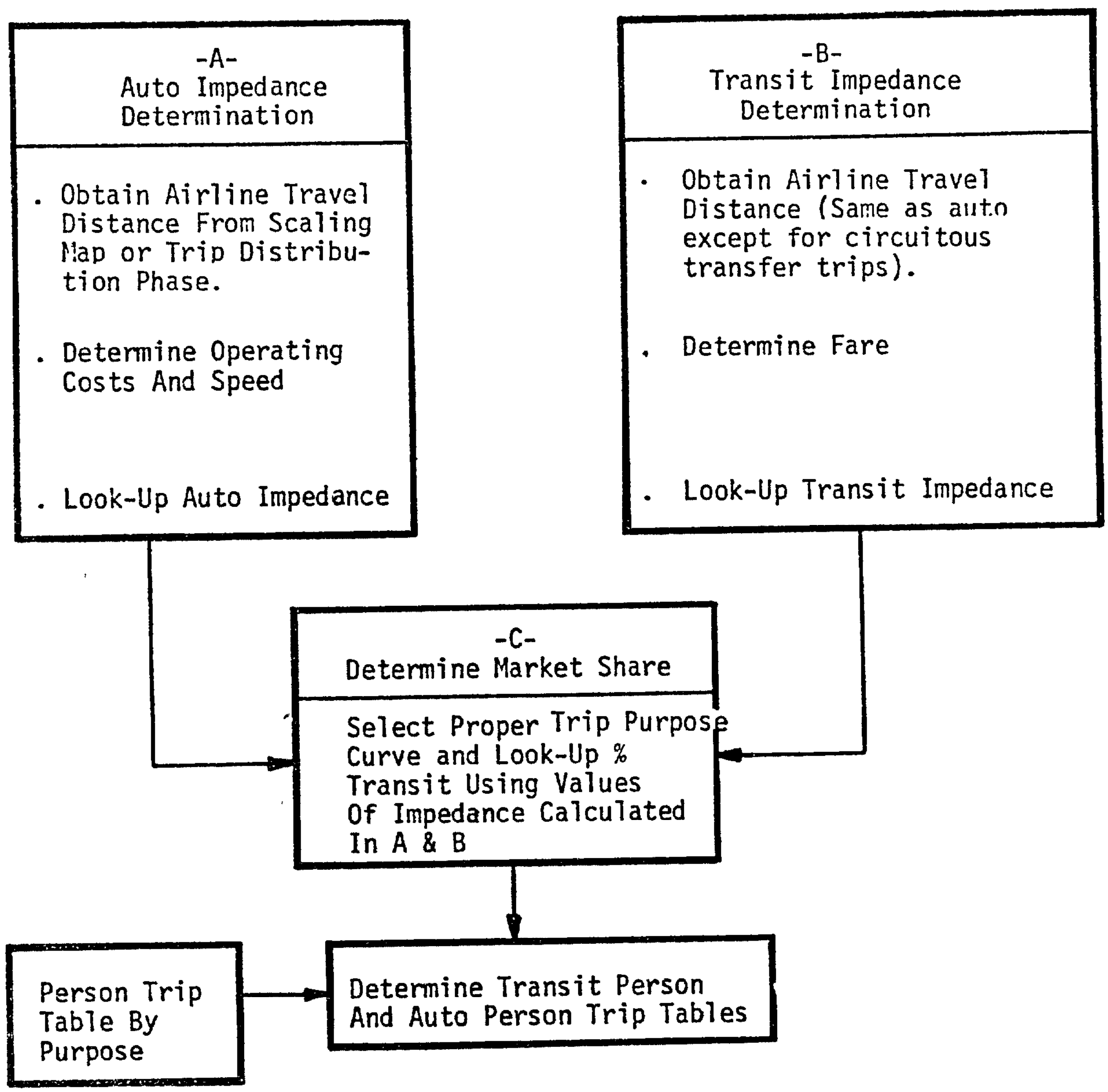


FIGURE C-2

FLOWCHART OF THE MANUAL
MODE CHOICE ESTIMATION PROCEDURE

FOOTNOTES:

* Denotes access mode: W=walk, A=auto. Note that egress mode always assumed to be W=walk.

\+ If triangular work sheet is desired, all cells vertically below the shaded cells should be eliminated.

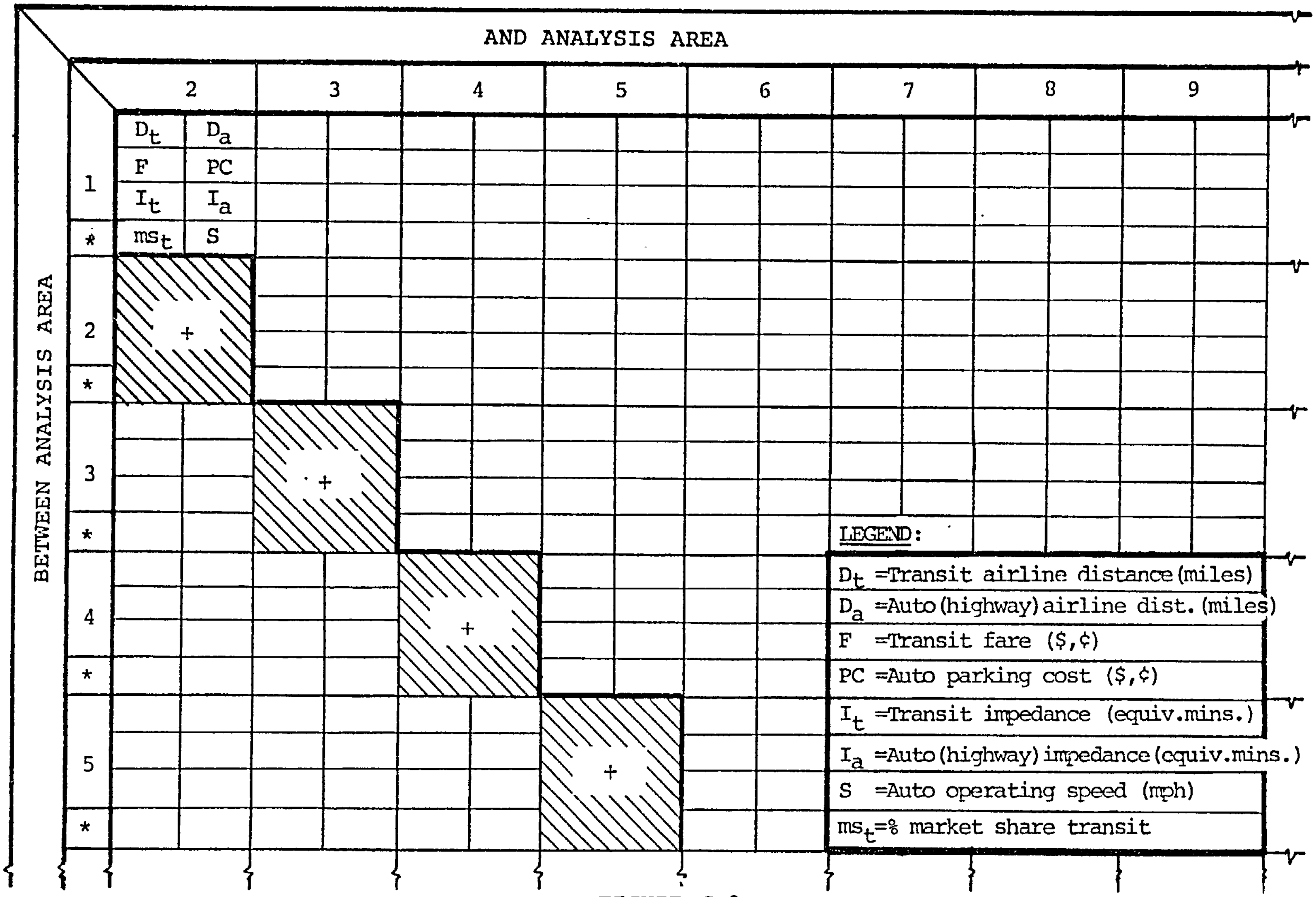


FIGURE C-3

MODE CHOICE ANALYSIS WORK SHEET A

where inbound transit service differs markedly from outbound service. For example, where a substantial peak commuter bus operation is provided in the peak direction, separate peak direction and off-peak direction calculations may be appropriate.

The analyst must supply the following information for each analysis area pair (See section entitled, "Input Data Elements" above.):

INPUT		SOURCE
o Highway distance	-	Map of study area
o Transit distance	-	Equal to highway distance except where trip requires additional trip distance due to transfer location. In those cases the airline distance is equal to the airline distance from origin to transfer point to destination.
o Highway operating speed	-	User judgment
o Transit fare	-	Local transit system
o Parking cost	-	User knowledge of study area

Additionally, the user must determine the access mode (walk or auto) for each production analysis area. (See asterisk in Figure C-3.) It may be assumed the access mode is the same for each cell of a particular row on the analysis work sheet.

For those analysis areas without transit service, the user can simply record "0%" transit in the appropriate space on "Work Sheet A" and analysis of those areas can be considered complete.

The above information should be recorded on "Work Sheet A" for each analysis area pair. When Work Sheet A is completed, the technician will be prepared to determine the market share from the appropriate mode choice nomographs (Figures C-9 through C-11) and prepare the modal person trip estimates.

To determine the transit and auto impedances, the user is directed to the "Transit and Auto Total Impedance Nomographs" (Figures C-4 and C-5 for transit, and Figures C-6 through C-8 for auto). The transit impedance nomographs for walk access have an assumed walking-plus-waiting time at the production end of the trip of fifteen (15) minutes before weighting. The user may desire to alter that assumption. To change the assumption the user should subtract 2.5 times 15 minutes (37.5 equivalent minutes) from the impedance quantity and add 2.5 times the desired access time. The user may wish to keep the assumed walk time (5 minutes) and modify the wait time to equal one-half (½) the headway in the analysis area. To

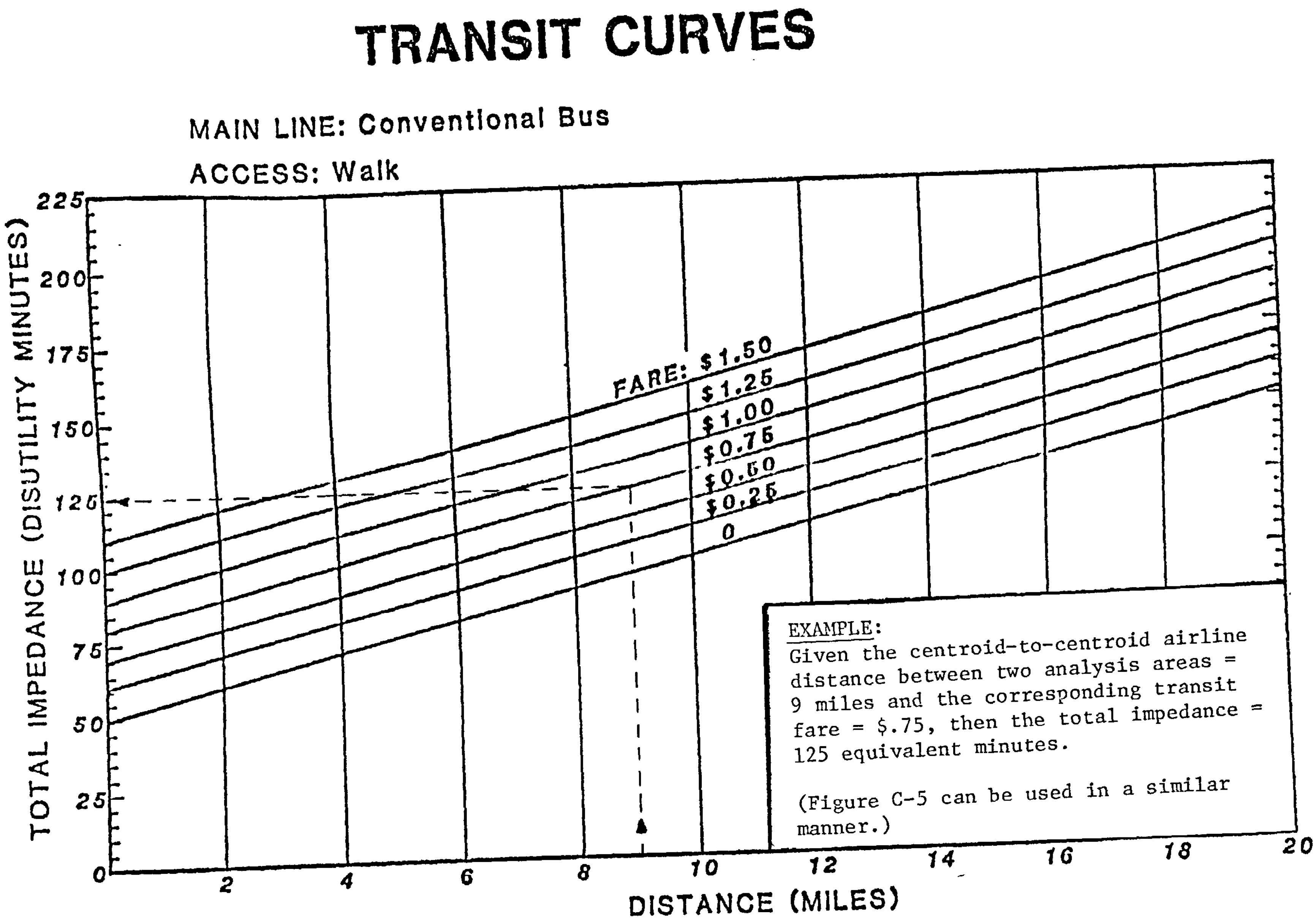


FIGURE C-4
NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE - TRANSIT:
(ACCESS MODE = WALK)

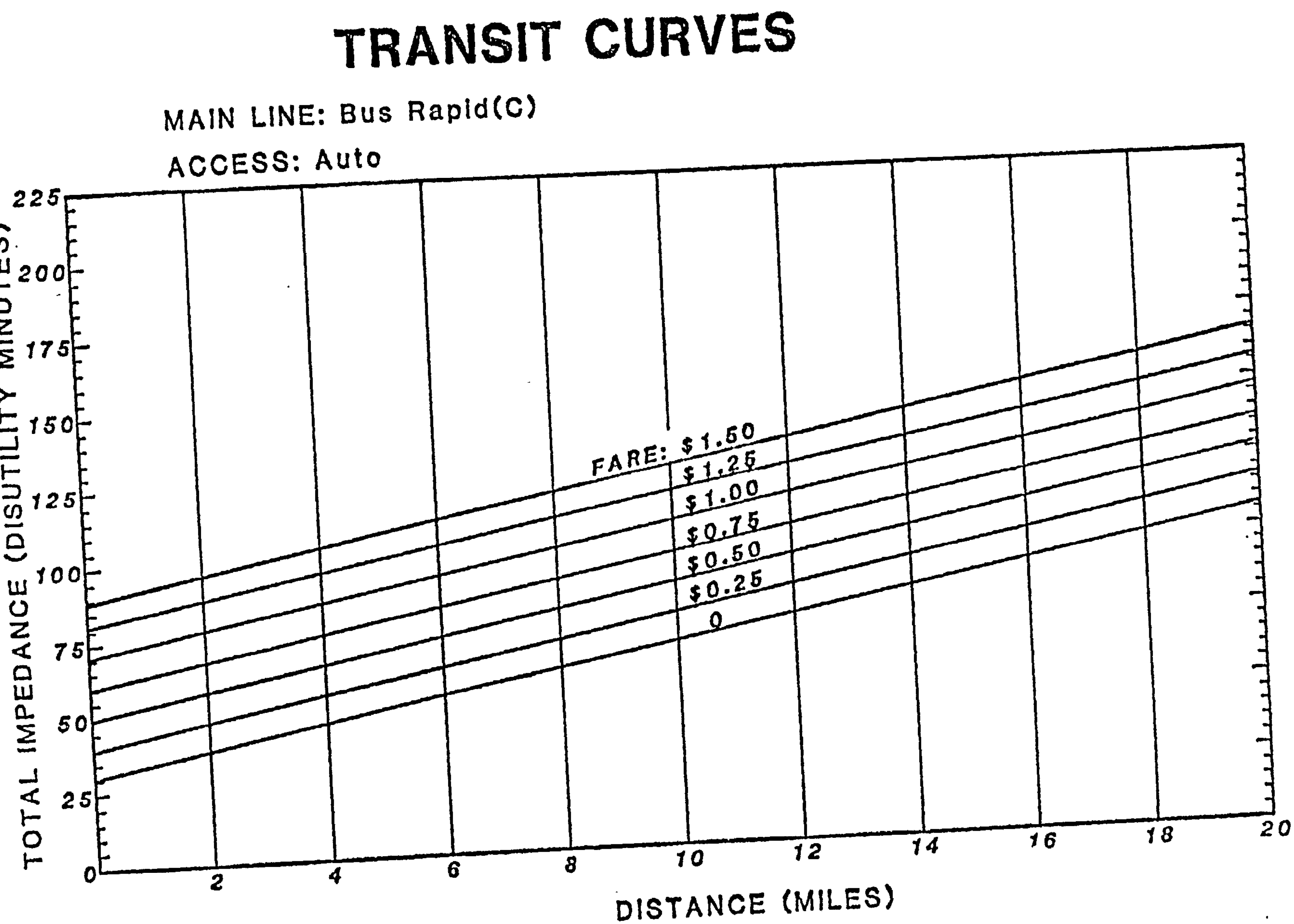


FIGURE C-5
NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE - TRANSIT
(ACCESS MODE = AUTO)

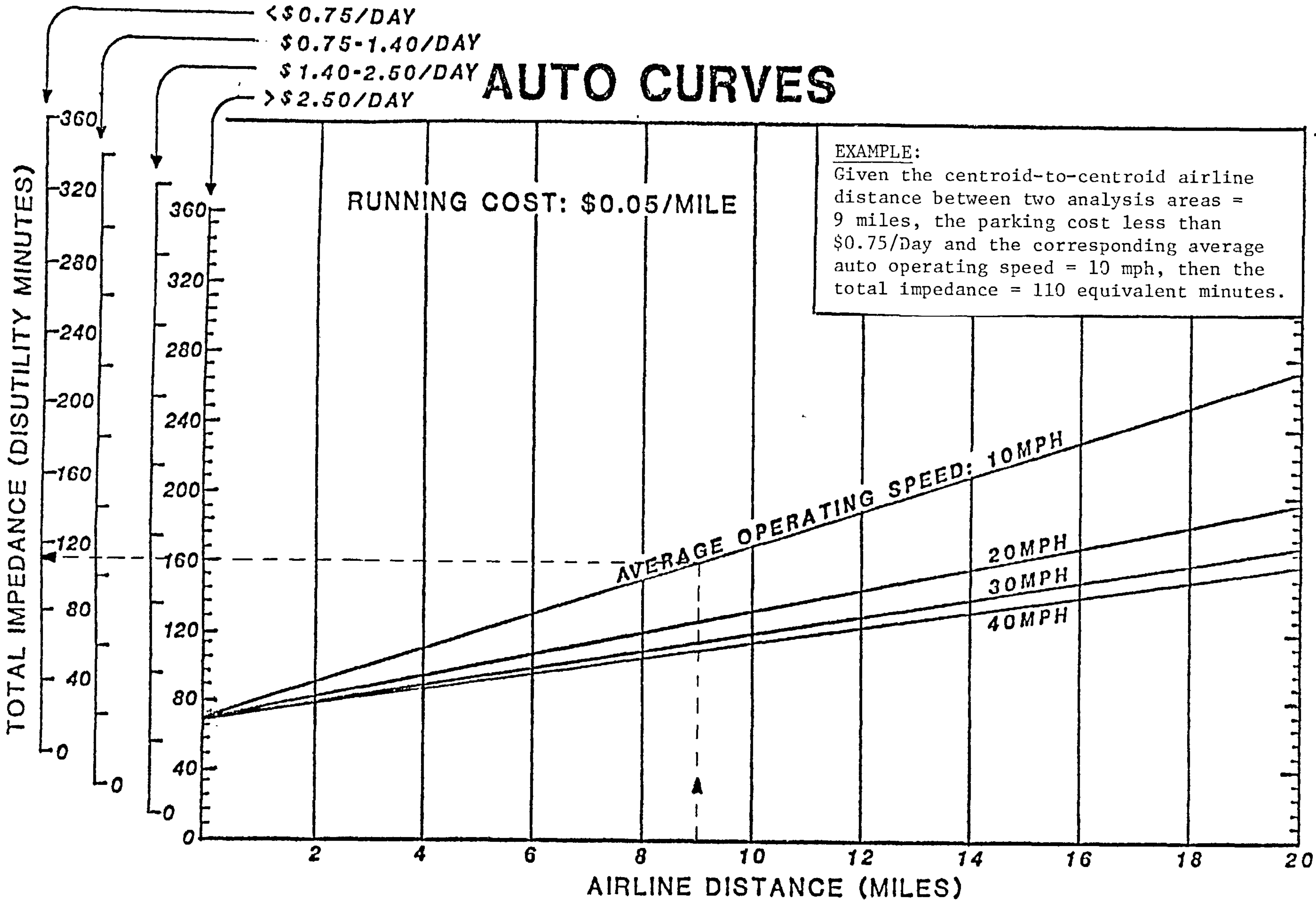


FIGURE C-6
NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE - AUTO:
OPERATING COST: $0.05/MILE

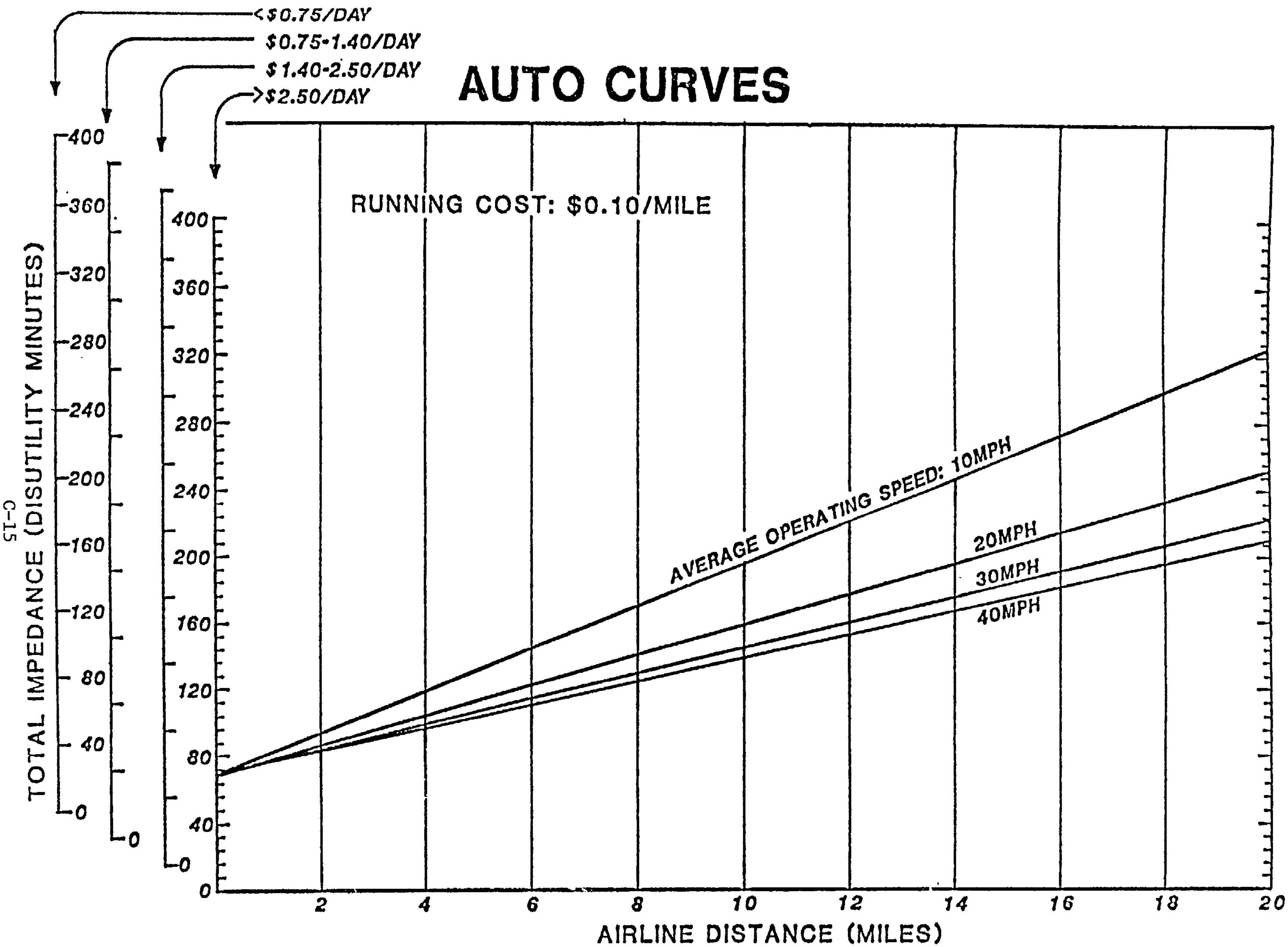


FIGURE C-7

NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE - AUTO:
OPERATING COST: $0.10/MILE

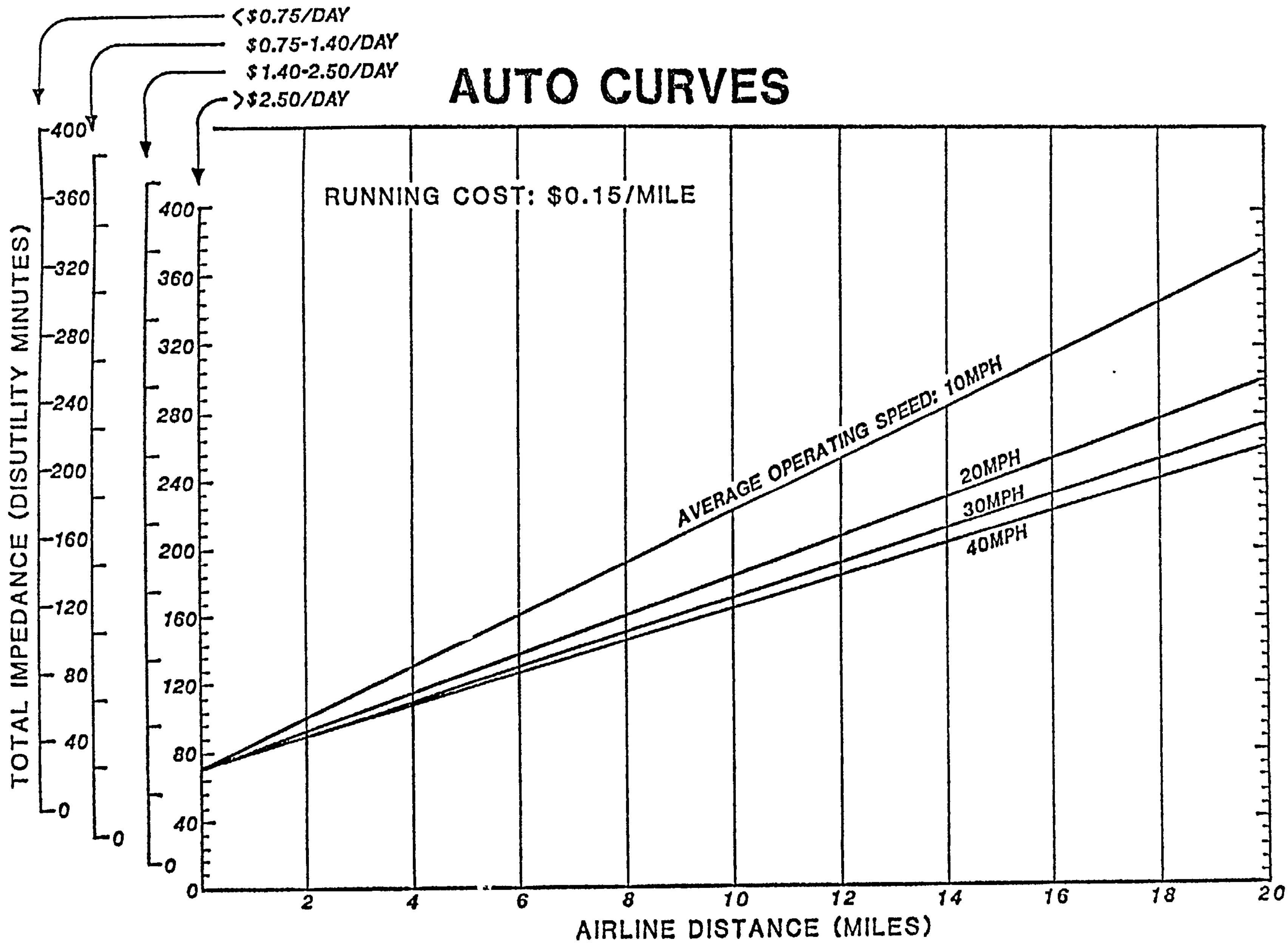


FIGURE C-8

NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE - AUTO: OPERATING COST: $0.15/MILE

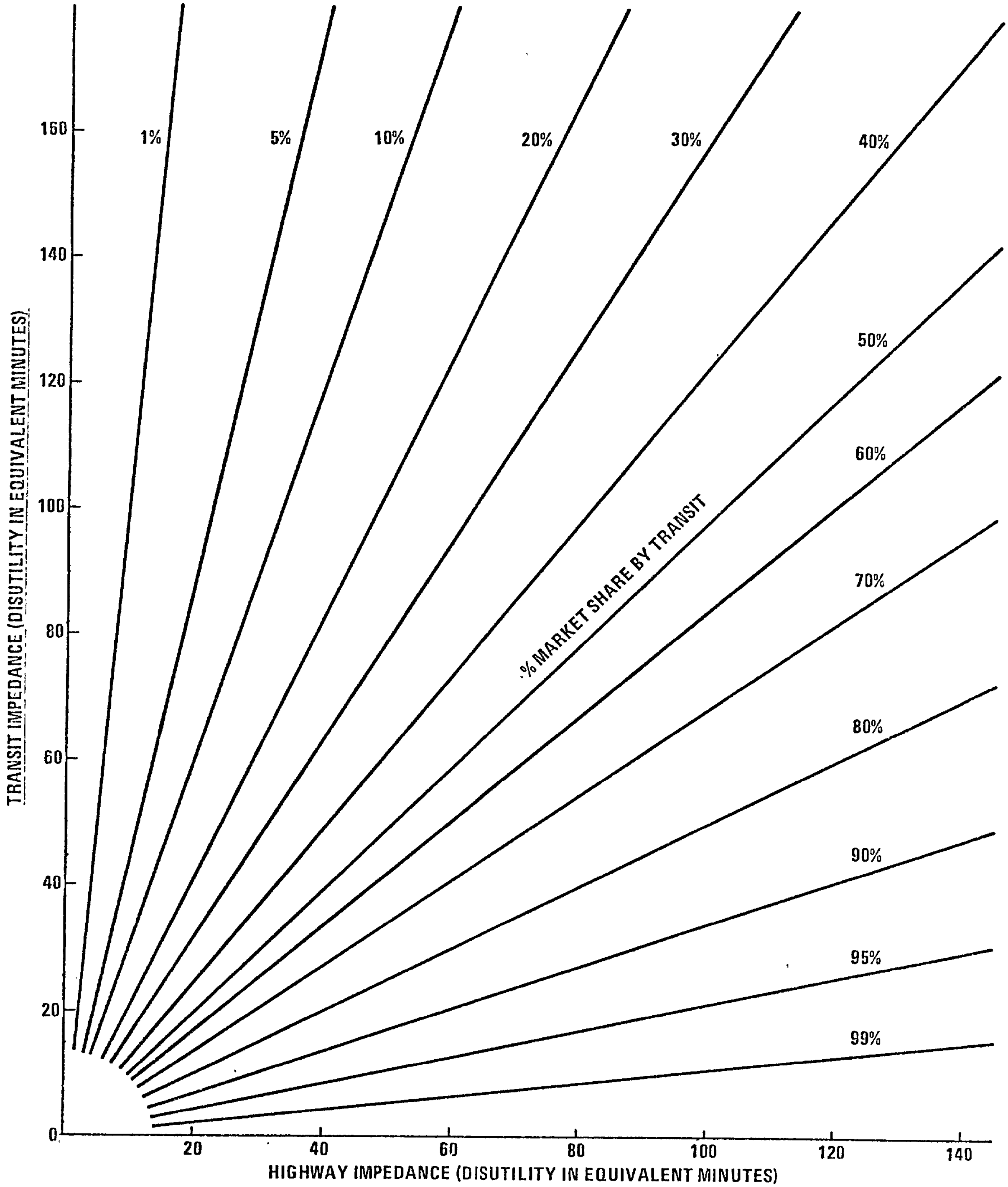


FIGURE C-9

SLM MODE CHOICE MODEL
TRIP PURPOSE = HBW

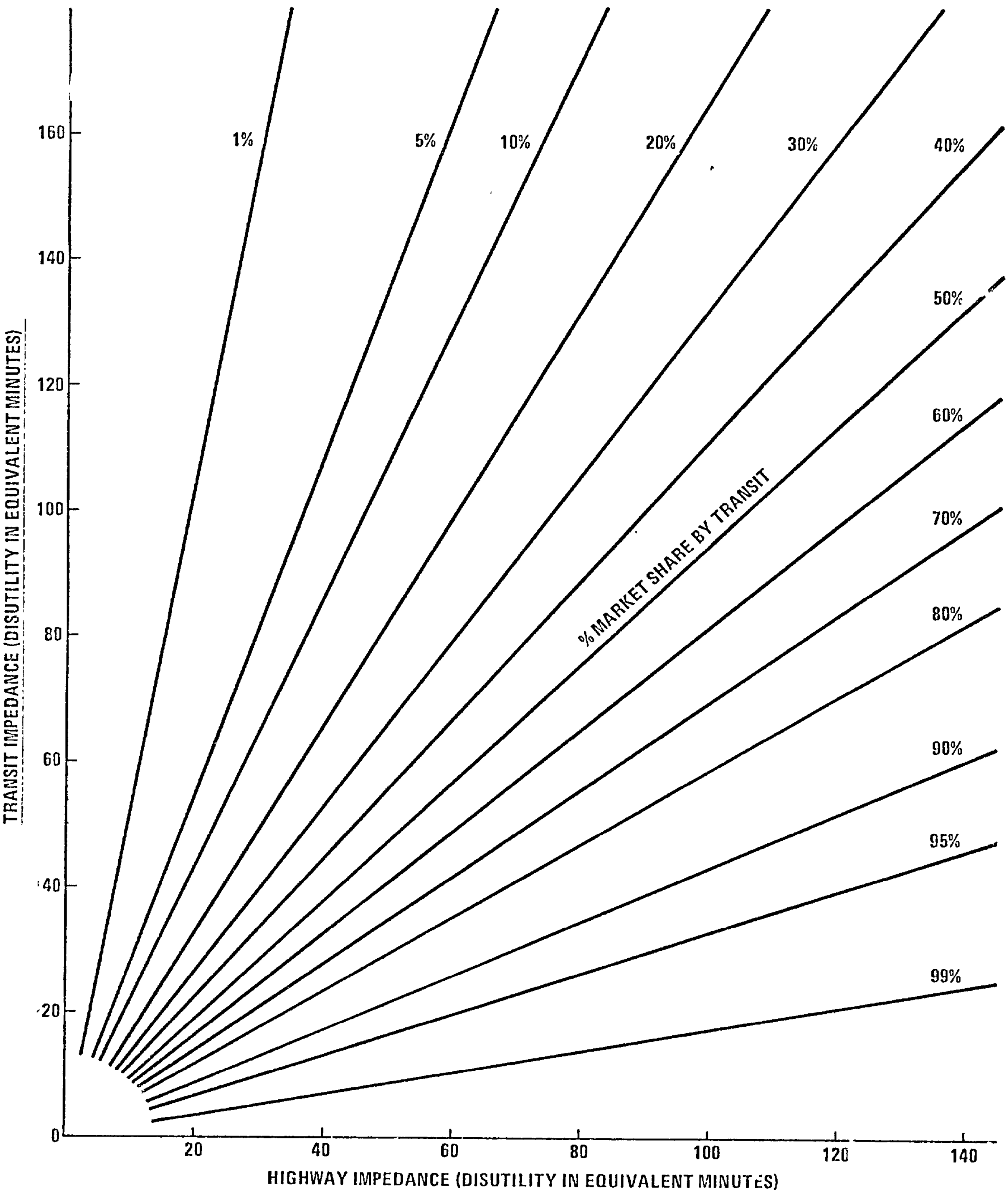


FIGURE C-10

SLM MODE CHOICE MODEL
TRIP PURPOSE = HBNW

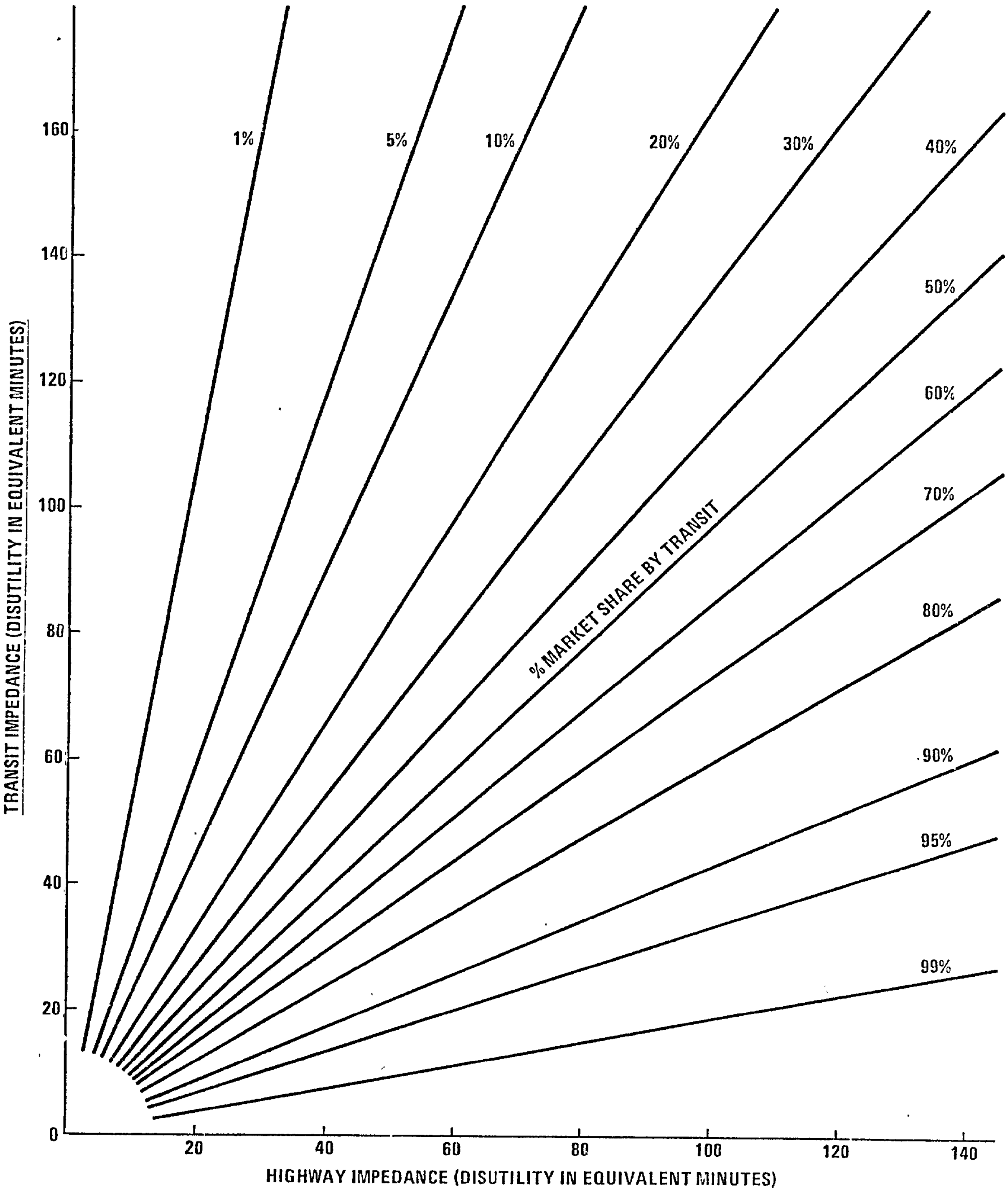


FIGURE C-11

SLM MODE CHOICE MODEL
TRIP PURPOSE = NHB

modify the default auto access time of 3 minutes (Figure C-5), the user is cautioned that it is not, and should not be, weighted since it is an in-vehicle travel time. Likewise, the user may wish to adjust the default walking time at the attraction end of the trip. The default destination walk time of 5 minutes can be adjusted by subtracting 5 times 2.5 (12.5 equivalent minutes) from the impedance and adding 2.5 times the desired destination walk time.

Further modifications can be made to the impedance nomographs for transit trips requiring a transfer. These default curves assume no transit-to-transit transfer. It is customary to incorporate a waiting time equal to one-half the headway of the bus line being "transferred to." The user is encouraged to make these adjustments where appropriate for transit trips in order to prevent an over-estimation of non-radial transit travel. As a default condition, the user can assume an additional 30 equivalent minutes (10 minutes unweighted transfer time) for trips of this type. When incorporating this transfer trip modification, the user can simply add the transfer penalty to the values determined from the transit impedance nomographs since it causes a constant vertical shift to the default curves.

Two transit nomographs are provided, one for walk access. and the other for auto access; the curves within each nomograph are stratified by transit fare. Auto total impedance nomographs are categorized by out-of-pocket auto operating costs and actual parking cost at the attraction end of the trip; the curves within each nomograph are stratified by highway operating speed.

By looking up the airline distance on the appropriate nomograph and curve, the total impedance for either mode can be read off the y axis and recorded on "Work Sheet A" (i.e., I_t for transit and I_a for auto).

The user should be aware of all the assumptions that have entered into the development of the total impedance curves for transit and auto trip paths.

The assumption used in the above reference to convert highway and transit airline distance to actual miles of route was 1.27 (the circuity factor). Other assumptions are as follows:

- Parking Costs:

PARKING COST STRATA	VALUE REPRESENTED	½ PARKING COST
0 - $.75	$0.37	$0.185
$.75 - $1.40	$1.07	$0.535
$1.41 - $2.50	$1.95	$0.975
Over - $2.50	$3.00	$1.500

- Total auto origin and destination terminal time = 5 minutes or 12.5 disutility equivalent minutes.

o Average Transit Access Times (mins.):

	IN-VEHICLE	OUT-OF-VEHICLE (unweighted)			
	Auto Access	Origin Walk & Wait		Transfer & Wait	Destination Walk
Walk Access	0	5	10	0	5
Auto Access	3	1	0	7	5

o General Impedance Equation:

Total Impedance = In-vehicle Time + 2.5 (out-of-vehicle time) + [Costs (¢)/2.5]

The cost conversion factor (2.5) assumes an average income of $9,000 per year.

STEP 2. Determine Market Share. The next step in determining the market share and completing "Work Sheet A" is accomplished using the appropriate mode choice nomographs shown in Figures C-9 through C-11 (HBW, HBNW, NHB).

Using the determined highway and transit impedance for each analysis area pair and the appropriate trip purpose modal choice model, the user can determine the percentage of trips occurring between the analysis area pair that can be expected to use transit. To determine modal split, the appropriate nomograph is entered on both the x and y axes using the determined highway and transit impedances respectively; then, the intercept will show the percent of trips by transit (ms_t). The user will, most likely need to interpolate between the curves supplied on the nomograph. The ms_t result should be recorded on "Work Sheet A" and "Work Sheet B" (Figure C-12). "Work Sheet A" will now be complete and the user can, with a calculator, proceed to complete "Work Sheet B."

STEP 3. Determine Transit and Auto Person Trips. The compressed (triangular) person trips for each analysis area pair of the trip purpose under investigation should be recorded on "Work Sheet B." Multiplying the trips by the percent transit market share (ms_t) will yield the number of transit person trips anticipated to occur between the analysis areas. Subtracting transit person trips from the total person trips for that particular interchange yields the number of auto person trips for the interchange.

The completion of "Work Sheet B" finishes the mode choice analysis for the trip purpose. The procedure can be repeated for all trip purposes to be analyzed. Upon completion of the analysis of all trip types, the transit and auto person trips, by purpose, can each be summed to obtain total transit and total auto person trip tables.

FOOTNOTE:

+ If triangular work sheet is desired, all cells vertically below the shaded cells should by elimiated.

AND ANALYSIS AREA

BETWEEN ANALYSIS AREA		2	3	4	5	6	7	8	9
1	Σ Trips								
	ms_t								
	T_t								
	T_a								
2		+							
3			+						
4				+					
5					+				

LEGEND:

Σ Trips	=	Person trips between i & j for purpose p
ms_t	=	% market share transit
T_t	=	ms_t x (Σ trips)
T_a	=	(Σ trips) - T_t

FIGURE C-12

MODE CHOICE ANALYSIS WORK SHEET B

For an example of the application of the above procedure to estimates for selected transit route possibilities, the reader is referred to Chapter Ten of the Users Guide 6/.

Single Purpose Modal Split Model

Chapter Two describes procedures which permit the development of a single purpose (combining home-based work, home-based non-work and non-home based) person trip table. Should the user elect to invoke that technique as part of a transportation planning process, the model and nomographs presented here may be used to continue the mode choice analysis.

The model described here is of the Simplified Logit (SLM) described previously. Charts and nomographs are supplied to assist in the manual application of the model. The user is required to code the specific FORTRAN routines for input to the UTPS program UMODEL which will be specific to the input parameters established.

The calibration exponent used for the single purpose SLM has been calculated to be 2.6. Thus, the mathematical expression of the model becomes:

$$ms_{t(i,j)} = \frac{1}{1 + \left(\frac{I_t}{I_a}\right)^{2.6}_{(i,j)}}$$

where:

$ms_{t(i,j)}$ = Market share of person trips estimated to travel via transit between two analysis areas

I_t = Impedance (in equivalent minutes) to travel by transit between two analysis areas

I_a = Impedance (in equivalent minutes) to travel by auto between two analysis areas.

Impedance is further defined as:

- 2.5(out-of-vehicle time) + (In-vehicle travel time) + Travel cost/(1/3 x Income)

The single purpose mode choice model is shown in Figure C-17. The graphical model can be used manually, as previously described.

Input variables, and their values, used in developing the impedance charts are found in Table C-3.

TABLE C-3

IMPEDANCE VARIABLES FOR SINGLE PURPOSE SLM

VARIABLE	PEAK PERIOD	OFF-PEAK PERIOD	WEIGHTED AVG.
Out-of-vehicle Time			
Walk Time	10 mins.	10 mins.	10 mins.
First Wait Time	10 mins.	15 mins.	14 mins.
Second Wait Time	-0-	-0-	-0-
Terminal Time	5 mins.	5 mins.	5 mins.
In-Vehicle Time			
Bus	(Varies by trip length; Peak = Off-Peak)		
Auto	(Varies by trip length and speed; Peak = Off-Peak)		
Travel Costs			
Auto Operating Cost:			
5¢/mile	5¢/mile	5¢/mile	5¢/mile
10¢/mile	10¢/mile	10¢/mile	10¢/mile
15¢/mile	15¢/mile	15¢/mile	15¢/mile
Parking Cost			
< 75¢/day	37¢	19¢	23¢
75¢-$1.40/day	$1.07	54¢	65¢
$1.40-2.50/day	$1.95	98¢	$1.17
> $2.50/day	$3.00	$1.50	$1.80

TABLE C-3 (Continued)

VARIABLE	PEAK PERIOD	OFF-PEAK PERIOD	WEIGHTED AVG.
Fare:			
0¢	0¢	0¢	0¢
25¢	25¢	17¢	19¢
50¢	50¢	33¢	36¢
75¢	75¢	50¢	55¢
$1.00	$1.00	67¢	74¢
$1.25	$1.25	83¢	91¢
$1.50	$1.50	$1.00	$1.10

Using the general impedance relationship and the impedance variable values found in Table C-3, the auto and transit impedance nomographs (Figure C-13 through Figure C-16) were developed.

The procedure for applying the single purpose model, including the layout of the work sheets for manual analysis, is identical to the SLM presentation in the previous section. The only change would be to enter total person trips on "Work Sheet B" (Figure C-12).

In order to simplify the application procedures of the single purpose SLM, several assumptions are necessary regarding input parameters and relationships between the peak period and off-peak period transit services. It is assumed the analyst will define the transit system in terms of peak period requirements. The impedance charts are expressed in terms of peak service characteristics - including the cost functions of transit fare and parking cost. The parking charge stratification is stated as the full cost associated with the work trip.

It is also assumed that the peak period characteristics are associated with the work purpose and off-peak characteristics are associated with the non-work trip purposes. The trip generation procedures describe the total residential person trip estimate to be comprised of 20% work trips and 80% non-work trips. Each impedance variable, where average variable values differ between peak and off-peak periods, have been weighted by the 20/80 ratio to properly reflect their contribution to this single purpose modal split model.

Other assumptions include:

- Off-peak parking cost = 1/2 peak parking cost
- Off-peak average transit fare = 2/3 peak average transit fare
- Average bus speed (peak and off-peak) = 15 m.p.h.
- Average household income = $9,000/year
- All transit access is via a walk trip
- Actual distance = 1.27 x airline distance

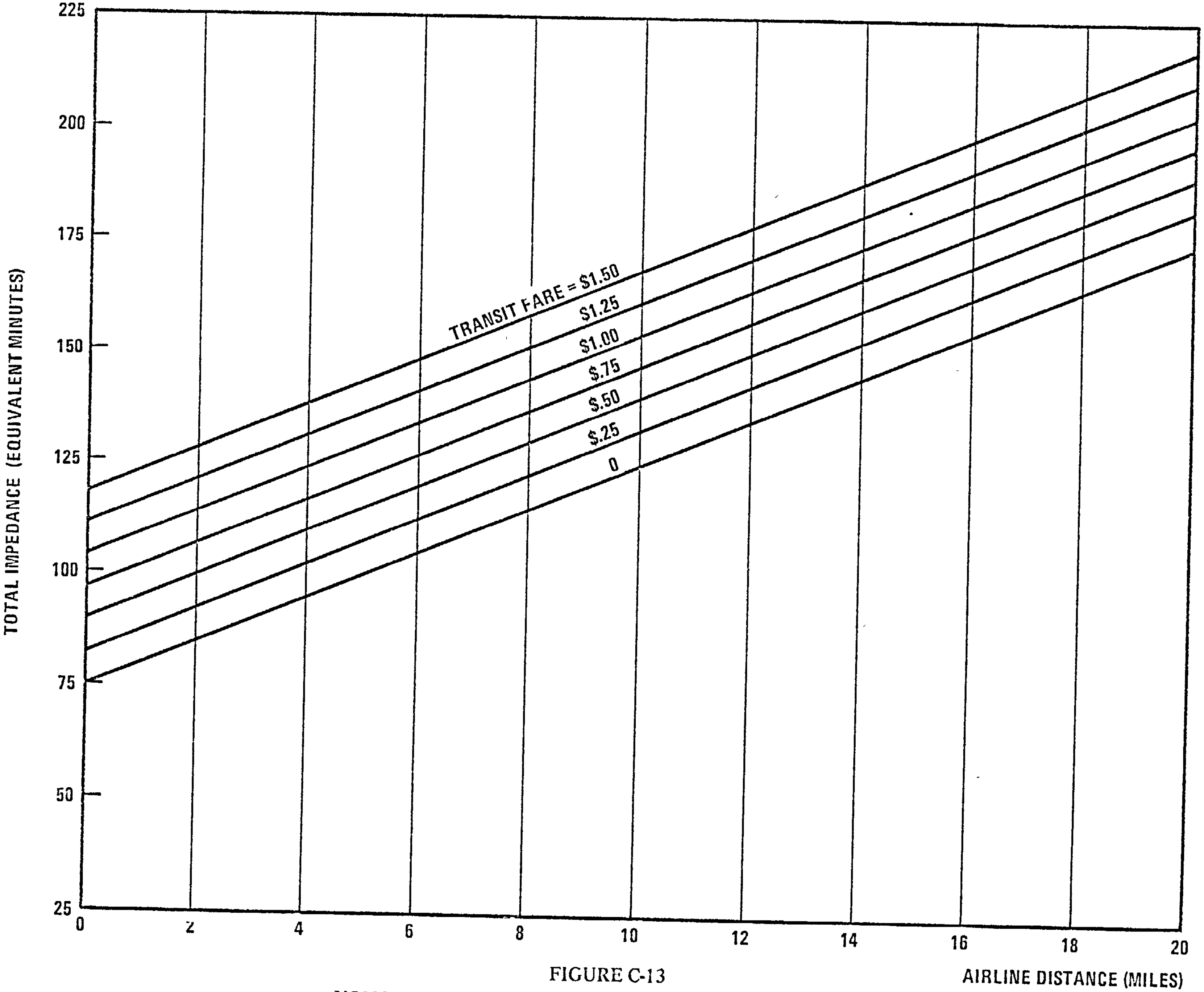


FIGURE C-13
NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE TRANSIT; SINGLE PURPOSE MODEL

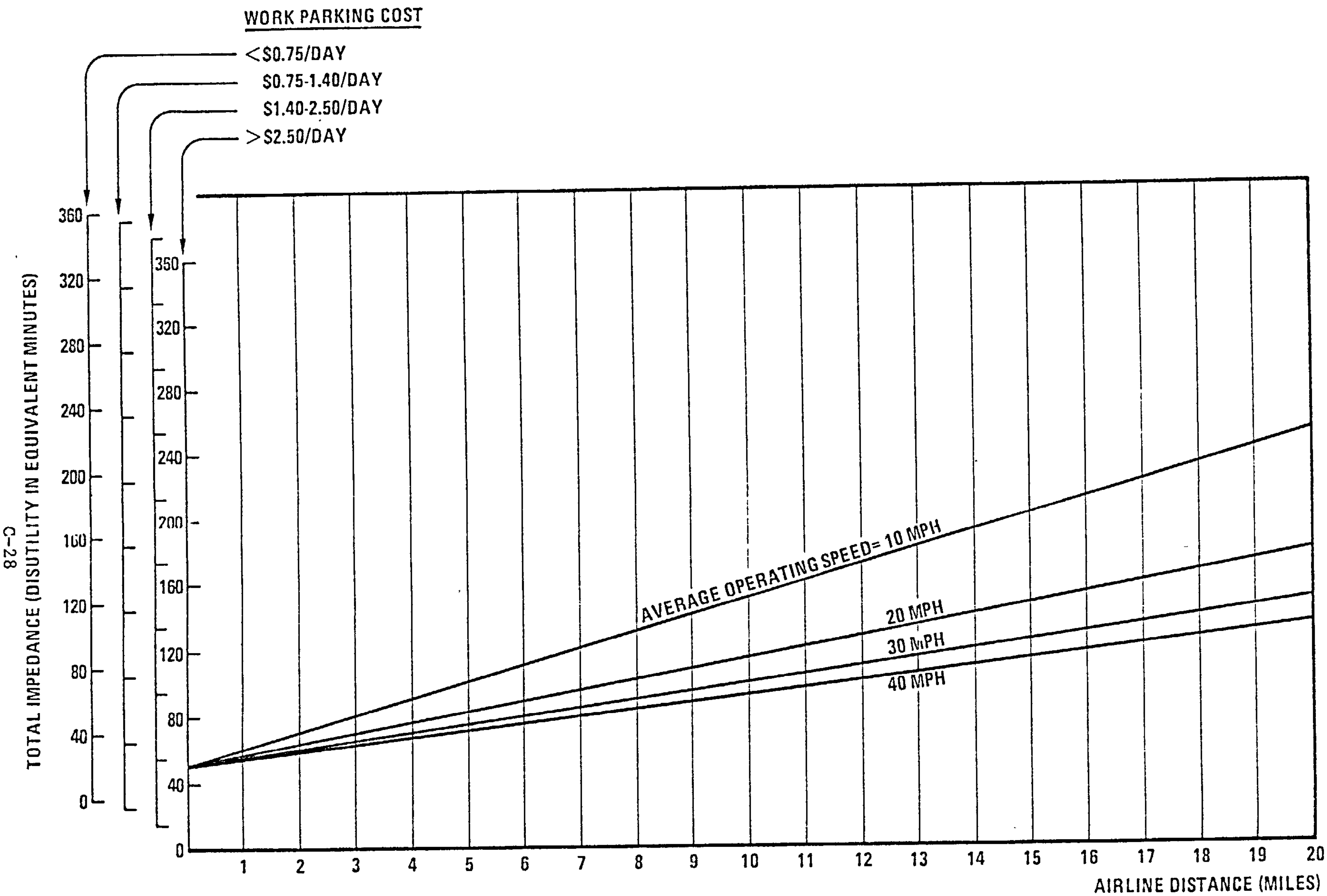


FIGURE C-14

NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO
TOTAL IMPEDANCE - AUTO: SINGLE PURPOSE MODEL
OPERATING COST: $0.05 / MILE

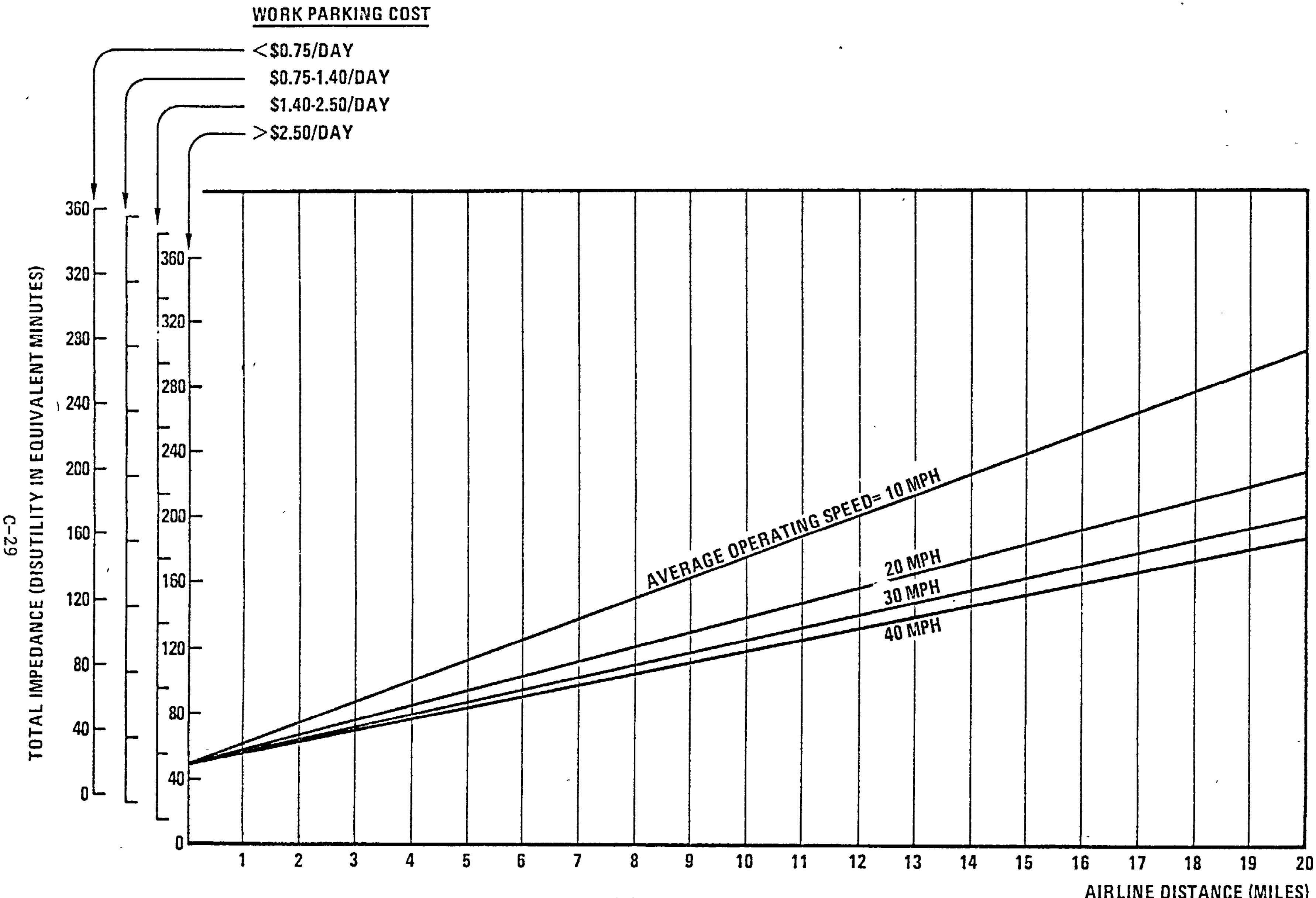


FIGURE C-15

NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO
TOTAL IMPEDANCE - AUTO: SINGLE PURPOSE MODEL
OPERATING COST: $0.10 / MILE

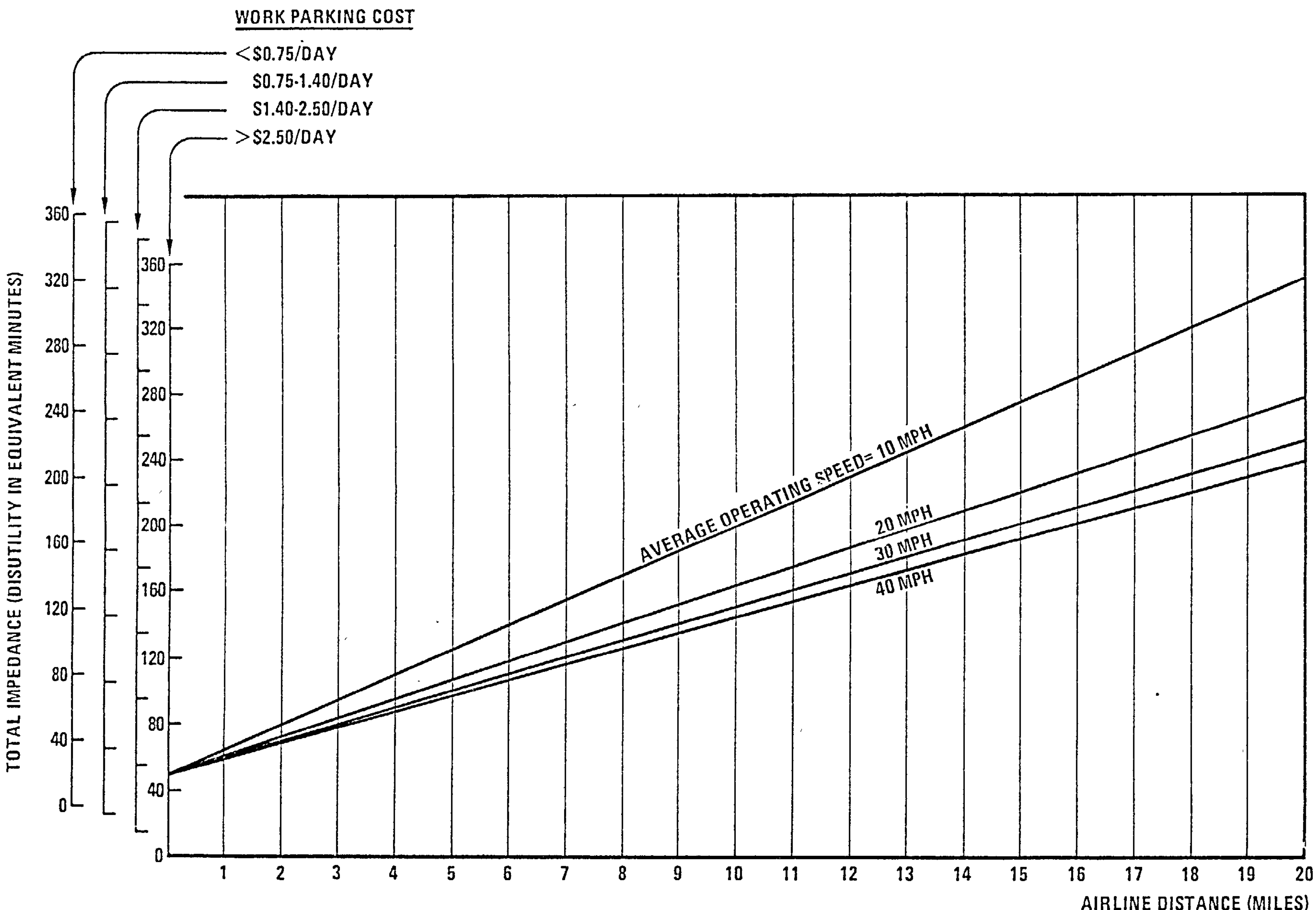


FIGURE C-16

NOMOGRAPH FOR CONVERSION OF AIRLINE DISTANCE TO TOTAL IMPEDANCE - AUTO; SINGLE PURPOSE MODEL OPERATING COST: $0.15 / MILE

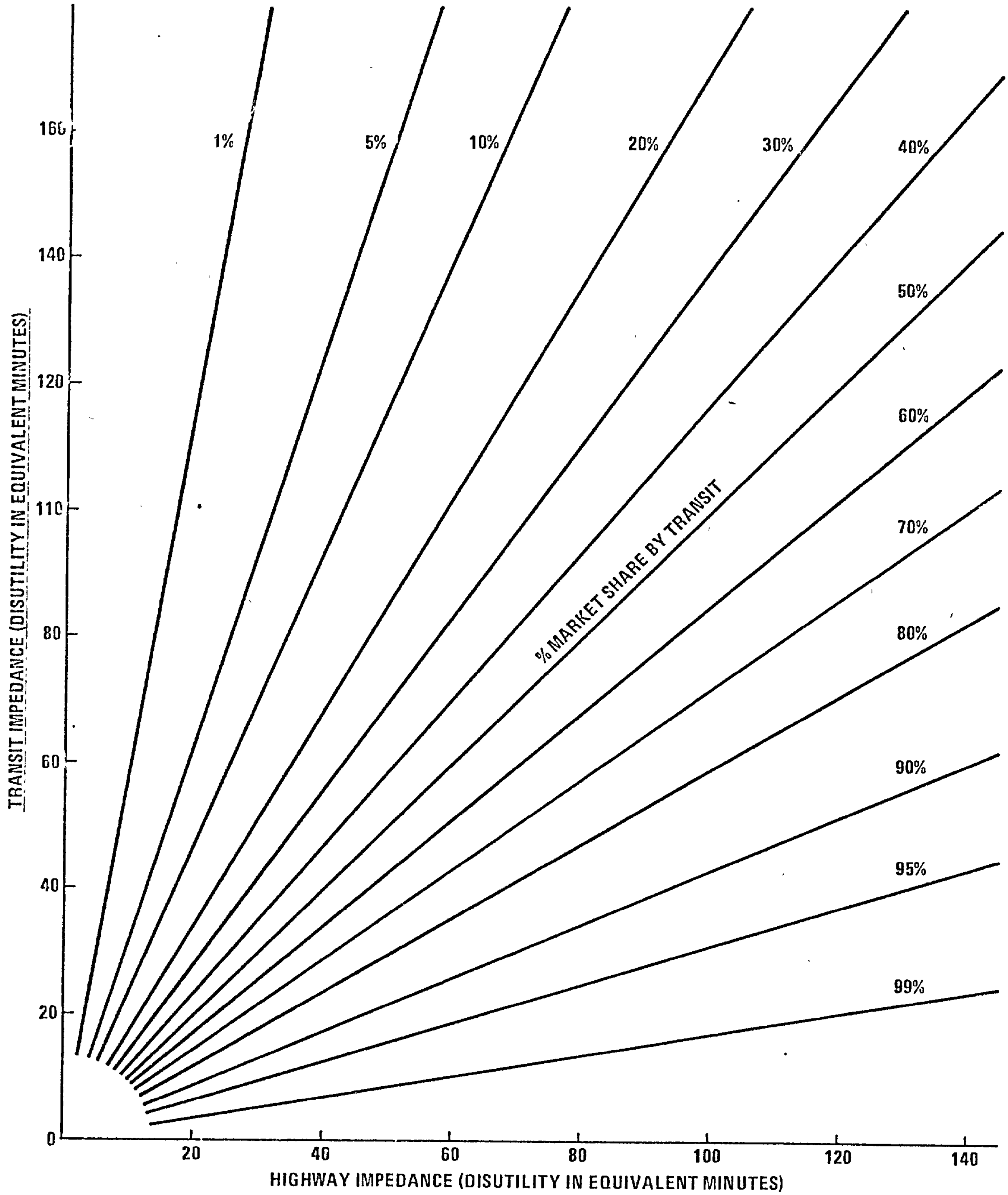


FIGURE C-17

SLM MODE CHOICE MODEL
ALL TRIP PURPOSES

APPENDIX D

GUIDE TO UTPS PROGRAMS FORMING SIMPLIFIED CHAIN FOR FOUR-STEP TRANSPORTATION PLANNING

The four-step transportation planning process has been assembled into a string of appropriate UTPS programs that incorporate the procedures and default tables discussed in this report. The relationship of the various programs and inputs is shown in Figure 4. Descriptions of each component with necessary inputs and suggested program options follow.

Program HR

This program is used to produce a "historical record" from user coded link data cards. This data set is input to program UROAD to produce skim trees and for traffic assignment purposes. The reports and plots produced by program HR are useful in editing and debugging the coded network.

Parameters	(Default)	
ZONES	(400)	Highest zone number
NODES	(400)	Highest node number
MAXSPD	(9.99)	Highest permissible link speed
MAXDST	(99.99)	Longest permissible link

All of the above parameters must be user specified to conform to the network coded. The network coding will produce link data cards in a format prescribed in the HR program documentation.

The basic information which the user must provide on a link-by-link basis is:

A-node
B-node
Distance
Time or Speed

Optional data which may be required for various assignment options or special summaries include:

Count
Number of Lanes
Future Additional Lanes
Parking Code
Land-Use
Facility Type
Area Type

Facility type and area type are required for the automatic capacity restraint feature of UROAD.

It is suggested that the network editing function of HR be utilized to uncover coding problems prior to continuing through the process.

The reader is directed to the FHWA document, PLANPAC/BACKPAC General Information 8/ for additional information related to developing a network for assignment purposes.

Program UROAD (Time Matrix Preparation)

This program is used twice during the procedure outlined. In this application, UROAD is used to produce a matrix of travel times. The required input is the historical record produced by program HR as previously discussed.

Parameters	(Default)	
TFIELD	(0)	Field containing initial link travel time for tree building
Options		
TIME	(F)	Option to have a time matrix file written

In order to produce a time matrix which can be used for trip distribution, the user must code both of the above fields. The sample below illustrates this coding:

```
&PARAM      TFIELD=32      &END

&OPTION     TIME=T         &END
```

UROAD is informed that only the time matrix output is desired by not providing an input dataset containing a trip table. The specification of TFIELD=32 informs the program that observed travel time is to be used for tree building.

Program SCAGM (Small City Trip Generation and Gravity Model)

This is a special UTPS program for users wishing to implement the methods of this report with a minimum of complexity. As described more fully in the following pages, it includes the following general functions:

1. Terminal time and intrazonal time updates to an input highway travel time matrix.

2. Trip generation using rates as shown in this manual by three purposes, and three city size groupings

3. Regional balancing of attractions to equal productions

4. Trip distribution using friction factors as shown in this manual by three purposes, and two city size groupings.

The SCAGM program is a modified version of the standard UTPS program AGM. The SCAGM user must study the full UTPS AGM documentation for program control (parameters, options, etc.), file formats and reports. The SCAGM user would normally be concerned with only the following (subset) of the full AGM control:

Parameters	(Default)	
ZONES	off input skims	Highest zone number
DISTS	0	Highest district number
AITER	1	Maximum iteration on attractions
DELA	0.1	Criterion to stop iteration on attractions
MAXT	60	Highest time on F-factor cards
SKIMS	101	Table number of time matrix
TABOUT	1	Number of output trip tables
NAME (N)	-	Names for output trip tables
UPARMS(1)	1.7	Attraction Factor 1 (See Trip Attraction section for explanation.)
UPARMS(2)	10.0	Attraction Factor 2
UPARMS(3)	0.5	Attraction Factor 3
UPARMS(4)	1.0	Attraction Factor 4
UPARMS(5)	2.0	Attraction Factor 5
UPARMS(6)	2.5	Attraction Factor 6
UPARMS(7)	0.5	Attraction Factor 7
UPARMS(8)		Trip generation run only if UPARMS(8)=99999.

Input Files

Table D-1 shows the files necessary to use program SCAGM. A complete description of these files and their use is found in the UTPS AGM program write up.

	FILE NAME	DD NAME	CONTENTS OR FUNCTION
INPUT	SYSIN	FT05F001	PROGRAM CONTROL CARDS
	J1	FT11F001	TIME MATRIX (FROM UROAD)
	P	A1	PRODUCTIONS (Optional Special
	A	A2	ATTRACTIONS Generator Overrides)
	F	A3	FRICTION FACTORS (Default Files are on UTPS Tape)
	K	A4	"K" FACTORS (Optional)
	ZONAL1	A5	ZONAL TYPE 1 DATA
	ZONAL2	FT44F001	ZONAL TYPE 2 DATA
	PRATES	FT46F001	TRIP PRODUCTION RATES (Default files are on UTPS Tape)
OUTPUT	--	FT06F001	PROGRAM REPORTS AND MESSAGES
	J9	FT19F001	TRIP TABLES (To UROAD)

TABLE D-1

FILES FOR SCAGM

SYSIN File

This is a standard AGM card file containing the training UTPS program control information (i.e., parameters, options, etc.). These are discussed elsewhere in this description and in the UTPS AGM documentation.

J1 File

This is a standard UTPS time matrix as output, in this case, by UROAD. It contains zone-to-zone auto travel times in whole minutes, including times for external stations. It does not include intrazonal times (the diagonal of the matrix is zero) or terminal times (getting to and from the car at each end). These will be added in SCAGM. [Users desiring to input a time matrix from other than UTPS software (e.g., PLANPAC) should refer to the UTPS program UMCON documentation for conversion information.]

P & A Files

The P and/or A files are optional in SCAGM and values are coded only where the internally computed productions and/or attractions (by purpose) are to be overridden as for special generators or external stations. Leave out the zonal card entirely or leave any purpose blank (not zero) where it is desired to use internally computed productions and attractions. Use only the first three values on the standard AGM P & A formats for HBW, HBNW and NHB, respectively (as shown in Figure D-1). See the UTPS AGM documentation for this format.

Note that any override is done prior to balancing of regional productions so output values may be different than those input. Note that non-home-based productions for each zone are set equal to non-home-based attractions internally so overrides of these would also logically be equal on input.

F File

The F file is required in SCAGM if both trip generation and trip distribution are to be performed (See parameter "UPARMS(8)."). Use only the first three values on the standard AGM F file format for HBW, HBNW and NHB, respectively. See the UTPS AGM documentation for this standard format.

There are two such files on the UTPS tape, one for each population group. The user may pick one or edit one to change the friction factors and time intervals, if desired. These files on the UTPS tape are named:

POP(000)	DSNAME
25 - 100	URD.FFACS1
100 - 200	URD.FFACS2

Table D-2 shows the default values contained on the above files.

MULTI PURPOSE CODING FORM

PROGRAMMER ____________

PAGE	SERIAL	CONT	COBOL MARGIN A	COBOL MARGIN B
C for COMMENT STATEMENT NO		CONT	FORTRAN STATEMENT	
* LOCATION			OPERATION	MAP/FAP VARIABLE FIELD
NAME			OPERATION	OPERAND — COMMENTS

```
(PRODUCTIONS)
   5     11112 31234 19814

(ATTRACTIONS)
   5      1700  8600  6800
```

(ZONE 5 IS AN EXTERNAL STATION. ALL PRODUCTIONS AND ATTRACTIONS ARE INPUT HERE.)

FIGURE D-1

SAMPLE ZONE PRODUCTION AND ATTRACTION DATA

TABLE D-2

DISTRIBUTION FACTORS BY URBANIZED AREA POPULATION
AND BY TRIP PURPOSE

	URD.FFACS1				URD.FFACS2			
	URBANIZED AREA POPULATION UNDER 100,000				URBANIZED AREA POPULATION OVER 100,000			
TRAVEL TIME (mins.)	HBW	HBNW	NHB	ALL	HBW	HBNW	NHB	ALL
1	30	70	33	51	15	75	50	57
2	20	40	20	30	10	50	25	35
3	15	22	15	18	8.0	30	15	22
4	10	15	10	12	6.0	20	10	15
5	8.0	9.6	7.5	8.7	5.0	12	8.0	10
6	5.6	8.0	6.0	6.9	4.0	9.0	6.0	7.3
7	4.5	5.2	4.5	4.9	3.2	6.0	4.2	5.0
8	3.5	3.8	3.4	3.6	2.8	4.3	3.3	3.7
9	2.8	2.7	2.8	2.7	2.2	3.2	2.6	2.9
10	2.2	2.0	2.2	2.1	2.1	2.5	2.2	2.4
11	1.8	1.8	1.8	1.8	1.8	1.9	1.7	1.8
12	1.5	1.4	1.5	1.4	1.6	1.6	1.5	1.6
13	1.3	1.0	1.2	1.1	1.3	1.2	1.2	1.2
14	1.1	0.85	1.0	0.94	1.1	0.90	1.0	1.0
15	0.9	0.80	0.8	0.81	1.0	0.78	0.80	0.82
16	0.74	0.60	0.70	0.66	0.80	0.61	0.67	0.66
17	0.62	0.52	0.60	0.56	0.70	0.50	0.58	0.56
18	0.55	0.45	0.50	0.48	0.63	0.42	0.52	0.48
19	0.50	0.40	0.42	0.42	0.57	0.38	0.45	0.43
20	0.44	0.34	0.36	0.36	0.50	0.33	0.40	0.38
21	0.38	0.30	0.31	0.32	0.45	0.29	0.32	0.33
22	0.35	0.26	0.27	0.28	0.40	0.25	0.29	0.29
23	0.32	0.24	0.25	0.26	0.36	0.23	0.25	0.26
24	0.29	0.21	0.22	0.23	0.33	0.20	0.22	0.23
25	0.28	0.18	0.19	0.20	0.28	0.18	0.18	0.20
26	0.25	0.16	0.16	0.18	0.26	0.17	0.16	0.19
27	0.24	0.15	0.16	0.17	0.23	0.15	0.15	0.17
28	0.23	0.13	0.14	0.15	0.21	0.14	0.13	0.15
29	0.22	0.13	0.13	0.15	0.19	0.13	0.12	0.13
30	0.20	0.12	0.13	0.14	0.18	0.12	0.10	0.13
31	0.19	0.10	0.10	0.11	0.16	0.13	0.09	0.13
32	0.18	0.09	0.10	0.10	0.15	0.12	0.09	0.12
33	0.17	0.08	0.09	0.10	0.14	0.09	0.08	0.09
34	0.17	0.07	0.09	0.09	0.13	0.08	0.07	0.09
35	0.16	0.07	0.08	0.09	0.12	0.08	0.06	0.08

K File

The K file is optional in SCAGM. K-Factors are zone-to-zone (or district-to-district) adjustment factors. Use only the first three values on the standard AGM K-factor format for HBW, HBNW and NHB, respectively. Read the AGM write up carefully for how to input these, if desired.

ZONAL1 File

The ZONAL1 file is not a standard AGM file but is mandatory for SCAGM. It is for the input of income, auto and dwelling unit data used primarily in the trip production model. It is quite flexible in that zonal averages of income and/or autos may be input as may categories of either or both of these. Where income or autos is not known at all, a special "nines" value is provided. Output accuracy will, of course, vary with input detail and the user must be the judge of adequacy of his/her data.

Each ZONAL1 data card has fields for up to four dwelling unit categories with income and autos for each category (See Table D-3.). All four need not be used on any card. If more than four categories per zone are needed, additional ZONAL1 cards may be used as long as these follow immediately after the first card for the zone.

On the ZONAL1 card(s) for the first zone, the income and auto fields must be completed for each dwelling unit field used even if only "nines" are used for income or autos. For subsequent zones, the income and auto fields need not be coded as long as the categories, and their sequence on the cards, are the same as for the immediately preceeding zone. Thus, as an extreme example, if all 20 categories are being used (5 income times 4 auto), then 20 dwelling unit fields, with complete income and auto information for each, would appear on five ZONAL1 data cards for zone 1. For each subsequent zone, five cards would also be input with 20 dwelling unit fields filled out for each zone but blank (not zero) income and auto fields. The sequence of dwelling unit categories for each zone after the first must, of course, be the same as for the first zone. Users of multiple cards per zone are required to place a sequence number in column 71 on the ZONAL1 cards and all cards must be in ascending sort sequenced by zone number (primary) and by card sequence number (secondary).

ZONAL1 data cards need not be provided for external stations or special generators where P's and A's for all purposes are input on the special generator P and A cards. Where the ZONAL1 data cards are not input for a zone, employment data, if present on the ZONAL2 data card, will be ignored and all P and A data taken directly from the P and A cards. The example card set ups (Figures D-2, D-3, D-4) following will clarify these points.

ZONAL2 File

The ZONAL2 file is not a standard AGM file but is mandatory for SCAGM. It is for the input of employment data used in the trip attraction model and for intrazonal and terminal times (See Table D-4.). One card per zone is input, including external stations. For external stations and other special generators the employment figures may be left blank since attractions should be

TABLE D-3

PRODUCTION ZONE ACTIVITY DATA FORMAT

ITEM	COLUMNS	RANGE	TYPE	EXPLANATION
ZONE NUMBER	1- 4	1-2500	Integer Right Justified	May be repeated on consecutive cards if necessary to complete income, autos and dwelling data for a zone.
INCOME	6-10 22-26 38-42 54-58	0.20,000 or 99999 or Blank	Integer Right Justified	In whole dollars, 1970. Either the zonal median income or the median of an income category for the zone. Income may repeat on the same or consecutive cards as necessary to include all categories for a zone. The value 99999 is a special code meaning that no income information is being input. All five nines must be coded in this case. Blanks are interpreted in a special fashion as discussed elsewhere in this manual.
AUTOS	12-14 28-30 44-46 60-62	0.0-3.1 or 9.9 or Blank	Decimal	Either the zonal average autos or the number of autos for discrete auto categories (i.e., 0.0, 1.0, 2.0, 3.0 up). Autos may repeat on the same or consecutive cards as necessary to include all categories for a zone. If the decimal is not coded it will be assumed in the position shown. The value 9.9 is a special code meaning that no auto information is being input. Both nines must be coded. Blanks are interpreted in a special fashion as discussed elsewhere in this manual.
DWELLINGS	16-20 32-36 48-52 64-68	0-99999	Integer Right Justified	Either dwellings for the zone or dwellings for the income and/or auto category being coded. Dwellings may repeat on the same or consecutive cards as necessary to include all categories for a zone. The value 99999 is not a special code. Blanks will be interpreted as zero dwellings.
CARD SEQUENCE NUMBER	71	1-5	Integer	Where more than one card is necessary for a zone, a sequence number from 1 to 5 must be used.

PROGRAMMER

MULTI PURPOSE CODING FORM

PAGE | SERIAL | CONT | COBOL MARGIN A | COBOL MARGIN B

C for COMMENT STATEMENT NO | CONT | FORTRAN STATEMENT

* LOCATION | OPERATION | MAP/FAP VARIABLE FIELD

NAME | OPERATION | OPERAND | COMMENTS

Cols 1–5	Cols 6–10	Cols 12–14	Cols 16–20
1	10000	1.0	1000
2	4000	1.5	10000
3	12000	1.0	6000
4	6000	1.2	4000

(5 NO CARD NEEDED FOR ZONE 5 SINCE IT IS AN EXTERNAL STATION AND ALL P'S AND A'S WILL BE INPUT ON SPECIAL GENERATOR P&A CARDS. THE ZONES KEYWORD ON THE &PARAM CARD TELLS SCAGM HOW MANY ZONES THERE ARE.)

FIGURE D-2

SAMPLE PRODUCTION ZONE ACTIVITY INPUT DATA (ZONAL 1 DATA)

PROGRAMMER ______________

MULTI PURPOSE CODING FORM

PAGE	SERIAL	CONT	COBOL MARGIN A	COBOL MARGIN B
C for COMMENT STATEMENT NO		CONT	FORTRAN STATEMENT	
* LOCATION			OPERATION	MAP/FAP VARIABLE FIELD
NAME			OPERATION	OPERAND / COMMENTS

```
         1         2         3         4         5
1234567890123456789012345678901234567890123456789012
   1 99999 0.0    78 99999 1.0   462 99999 2.4   470
   2            3846            4544            1610
   3             330            2365            3305
   4             851            1964            1184
```

(THE AVERAGE AUTOS FOR THE 2^+ CATEGORY IS INPUT AS 2.4. THE INCOME IS NOT KNOWN SO 99999 IS CODED. INCOME AND AUTOS IS NOT REPEATED AFTER ZONE 1 SINCE THE CATEGORIES ARE TO BE THE SAME FOR EACH ZONE. SCAGM WILL INTERPOLATE TO GET A RATE FOR 2.4 AUTOS.)

FIGURE D-3

SAMPLE PRODUCTION ZONE ACTIVITY INPUT DATA–INCOME NOT INPUT

PROGRAMMER ____________

MULTI PURPOSE CODING FORM

PAGE | SERIAL | CONT | COBOL MARGIN A | COBOL MARGIN B

C for COMMENT / STATEMENT NO | CONT | FORTRAN STATEMENT

* LOCATION | OPERATION | MAP/FAP VARIABLE FIELD

NAME | OPERATION | OPERAND | COMMENTS

1	4500	0.0	50	4500	1.0	42	4500	2.4	8	1
1	10000	0.0	20	10000	1.0	290	10000	2.4	190	2
1	14000	0.0	4	14000	1.0	60	14000	2.4	136	3
1	20000	0.0	4	20000	1.0	60	20000	2.4	136	4
2			3750			3250			600	1
2			92			1334			874	2
2			2			30			68	3
2			2			30			68	4

(DATA FOR ZONES 3 & 4 WOULD BE SIMILAR TO THAT FOR 2. INCOME AND AUTOS ARE NOT REPEATED SINCE CATEGORIES ARE THE SAME. SCAGM WILL INTERPOLATE TO GET RATES FOR INCOME=4,500 SINCE THIS IS NOT A DEFAULT CATEGORY. THE SEQUENCE NUMBER IN COL. 71 IS REQUIRED.)

FIGURE D-4

SAMPLE PRODUCTION ZONE ACTIVITY INPUT DATA–SINGLE AREAWIDE INCOME AND AUTO OWNERSHIP (ZONAL 1 DATA)

TABLE D-4

ATTRACTION ZONE ACTIVITY DATA FORMAT
(ZONAL2 data)

ITEM	COLUMNS	RANGE	TYPE	EXPLANATION
ZONE NUMBER	1- 4	1-2500	Integer Right Justified	Unique to this card. May not be repeated on consecutive cards.
RETAIL EMPLOYMENT	6-10	0-99999	Integer Right Justified	Retail employment for zone. Number of employees.
NON-RETAIL EMPLOYMENT	12-16	0-99999	Integer Right Justified	Remainder of employment for zone. Number of employees.
INTRAZONAL TIME	18-19	0-99	Integer Right Justified	Average travel time for trips which remain within the zone. Does not include terminal time at each end.
TERMINAL TIME PRODUCTION	21-22	0-99	Integer Right Justified	Terminal time for trips produced in this zone. Will be added to travel times.
TERMINAL TIME ATTRACTION	24-25	0-99	Integer Right Justified	Terminal time for trips attracted to this zone. Will be added to travel time.

input in the special generator A file. A sample of the coding for this file is shown on Figure D-5.

PRATES File

The PRATES file is not a standard AGM file but is mandatory for SCAGM. It contains the person trip production rates per dwelling unit stratified by purpose, income and autos owned. Default tables by three population groups as shown in Tables D-5, D-6 and D-7 are included on the UTPS tape and may be used as shown or edited by the user. The income is in 1970 dollars. The production rates for income = 99999 and Autos = 9.9 are weighted averages for use where either one or the other is not known. The "3 or more" auto category is represented by the average of 3.1 autos for this group.

The user is not restricted to the income and auto categories shown since interpolation will be performed for input values other than these. Thus, inputs may be zonal averages (e.g., autos = 1.7) or categories other than these and interpolation will approximate the correct production rates. For input values beyond the range of the table, no extrapolation is performed, rather the lowest or highest appropriate category is used.

NHB productions, while computed on a zonal basis, are used by SCAGM only as a regional control total. NHB attractions are factored to equal productions regionally and these attractions are used at the zonal level for both productions and attractions.

PRATES File Format

Users who wish to edit the default production rates will need to recognize the PRATES file format. It consists of a group of six cards for each of three trip purposes (HBW, HBNW, NHB), each group separated by a blank card. Each of the six cards represents a different income level (3000, 6500, 10,000, 14,000, 20,000, and 99,999) and these levels cannot be changed in SCAGM. On each card, the first two columns are left blank then five fields, each ten columns wide, follow where each field contains the trips per dwelling unit (in an F10.2 format) for each of the five auto ownership groups (0.0, 1.0, 2.0, 3.1, 9.9) and these cannot be changed in SCAGM.

There are three such files on the UTPS tape, one for each population group, and the user may pick one or edit one to change the rates (but not the categories). These files on the UTPS tape are named:

POP (000)	DSNAME	Default Values
25 - 50	URD.PRATES1	See Table D-5.
50 - 100	URD.PRATES2	See Table D-6.
100 - 200	URD.PRATES3	See Table D-7.

PROGRAMMER ____________

MULTI PURPOSE CODING FORM

PAGE	SERIAL	CONT	COBOL MARGIN A	COBOL MARGIN B
C for COMMENT STATEMENT NO	CONT	FORTRAN STATEMENT		
✱ LOCATION		OPERATION	MAP/FAP VARIABLE FIELD	
NAME		OPERATION	OPERAND	COMMENTS

Cols 1–6	Cols 7–11	Cols 12–17	Cols 18–20	Cols 21–23	Cols 24–26
1	4000	14000	4	3	4
2	1000	4000	9	2	3
3	200	1000	10	1	2
4	600	600	12	1	2
5			99	0	0

(ZONE 5 IS EXTERNAL STATION SO EMPLOYMENT DATA ARE BLANK WITH PRODUCTIONS AND ATTRACTIONS INPUT ON "P" AND "A" FILES. NOTE HIGH INTRAZONAL TIME TO DISCOURAGE UNREALISTIC INTRASTATION TRIP.)

FIGURE D-5

SAMPLE ATTRACTION ZONE ACTIVITY INPUT DATA

TABLE D-5

DEFAULT PRATES1 (PERSON TRIPS)

Population: 25,000 - 50,000

INCOME / CARS/D.U.	TRIPS/HH 0.0	1.0	2.0	3.1	9.9
3,000	0.64* 1.51* 0.64*	2.02 4.85 2.07	3.10 7.28 3.10	3.54 8.42 3.59	1.68 3.94 1.68
6,500	0.50 1.86 0.74	2.11 7.92 3.17	2.73 10.24 4.09	3.37 12.63 5.05	2.04 7.65 3.06
10,000	0.89 3.69 1.46	2.19 9.83 3.59	2.71 12.19 4.45	3.52 15.83 5.78	2.36 10.60 3.87
14,000	0.84 4.48 1.68	1.94 10.37 3.89	2.47 13.18 4.94	3.24 17.28 6.48	2.31 12.35 4.63
20,000 Do not extrapolate beyond this category	0.73 4.59 1.97	1.48 9.34 4.00	2.12 13.37 5.73	2.52 15.88 6.80	1.98 12.49 5.35
99,999	0.95 2.28 2.07	2.48 5.93 5.38	3.29 7.87 7.14	4.10 9.80 8.89	2.59 6.19 5.62

*Values in each cell represent trip rates for HBW, HBNW and NHB, respectively.

TABLE D-6

DEFAULT PRATES2

Population: 50,000 - 100,000

TRIPS/HH

INCOME/ CARS/D.U.	0.0	1.0	2.0	3.1	9.9
3,000	0.48* 1.31* 0.51*	1.58 4.28 1.65	2.73 7.41 2.86	3.04 8.26 3.19	1.29 3.51 1.35
6,500	0.53 1.86 0.71	2.10 7.44 2.85	2.73 9.78 3.75	3.28 11.58 4.44	2.01 7.11 2.73
10,000	0.91 3.48 1.31	2.32 8.84 3.33	2.88 10.98 4.14	3.87 14.76 5.57	2.49 9.47 3.57
14,000	6.87 3.84 1.49	2.10 9.30 3.60	2.67 11.78 4.56	3.57 15.81 6.12	2.47 10.97 4.25
20,000 Do Not Extrapolate Beyond This Category Use rates Shown	0.78 3.72 1.50	1.69 8.06 3.25	2.57 12.28 4.95	2.99 14.26 5.75	2.37 11.30 4.56
99,999	0.74 2.81 1.06	2.02 7.69 2.90	2.75 10.49 3.96	3.42 13.05 4.92	2.26 8.60 3.24

*Values in each cell represent trip rates for HBW, HBNW and NHB, respectively.

TABLE D-7

DEFAULT PRATES3

Population: 100,000 - 200,000

TRIPS/HH

INCOME/ CARS/D.U.	0.0	1.0	2.0	3.1	9.9
3,000	0.33* 0.95* 0.30*	1.82 5.21 1.65	2.59 7.39 2.34	3.26 9.31 2.95	1.24 3.56 1.13
6,500	0.89 2.59 0.98	2.53 7.34 2.78	3.16 9.16 3.47	4.14 11.99 4.55	2.39 6.93 2.63
10,000	1.22 3.65 1.54	2.98 8.94 3.76	3.48 10.45 4.40	4.53 13.59 5.72	3.13 9.40 3.96
14,000	1.33 3.92 1.75	3.04 8.96 4.00	3.88 11.42 5.10	4.75 14.00 6.25	3.55 10.47 4.68
20,000 Do not extrapolate beyond this category. Use rates as shown.	1.31 4.02 1.97	2.70 8.25 4.05	3.78 11.55 5.67	4.59 14.03 6.88	3.62 11.07 5.43
99,999	1.08 3.08 1.24	2.74 7.81 3.15	3.68 10.49 4.23	4.48 12.77 5.15	2.90 8.26 3.34

*Values in each cell represent trip rates for HBW, HBNW and NHB, respectively.

J9 File

This is a standard AGM output file and will contain three trip tables in sequence by purpose (HBW, HBNW, NHB) in the production to attraction format.

Trip Attraction Rates

The default trip attraction model is as follows:

$$\text{HBW} = 1.7\ (\text{Total Employment})$$

$$\text{HBNW} = 10.0 \begin{bmatrix}\text{Retail}\\ \text{Employment}\end{bmatrix} + 0.5 \begin{bmatrix}\text{Non-Retail}\\ \text{Employment}\end{bmatrix} + 1.0 \begin{bmatrix}\text{Dwelling}\\ \text{Units}\end{bmatrix}$$

$$\text{NHB} = 2.0 \begin{bmatrix}\text{Retail}\\ \text{Employment}\end{bmatrix} + 2.5 \begin{bmatrix}\text{Non-Retail}\\ \text{Employment}\end{bmatrix} + 0.5 \begin{bmatrix}\text{Dwelling}\\ \text{Units}\end{bmatrix}$$

The user can override the seven multipliers above by use of the UPARMS(1) through UPARMS(7), respectively, in sequence as shown above. For example, UPARMS(6) controls the multiplier on Non-Retail Employment for NHB attractions and defaults to 2.5.

Internal-External Trips

The default production rates include internal-external person trips by internal residents. The external station end of these person trips should be estimated by purpose for each station and input on the A file as attractions for the external station.

For internal-external person trips by external residents, an estimate should be made by purpose for each external station and input on the P file as productions for the external station. The process of estimating these external trip ends by purpose is described below as well as referenced elsewhere in the System Planning manual.

Internal-external travel is quite variable by area, dependent upon the characteristics and size of the area as well as its geographic location and relation to major highway facilities. The most appropriate means to obtain the travel at external stations is through the use of a previously collected external travel survey, or when necessary, a new one. The data required for external station locations are productions and attractions for internal-external travel, to allow use of SCAGM. External-external trips should be developed separately through a factoring of known through trips, or by some means such as described in Chapter Three of the System Planning manual. (See the "Non-Computer Techniques" section and Table A-4, Part B.)

When using external survey data, trips made by internal residents crossing the cordon are treated by SCAGM as attractions at the stations. Trips made by persons living outside the area are treated by SCAGM as productions at the cordon stations. This assumes external-external travel has been removed and will be handled by a factoring process.

Where an older external survey is available, it is advisable to take current counts at the external station locations and apply the knowledge regarding through travel and resident and non-resident external-internal travel to these to obtain productions and attractions at the external stations. More detailed discussion of this is provided in Chapter Two of the System Planning manual, in the "External Travel" section.

The default person trip attraction rates include all attractions from whatever source (internal or external) and thus need not be adjusted to work with the above external station treatment.

Note that intrazonal times for external stations (input on the ZONAL2 file) should be very high to eliminate unrealistic intrastation trips between the P's and A's at each station as described above.

Auto Driver Trips

The trip tables resulting from SCAGM default trip rates are person trips. From these, auto driver trips must be estimated for assignment. Two methods for doing so are as follows:

1. Multiply person trip tables (by purpose) by the factors below using UMATRIX:

POPULATION (000)	Auto Driver Factor HBW	HBNW	NHB
25 - 50	0.71	0.54	0.69
50 - 100	0.70	0.54	0.68
100 - 200	0.64	0.54	0.66

2. Use locally developed mode choice/auto occupancy factors as from a mode choice model or from "what if" policy type assumptions as to mode choice and auto occupancy.

Truck Trips

SCAGM does not directly estimate truck trips. Two methods of doing so are as follows:

1. Multiply auto driver trip tables, using UMATRIX, by the factors below to expand to an approximate total vehicle trip table prior to assignment;

POPULATION (000)	TRUCK MULTIPLIER
25 - 50	1.30
50 - 100	1.27
100 - 200	1.17

2. If a separate truck trip table is known, it can be input to UMATRIX and added to the other trips prior to UROAD assignment.

External-External Trips

These cannot be estimated in SCAGM but should be developed externally and combined with the other trip tables using UMATRIX prior to UROAD assignment.

Program UMATRIX

A UMATRIX run will usually be necessary prior to assignment with UROAD. This UMATRIX run would be to perform one or more of the following functions:

1. "Split" the person trips (HBW,HBNW,NHB) from the production-attraction format of SCAGM to the origin-destination format for assignment in UROAD.

2. Convert person trips to auto driver trips using methods discussed elsewhere in this manual.

3. Factor auto driver trips to include truck trips or bring these in from an external source as discussed elsewhere in this manual.

4. Bring in external-external trips from another source as discussed elsewhere in this manual.

5. Add all of the above together prior to assignment.

The parameters and options for UMATRIX are few and are shown in the UMATRIX documentation. The COMBIN(N) statement on the &PARM card is of particular interest as it determines how input tables will be combined. An example relevant to processing SCAGM output is given below.

The example assumes that the three purpose (HBW,HBNW,NHB) person trip tables output from SCAGM are Tables 101, 102 and 103, respectively. Through trips (external-external) are on Table 201. Factors shown elsewhere are to be used to convert person trips to auto driver trips and to adjust for truck trips. Population 50,000-100,000 is assumed.

1. Factor to auto driver by purpose and add:

   COMBIN1='.70*T101+.54*T102+.68*T103'

2. Split 50-50 from P and A to O and D daily trip table:

   COMBIN2='.50*T901+TR(.50*T901)'

3. Factor up to truck trips and add through trips;

   COMBIN3='1.27*T902+T201'

This would output three tables, one for each COMBIN(N) statement, although only the last (T903) would be of further use. The above statement could be reduced to one for greater efficiency but less clarity in presentation.

As an alternative to Step #1, which uses default assumptions of mode choice and auto occupancies, policy levels of these could be tested. For example, "what if" mode choice for CBD work trips was 25% transit and auto occupancy for CBD work trips was 2.0 while default rates apply to other destinations? The CBD is Zones 1, 2 and 3. Thus:

1. Factor work trips to auto driver:

   COMBIN1='IF J=1 OR J=2 OR J=3 THEN .75*T101/2.0 ELSE .70*T101'

Many other policies or simple modal choice models can be applied similarly with knowledge of UMATRIX.

Program UROAD (Traffic Assignment)

This program was described previously in its function as a means of obtaining a skim tree dataset for use in trip distribution. In this phase of the process, program UROAD is used to combine a historical record (produced by program HR) with a trip matrix (produced by program AGM) to obtain simulated traffic volumes on each link. The method of assignment can be selected by the user from among the following:

1. All-or-Nothing
2. All Shortest Paths
3. Probabilistic Multipath (Stochastic)
4. Capacity Restraint (Iterative or CATS Incremental)

Parameters	(Default)	
SPLIT1	(1.0,0)	Origin-Destination factors for Trip Table 1. Since the input trip tables will be in production-attraction format, this parameter should be coded SPLIT1=.5,5. If additional trip tables are input, this parameter is coded SPLIT2, SPLIT3, SPLIT4.
TABLES	(0,0,0,0)	Trip table numbers (up to 4) to be factored, summed and assigned.
THETA	(0,-1,...,-1)	Assignment diversion parameters used to specify the number and type of iterations to be performed. Up to 9 values for THETA may be specified with the following meaning:

-1 = Do nothing for this iteration
0 = Perform all-or-nothing assignment
0.0<THETA<10.0 = Perform a multipath probablistic assignment. The lower the value, the more dispersion is obtained.
10.0 = Perform an all shortest path assignment--trips are split equally among all minimum paths connecting a given O-D pair.

The Default for THETA produces one iteration of all-or-nothing assignment.

VFIELD	(-1)	Field number in the updated historical record in which assigned link volumes are to be inserted.

0 = Indicates that the assignment results are to be appended at the end of the historical record.
-1 = Indicates that a new historical record is not to be produced.

TFIELD	(0)	Location in the historical record file from which initial link time is to be taken. Normally, TFIELD=32 is specified.

Several reports are available from program UROAD. Those of particular interest during the assignment process are the following:

Report 4 - Link and Turn Volumes

6 - Summary of VMT and Balance Speed by V/C Ratio, Facility Type and Geographic Location

7 - Same as 6, except V/C Ratio is Volume/Count rather than Volume/Capacity

8 - Summary of Volume/Capacity Ratio and Total Volume by Link Group

9 - Same as 8, except Volume/Count Ratio is Used.

11 - Impact Estimates (Pollutants, Fuel, Cost, Accidents) by Geographic Location

12 - Vehicle Cost of Travel Summary

To obtain reports, the user codes a select card as follows:

```
&SELECT REPORT=4,6,8,11,12 &END
```

specifying the desired reports.

APPENDIX E

DETAILS OF TRAFFIC ESTIMATION BASED ON GROUND COUNTS - MANUAL APPLICATION

Input Requirements and Steps in Application

The data requirements for the procedure include:

- o A functionally classified road system (See Chapter One of this manual and the NCUT manual, Determining Street Use 9/.
- o A map of the system and a determination of facility travel times. This may be coded for computer application.
- o An external cordon roadside O-D survey with a resultant matrix of trips between stations and between internal zones and stations.
- o Traffic counts on all facilities for which future estimates are required. The reader is referred to the NCUT manual, Measuring Traffic Volumes 9/.
- o Social-economic data by internal analysis area to allow trip production and attraction estimates by zone. These data usually include dwelling units, auto ownership and/or income and employment by category. Tables are provided in this document as default values in lieu of locally collected data. These estimates are required for both the base year and future year.

The first steps in the process are for the base year:

- o First, the external cordon survey trip table is assigned to the highway network. This includes through (E-E) trips as well as internal-external (I-E) trips.
- o The resulting assigned volumes are next subtracted from traffic counts on those links where forecasts are desired and where counts are provided. The difference, therefore, between the count and external traffic is the internal-internal (I-I) volume.

  There may be some links where a negative difference is obtained, resulting from one of several conditions: inconsistencies between counts and the external cordon survey due to time of data collection, sampling and factoring procedures, etc.; and from the assignment, which is recommended to be done as an all-or-nothing minimum route assignment. Where negative results are obtained, a review should be made of the specific count and the assignment process and adjustments made to at least ensure reasonableness and a positive traffic volume. A grouping of links into corridors may help here.

- o An estimate is made of trip productions and trip attractions for the base year using locally available generation rates or the "default" values provided in this manual.

For the future year, four primary steps are required: 1) the forecast and assignment of through trips; 2) the forecast and assignment of internal-external trips; 3) the factoring of base year internal-internal volumes; and 4) the summation of the results of steps 1 through 3.

Through (E-E) trips are usually forecast by estimating growth factors for the external cordon stations and applying these growth factors to the trip interchange between stations through a technique such as the Fratar procedure 8/. If a computer is used to apply this technique, the Fratar technique is recommended. The UTPS package contains a trip table scaling function similar to Fratar in the program UMCOM 10/. If done manually, an average growth factor should be suitable, where the growth factor for the two stations related to a trip are averaged and applied to the base year trips. The resultant trip table is assigned to the network, thus providing the external portion of each link's total load.

To estimate growth factors for external cordon stations, statewide and regional growth trends are normally analyzed to determine growth factors for each station. Areas contributing trips to the external station are evaluated along with past growth measured at the external stations, if available.

To obtain the internal-external (I-E) portion of each link's load the observed trips from the external cordon survey can again be factored based upon growth in the internal zones and at the external stations. The same growth factors developed for the external stations as described above are used. Likewise, the growth factors are developed for internal zones using the technique described below for estimation of present and future productions and attractions. The growth factor would be calculated for each zone as:

$$\text{Zonal Growth Factor} = \frac{\text{Future Year Productions} + \text{Future Year Attractions}}{\text{Base Year Productions} + \text{Base Year Attractions}} \quad \text{...........(1)}$$

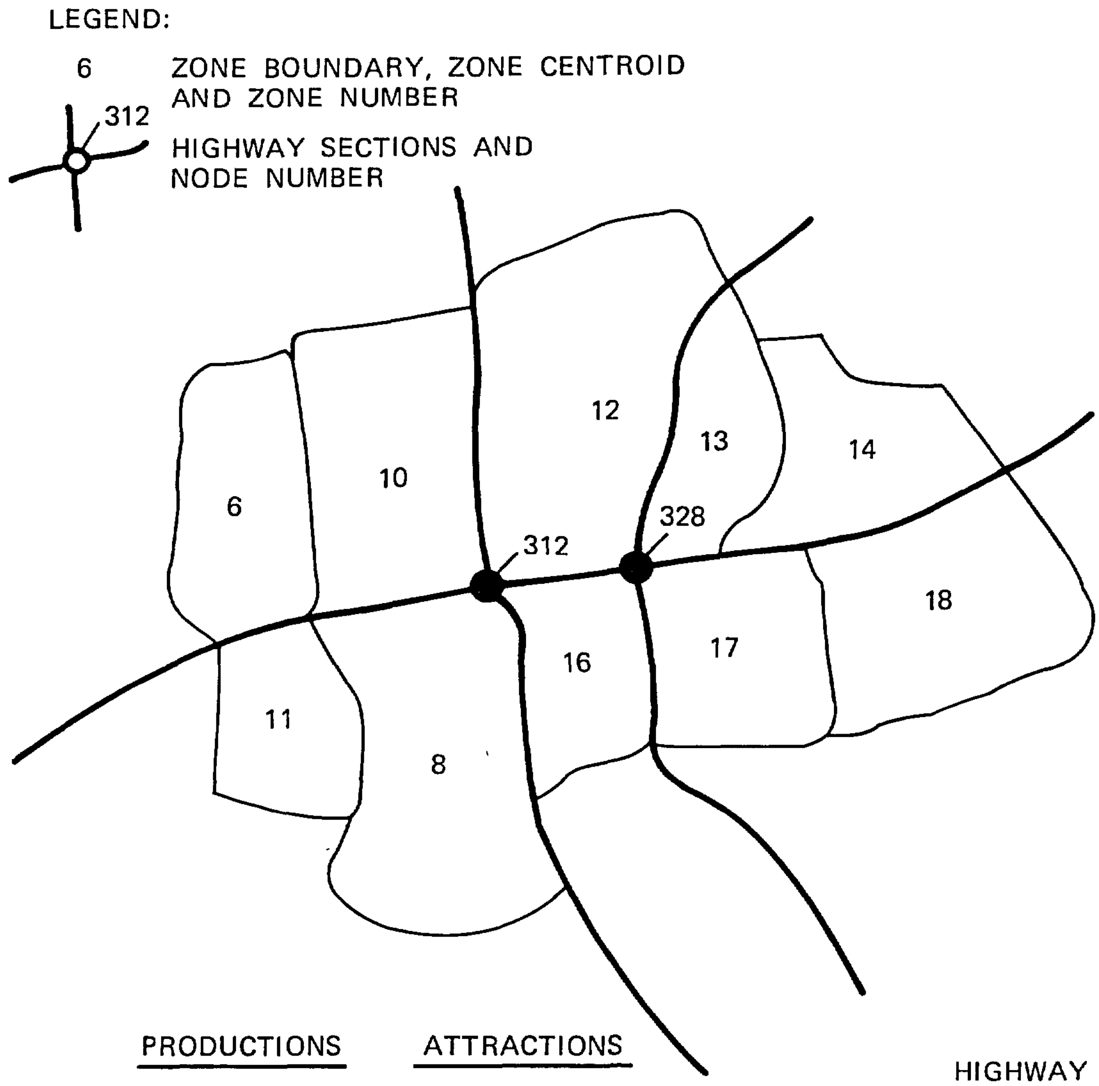
The internal-external trips related to each station-zone pair would be factored by the average of the growth factors associated with the station and zone if done manually, or, if applied by computer, the Fratar method would be used. The resultant factored internal-external trip table is also assigned to the network.

The internal-internal (I-I) traffic counts obtained for the base year must next be factored to represent future year conditions. Two approaches are described below. The first is based upon the determination of growth for each zone as shown by Equation (1) and the determination of "zones of influence" which are determined to affect the volume of any particular link. These "zones of influence" can be assumed to include those zones that actually abut the highway section or, are determined to directly affect internal traffic on the section. A simple determination of the average growth factor for a link would be made as shown in Figure E-1.

It may appear desirable in some instances to calculate a weighted growth factor based upon proximity of zones to a link and/or the expected directionality of trips to a zone related to the link. For example, some zone may be expected to contribute much of its traffic to a link based upon the configuration of highways in the immediate area. Other zones may have a small expected contribution based upon the system configuration. To demonstrate the weighting technique, assume for the previous example that all zones are expected to contribute volume somewhat equally to Link 312-328, except that Zone 12 is expected to contribute 4 times the average, Zone 16 is expected to contribute 5 times the average and Zone 18, one-half the average. The weighted growth factor would then be developed as follows:

		Weighted Productions		Weighted Attractions	
Zone	Weight	Base	Future	Base	Future
6	1	600	700	0	100
8	1	1,500	1,700	1,200	1,500
10	1	1,800	2,200	1,500	1,500
11	1	1,000	1,500	1,800	2,000
12	(4)	800	4,800	0	1,200
13	1	800	1,600	1,800	2,000
14	1	600	700	2,500	3,000
16	(5)	5,000	7,000	6,000	9,000
17	1	1,500	1,700	200	400
18	(0.5)	750	1,000	1,750	2,000
		14,350	22,900	16,750	22,700

$$\text{Weighted Growth Factor} = \frac{22{,}900 + 22{,}700}{14{,}350 + 16{,}750} = 1.47$$



ZONE	PRODUCTIONS BASE	PRODUCTIONS FUTURE	ATTRACTIONS BASE	ATTRACTIONS FUTURE
6	600	700	0	100
8	1,500	1,700	1,200	1,500
10	1,800	2,200	1,500	1,500
11	1,000	1,500	1,800	2,000
12	200	1,200	0	300
13	800	1,600	800	2,000
14	600	700	500	3,000
16	1,000	1,400	1,200	1,800
17	1,500	1,700	200	400
18	1,500	2,000	3,500	4,000
	10,500	14,700	11,700	16,600

HIGHWAY SECTION 312–328

TOTAL COUNT	=17,000
THROUGH TRIPS	= 4,200
I-E TRIPS	= 6,800
I-I TRIPS	= 6,000*

*(17,000–4,200–6,800)

$$\text{AVERAGE GROWTH FACTOR} = \frac{14{,}700+16{,}600}{10{,}500+11{,}700} = 1.41$$

FIGURE E-1

COMPUTATION OF THE AVERAGE GROWTH FACTOR BY HIGHWAY SECTION USING BASE YEAR AND FUTURE YEAR PRODUCTIONS AND ATTRACTIONS

The second method for obtaining link growth factors is based upon the use of a one-purpose (i.e., HBW + HBNW + NHB trips) gravity model for the internal-internal portion of the link volumes. A one-purpose model is applied using current year productions and attractions and assigned to the network (manually or by computer). The one-purpose model is also applied using future productions and attractions and assigned to the network. The ratio of future assigned volume for each link to present assigned volume for each link is the growth factor to be applied to the internal-internal count. To the factored internal-internal count is added the external assigned volume and the internal-external assigned volume. This could also be done using a spiderweb network for aggregation and to reduce assignment errors to individual facilities.

To obtain the trip productions and attractions for each zone, local data or the default values provided in this manual may be used. Also provided in the "Default Value" section are the friction factors to be used in the gravity model application. If work is to be done manually, the user is referred to the report, Quick-Response Urban Travel Estimation Manual Techniques and Transferable Parameters--A Users Guide 6/. A manual gravity model application is described in Chapter Three of the Users Guide 6/. A manual traffic assignment is described in Chapter Seven of the same.

Where conditions are appropriate, the count procedures may be further simplified. Where little growth in population and employment is anticipated, less than about one-half percent per year, and where any growth is expected to be uniform throughout much of an area, an average "growth" factor may be applied to the internal-internal portion of the ground count. That is, a single growth factor for the entire area would be developed based upon anticipated increase in travel due to the small growth, and increase in trip making anticipated based upon increased income and auto ownership, if expected. Further, if through trips and internal-external travel are expected to also grow in approximate proportion to the internal-internal traffic, and a quick estimate of potential problem areas is desired, the actual ground counts can be factored by the anticipated total average growth to arrive at an estimate of future traffic volumes. These would be evaluated to assess the emergence of any congestion problems.

In order to enable the transportation planner to manually apply the traffic estimation methodology described above, an illustrative example is provided below.

An Example Application

Suppose that the future ground counts are to be estimated on the highway network for a small urban area with a population of 60,000. It is anticipated that this area will undergo a low to moderate growth. Input information such as that described below is available.

Input Information. Essentially, the input data consists of the following items:

1. A map of the study area showing the layout of the analysis areas and their respective centroids, boundary limits of the CBD, central city and suburban subregions, and a highway map delineating the freeway and major arterial network. The outer limit of the sururban boundary can also be considered to form a cordon for the study area, and external stations are considered to be located wherever this cordon intersects the highways. (See Step 1 below.)

2. The base year average daily vehicle ground counts for each link of the highway network. (See Step 13 below.)

3. The base year external trip matrix, i.e., a trip matrix for the average daily internal-external (I-E) traffic and the average daily external-external (E-E) through traffic. (See Step 2 below.)

4. The base year all purpose (i.e., the HBW, HBNW and NHB trip purposes combined) internal-internal (I-I) average daily vehicle productions and attractions by analysis area. (See Step 5 below.)

5. The base year analysis area-to-area travel time matrix and the corresponding all-purpose friction factors. (See Step 6 below.)

6. The future year all purpose I-I average daily vehicle productions and attractions by analysis area. (See Step 8 below.)

7. The future year analysis area-to-area travel time matrix and the corresponding all-purpose friction factors. (See Step 9 below.)

8. The traffic growth factors (from base to future year) at the external stations located on the cordon.

This information then constitutes the input data required for the traffic estimation technique, and is utilized as described below.

Methodology. The traffic estimation technique based on ground counts is applied in a step-by-step manner as follows and as depicted in the flowchart shown in Figure E-2.

STEP 1: Lay Out Map of Study Area. A part of the study area in question is illustrated in Figure E-3 which displays the 5 districts and the highway network selected for analysis. Also shown are the subregional boundaries and the 6 external stations at the cordon (A through F). The freeway links (16 in number) in the network are numbered consecutively from #101 onwards, and the arterial links (17 in number) from #117 onwards.

STEP 2: Tabulate Base Year Ground Counts by Link. The base year ground counts (which must be available as input) are shown tabulated in the summary table shown later in the text in Figure E-15, column a. The computational use of these counts does not occur until Step 4.

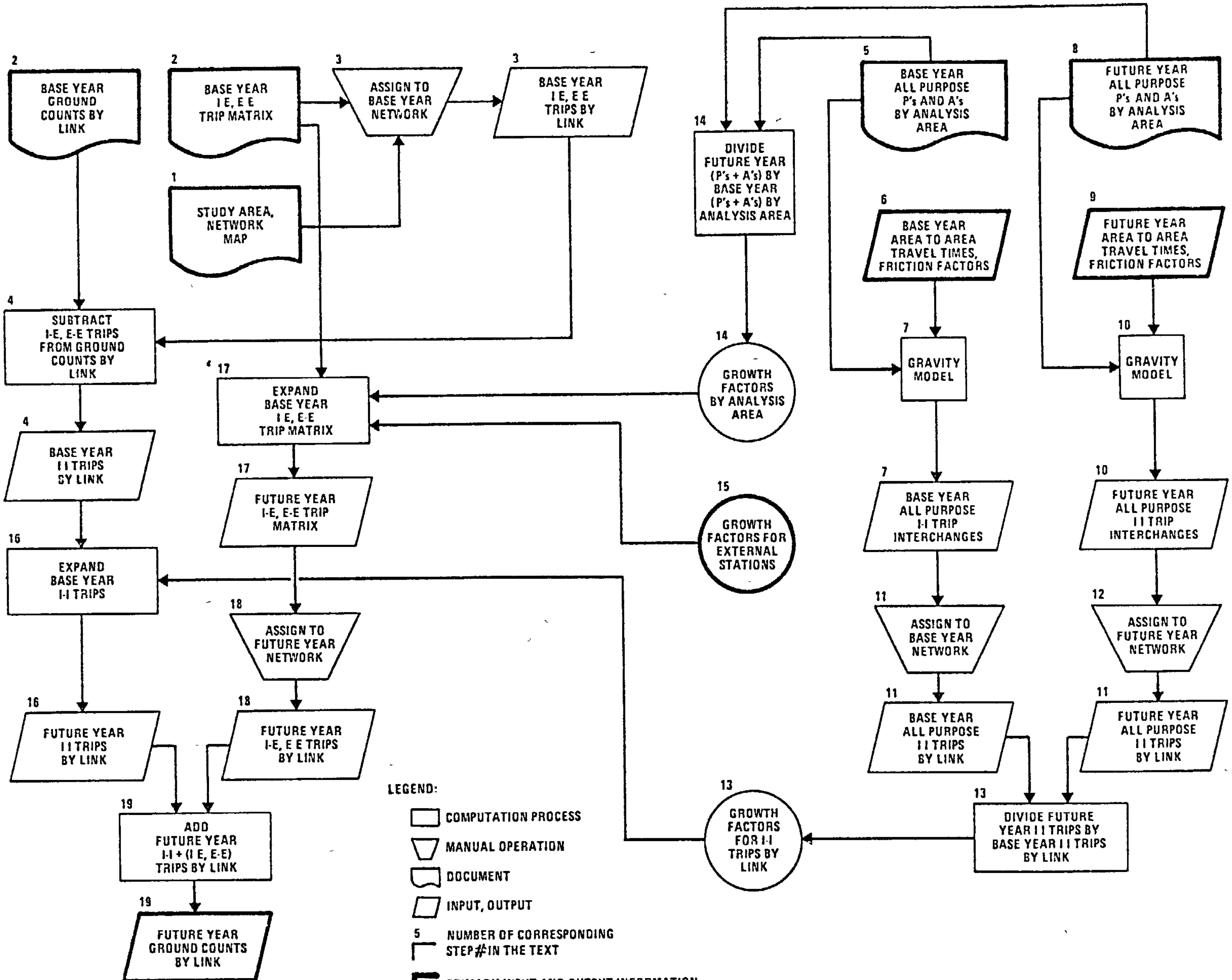
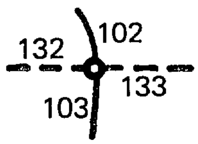


FIGURE E-2

FLOWCHART REPRESENTATION OF THE TRAFFIC ESTIMATION METHOD BASED ON GROUND COUNTS

LEGEND:

03	DISTRICT NUMBER AND CENTROID
01	CBD SUBREGION
02, 03, 04	CENTRAL CITY AND SUBURB SUBREGIONS
	FREEWAY AND ARTERIAL LINKS, LINK NUMBERS AND NODE
O F	EXTERNAL STATION (AT CORDON)

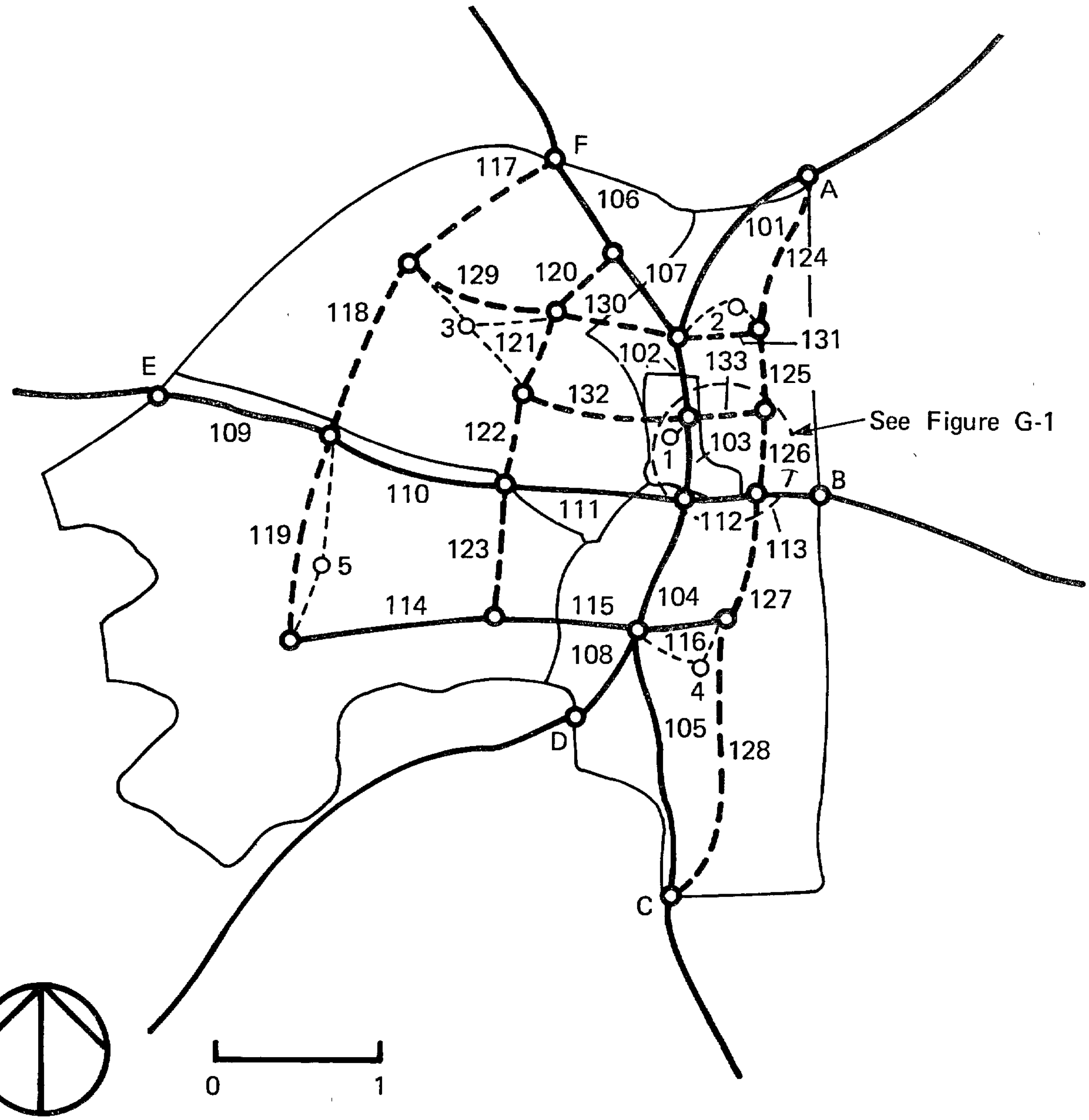


FIGURE E-3

MAP OF STUDY AREA SHOWING DISTRICTS AND HIGHWAY NETWORK SELECTED FOR ANALYSIS (STEP 1)

STEP 3: Assign Base Year I-E, E-E Vehicle Trip Matrix to the Base Year Highway Network. The base year external trip matrix (which must also be available as input) for the study area is shown in Figure E-4. The matrix indicates that the study area and its external environs generate a total of 20,000 vehicle trips in the base year, of which 15,100 (i.e., 7,200 + 7,900) are I-E-I trips and 4,900 are E-E trips.

The actual trip assignment entails the use of the commonly used "all-or-nothing" procedure described in the Users Guide 6/. Figure E-5 exhibits the assignment worksheets--trip interchanges and the corresponding trip volumes form the left-hand columns of the worksheets, whereas the highway link numbers are arranged across the top. The tick marks indicate the "minimum" highway path followed by a particular trip interchange. Thus, for example, the trip interchange from district #4 to external station B and back (i.e., 4-B-4) corresponds to a trip volume of 200 + 300 = 500 vehicles (Figure E-4). The highway path followed by this trip interchange is judged to be via link numbers 127 and 113 (Figure E-5). The tick marks are then inserted in the appropriate cells in the assignment worksheets. Note that it is assumed that the "minimum" highway path is the same for trips from area i to area j, as it is (in reverse order) from j to i and is determined visually from a map.

When all the trip interchanges and volumes have been inserted in the proper cells, the marked cells are summed vertically for each link to obtain the total traffic on that link. For instance, freeway link #115 carries 400 + 300 + 300 + 300 + 300 + 300 = 1,900 vehicles or I-E and E-E traffic (Figure E-5). The base year external traffic by link is tabulated in Figure E-15, column b.

STEP 4: Subtract Base Year I-E, E-E Vehicle Trips from Base Year Ground Counts by Link to Obtain Base Year I-I Vehicle Trips by Link. This subtraction is undertaken on a link-by-link basis and the resultant I-I trips are recorded in Figure E-15, column c. Hence, for freeway link #115, the base year I-I trips are given by: 30,100 - 1,900 = 28,200 vehicles.

The next 15 steps are necessitated in order to generate the traffic growth factors for I-I trips by link (Steps 5 through 19), and the growth factors by analysis area (Step 14). Steps 5 through 12 include vehicle trip generation, trip distribution and trip assignment for both the base year and future year conditions.

STEP 5: Generate the Base Year All Purpose I-I Vehicle Productions and Attractions by Analysis Area. The trip generation procedures employed are those described in Chapter Two. By using the base year socio-economic characteristics (such as household size, income and auto ownership) for each of the 5 districts in the study area, the average daily person trips per household (and thence by district) are estimated. Then, by employing auto occupancy rates and a transit estimate, the average daily vehicle productions (P's) and attractions (A's) are calculated. These P's and A's are then entered into the appropriate locations in Figure E-6. District #4, for example, produces 18,200 all purpose I-I vehicle trips and attracts 17,600 trips on an average daily basis. In all, the 5 districts generate a total of 100,000 I-I vehicle trips.

STEP 6: Develop the Base Year Analysis Area-to-Area Travel Times and All Purpose Friction Factors. The travel times and the corresponding all purpose friction factors are developed by using the "Airline Distance vs. Travel Time vs. Friction Factor" graphs contained in Appendix A (for this example, for urbanized areas with less than 100,000 population). The use of these graphs has been documented in the Users Guide 6/. The basic input to these graphs

		DISTRICTS					STATIONS						
		1	2	3	4	5	A	B	C	D	E	F	
DISTRICTS	1						400	200	900	600	100	100	2,300
	2						200	100	100	100	0	100	600
	3						0	200	200	100	400	600	1,500
	4						100	200	300	400	200	100	1,300
	5						200	300	100	300	500	100	1,500
STATIONS	A	600	300	100	100	300		100	400	300	200	0	2,400
	B	500	200	100	300	100	100		100	100	400	300	2,200
	C	800	100	200	400	200	300	0		0	200	400	2,600
	D	400	200	200	200	0	400	100	0		0	200	1,700
	E	300	0	300	100	500	200	400	100	0		0	1,900
	F	200	300	500	0	400	0	0	400	200	0		2,000
		2,800	1,100	1,400	1,100	1,500	1,900	1,600	2,600	2,100	2,000	1,900	20,000

II=0	IE=7,200
EI=7,900	EE=4,900

FIGURE E-4
BASE YEAR I-E, E-E VEHICLE TRIP MATRIX (STEP 3)

TRIP INTER-CHANGE	TRIP VOLUME	← FREEWAY LINK #s →																← ARTERIAL LINK #s →																		
		101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133		
1-A-1	1,000	√	√																																	
1-B-1	700			√									√	√																						
1-C-1	1,700			√	√	√																														
1-D-1	1,000			√	√				√																											
1-E-1	400			√						√	√	√																								
1-F-1	300		√				√	√																												
2-A-2	500																								√											
2-B-2	300													√												√	√									
2-C-2	200		√	√	√	√																														
2-D-2	300		√	√	√				√																											
2-E-2	0																																			
2-F-2	400						√	√																												
3-A-3	100	√																													√					
3-B-3	300											√	√	√									√													
3-C-3	400					√										√							√	√												
3-D-3	300								√							√							√	√												
3-E-3	700									√									√																	
3-F-3	1,100																	√																		
4-A-4	200																								√	√	√	√								
4-B-4	500													√														√								
4-C-4	700																												√							
4-D-4	600								√								√																			
4-E-4	300									√					√	√				√																
4-F-4	100		√	√	√		√	√																												

FIGURE E-5

ASSIGNMENT WORKSHEET SHOWING BASE YEAR I-E, E-E VEHICLE TRIPS (STEP 3)

TRIP INTER-CHANGE	TRIP VOLUME	FREEWAY LINK #s															
		101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116
5-A-5	500	√									√						
5-B-5	400										√	√	√	√			
5-C-5	300					√									√	√	
5-D-5	300								√						√	√	
5-E-5	1,000									√							
5-F-5	500																
A-B-A	200	√	√	√									√	√			
A-C-A	700	√	√	√	√	√											
A-D-A	700	√	√	√	√				√								
A-E-A	400	√								√							
A-F-A	0																
B-C-B	100					√								√			√
B-D-B	200								√					√			√
B-E-B	800									√	√	√	√	√			
B-F-B	300						√	√						√			
C-D-C	0																
C-E-C	300					√				√					√	√	
C-F-C	800		√	√	√	√	√	√									
D-E-D	0																
D-F-D	400		√	√	√		√	√	√								
E-F-E	0																
Σ	20,000																
BASE YEAR I E, & E E TRIPS		3,600	4,700	7,200	5,900	4,500	2,300	2,300	3,800	3,900	2,100	1,900	2,400	3,800	1,200	1,900	900

TRIP INTER-CHANGE	ARTERIAL LINK #s																
	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133
5-A-5					√	√								√			
5-B-5																	
5-C-5																	
5-D-5																	
5-E-5																	
5-F-5	√	√															
A-B-A																	
A-C-A																	
A-D-A																	
A-E-A		√											√	√			
A-F-A																	
B-C-B											√						
B-D-B											√						
B-E-B																	
B-F-B									√	√					√		
C-D-C																	
C-E-C			√														
C-F-C																	
D-E-D																	
D-F-D																	
E-F-E																	
Σ																	
BASE YEAR I E, & E E TRIPS	1,600	1,600	600	0	500	1,500	700	700	800	800	1,000	700	400	1,000	300	0	0

FIGURE E-5 (continued)

is the centroid-to-centroid airline distance and the corresponding mix of travel by highway facility (arterial or freeway). Note that it is assumed that the travel time (and therefore the all purpose friction factor) is the same for trips from area i to area j, as it is from j to i.

NOTE: The Friction Factors for the example used in this Appendix are not from Figures in Appendix A, but were fabricated for the example presentation.

The travel times and friction factors are inserted in the appropriate locations in Figure E-6. For instance, the trip interchange between districts #4 and #3 entails a travel time of 10 minutes and the corresponding all purpose friction factor is 0.17. (The same condition is assumed to hold true for the #3 to #4 trip interchange.)

Having entered all the area-to-area travel times and the friction factors in Figure E-6, the user is now ready to distribute the base year trips between the 5 districts.

STEP 7: Distribute the Base Year All Purpose I-I Vehicle Trips. The trip distribution is accomplished by applying the manual trip distribution (Gravity Model) method described in Appendix B. The Gravity Model is applied for two iterations at the end of which the P's and the A's should be "balanced." All the computations necessary to conduct the trip distribution are shown in Figure E-6. Figure E-7 summarizes the base year all purpose I-I vehicle trip matrix. Thus, 1,700 vehicle trips result from district #4 to #3, and 2,900 trips from #3 to #4. A total of 100,000 vehicle trips have been distributed between the 5 districts.

STEP 8: Generate the Future Year All Purpose I-I Vehicle Productions and Attractions by Analysis Area. This step is identical to Step 5 except that the P's and A's now represent the trip generation potential for the study area for the future year. These P's and A's are entered in the appropriate locations in Figure E-8. Due to the anticipated growth in the study area, it can be observed that the district #4, for example, will produce 19,000 all purpose I-I vehicle trips and will attract 18,000 trips on an average daily basis. In all, it has been estimated that the 5 districts will generate a total of 110,000 I-I vehicle trips, an increase of 10% over the base year condition.

STEP 9: Develop the Future Year Analysis Area-to-Area Travel Times and All Purpose Friction Factors. This step is identical to Step 6 except that the travel times and the corresponding all purpose friction factors are developed for the future year. It must be pointed out that since the centroid-to-centroid airline distances between the 5 districts will remain unchanged, the "Airline Distance vs. Travel Time vs. Friction Factor" graphs will exactly generate the base year travel times. For this example, however, travel times have been altered from those in the base year simply to account for some hypothetical future year conditions--such as congestion and therefore increased travel times on some links, and traffic improvement programs and therefore decreased travel times on other links. The alterations in base year travel times have been made on a purely judgmental basis.

TRIP	AREA	AREA		ATTRACTION												
	TYPE			CBD		CENTRAL CITY						SUBURB				
		#		1		2		3		4		5		ΣA_j	$\Sigma A_j F_{ij}$	$R_i = \frac{P_i}{\Sigma A_j F_{ij}}$
			P_i \ A_j	42,300		11,600		20,500		17,600		8,000		100,000		
PRODUCTION	CBD	1	5,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20			
				17,800		3,900		5,700		6,000		1,600			35,000	0.168571
				3,000		700		1,000		1,000		300		5,900		
				18,200		4,200		5,300		6,000		1,500			35,200	0.167614
				3,100		700		900		1,000		300		5,900		
	CENTRAL CITY	2	10,400	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17			
				14,400		6,100		4,700		6,000		1,400			32,600	0.319018
				4,600		2,000		1,500		1,900		400		10,400		
				14,800		6,500		4,300		6,000		1,300			32,900	0.316109
				4,700		2,100		1,400		1,900		400		10,400		
		3	27,100	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28			
				11,800		2,700		8,600		3,000		2,200			28,300	0.957597
				11,300		2,600		8,200		2,900		2,100		27,100		
				12,200		2,800		7,900		3,000		2,200			28,100	0.964413
				11,800		2,700		7,600		2,900		2,100		27,100		
		4	18,200	6	0.34	6	0.34	10	0.17	4	0.53	8	0.23			
				14,400		3,900		3,500		9,300		1,800			32,900	0.553191
				8,000		2,200		1,900		5,100		1,000		18,200		
				14,800		4,200		3,200		9,300		1,800			33,300	0.546547
				8,100		2,300		1,700		5,100		1,000		18,200		
	SUBURB	5	38,400	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34			
				8,500		2,000		5,700		4,000		2,700			22,900	1.676856
				14,300		3,400		9,600		6,700		4,500		38,400		
				8,700		2,100		5,300		4,000		2,600			22,700	1.691630
				14,700		3,600		9,000		6,800		4,400		38,400		
		ΣP_i	100,000	41,200		10,900		22,200		17,600		8,300		100,000	Attraction totals at the end of iteration #1	
				−3%		−6%		+8%		0%		+4%			% difference from true attractions	
				43,400		12,300		18,900		17,600		7,700			Adjusted attraction totals for iteration #2	
				42,400		11,400		20,600		17,700		8,200		100,000	Attraction totals at the end of iteration #2	
				0%		−2%		0%		+1%		+3%			% difference from true attractions	
															Adjusted attraction totals for iteration #3, if required	

NOTE: Friction Factors are *not* from Appendix A, but fabricated for this example.

FIGURE E-6

BASE YEAR ALL PURPOSE I-I VEHICLE TRIP DISTRIBUTION USING THE GRAVITY MODEL (STEPS 5, 6, 7)

	DISTRICTS 1	2	3	4	5	STATIONS A	B	C	D	E	F	
DISTRICTS 1	3,100	700	900	1,000	300							5,900
2	4,700	2,100	1,400	1,900	400							10,400
3	11,800	2,700	7,600	2,900	2,100							27,100
4	8,100	2,300	1,700	5,100	1,000							18,200
5	14,700	3,600	9,000	6,800	4,400							38,400
STATIONS A												
B												
C												
D												
E												
F												
	42,300	11,600	20,500	17,600	8,000							100,000

FIGURE E-7

BASE YEAR ALL PURPOSE I-I VEHICLE TRIP MATRIX (STEP 7)

TRIP	AREA TYPE	AREA #	P_i \ A_j	ATTRACTION: CBD 1	CENTRAL CITY 2	CENTRAL CITY 3	CENTRAL CITY 4	SUBURB 5	ΣA_j	$\Sigma A_j F_{ij}$	$Ri = \frac{P_i}{\Sigma A_j F_{ij}}$
				46,000	14,000	23,500	18,000	8,500	110,000		
PRODUCTION	CBD	1	6,500	6 0.34	8 0.23	9 0.20	8 0.23	11 0.14			
				15,600	3,200	4,700	4,100	1,200		28,800	0.225694
				3,500	700	1,100	900	300	6,500		
				19,600	3,500	3,600	3,900	1,000		31,600	0.205696
				4,000	700	700	800	200	6,500		
	CENTRAL CITY	2	12,000	8 0.23	5 0.42	8 0.23	7 0.28	11 0.14			
				10,600	5,900	5,400	5,000	1,200		28,100	0.427046
				4,500	2,500	2,300	2,100	500	12,000		
				13,300	6,400	4,200	4,700	1,000		29,600	0.405405
				5,400	2,600	1,700	1,900	400	12,000		
		3	29,500	9 0.20	8 0.23	5 0.42	12 0.12	6 0.34			
				9,200	3,200	9,900	2,200	2,900		27,400	1.076642
				9,900	3,400	10,700	2,400	3,100	29,500		
				11,500	3,500	7,600	2,000	2,300		26,900	1.096654
				12,600	3,800	8,300	2,200	2,500	29,500		
		4	19,000	8 0.23	7 0.28	12 0.12	4 0.53	8 0.23			
				10,600	3,900	2,800	9,500	2,000		28,800	0.659722
				7,000	2,600	1,800	6,300	1,300	19,000		
				13,300	4,300	2,200	8,900	1,600		30,300	0.627063
				8,300	2,700	1,400	5,600	1,000	19,000		
	SUBURB	5	43,000	11 0.14	11 0.14	6 0.34	8 0.23	6 0.34			
				6,400	2,000	8,000	4,100	2,900		23,400	1.837607
				11,800	3,700	14,700	7,500	5,300	43,000		
				8,100	2,100	6,100	3,900	2,300		22,500	1.911111
				15,500	4,000	11,700	7,500	4,400	43,000		
		ΣP_i	110,000	36,700	12,900	30,600	19,200	10,500	110,000	Attraction totals at the end of iteration #1	
				−20%	−8%	+30%	+7%	+24%		% difference from true attractions	
				57,700	15,200	18,000	16,900	6,900		Adjusted attraction totals for iteration #2	
				45,800	13,800	23,800	18,000	8,500	110,000	Attraction totals at the end of iteration #2	
				0%	−1%	+1%	0%	0%		% difference from true attractions	
										Adjusted attraction totals for iteration #3, if required	

NOTE: Friction Factors for this example are *not* from Appendix A, but are fabricated for example.

FIGURE E-8

FUTURE YEAR ALL PURPOSE I-I VEHICLE TRIP DISTRIBUTION USING THE GRAVITY MODEL (STEPS 8, 9, 10)

The travel times and friction factors developed are recorded in the appropriate locations in Figure E-8. For instance, the trip interchange between districts #4 and #3 now entails a travel time of 12 minutes and the corresponding all purpose friction factor is 0.12. (The same condition is assumed to hold true for the #3 to #4 trip interchange.)

After entering all the area-to-area travel times and friction factors in Figure E-8, the future year trips can then be distributed between the 5 districts.

STEP 10: Distribute the Future Year All Purpose I-I Vehicle Trips. This step is conducted in a fashion identical to that of Step 7, i.e., by using the manual trip distribution (Gravity Model) method described in Appendix B. All computations carried out for this step are shown in Figure E-8 and Figure E-9 summarizes the future year all purpose I-I vehicle trip matrix. It can be observed from these two figures that 1,400 vehicle trips result from district #4 to #3, and 2,200 trips from #3 to #4 (in both cases, a decrease in the number of trips as compared to the base year trips). A total of 110,000 vehicle trips have been distributed between the 5 districts.

STEP 11: Assign the Base Year All Purpose I-I Vehicle Trips to the Base Year Highway Network. As before, using the "all-or-nothing" assignment procedure documented in NCHRP (1) and the base year highway network graphically represented in Figure E-3, the base year all purpose I-I trip matrix (Figure E-7) was assigned on the assignment worksheet shown in Figure E-10. Thus, freeway link #115 carries 15,000 + 4,600 + 7,800 = 27,400 vehicles of base year all purpose I-I traffic. This traffic (by link) is tabulated in Figure E-15, column d.

STEP 12: Assign the Future Year All Purpose I-I Vehicle Trips to the Future Year Highway Network. Since there are a few changes in the highway network attributes as compared to the base year (See Step 9.), the future year assignment is assumed to be identical to that of Step 11, except that the future year all purpose I-I trip matrix (Figure E-9) is assigned. The actual assignment is also accomplished in Figure E-10. Thus, freeway link #115 now carries 15,700 + 3,600 + 8,500 = 27,800 vehicles of future year all purpose I-I traffic. This traffic (by link) is tabulated in Figure E-15, column e.

STEP 13: Divide Future Year All Purpose I-I Vehicle Trips by Base Year All Purpose I-I Vehicle Trips by Link to Obtain Growth Factors by Link. This division is underataken on a link-by-link basis and the resultant growth factors are recorded in Figure #115, column f. The growth factor for freeway link #115, for instance, is given by 27,800 ÷ 27,400 = 1.01. Note that where there is no (zero) traffic on a link for both the base and future years, the growth factor is considered to be 1.00.

STEP 14: Divide the Sum of Future Year All Purpose Productions and Attractions by the Sum of Base Year All Purpose Productions and Attractions to Obtain Growth Factors by Analysis Area. This step is accomplished for the five districts and the necessary computations are exhibited in Figure E-11. The

	DISTRICTS 1	2	3	4	5	STATIONS A	B	C	D	E	F	
DISTRICTS 1	4,000	700	700	800	200							6,500
2	5,400	2,600	1,700	1,900	400							12,000
3	12,600	3,800	8,300	2,200	2,500							29,500
4	8,300	2,700	1,400	5,600	1,000							19,000
5	15,500	4,000	11,700	7,500	4,400							43,000
STATIONS A												
B												
C												
D												
E												
F												
	46,000	14,000	23,500	18,000	8,500							110,000

FIGURE E-9

FUTURE YEAR ALL PURPOSE I-I VEHICLE TRIP MATRIX (STEP 10)

TRIP INTERCHANGE	TRIP VOLUME	FREEWAY LINK #s																ARTERIAL LINK #s																
		101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133
1-2-1	5,400		√																															
1-3-1	12,700																																√	
1-4-1	9,100			√	√																													
1-5-1	15,000			√	√										√	√																		
2-3-2	4,100																														√	√		
2-4-2	4,200																									√	√	√						
2-5-2	4,000														√							√	√	√							√	√		
3-4-3	4,600															√							√	√										
3-5-3	11,100																		√															
4-5-4	7,800														√	√																		
BASE YEAR I I TRIPS		0	5,400	24,100	24,100	0	0	0	0	0	0	0	0	0	26,800	27,400	0	0	11,100	0	0	4,000	8,600	8,600	0	4,200	4,200	4,200	0	0	8,100	8,100	12,700	0
1-2-1	6,100		√																															
1-3-1	13,300																																√	
1-4-1	9,100			√	√																													
1-5-1	15,700			√	√										√	√																		
2-3-2	5,500																														√	√		
2-4-2	4,600																									√	√	√						
2-5-2	4,400														√							√	√	√							√	√		
3-4-3	3,600															√							√	√										
3-5-3	14,200																		√															
4-5-4	8,500														√	√																		
FUTURE YEAR I I TRIPS		0	6,100	24,800	24,800	0	0	0	0	0	0	0	0	0	28,600	27,800	0	0	14,200	0	0	4,400	8,000	8,000	0	4,600	4,600	4,600	0	0	9,900	9,900	13,300	0
GF FOR I I TRIPS		1.00	1.13	1.03	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.07	1.01	1.00	1.00	1.28	1.00	1.00	1.10	0.93	0.93	1.00	1.10	1.10	1.10	1.00	1.22	1.00	1.22	1.05	1.00

FIGURE E-10

ASSIGNMENT WORKSHEET SHOWING BASE YEAR AND FUTURE YEAR ALL PURPOSE I-I VEHICLE TRIPS BY LINK (STEPS 11, 12)

DISTRICT/ STATION	BASE YEAR			FUTURE YEAR			GROWTH FACTOR
	P	A	P + A	P	A	P + A	
1	5,900	42,300	48,200	6,500	46,000	52,500	1.09
2	10,400	11,600	22,000	12,000	14,000	26,000	1.18
3	27,100	20,500	47,600	29,500	23,500	53,000	1.11
4	18,200	17,600	35,800	19,000	18,000	37,000	1.03
5	38,400	8,000	46,400	43,000	8,500	51,500	1.11
A							1.20
B							1.15
C							1.22
D							1.19
E							1.13
F							1.07

FIGURE E-11

GROWTH FACTORS FOR DISTRICTS AND EXTERNAL STATIONS (STEP 14) base year P's and A's for district #4, for example, sum up to 35,800 vehicle trip ends and those for the future year to 37,000, thus yielding a growth factor of 37,000 ÷ 35,800 = 1.03. Figure E-11 also contains the growth factors for traffic at the external stations (A through F); these factors are readily available for most study areas.

STEP 15: Compute Average Growth Factors for District/Station Trip Interchanges. These factors are merely the arithmetic mean of the growth factors at the origin and destination ends of the trip interchanges. So, for the district #4 to Station B interchange, the average growth factor is given by (1.03 + 1.15) ÷ 2 = 1.09. The average growth factor matrix is tabulated in Figure E-12.

The next two steps involve the application of the growth factors developed in Steps 13 and 15 to expand (respectively) the base year I-I trips by link output from Step 4, and the base year I-E, E-E trip matrix used in Step 3. The result of these expansions is the future year I-I, and I-E, E-E vehicle trips by link.

STEP 16: Expand Base Year I-I Vehicle Trips by Link. This expansion is accomplished in Figure E-15, where the product of column c (the base year I-I trips by link) and column f (the growth factors for I-I trips by link) constitutes the future year I-I trips by link (column g). As an example, the 28,200 base year I-I trips on freeway link #115 are multiplied by the corresponding growth factor of 1.01 to produce 28,500 future year I-I trips. All future year I-I trips are recorded (by link) in Figure E-15, column g.

STEP 17: Expand the Base Year I-E, E-E Vehicle Trip Matrix. This expansion is conducted by multiplying the base year I-E, E-E trip interchanges in the matrix (Figure E-4) by the corresponding average growth factors shown in Figure E-12. Therefore, for the 200 base year I-E, E-E trips from district #4 to Station B, say, the product with the corresponding average growth factor of 1.09 yields the future year I-E, E-E trips equal to 218 (or 200, if rounded to the nearest 50 trips). The future year I-E, E-E trip matrix is exhibited in Figure E-13.

The future year I-E, E-E trip matrix indicates that there are a total of 22,850 vehicle trips, an increase of 2,850 trips over the base year condition. The I-E-I trips consititue 17,150 trips and the E-E trips add up to 5;700 trips.

STEP 18: Assign the Future Year I-E, E-E Vehicle Trip Matrix to the Future Year Highway Network. Again, since there are a few changes in the highway network attributes in the future year (See Step 9.), this assignment is assumed to be identical to that undertaken in Step 3. Further, the "minimum" paths are assumed to stay the same as those for the base year. So, for the trip interchange from district #4 to external station B and back (i.e., 4-B-4), the "minimum" path, as before, is via link numbers 127 and 113 (Figure E-5); however, the 4-B-4 interchange in the future year has a magnitude of 550 vehicle trips (as opposed to 500 vehicle trips in the base year). The trip assignment worksheet is displayed in Figure E-14.

			DISTRICTS					STATIONS					
			1.09	1.18	1.11	1.03	1.11	1.20	1.15	1.22	1.19	1.13	1.07
			1	2	3	4	5	A	B	C	D	E	F
DISTRICTS	1.09	1						1.15	1.12	1.16	1.14	1.11	1.08
	1.18	2						1.19	1.17	1.20	1.19	1.16	1.13
	1.11	3						1.16	1.13	1.17	1.15	1.12	1.09
	1.03	4						1.12	1.09	1.13	1.11	1.08	1.05
	1.11	5						1.16	1.13	1.17	1.15	1.12	1.09
STATIONS	1.20	A	1.15	1.19	1.16	1.12	1.16		1.18	1.21	1.20	1.17	1.14
	1.15	B	1.12	1.17	1.13	1.09	1.13	1.18		1.19	1.17	1.14	1.11
	1.22	C	1.16	1.20	1.17	1.13	1.17	1.21	1.19		1.21	1.18	1.15
	1.19	D	1.14	1.19	1.15	1.11	1.15	1.20	1.17	1.21		1.16	1.13
	1.13	E	1.11	1.16	1.12	1.08	1.12	1.17	1.14	1.18	1.16		1.10
	1.07	F	1.08	1.13	1.09	1.05	1.09	1.14	1.11	1.15	1.13	1.10	

FIGURE E-12

AVERAGE GROWTH FACTORS FOR
DISTRICT/EXTERNAL STATION TRIP INTERCHANGES (STEP 15)

	1	2	3	4	5	A	B	C	D	E	F	
	DISTRICTS					STATIONS						
DISTRICTS 1						500	200	1,050	700	100	100	2,650
2						250	100	100	100	0	100	650
3						0	250	250	100	450	700	1,750
4						100	200	350	450	200	100	1,400
5						250	350	100	350	550	100	1,700
STATIONS A	700	350	100	100	350		100	500	350	250	0	2,800
B	550	250	100	350	100	100		100	100	450	350	2,450
C	950	100	250	450	250	350	0		0	250	450	3,050
D	450	250	250	200	0	500	100	0		0	250	2,000
E	350	0	350	100	550	250	450	100	0		0	2,150
F	200	350	550	0	450	0	0	450	250	0		2,250
	3,200	1,300	1,600	1,200	1,700	2,300	1,750	3,000	2,400	2,250	2,150	22,850

II=0	IE=8,150
EI=9,000	EE=5,700

FIGURE E-13

FUTURE YEAR (EXPANDED) I-E, E-E VEHICLE TRIP MATRIX (STEP 17)

TRIP INTER-CHANGE	TRIP VOLUME	FREEWAY LINK #s																ARTERIAL LINK #s																		
		101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133		
1-A-1	1,200	√	√																																	
1-B-1	750			√									√	√																						
1-C-1	2,000			√	√	√																														
1-D-1	1,150			√	√				√																											
1-E-1	450			√						√	√	√																								
1-F-1	300		√				√	√																												
2-A-2	600																								√											
2-B-2	350													√												√	√									
2-C-2	200		√	√	√	√																														
2-D-2	350		√	√	√				√																											
2-E-2	0																																			
2-F-2	450						√	√																												
3-A-3	100	√																													√					
3-B-3	350											√	√	√									√													
3-C-3	500					√										√							√	√												
3-D-3	350								√							√							√	√												
3-E-3	800									√									√																	
3-F-3	1,250																	√																		
4-A-4	200																								√	√	√	√								
4-B-4	550													√														√								
4-C-4	800																												√							
4-D-4	650								√								√																			
4-E-4	300									√					√	√				√																
4-F-4	100		√	√	√		√	√																												

FIGURE E-14

ASSIGNMENT WORKSHEET SHOWING FUTURE YEAR I-E, E-E VEHICLE TRIPS (STEP 18)

TRIP INTER-CHANGE	TRIP VOLUME	← FREEWAY LINK #s →																← ARTERIAL LINK #s →																		
		101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133		
5-A-5	600	√									√											√	√								√					
5-B-5	450										√	√	√	√																						
5-C-5	350					√									√	√																				
5-D-5	350								√						√	√																				
5-E-5	1,100									√																										
5-F-5	550																	√	√																	
A-B-A	200	√	√	√									√	√																						
A-C-A	850	√	√	√	√	√																														
A-D-A	850	√	√	√	√				√																											
A-E-A	500	√								√									√											√	√					
A-F-A	0																																			
B-C-B	100					√								√			√											√								
B-D-B	200								√					√			√											√								
B-E-B	900									√	√	√	√	√																						
B-F-B	350						√	√						√												√	√					√				
C-D-C	0																																			
C-E-C	350					√				√					√	√				√																
C-F-C	900		√	√	√	√	√	√																												
D-E-D	0																																			
D-F-D	500		√	√	√		√	√	√																											
E-F-E	0																																			
FUTURE YEAR (EXPANDED) I E, E E TRIPS		4,300	5,450	8,200	6,900	5,250	2,600	2,600	4,400	4,400	2,400	2,150	2,650	4,200	1,350	2,200	950	1,800	1,850	650	0	600	1,800	850	800	900	900	1,050	800	500	1,200	350	0	0	–	–

FIGURE E-14 (continued)

STEP #s →		2	3	4	11	12	13	16	18	19	13
	LINK #s	BASE YEAR GROUND COUNTS a	BASE YEAR I-E, E-E TRIPS b	BASE YEAR I-I TRIPS c=(a-b)	BASE YEAR ALL PURP. I-I TRIPS d	FUTURE YEAR ALL PURP. I-I TRIPS e	GROWTH FACTOR FOR ALL PURP. I-I TRIPS f=(e ÷ d)	FUTURE YEAR (EXP.) I-I TRIPS g=(c × f)	FUTURE YEAR (EXP.) I-E, E-E TRIPS h	FUTURE YEAR GROUND COUNTS i=(g+h)	% CHANGE FUTURE-BASE YEAR GROUND COUNT $\%=\frac{i-a}{a}\times 100$
FREEWAY LINK #s	101	6,000	3,600	2,400	0	0	1.00	2,400	4,300	6,700	+11.6
	102	12,100	4,700	7,400	5,400	6,100	1.13	8,400	5,450	13,850	+14.5
	103	32,300	7,200	25,100	24,100	24,800	1.03	25,900	8,200	34,100	+ 5.6
	104	30,400	5,900	24,500	24,100	24,800	1.03	25,200	6,900	32,100	+ 5.6
	105	5,900	4,500	1,400	0	0	1.00	1,400	5,250	6,650	+12.7
	106	3,700	2,300	1,400	0	0	1.00	1,400	2,600	4,000	+ 8.1
	107	4,400	2,300	2,100	0	0	1.00	2,100	2,600	4,700	+ 6.8
	108	4,200	3,800	400	0	0	1.00	400	4,400	4,800	+12.5
	109	4,700	3,900	800	0	0	1.00	800	4,400	5,200	+10.6
	110	5,600	2,100	3,500	0	0	1.00	3,500	2,400	5,900	+ 5.4
	111	7,300	1,900	5,400	0	0	1.00	5,400	2,150	7,550	+ 3.4
	112	6,900	2,400	4,500	0	0	1.00	4,500	2,650	7,150	+ 3.6
	113	4,800	3,800	1,000	0	0	1.00	1,000	4,200	5,200	+ 8.3
	114	27,800	1,200	26,600	26,800	28,600	1.07	28,500	1,350	29,850	+ 7.4
	115	30,100	1,900	28,200	27,400	27,800	1.01	28,500	2,200	30,700	+ 2.0
	116	8,000	900	7,100	0	0	1.00	7,100	950	8,050	+ 0.6
ARTERIAL LINK #s	117	2,200	1,600	600	0	0	1.00	600	1,800	2,400	+ 9.1
	118	14,900	1,600	13,300	11,100	14,200	1.28	17,000	1,850	18,850	+26.5
	119	5,000	600	4,400	0	0	1.00	4,400	650	5,050	+ 1.0
	120	200	0	200	0	0	1.00	200	0	200	0.0
	121	5,000	500	4,500	4,000	4,400	1.10	5,000	600	5,600	+12.0
	122	10,700	1,500	9,200	8,600	8,000	0.93	8,600	1,800	10,400	- 2.8
	123	9,600	700	8,900	8,600	8,000	0.93	8,300	850	9,150	– 4.7
	124	1,100	700	400	0	0	1.00	400	800	1,200	+ 9.1
	125	5,200	800	4,400	4,200	4,600	1.10	4,800	900	5,700	+ 9.6
	126	5,300	800	4,500	4,200	4,600	1.10	5,000	900	5,900	+11.3
	127	4,900	1,000	3,900	4,200	4,600	1.10	4,300	1,050	5,350	+ 9.2
	128	1,300	700	600	0	0	1.00	600	800	1,400	+ 7.7
	129	1,700	400	1,300	0	0	1.00	1,300	500	1,800	+ 5.9
	130	9,600	1,000	8,600	8,100	9,900	1.22	10,500	1,200	11,700	+21.9
	131	8,700	300	8,400	8,100	9,900	1.22	10,200	350	10,550	+21.3
	132	13,000	0	13,000	12,700	13,300	1.05	13,700	0	13,700	+ 5.4
	133	400	0	400	0	0	1.00	400	0	400	0.0
SOURCE											

FIGURE E-15: SUMMARY OF BASE YEAR AND FUTURE YEAR VEHICLE TRIPS BY LINK

As noted before, the vertical summation by link results in the total traffic assigned to that link. Thus, for freeway link #115, the total I-E, E-E traffic is given by 500 + 350 + 300 + 350 + 350 + 350 = 2,200 vehicles (as opposed to the 1,900 vehicles in the base year). The future year external traffic by link is tabulated in Figure E-15, column h.

STEP 19: Add the Future Year I-I Vehicle Trips to the Future Year I-E, E-E Vehicle Trips by Link to Obtain the Future Year Ground Counts. The summation of the future year I-I trips by link (Figure E-15, column g) and the future year I-E, E-E trips by link (Figure E-15, column h) is performed and recorded in Figure E-15, column i. For freeway link #115 then, the future year ground count is given by 28,500 + 2,200 = 30,700 vehicles.

On observing the base year and future year ground counts in columns a and i, respectively, in Figure E-15, it can be seen that except for arterial link numbers 120, 122, 123 and 133, all other links show an increase in the future year ground counts. Link #118 exhibits the highest growth in traffic (+26.5%), with link numbers 130 and 131 following with +21.9% and +21.3%, respectively. The lowest increases occur on link numbers 115, 116 and 119 (+2.0%, +0.6%, and +1.0%, respectively).

In absolute terms, the highest volume of freeway traffic occurs on link numbers 103, 104, 115 and 114 (in descending order of magnitude). For arterial traffic, the larger volumes occur on link numbers 118, 132, 130, 131, 122 and 123 (in descending order of magnitude).

In general, it appears that the future ground counts are consistent with the anticipated growth in the study area. At this point, all high-growth or high-magnitude links would be subjected to a capacity analysis to check whether or not the future year traffic can be accommodated at some level of service. Critical and over-loaded links or corridors would be candidates for system improvements. (See Chapter Three, System Planning manual.)

APPENDIX F

COMPUTER PROGRAMS FOR GROUND COUNT FACTORING

The chain of programs that could be used to accomplish the count factoring process is shown in Figure F-1. The programs shown are not the only software that will accomplish the task. These programs were selected because: (1) they make use of previously described UTPS software that incorporates default conditions and (2) all programs are included in the UTPS package, which saves the user from having to obtain, install and learn other software packages.

The program flowchart shown in Figure F-1 is effectively two parallel paths. Each path consists of obtaining both internal and external trip matrices and assigning these trips to a network using program UROAD. Internal travel is obtained by using the default model built into program AGM and previously discussed. Base year external travel is obtained from an external O-D survey. Forecast year external travel is obtained by using growth factors which can be applied with program UMCON.

Two assignments are performed using program UROAD. UROAD application (1) produces a historical record containing the basic link data and the base year assigned volumes. It should be kept in mind that the assigned volumes produced are based on a single purpose model not adjusted to the area and should only be used to obtain factors for the expansion of the ground counts. UROAD application (2) assigns the forecast year trips and by utilizing a user-coded subroutine, factors and the ground counts and prints a report showing forecast year volumes.

The programs used in this process have been previously discussed. The following discussion will cover areas that are unique to the link count factoring process.

<u>UROAD - Application (1)</u>. Two trip matrices are input to the assignment process. Assuming that these matrices are each Table 1 on two separate datasets, the TABLES parameter would be coded as follows:

TABLES=101,201

This implies that the trip matrices will be specified on DDCARDS FT11F001 and FT12F001. In order to achieve assigned volumes that are in balance directionally (i.e., consistent with the counts) it is necessary to utilize the SPLITn parameters. They are coded as follows: SPLIT1=.5,.5,SPLIT2=.5,.5. Since an updated historical record is necessary for UROAD application (2), the user should code the VFIELD parameter as follows:

VFIELD=0

This implies that the assigned volume would be appended to the historical record immediately after the last word in the input record. The updated historical record will be output on a dataset defined on DDCARD FT03F001. A complete example of a parameter card would be:

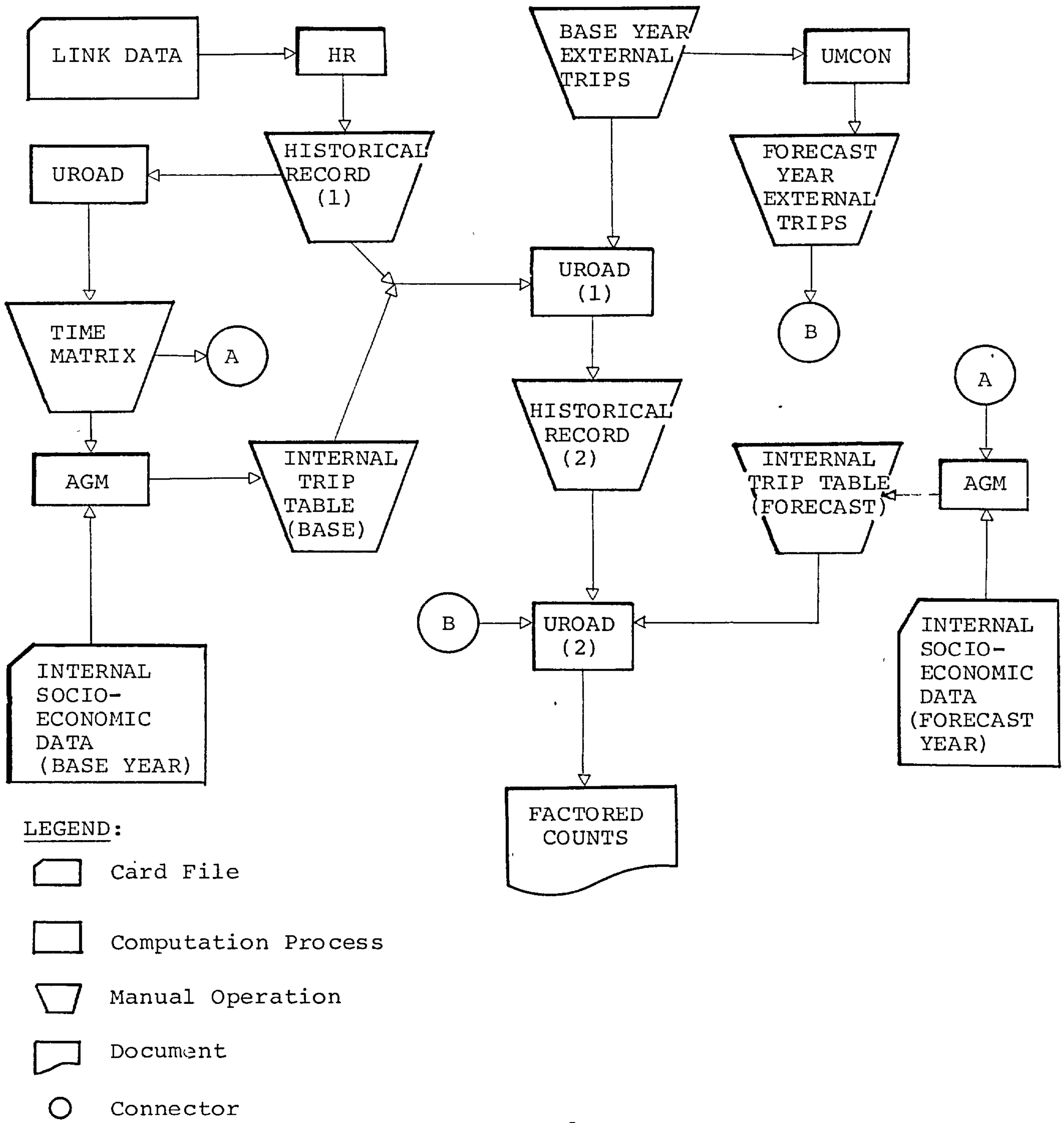


FIGURE F-1

PROGRAM CHAIN FOR COMPUTERIZED
TRAFFIC ESTIMATION BASED ON GROUND COUNTS

&PARAM TABLES=101,201,VFIELD=0,SPLIT1=.5,.5,SPLIT2=.5,.5 &END

UROAD - Application (2). Once again, two matrices are input to the assignment process in the same manner as in UROAD application (1). The UROAD program which is used in this case is one that has the user-coded subroutine (supplied with the program tape) incorporated into the program. The historical record produced in UROAD application (1) (FT03F001) is used as input and is defined on DDCARD FT02F001.

The parameter card coding for this application is similar to UROAD application (1) but does not contain the VFIELD specification;

&PARAM TABLES=101,201,SPLIT1=.5,.5,SPLIT2=.5,.5 &END

Program UMCON. Program UMCON is used to apply growth factors to the base year external trip matrix to produce forecast year external trips. Two options exist for applying growth factors. The user can supply a card for each external zone coded as follows:

4-8	Zone number
9-16	Required Zonal Productions
17-24	Required Zonal Attractions

UMCON will scale the input trip matrix to achieve the desired productions and attractions. Alternately, the user can code growth factors to be applied to each external zone. The growth factors are coded (with decimals) in place of the production and attraction fields shown above. The program is informed that these values are growth factors rather than desired trip totals by coding the FACTOR option on the &OPTION control card. This is accomplished as follows:

&OPTION FACTOR=T &END

APPENDIX G

EXAMPLE OF REDISTRIBUTION OF ASSIGNED VOLUMES AMONG AVAILABLE FACILITIES

Consider the north-south corridor delineated in Figure E-3 for redistribution analysis; the corridor is also shown on an expanded scale in Figure G-1. Redistribution is to be performed across screenline A-A. The redistribution technique requires that it be conducted across cutlines (i.e., subdivisions of screenlines) intercepting at least 3 highway links. So for illustrative purposes only, assume that the corridor under consideration (Figure G-1) has, in addition to the original links (#'s 103 and 126), link #'s 140 and 141. Further, link #200 is a proposed facility for the future year and is expected to add capacity (and relieve congestion) across screenline A-A.

All the necessary traffic data for the north-south corridor and screenline A-A are shown in Table G-1. Note that traffic data for link #'s 103 and 126 have been obtained from the traffic estimation technique described in the preceding sections and Figure E-15, whereas that for link #'s 140, 141 and 200, and all capacity data, are hypothetical numbers.

The redistribution technique is applied in the following fashion. The manner in which screenline A-A is subdivided into cutlines is as follows. Starting at one end of the screenline the first cutline should normally extend across at least 3 facilities (Figure G-1). The second cutline should do the same, and overlap the first cutline such that the overlap extends across about half of each individual cutline. Preferably, more than one facility should be intercepted within the overlap. The third cutline should be similarly laid out, and should start where the first cutline terminates. Additional cutlines as needed should be similarly established. Unless irregularities in the street system dictate otherwise, the cutlines in parallel screenlines should be opposite each other so as to intercept the same sets of highway facilities. As an example, Figure G-1 shows the subdivision of screenline A-A into three overlapping cutlines (i.e., p-p, q-q and r-r) to be used in the redistribution of forecast year assignment volumes. Screenline A-A will be analyzed using the hypothetical traffic data exhibited in Table G-1.

Table G-2 shows the worksheet used for the redistribution of assigned volumes. Link description, plus traffic data for columns a, c and e are filled in Table G-2 using the data given in Table G-1. Such information is recorded for each of the three cutlines of screenline A-A shown in Figure G-1. The cutlines are processed one at a time and the total assignment adjustment volumes (column h, Table G-2) are input, when appropriate, into column e of the subsequent cutline analysis. The order in which the cutlines are processed is arbitrary, but such computations should proceed in an orderly fashion from one end of the screenline to the other (say, from left to right).

The calculations necessary for completing Table G-2 are as follows (cutline p-p calculations are obvious from Table G-2, so the following steps pertain to cutline q-q):

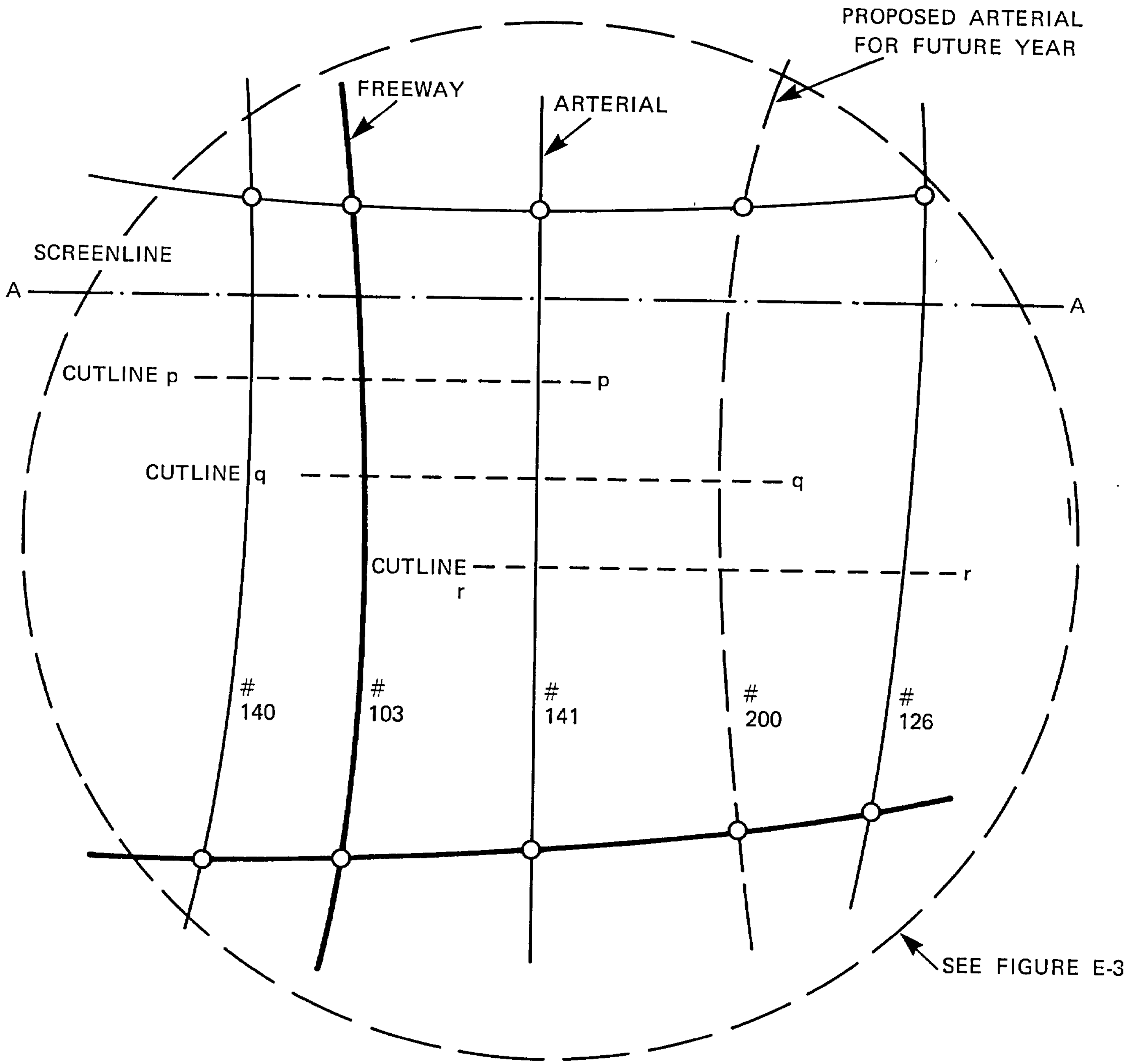


FIGURE G-1

CUTLINES OF SCREENLINE A-A FOR
REDISTRIBUTION ANALYSIS WITHIN THE NORTH-SOUTH CORRIDOR

TABLE G-1

TRAFFIC DATA FOR HIGHWAY LINKS
WITHIN THE NORTH-SOUTH CORRIDOR AND CROSSING SCREENLINE A-A[a]

LINK #	BASE YEAR GROUND COUNT[b]	CAPACITY	FUTURE YEAR ASSIGNMENT[c]
140	9,600	9,000	12,000
103	32,300	30,000	34,100
141	4,400	5,000	0
200[d]	--	8,000[d]	4,000[d]
126	5,300	6,000	5,900
TOTAL	51,600	58,000	56,000

FOOTNOTES:

a. All traffic data is 2-directional and measured as average daily traffic (ADT).

b. Figure E-15, Column a for link #'s 103, 126.*

c. Figure E-15, Column i for link #'s 103, 126.*

d. Link #200 is a new link contributing additional capacity to the screenline capacity for the future year.

* All other data are hypothetical.

TABLE G-2

WORKSHEET FOR REDISTRIBUTING FUTURE YEAR GROUND COUNTS[a]

SCREENLINE: AA

CUT-LINE #	LINK DESCRIPTOR	BASE YEAR VOLUME (a)	% BASE YEAR VOL. ON CUTLINE (b)	CAPACITY (c)	% OF TOTAL CAP. ON CUTLINE (d)	FORECAST YEAR ASSIGNMENT VOLUME (e)	CAPACITY ASSIGNMENT ADJUSTMENT (f)	VOLUME ASSIGNMENT ADJUSTMENT (g)=(b)×Σ(e)	TOTAL ASSIGNMENT ADJUSTMENT (h)=(f)+(g)
p–p	140	9,600	20.7	No new facilities proposed across this cutline; ∴ calculations not necessary for these columns.		12,000	See note in columns c & d	9,542	9,542*
	103	32,300	69.8			34,100		32,178	32,178
	141	4,400	9.5			0		4,380	4,380
Σ		46,300	100.0			46,100		46,100	46,100
q–q	103	32,300	88.0	30,000	69.8	32,178	–	29,052	29,052*
	141	4,400	12.0	5,000	11.6	4,380	–	3,962	3,962
	200	–	–	8,000	18.6	4,000	7,544	–	7,544
Σ		36,700	100.0	43,000	100.0	40,558	7,544	33,014	40,558
r–r	141	4,400	45.4	5,000	26.3	3,962	–	4,575	4,575*
	200	–	–	8,000	42.1	7,544	7,328	–	7,328*
	126	5,300	54.6	6,000	31.6	5,900	–	5,503	5,503*
Σ		9,700	100.0	19,000	100.0	17,406	7,328	10,078	17,406

FOOTNOTES:

[a] All traffic data is 2-directional and measured as average daily traffic (ADT).
* Final, redistributed volumes as a result of traffic redistribution.

1. Sum the base year volumes, i.e., traffic counts (column a) and determine the % volume contribution (column b) for each link of cutline q-q. Note that since link #200 is a new facility, base year traffic counts do not exist and therefore columns a and b are left blank.

2. Since link #200 contributes additional capacity in the forecast year, columns c and d are filled in a manner similar to the preceding step.

3. Column e is now completed using the future year assignment volumes (from the all-or-nothing assignment) using data from Table G-1.

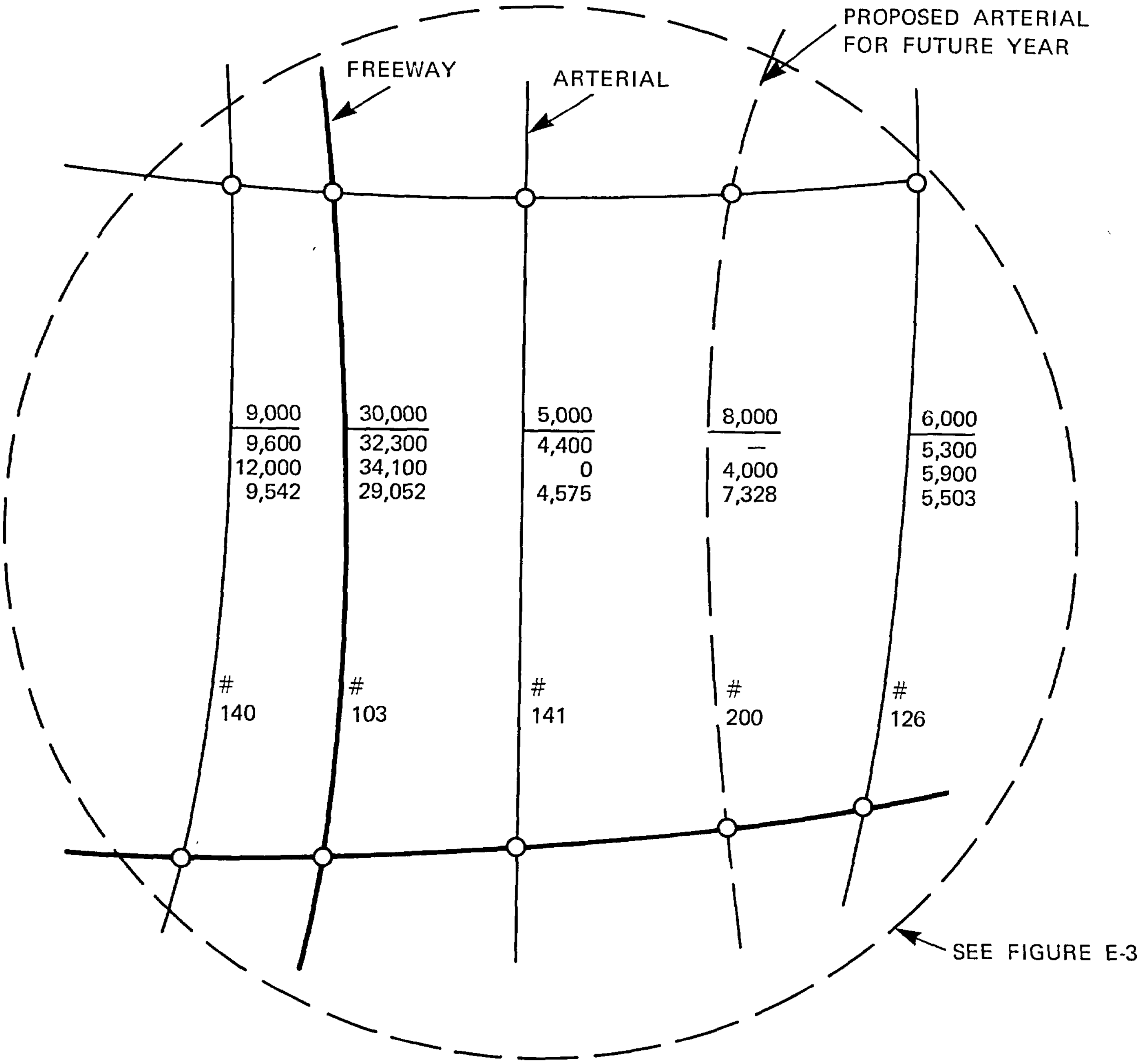
4. As a capacity change is expected to occur across cutline q-q, column f is completed for link #200. Thus, the capacity assignment adjustment for link #200 is 18.6% x 40,558 = 7,544, i.e., this volume of traffic can be expected for the new facility. The remaining forecast year assignment volume in column f, i.e., 40,558 - 7,544 = 33,014, is distributed to the other links of cutline q-q.

5. Hence the volume assignment adjustments (column g) for link #'s 103 and 141 can be computed in the proportion given in column b. Hence, for the former link, this adjustment is 88.0% x 33,014 = 29,052, i.e., this volume of traffic can be expected for link #103. A similar computation is done for link #141.

6. Finally, the total assignment adjustment for each link crossing cutline q-q is computed by adding the volumes in columns f and g. Note that the totals for column e and h are the same for cutline q-q; only the traffic within the cutline has been redistributed among the three links.

The six steps are similarly undertaken for cutline r-r. For r-r, the volumes for link #'s 141 and 200 in column e are the assignment adjustments from column h of the previous calculations for cutline q-q. Note that similar transformation was made for q-q, (the volumes for link #'s 103 and 141 in column e are adjustments from column h for cutline p-p). For p-p, however, no new facilities cross the cutline. Therefore, the computations in columns c, d and f are not necessary. The adjustments in column g are arrived at by proportioning the sum of traffic in column e using the percentages in column b. Thus, for link #140, the proportioned traffic equals 20.7% x 46,100 = 9,542. The asterisks in column h of Table G-2 indicate the final balanced volumes resulting from the redistribution technique. To refine these volumes, screenline A-A could be re-processed through the six steps outlined above. The second iteration might result in a small gain in accuracy of the balanced volumes. Iterations beyond the second iteration are not recommended.

Figure G-2 illustrates the capacity, the base year volumes, the future year assignment volumes and the balanced volumes for links crossing screenline A-A. The user can observe the effect of the redistribution of volumes among the facilities. The redistribution technique can be similarly applied, if need be, to other corridors in the study area shown in Figure E-3.



LEGEND:

9,000 → CAPACITY
9,600 → BASE YEAR GROUND COUNT
12,000 → FUTURE YEAR GROUND COUNT
9,542 → REDISTRIBUTED ASSIGNMENT VOLUME
(ALL TRAFFIC IN ADT)

FIGURE G-2

COMPARISON OF CAPACITY AND BASE YEAR, FUTURE YEAR AND REDISTRIBUTED TRAFFIC VOLUMES FOR HIGHWAY LINKS CROSSING SCREENLINE A-A

APPENDIX H

DETAILS OF THE PARTIAL MATRIX TECHNIQUE (PMT)

Theory of the PMT

The PMT is based on a straightforward extension and application of the theoretical work by Kirby 10/. A brief discussion of this theory and usage of the PMT is contained in reference 10/. Two of the results of Kirby's theoretical work used in the application of the PMT are as follows:

1. That the unknowns in the Gravity Model formulation can be derived from a partial set of observed trips;

2. That the solution from the partial set is unique, provided that the trip matrix cannot be partitioned such that diametrically opposite quadrants are zero.

The implication of these results is that having calibrated a Gravity Model to a partially observed matrix, one can use the parameters that have been derived to estimate the values of the unobserved trips of the matrix.

To demonstrate the capabilities of the PMT, consider a simple example where a study area is bounded by an external cordon and divided by a screenline running north-south (Figure H-1). Suppose that the analysis areas in the study area can be grouped into internal eastern zones (E) and internal western zones (W), and external zones (X). If the trip movements have been observed through screenline and cordon interviews, then such observations would be inserted in the "ticked" cells of the matrix. This partial set of trip observations would, in effect, constitute the partial trip matrix. The ultimate objective then is to estimate the trips in the unobserved cells of this matrix, thus yielding a total trip matrix. (In this particular example, the unobserved trips represent the intra-analysis area trips.)

Now, the Gravity Model relationship in its most elementary form is given by:

$$T_{ij} = a_i P_i \cdot b_j A_j \cdot f(I_{ij}) \cdot K_{ij} \quad \dots\dots\dots\dots\dots \quad (1)$$

where:

T_{ij} = trips produced in analysis area i and attracted at analysis area j

a_i = a constant associated with the production of trips at i

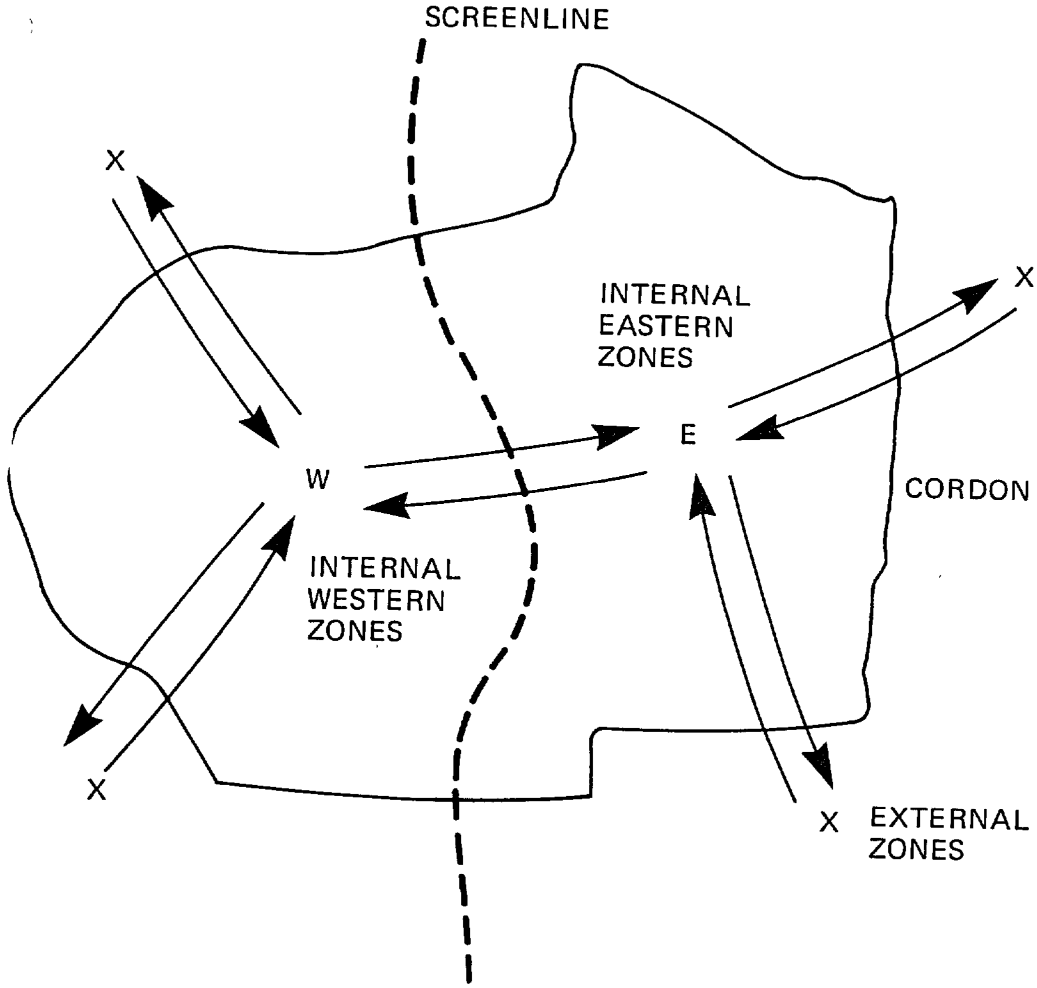
P_i = total trip production at i

b_j = a constant associated with the attraction of trips at j

A_j = total trip attraction at j

$f(I_{ij})$ = a function of the generalized impedance between interchange ij (usually the friction factor F_{ij})

K_{ij} = socio-economic adjustment factor (if necessary) for interchange ij



	E	W	X
E		√	√
W	√		√
X	√	√	

PARTIAL TRIP MATRIX

FIGURE H-1

HYPOTHETICAL STUDY AREA AND TRIP MOVEMENTS i = origin analysis area number, i=1,2,3...n

j = destination analysis area number, j=1,2,3...n

n = total number of analysis areas.

If K_{ij} is assumed to equal 1 for all trip interchanges, and if the total productions and total attractions for all the analysis areas are not known (as would be the case if one were to obtain trip interchange input from interviews only, as in the case of the PMT), then the Gravity Model formulation given by Equation (1) reduces to the following:

$$T^E_{ij} = X_i \cdot Y_j \cdot f(I_{ij}) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where:

T^E_{ij} = the estimated number of partial trips produced in analysis area i and attracted at analysis area j

X_i = a unique row factor associated with the production of trips at i (i.e., $X_i = a_i P_i \geq 0$)

Y_j = a unique column factor associated with the attraction of trips at j (i.e., $Y_j = b_j A_j \geq 0$)

If T^O_{ij} is the observed number of total trips between i and j (obtained from the screenline and cordon interviews), then the calibration process entails the determination of $f(I_{ij})$ such that the estimated partial trip interchanges (T^E_{ij}) "fit" the observed trip interchanges (T^O_{ij}).

Using the maximum likelihood function as the criterion for fitting the Gravity Model given by Equation (2), Kirby has shown that the values of X_i, Y_j and $f(I_{ij})$ are such that the following conditions are satisfied:

1. The sum of the estimated partial trips must equal the sum of the observed partial trips for each production analysis area (row partial totals), i.e.,

$$\sum_j T^E_{ij} = \sum_j T^O_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

2. The sum of the estimated partial trips must equal the sum of the observed partial trips for each attraction analysis area (column partial totals), i.e.,

$$\sum_i T^E_{ij} = \sum_i T^O_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

3. The total travel cost of the estimated partial trips must equal the total travel cost of the observed partial trips, i.e.,

$$\sum_i \sum_j T^E_{ij} \cdot I_{ij} = \sum_i \sum_j T^O_{ij} \cdot I_{ij} \quad \ldots\ldots\ldots\ldots (5)$$

The calibration process is thus one of establishing values of X_i and Y_j (in an iterative manner described below) and ensuring that the estimated partial matrix row sums equal the observed partial matrix row sums, and likewise for columns, and ensuring that the average trip lengths of the estimated and observed partial matrices are the same.

Once the values of X_i and Y_j and the calibrated impedance function are established, these factors can then be applied to determine the unobserved elements of the partial matrix, and thence the total production and attractions for each analysis area.

It must be noted that the matrix cells which were previously filled from the partial observations retain approximately the same value in the total synthetic matrix and should therefore be accurately observed. A very important assumption of the PMT is that for those cells of the partial trip matrix for which trip data is available (observed), this data represents all trips for that particular ij pair. Note also that the trip data collected from the interviews at the screenline and cordon stations could be for HBW or HBNW or NHB trips, or for all purpose trips. In many cases it would be most practical to record all trips without a purpose stratification. Such an interview would be of particular relevance for smaller urban areas where a distinction between the trip purposes may not be worthwhile for quick-response planning. (See subsection of Chapter Two entitled, "One-Purpose Gravity Model.")

Computational Steps for Application of the PMT

In actual application of the PMT, the iterative manner in which the X_i and Y_j factors are established is by successively balancing the row and column totals of the partial observed trip matrix. These successive steps are algebraically described below. This series of steps has been labelled Series B and Series C in order to correspond with the steps described later in the section entitled "An Example Application." Series A steps constitute those preliminary steps that are accomplished "external" to the PMT and precede the Series B steps. The Series B steps are as follows (except where noted, these steps apply only to the observed cells of the partial observed matrix):

STEP B1: Compute Row Balancing Factors 1 = ${}_1R_i$: For each row, the row balancing factor is given by:

$$ {}_1R_i = \frac{1}{\sum_j A_j F_{ij}} $$

STEP B2: Compute Trip Interchanges 1 for the Observed Cells of the Partial Matrix = ${}_1T^E_{ij}$: For each observed cell, the trip interchanges are given by:

$$ {}_1T^E_{ij} = P_i A_j F_{ij} \cdot {}_1R_i $$

Note that it has been assumed that $K_{ij} = 1$ for all the observed cells of the trip matrix in order to simplify the computational steps. Where and when necessary the K_{ij} factors can, of course, be incorporated. For the unobserved cells, K_{ij} is constrained to be zero; this constraint is relaxed in Step C4 when K_{ij} for these cells equals one (or the actual value if so desired or necessary).

STEP B3: Compute Column (Attraction Areas) Totals 1 = $\sum_i {}_1T^E_{ij}$: For each column, the total (partial) attractions are given by:

$$ \text{Column Total} = \sum_i {}_1T^E_{ij} $$

STEP B4: Compute Column Balancing Factors 2 = $_2C_j$: Since the column totals derived from Step B3 will not agree with the partial attraction totals, the column balancing factor for each column needs to be calculated as follows:

$$_2C_j = \frac{A_j}{\sum_i {}_1T^E_{ij}}$$

STEP B5: Compute Trip Interchanges 2 for the Observed Cells of the Partial Matrix = $_2T^E_{ij}$: The trip interchanges computed from Step B2 are now adjusted by using the column balancing factor from Step B4. Therefore, for each observed cell, the new trip interchanges are given by:

$$_2T^E_{ij} = {}_2C_j \cdot {}_1T^E_{ij}$$

STEP B6: Compute Row (Production Areas) Totals 2 = $\sum_j {}_2T^E_{ij}$: For each row, the total (partial) productions are given by:

$$\text{Row Total} = \sum_j {}_2T^E_{ij}$$

STEP B7: Compute Row Balancing Factors 3 = $_3R_i$: Now since the row totals derived from Step B6 will not be in agreement with the partial production totals, the row balancing factor for each row needs to be calculated as follows:

$$_3R_i = \frac{P_i}{\sum_j {}_2T^E_{ij}}$$

STEP B8: Compute Trip Interchanges 3 for the Observed Cells of the Partial Matrix = $_3T^E_{ij}$: The trip interchanges computed from Step B5 are now adjusted by using the row balancing factor from Step B7. Therefore, for each observed cell, the new trip interchanges are given by:

$$_3T^E_{ij} = {}_3R_i \cdot {}_2T^E_{ij}$$

STEP B9: Compute Column (Attraction Area) totals 3 = $\sum {}_3T^E_{ij}$: This step is similar to Step B3. Thus, for each column, the total (partial) attractions are given by:

$$\text{Column Total} = \sum_i {}_3T^E_{ij}$$

STEP B10: Compute Column Balancing Factors 4 = $_4C_j$: This step is similar to Step B4. Since the column totals derived from Step B9 will not agree with the partial attraction totals, the column balancing factor for each column needs to be calculated as follows:

$$_4C_j = \frac{A_j}{\sum_i {}_3T^E_{ij}}$$

STEP B11: Compute Trip Interchanges 4 for the Observed Cells of the Partial Matrix = ${}_4T^E_{ij}$: This step is similar to Step B5. The trip interchanges computed from Step B8 are now adjusted by using the column balancing factor from Step B10. Therefore, for each observed cell, the new trip interchanges are given by:

$${}_4T^E_{ij} = {}_4C_j \cdot {}_3T^E_{ij}$$

STEP B12: Compute Row (Production Area) Totals 4 = $\sum_j {}_4T^E_{ij}$: This step is similar to step B6. Thus, for each row, the total (partial) productions are given by:

$$\text{Row Total} = \sum_j {}_4T^E_{ij}$$

STEP B13: Compute Row Balancing Factors 5 = ${}_5R_i$: This step is similar to Step B7. Since the row totals derived from Step B12 will not be in agreement with the partial production totals, the row balancing factor for each row needs to be calculated as follows:

$${}_5R_i = \frac{P_i}{\sum_j {}_4T^E_{ij}}$$

STEP B14: Compute Trip Interchanges 5 for the Observed Cells of the Partial Matrix = ${}_5T^E_{ij}$: This step is similar to Step B8. The trip interchanges computed from Step B11 are now adjusted by using the row balancing factor from Step B13. Therefore, for each observed cell, the new trip interchanges are given by:

$${}_5T^E_{ij} = {}_5R_i \cdot {}_4T^E_{ij}$$

It can be seen therefore, that except for the initial two steps (i.e., Steps, B1 and B2), the subsequent steps represent the successive adjustments of trip interchanges - a series of adjustments by each column, and then a series of adjustments by each row. (Note that in the normal application of the Gravity Model, the production/row totals are constrained such that the estimated row totals are equal to the observed productions; it is the attraction/column totals that are iteratively "balanced.") Hence, Steps B3-B5 and Steps B9-B11 (and Steps B15-B17, Steps B21-B23, etc.) constitute a series of steps that perform adjustments by each column, whereas Steps B6-B8 and Steps B12-B14 (and Steps B18-B20, Steps B24-B26,etc.) constitute a series of steps that perform adjustments by each row.

Ultimately, the successive adjustments will result in the convergence of the trip interchanges, i.e., the estimated trip interchanges (T^E_{ij}) for the observed cells will equal the observed trip interchanges (T^O_{ij}). In other words, at some point, the column and row balancing factors will equal unity. thus, if n is the number of adjustments, then at the point of convergence:

$${}_nC_j = 1 \quad \text{and} \quad {}_{n+1}R_i = 1$$

In practice and actual application of the PMT, near convergence occurs when $8 \leq n < 10$, at which point the column and row adjustment factors are <u>approximately</u>

equal to 1. At this juncture, the Series C Steps are entered in the following manner:

STEP C1: Compute the Unique Row Factor X_i and the Unique Column Factor Y_j: These unique factors, used in Equation (2) above are computed as follows:

$$X_i = P_i \left(\prod_n {}_nR_i\right) \quad \text{-- for each row}$$

$$Y_j = A_j \left(\prod_n {}_nC_j\right) \quad \text{-- for each column}$$

where π represents the product, over n adjustments, of R_i and C_j

STEP C2: Compute Trip Interchanges for the Observed Cells = T^E_{ij}: The trip interchanges are computed using Equation (2), for the observed cells of the partial matrix. Thus:

$$T^E_{ij} = X_i \cdot Y_j \cdot F_{ij}$$

STEP C3: Plot Trip Length Frequence Distribution of the Estimated Partial Trips = T^E_{ij} and Compare with the Observed Partial Trips = T^O_{ij}: The purpose of this comparison is to check whether the estimated trip length frequency distribution agrees with that for the observed trips. In actuality, this process is the calibration of the friction factors. The calibration and the adjustments of the F-factors can be carried out in the usual manner. (See Reference 8 for example.) Then, using the calibrated friction factors, the Series B steps must be re-applied, Step C3 reentered, and then the estimated and observed trip length frequency distributions compared.

However, for sketch planning, this calibration can be bypassed, in particular if a calibrated set of friction factors has been used. Such calibrated friction factors can be obtained from local study area data, or default values as presented in Appendix A, may be used. In any case, when the friction factors are calibrated, i.e., when the trip length frequency distributions for the estimated and observed trips match, Step C4 is entered.

STEP C4: Compute Trip Interchanges for the Observed and Unobserved Cells = T^E_{ij}: These trip interchanges are computed using Equation (2) for the observed and unobserved cells of the partial matrix. Thus, for every cell in the matrix:

$$T^E_{ij} = X_i \cdot Y_j \cdot F_{ij}$$

As noted in the preceding discussion, the socio-economic factors (K_{ij}), if used at all, had been assumed to be unity for the observed cells of the partial matrix and constrained to be zero for the unobserved cells. In Step C4, the constraint for the unobserved cells is relaxed. Hence, $K_{ij} = 1$, or if required, K_{ij} is set to some other value particular to that interchange.

STEP C5: Compute Total Trip Productions and Attractions for All Analysis Areas: By using the now complete matrix, the total trip ends are computed as follows:

$$P_i = \sum_j T^E_{ij} \qquad \text{and} \qquad A_j = \sum_i T^E_{ij}$$

The PMT is now considered to be completely applied.

In order to illustrate the actual usage of the PMT, the following example application is provided. This sample application makes use of the Series A steps, and the Series B and C steps (the latter two as described above).

An Example Application

Suppose that the average daily internal travel for five districts in a hypothetical urban area of 60,000 population is to be analyzed (The internal travel includes trips by all three trip purposes, i.e., HBW + HBNW + NHB trips.) For this reason, a cordon has been imposed around the CBD and a screenline running north-south has also been sited.

The procedural steps required for the application of the PMT are described below. As mentioned in the preceding sections, the Series A steps constitute the preliminary set-up steps, whereas the Series B and C steps represent the computational steps.

STEP A1: Map of Study Area: Lay out a map showing the five districts, the district centroids and subregion boundaries (Figure H-2). Also, the cordon line, the screenline and the interview stations are located on the map.

STEP A2: Conduct Cordon and Screenline Roadside Interviews: These interviews can be conducted as described in Chapter Three. For this illustrative example, assume that these interviews resulted in the partial matrix of trips shown in Figure H-3.* Thus, for example, the screenline interview station between districts #2 and #3 yielded 1,400 all purpose internal trips from district #2 to #3, and 2,700 trips from district #3 to #2. Figure H-3 also shows the row and column summation of the partial-observed trips, i.e., the partial production and attraction trip ends. Hence, for district #2, there are 6,500 partial production trip ends and 7,000 partial attraction trip ends. In all, the partial trip matrix yields 58,100 trip interchanges between the 5 districts in the study area. The partial P's and A's are recorded in the PMT worksheet as shown in Figure H-4. Normally the analyst would use factors from Appendix A.

STEP A3: Develop District-to-District Travel Times and Distribution Factors = t_{ij}, F_{ij}: This step is identical to Step 3 described in Appendix B. These travel times and distribution factors are developed for all trip interchanges (actually, for one-half of the 5 x 5 interchanges) and recorded in the appropriate locations as exhibited in Figure H-4. It can be seen that it takes 8 minutes to travel (by highway) from district #2 to district #3, and the corresponding all purpose distribution factor is 0.23. (Note also that these same parameters hold for the district #3 to #2 trip interchange.) The friction factors for this example are not from Appendix A, but have been fabricated for this example.

*Note that for purely illustrative purposes, the trips for the partial-observed matrix have been made to correspond to those from a full-scale GM. (See Figure B-5.)

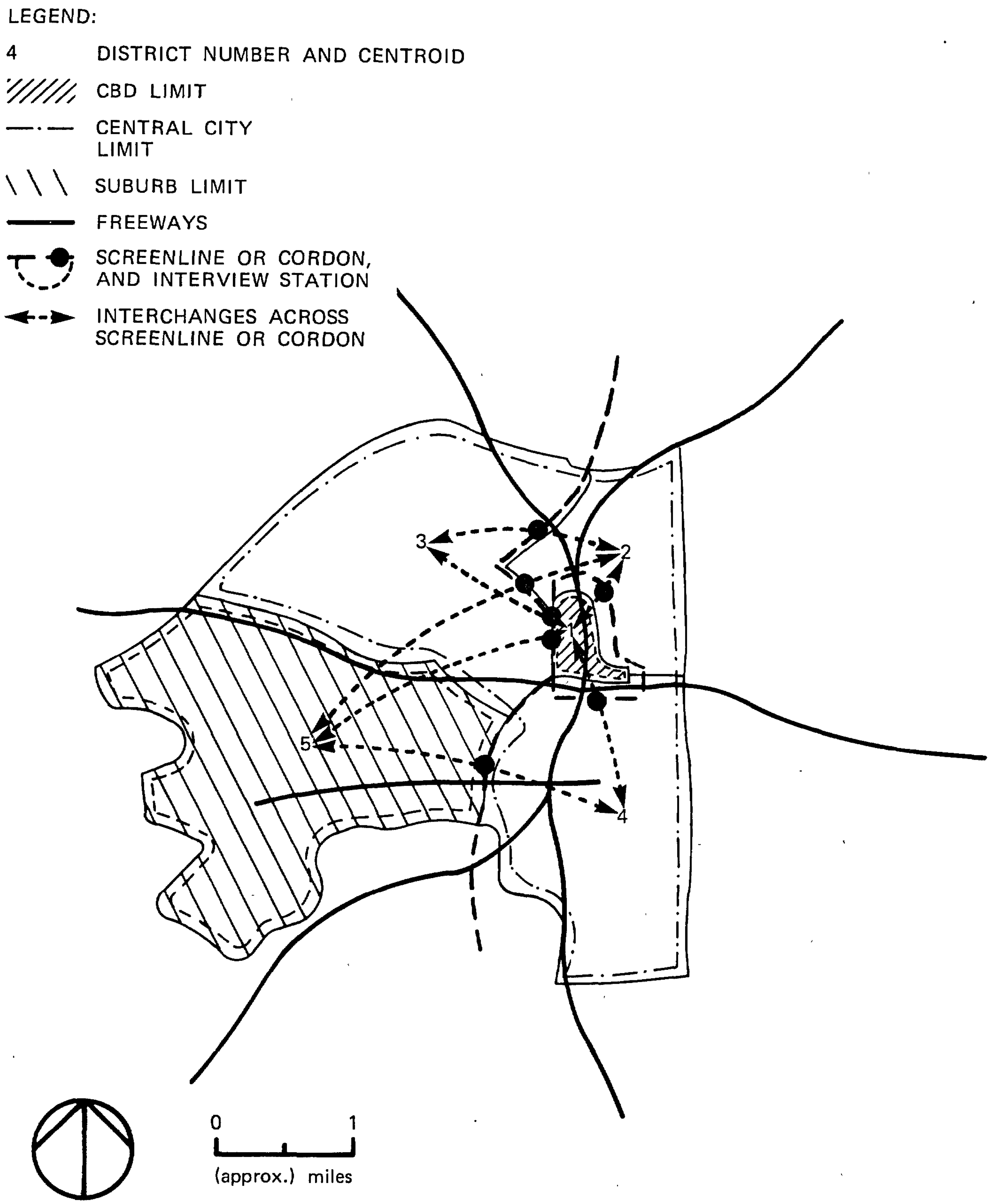


FIGURE H-2

MAP OF STUDY AREA:
HYPOTHETICAL CITY (STEP A1)

Production Districts \ Attraction Districts	1	2	3	4	5	ΣPi
1		700	900	1,000	300	2,900
2	4,700		1,400		400	6,500
3	11,800	2,700				14,500
4	8,100				1,000	9,100
5	14,700	3,600		6,800		25,100
ΣA_j	39,300	7,000	2,300	7,800	1,700	58,100

FIGURE H-3

PARTIAL AVERAGE DAILY VEHICLE TRIP MATRIX
RESULTING FROM TRIPS OBSERVED AT THE CORDON AND
SCREENLINE INTERVIEW STATIONS (STEP A2)

TRIP	AREA TYPE	AREA #	P_i \ A_j	ATTRACTION: CBD 1		CENTRAL CITY 2		CENTRAL CITY 3		CENTRAL CITY 4		SUBURB 5	
				39,300		7,000		2,300		7,800		1,700	
PRODUCTION	CBD	1	2,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20
PRODUCTION	CENTRAL CITY	2	6,500	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17
PRODUCTION	CENTRAL CITY	3	14,500	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28
PRODUCTION	CENTRAL CITY	4	9,100	6	0.34	6	0.34	10	0.17	4	0.53	8	0.23
PRODUCTION	SUBURB	5	25,100	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34

NOTE: Friction Factors for this example are *not* from Appendix A, but were fabricated for this example.

FIGURE H-4

PMT WORKSHEET SHOWING PARTIAL PRODUCTION AND ATTRACTION TRIP ENDS (STEP A2), AND DISTRICT-TO-DISTRICT TRAVEL TIMES AND DISTRIBUTION FACTORS (STEP A3)

Having completed the preliminary Steps A1-A3, the planner is now ready to embark on the Series B steps which enable the computation of the trip interchanges for the partial trip matrix. The Series B steps are applied in exactly the same manner as that described above. The computations can be carried out using a desk calculator with an accumulating memory.

STEP B1: Compute Row Balancing Factors 1 = ${}_1R_i$: This factor is best calculated by first computing the $\sum_j A_j F_{ij}$ for the partial-observed cells: ${}_1R_i$ can then be obtained by taking the reciprocal of $\sum_j A_j F_{ij}$. For production district #2 then:

$$A_j F_{2j} = (39{,}300 \times 0.34) + (2{,}300 \times 0.23) + (1{,}700 \times 0.17) = 14{,}180$$

$$\therefore\ {}_1R_2 = 1/14{,}180 = 0.705 \times 10^{-4}$$

This step is similarly undertaken for all rows. The PMT worksheet (Figure H-5) shows these computations.

STEP B2: Compute Trip Interchanges 1 for the Observed Cells of the Partial Matrix = ${}_1T^E_{ij}$: For each observed cell, the trip interchanges are given by:

$${}_1T^E_{ij} = P_i A_j F_{ij} \cdot {}_1R_i$$

Hence, for the district #2 to #3 interchange:

$${}_1T^E_{23} = 6{,}500 \times 2{,}300 \times 0.23 \times 0.705 \times 10^{-4} = 240 \text{ trips}$$

All such computations for the observed cells are recorded in Figure H-5. These computations can be performed most efficiently for each row by inserting the $(P_i \cdot {}_1R_i)$ factor into the memory of the desk calculator and then multiplying the appropriate A_j and F_{ij} factors for the observed cells.

STEP B3: Compute Column (Attraction Areas) Totals 1 = $\sum_i {}_1T^E_{ij}$: For each column, the total attractions are given by:

$$\text{Column Total} = \sum_i {}_1T^E_{ij}$$

For attraction district #3, for example, the column total is given by:

$$\sum_i {}_1T^E_{i3} = 310 + 240 = 550 \text{ trip ends}$$

These summations are also shown in Figure H-5.

Trip	Area Type	Area #	P_i \ A_j	CBD: 1		Central City: 2		Central City: 3		Central City: 4		Suburb: 5		$\Sigma_j A_jF_{ij}$	$\Sigma_j 2T_{ij}$	$_1R_i$ / $_3R_i$	
				39,300		7,000		2,300		7,800		1,700					
Production	CBD	1	2,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20	6,106		1.662	$\times 10^{-4}$
						1,150	1,400	310	1,300	1,280	1,840	160	490		5,030	0.577	
	Central City	2	6,500	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17	14,180		0.705	$\times 10^{-4}$
				6,130	5,260			240	1,000			130	400		6,660	0.976	
	Central City	3	14,500	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28	12,614		0.793	$\times 10^{-4}$
				12,650	10,850	1,850	2,250								13,100	1.107	
	Central City	4	9,100	6	.0.34	6	0.34	10	0.17	4	0.53	8	0.23	13,753		0.727	$\times 10^{-4}$
				8.840	7,580							260	800		8,380	1.086	
	Suburb	5	25,100	9	0.20	10	0:17	7	0.28	8	0.23	6	0.34	10,844		0.922	$\times 10^{-4}$
				18,190	15,600	2,750	3,350			4,150	5,960				24,910	1.008	
$\Sigma_j 1T_{ij}$	$2C_j$			45,810	0.858	5,750	1.217	550	4.182	5,430	1.436	550	3.091				

NOTE: Friction Factors for this example are *not* from Appendix A, but were fabricated for this example.

FIGURE H-5

PMT WORKSHEET SHOWING COMPUTATIONS FOR STEP B1 THROUGH STEP B7

STEP B4: Compute Column Balancing Factors 2 = $_2C_j$: The balancing factor for each column is given by:

$$_2C_j = \frac{A_j}{\sum_i {_1T^E_{ij}}}$$

So, for attraction district #3:

$$_2C_3 = \frac{2,300}{550} = 4.182$$

All the column balancing factors are recorded in Figure H-5.

STEP B5: Compute Trip Interchanges 2 for the Observed Cells of the Partial Matrix = $_2T^E_{ij}$: These interchanges can be computed by using:

$$_2T^E_{ij} = {_2C_j} \cdot {_1T^E_{ij}}$$

For the district #2 to #3 interchange:

$$_2T^E_{23} = 4.182 \times 240 = 1,000 \text{ trips}$$

The PMT worksheet in Figure H-5 exhibits all such computations. On the desk calculator, Steps B3-B5 can be performed sequentially for each column to achieve computational time savings.

STEP B6: Compute Row (Production Areas) Totals 2 = $\sum_j {_2T^E_{ij}}$: For each row, the total productions are are given by:

$$\text{Row Total} = \sum_j {_2T^E_{ij}}$$

For production district #2:

$$\sum_j {_2T^E_{2j}} = 5,260 + 1,000 + 400 = 6,660 \text{ trip ends}$$

All such computations are documented in Figure H-5.

STEP B7: Compute Row Balancing Factors 3 = $_3R_i$: The balancing factor for each row can be computed as follows:

$$_3R_i = \frac{P_i}{\sum_j {}_2T^E_{ij}}$$

Hence, for production district #2:

$$_3R_2 = \frac{6,500}{6,660} = 0.976$$

All the row balancing factors are shown in Figure H-5.

STEP B8: Compute Trip Interchanges 3 for the Observed Cells of the Partial Matrix = $_3T^E_{ij}$: For each observed cell, the trip interchanges can be calculated using:

$$_3T^E_{ij} = {}_3R_i \cdot {}_2T^E_{ij}$$

Hence, the trip interchange from district #2 to #3 is:

$$_3T^3_{23} = 0.976 \times 1,000 = 980 \text{ trips}$$

These calculations are recorded in Figure H-6. Again, to achieve computational time savings, Steps B6-B8 can be performed sequentially for each row on the desk calculator.

From this point on, the PMT computational steps are identical to those already accomplished. Thus, Steps B9 through B13 correspond to Steps B3 through B7, respectively. The computations resulting from Steps B9 through B13 are recorded in Figure H-6 (along with all the computations conducted for the preceding steps).

Figure H-7 exhibits the computations resulting from Steps B14 through B19 (corresponding to Steps B8 through B13, respectively) and computations resulting from the preceding steps.

At the end of the Series B steps, the row and column balancing factors (R_i and C_j) must approximate unity, otherwise an error must have been made in the calculations. In fact, for each successive calculation of the row or column balancing factor, the factor should be rapidly converging to unity. In Figure H-7, the final row balancing factor for production district #2 ($_7R_i$ = $_7R_2$) is 0.992 and the final column balancing factor for attraction distirct #3 ($_8C_j$ = $_8C_3$) is 1.013. For the purposes of quick, manual planning, these factors can be considered to be sufficiently close to unity. At this juncture, the Series C steps are entered as follows:

Trip	Area type	Area #	P_i \ A_j	1 (CBD)		2 (Central City)		3 (Central City)		4 (Central City)		5 (Suburb)		$\Sigma_j A_jF_{ij}$	$\Sigma_j 2T_{ij}$ / $\Sigma_j 4T_{ij}$	$_1R_i$ / $_3R_i$ / $_5R_i$	
				39,300		7,000		2,300		7,800		1,700					
PRODUCTION	CBD	1	2,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20	6,106		1.662	$\times 10^{-4}$
						1,150	1,400	310	1,300	1,280	1,840	160	490		5,030	0.577	
						810	850	750	1,000	1,060	1,170	280	310		3,330	0.871	
	CENTRAL CITY	2	6,500	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17	14,180		0.705	$\times 10^{-4}$
				6,130	5,260			240	1,000			130	400		6,660	0.976	
				5,130	4,910			980	1,300			390	430		6,649	0.979	
		3	14,500	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28	12,614		0.793	$\times 10^{-4}$
				12,650	10,850	1,850	2,250								13,100	1.107	
				12,010	11,490	2,490	2,610								14,100	1.028	
		4	9,100	6	0.34	6	0.34	10	0.17	4	0.53	8	0.23	13,753		0.727	$\times 10^{-4}$
				8,840	7,580							260	800		8,380	1.086	
				8,230	7,870							870	960		8,830	1.031	
	SUBURB	5	25,100	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34	10,844		0.922	$\times 10^{-4}$
				18,190	15,600	2,750	3,350			4,150	5,960				24,910	1.008	
				15,720	15,040	3,380	3,540			6,000	6,630				25,210	0.996	
$\Sigma_j 1T_{ij}$		$2C_j$		45,810	0.858	5,750	1.217	550	4.182	5,430	1.436	550	3.091				
$\Sigma_j 3T_{ij}$		$4C_j$		41,090	0.956	6,680	1.048	1,730	1.329	7,060	1.105	1,540	1.104				

NOTE: Friction Factors for this example are *not* from Appendix A, but were fabricated for this example.

FIGURE H-6

PMT WORKSHEET SHOWING COMPUTATIONS FOR STEP B8 THROUGH STEP B13

TRIP	AREA TYPE	AREA #	P_i \ A_j	CBD 1		CENTRAL CITY 2		CENTRAL CITY 3		CENTRAL CITY 4		SUBURB 5		$\Sigma_j A_jF_{ij}$	$\Sigma_j 2T_{ij}$ / $\Sigma_j 4T_{ij}$ / $\Sigma_j 6T_{ij}$	$_1R_i$ / $_3R_i$ / $_5R_i$ / $_7R_i$	
			A_j	39,300		7,000		2,300		7,800		1,700					
PRODUCTION	CBD	1	2,900	5	0.42	6	0.34	7	0.28	6	0.34	9	0.20	6,106		1.662	$\times 10^{-4}$
						1,150	1,400	310	1,300	1,280	1,840	160	490		5,030	0.577	
						810	850	750	1,000	1,060	1,170	280	310		3,330	0.871	
						740	750	870	940	1,020	1,040	270	270		3,000	0.967	
						730		910		1,010		260					
	CENTRAL CITY	2	6,500	6	0.34	4	0.53	8	0.23	6	0.32	10	0.17	14,180		0.705	$\times 10^{-4}$
				6,130	5,260			240	1,000			130	400		6,660	0.976	
				5,130	4,910			980	1,300			390	430		6,640	0.979	
				4,800	4,750			1,270	1,370			420	430		6,550	0.992	
				4,710				1,360				430					
		3	14,500	7	0.28	8	0.23	5	0.42	10	0.17	7	0.28	12,614		0.793	$\times 10^{-4}$
				12,650	10,850	1,850	2,250								13,100	1.107	
				12,010	11,490	2,490	2,610								14,100	1.028	
				11,820	11,690	2,680	2,700								14,390	1.008	
				11,780		2,720											
		4	9,100	6	0.34	6	0.24	10	0.17	4	0.53	8	0.23	13,753		0.727	$\times 10^{-4}$
				8,840	7,580							260	800		8,380	1.086	
				8,230	7,870							870	960		8,830	1.031	
				8,110	8,020							990	1,000		9,020	1.009	
				8,090								1,010					
	SUBURB	5	25,100	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34	10,844		0.922	$\times 10^{-4}$
				18.180	15,600	2,750	3,350			4,150	5,960				24,910	1.008	
				15,720	15,040	3,380	3,540			6,000	6,630				25,210	0.996	
				14,970	14,800	3,520	3,550			6,660	6,760				25,110	1.000	
				14,800		3,550				6,760							
$\Sigma_j 1T_{ij}$		$2C_j$		45,810	0.858	5,750	1.217	550	4.182	5,430	1.436	550	3.091				
$\Sigma_j 3T_{ij}$		$4C_j$		41,090	0.956	6,680	1.048	1,730	1.329	7,060	1.105	1,540	1.104				
$\Sigma_j 5T_{ij}$		$6C_j$		39.700	0.989	6,940	1.009	2,140	1.075	7,620	1.024	1,680	1.012				
$\Sigma_j 7T_{ij}$		$8C_j$		39,380	0.998	7,000	1.000	2,270	1.013	7,770	1.004	1,700	1.000				

NOTE: Friction Factors for this example are *not* from Appendix A, but were fabricated for this example.

FIGURE H-7

PMT WORKSHEET SHOWING COMPUTATIONS FOR STEP B14 THROUGH STEP B19

STEP C1: Compute the Unique Row Factor X_i and the Unique Column Factor Y_j: For each row, the X_i factor is obtained from:

$$X_i = P_i \left(\prod_n {}_nR_i\right)$$

Thus, for production district #2:

$$X_2 = 6{,}500(0.705 \times 10^{-4} \times 0.976 \times 0.992) = 0.434$$

For each column, the Y_j factor is obtained from:

$$Y_j = A_j \left(\prod_n {}_nC_j\right)$$

Thus, for attraction district #3:

$$Y_3 = 2{,}300(4.182 \times 1.329 \times 1.075 \times 1.013) = 13{,}920$$

All computations resulting from this step are exhibited in Figure H-8.

STEP C2: Compute Trip Interchanges for the Observed Cells = T^E_{ij}: For each observed cell of the partial trip matrix, the trip interchanges can be calculated as follows:

$$T^E_{ij} = X_i \cdot Y_j \cdot F_{ij}$$

Hence, for the district #2 to #3 interchange:

$$T^E_{23} = 0.434 \times 13{,}920 \times 0.23 = 1{,}390 \text{ trips}$$

All such computations for the observed cells are recorded in Figure H-8.

STEP C3: Plot Trip Length Frequency Distribution of the Estimated Partial Trips = T^E_{ij} - and Compare with the Observed Partial Trips = T^o_{ij}: For the purposes of small urban area application, this step can be bypassed since it is assumed that calibrated friction factors have been utilized in the preceding steps. (See "STEP C3" under section entitled, "Computational Steps for Application of the PMT.") It is also assumed that the estimated trip length frequency distribution matches the observed trip length frequency distribution. Therefore, Step C4 can then be entered.

STEP C4: Compute Trip Interchanges for the Observed and Unobserved Cells = T^E_{ij}: Because Step C3 has been bypassed, Step C4 is applicable for the unobserved

TRIP / AREA TYPE	AREA #	P_i \ A_j	CBD 1		CENTRAL CITY 2		CENTRAL CITY 3		CENTRAL CITY 4		SUBURB 5		$\Sigma_j A_j F_{ij}$	$\Sigma_j 2T_{ij}$ / $\Sigma_j 4T_{ij}$ / $\Sigma_j 6T_{ij}$	$_1R_i$ / $_3R_i$ / $_5R_i$ / $_7R_i$
			39,300		7,000		2,300		7,800		1,700				
PRODUCTION CBD	1	2,900	5	0 42	6	0.34	7	0.28	6	0.34	9	0.20	6,106		1.662 $\times 10^{-4}$
					1,150	1,400	310	1,300	1,480	1,840	160	490		5,030	0.577
					810	850	750	1,000	1,060	1,170	280	310		3,330	0.871
					740	750	870	940	1,020	1,040	270	270		3,000	0.967
				3,130	730	720	910	910	1,010	1,010	260	270		0.234	
PRODUCTION CENTRAL CITY	2	6,500	6	0.34	4	0.53	8	0.23	6	0.34	10	0.17	14,180		0.705 $\times 10^{-4}$
			6,130	5,360			240	1,000			130	400		6,660	0.976
			5,130	4,910			980	1,300			390	430		6,640	0.979
			4,800	4,750			1,270	1,370			420	430		6,550	0.992
			4,710	4,690		20.70	1,360	1,390		1,880	430	430		0.434	
PRODUCTION CENTRAL CITY	3	14,500	7	0.18	8	0.23	5	0.42	10	0.17	7	0.28	12,614		0.793 $\times 10^{-4}$
			12,650	10,850	1,850	2,250								13,100	1.107
			12,010	11,490	2,490	2,610								14,100	1.028
			11,820	11,690	2,680	2,700								14,390	1.008
			11,780	11,750	2,720	2,730		7,710		2,850		2,170		1.319	
PRODUCTION CENTRAL CITY	4	9,100	6	0.34	6	0.34	10	0.17	4	0.53	8	0.23	13,753		0.727 $\times 10^{-4}$
			8,840	7,580							260	800		8,380	1.086
			8,230	7,870							870	960		8,830	1.031
			8,110	8,020							990	1,000		9,020	1.009
			8,090	8,080		2,290		1,770		5,040	1,010	1,010		0.747	
PRODUCTION SUBURB	5	25,100	9	0.20	10	0.17	7	0.28	8	0.23	6	0.34	10,844		0 922 $\times 10^{-4}$
			18,180	15,600	2,750	3,750			4,150	5,960				24,910	1.008
			15,720	15,040	3,380	3,540			6,000	6,630				25,210	0.996
			14,970	14,800	3,520	3,550			6,600	6,760				25,110	1.000
			14,800	14,780	3,550	3,560		9,050	6,760	6,800		4,640		2.323	
$\Sigma_j 1T_{ij}$	$2C_j$		45,810	0.858	5,750	1.217	550	4.182	5,430	1.436	550	3.091			
$\Sigma_j 3T_{ij}$	$4C_j$		41,090	0.956	6,680	1.048	1,730	1.329	7,060	1.105	1,540	1.104			
$\Sigma_j 5T_{ij}$	$6C_j$		39,700	0.989	6,940	1.009	2,140	1.075	7,620	1.024	1,680	1.012			
$\Sigma_j 7T_{ij}$	$8C_j$		39,380	0.998	7,000	1.000	2,270	1.013	7,770	1.004	1,700	1.000			
			31,817		9,008		13,920		12,724		5,870				

NOTE: Friction Factors for this example are *not* from Appendix A, but were fabricated for this example.

FIGURE H-8

PMT WORKSHEET SHOWING COMPUTATIONS FOR STEPS C-1, C2 AND C4 only since the estimated trips in the observed cells will remain unchanged. Thus, for the unobserved cells in the matrix, the trip interchanges can be computed using (once again):

$$T^E_{ij} = X_i \cdot Y_j \cdot F_{ij}$$

Hence, for the district #2 to #4 interchange:

$$T^E_{24} = 0.434 \times 12{,}724 \times 0.34 = 1{,}880 \text{ trips}$$

All such computations for the unobserved cells are shown in Figure H-8 also.

STEP C5: Compute Total Trip Productions and Attractions for All Analysis Areas: The total trip ends can be computed as follows:

$$P_i = \sum_j T^E_{ij} \quad \text{and}$$

$$A_j = \sum_i T^E_{ij}$$

For production district #2:

$$P_2 = 4{,}690 + 2{,}070 + 1{,}390 + 1{,}880 + 430 = 10{,}460 \text{ trip ends}$$

For attraction district #3:

$$A_3 = 910 + 1{,}390 + 7{,}710 + 1{,}770 + 9{,}050 = 20{,}830 \text{ trip ends}$$

The completed trip matrix (using the PMT) is displayed in Figure H-9. This figure also shows the trip matrix obtained from a full-scale GM. (See Figure H-9.) The superimposition of the PMT trip interchanges with those obtained from the GM enables a comparison to be made between these trips. It can be observed from Figure H-9 that the PMT trip interchanges compare extremely well with the GM trips, in particular between those districts that have relatively large numbers of both production and attraction trip ends (e.g., districts #2, #3 and #4). For these trip interchanges, the percentage difference between the PMT trips and the GM trips lies between -1.7% to +4.1%.

However, for district #1, which produces 6,000 trips (GM) this percentage error ranges from +1.0% to +10.0% for trips from district #1; for district #5, which attracts 8,200 trips (GM), the percentage error ranges from +1.0% to +10.0%.

As a final step, the trips actually observed at the cordon and screenline interview stations are inserted into the partial-observed cells, whereas the PMT trips are retained for the unobserved cells. The final, completed trip matrix is shown in Figure H-10.

PRODUCTION DISTRICTS \ ATTRACTION DISTRICTS	1	2	3	4	5	ΣP_i
1	3,130 3,100 +1.0	720 700 +2.9	910 900 +1.1	1,010 1,000 +1.0	270 300 +10.0	6,040 6,000 +0.7
2	4,690 4,700 −0.2	2,070 2,100 −1.4	1,390 1,400 −0.7	1,880 1,900 −1.1	430 400 +7.5	10,460 10,500 −0 4
3	11,750 11,800 −0.4	2,730 2,700 +1.1	7,710 7,600 +1.4	2,850 2,900 −1.7	2,170 2,100 +3.3	27,210 27,100 +0.4
4	8,080 8,100 −0.2	2,290 2,300 −0.4	1,770 1,700 +4.1	5,040 5,100 −0.6	1,010 1,000 +1.0	18,190 18,200 −0.1
5	14,780 14,700 +0.5	3,560 3,600 −1.1	9,050 9,000 +0.6	6,800 6,800 0 0	4,640 4,400 +5 5	38,830 38,500 +0.9
ΣA_j	42,430 42,400 +0.1	11,370 11,400 −0.3	20,830 20,600 +1.1	17,580 17,700 −0.7	8,520 8,200 +3.9	100,730 100,300 +0.4

LEGEND:

PARTIAL-OBSERVED CELL

3,370 → TRIP INTERCHANGES USING THE PMT (See Figure H-8)

3,100 → TRIP INTERCHANGES USING FULL-SCALE GM (See Figure B-5)*

+8 7 → % DIFFERENCE $\left(\frac{\text{PMT}-\text{GM}}{\text{GM}}\right) \times 100\%$

*The full-scale GM trip interchanges might not completely agree with those shown in Figure B-5 due to rounding of numbers.

FIGURE H-9

COMPARISON OF TRIP INTERCHANGES OBTAINED FROM THE PMT AND FROM A FULL-SCALE GM

Production Districts \ Attraction Districts	1	2	3	4	5	ΣPi
1	3,130	700	900	1,000	300	6,030
2	4,700	2,070	1,400	1,880	400	10,450
3	11,800	2,700	7,710	2,850	2,170	27,230
4	8,100	2,290	1,770	5,040	1,000	18,200
5	14,700	3,600	9,050	6,800	4,640	38,790
ΣA_j	42,430	11,360	20,830	17,570	8,510	100,700

FIGURE H-10

COMPLETED TRIP MATRIX
RESULTING FROM THE USE OF THE PMT

It can be seen that the use of the PMT enables not only the completion of a partially observed trip matrix, but also a synthesis of the production and attraction trip ends for the zones in the study area. Further, if a cordon can be positioned at the extremities of a study area, the PMT will also enable the estimation of external trip ends and external trip interchanges.

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