APPLICATION OF A PROBABILISTIC MULTIPATH TRAFFIC ASSIGNMENT MODEL TO LAWRENCE, KANSAS

by

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LIST OF FIGURES AND TABLES

CHAPTER I

INTRODUCTION

The Federal-Aid Highway Act of 1962 required that all urban areas of over 50,000 population have underway a continuing, comprehensive transportation planning process carried out in cooperation with the state and Federal governments. The basic steps in the process are shown in Figure I-1. The goals and objectives, social and economic characteristics, land use, transportation facilities and travel patterns are inventoried and analyzed for use in the calibration of forecasting techniques and projected for use in forecasting future travel.

An integral part of the calibration of forecasting techniques and the forecasts of future travel is the process of allocating the trip interchanges between all origin-destination (O-D) points to a transportation system (See Appendix E - Definitions for further explanation of terms). This process, called traffic assignment and shown in Figure I-2, can include the simulation of existing conditions or the simulation of future year traffic. The O-D survey is typically used for reproduction of existing conditions while in the future year a forecast must be made of trip interchange prior to assignment. Some of the uses of traffic assignment include:

1. Evaluation of alternate transportation systems.
2. Development of short range improvement programs and construction priorities.
3. Study of traffic generators and their effects on the system.
4. Evaluation of alternative locations of facilities and service within a corridor.
5. Provision of design volumes.
6. Provision of input and feedback to other areas of the planning process.[1]

CONTINUING URBAN TRANSPORTATION PLANNING PROCESS

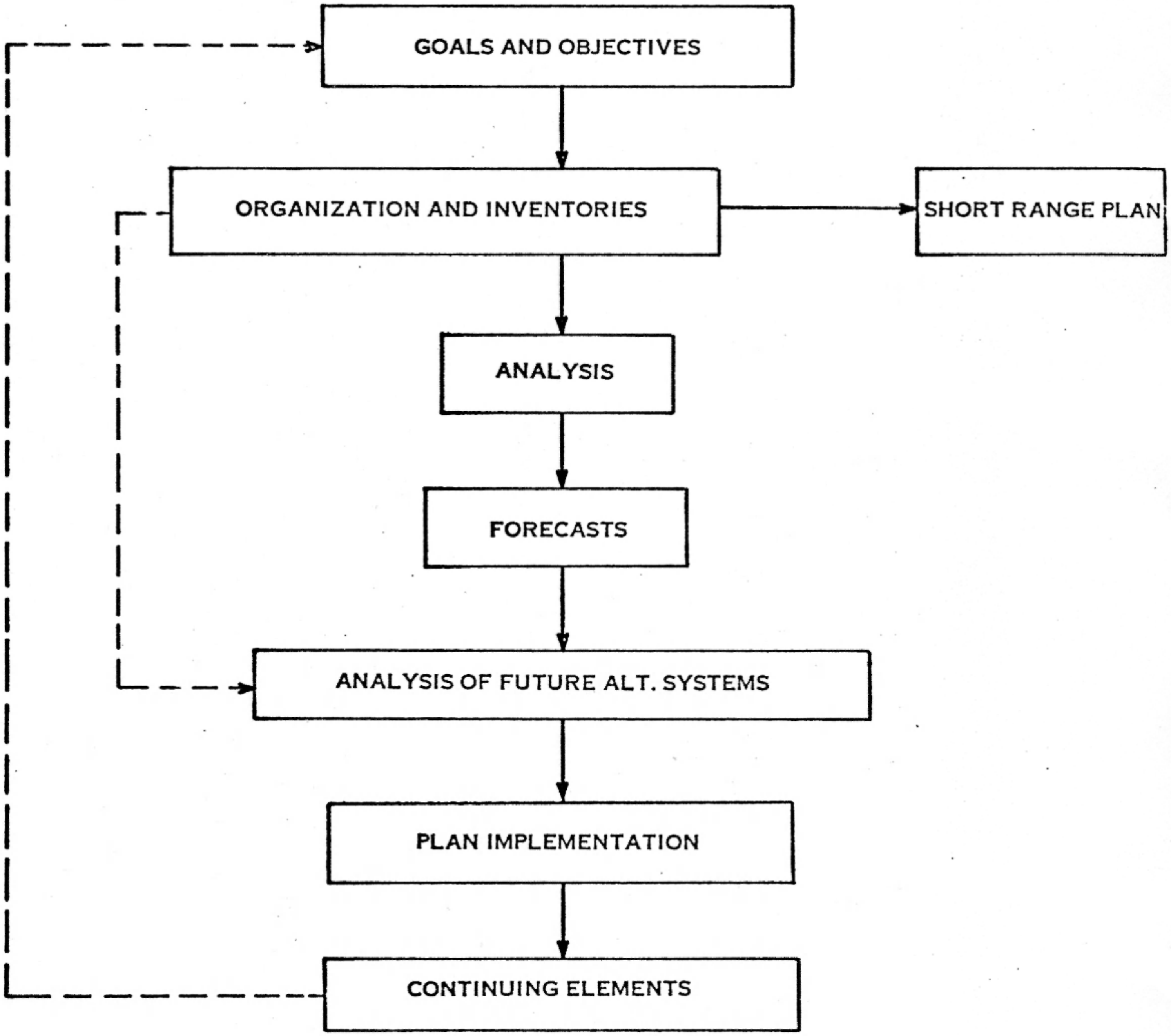
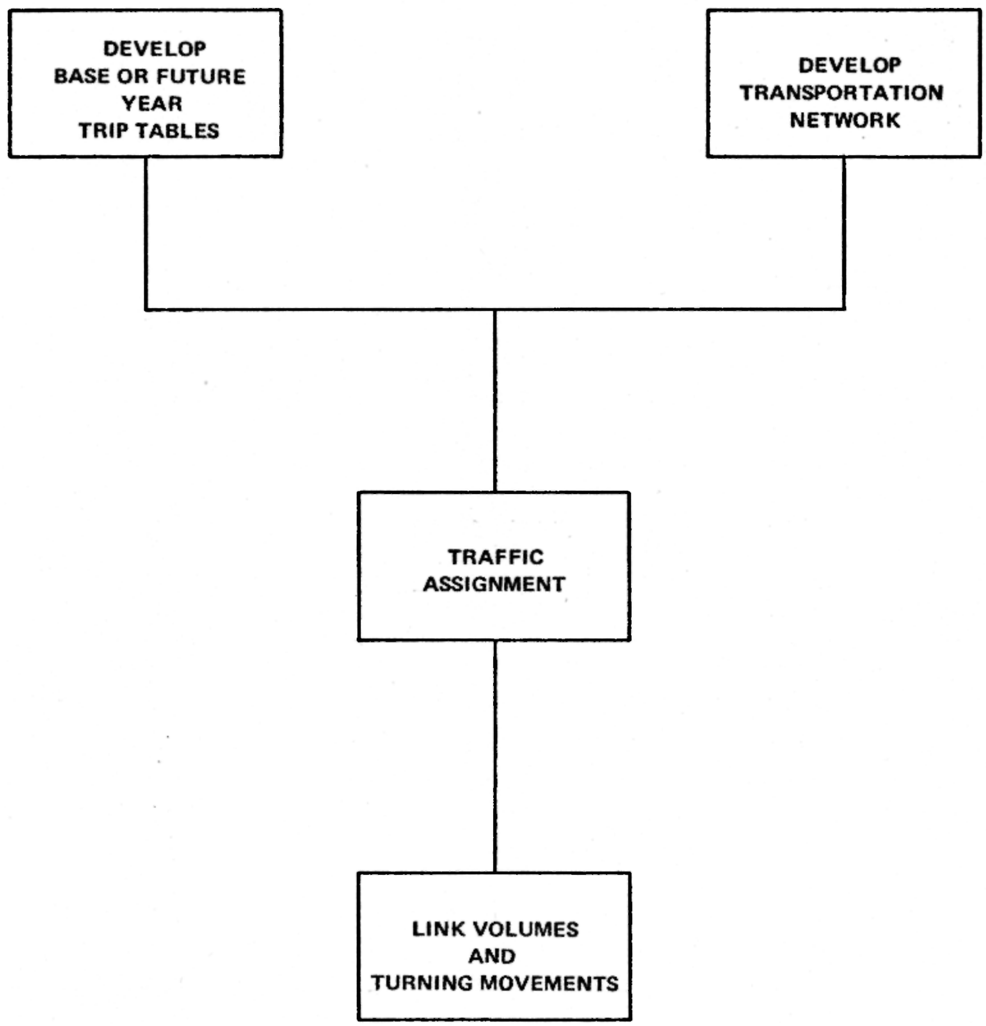


FIGURE I–1



THE TRAFFIC ASSIGNMENT PROCESS

FIGURE I–2

Input to the traffic assignment process includes:

1. A description of the transportation network geometry.

2. A description of network parameters for route evaluation. Such parameters might include distance, travel time or travel cost.

3. A set of trip interchanges described by an origin, destination and interchange value.[2]

The output of the traffic assignment process includes volumes on each individual segment of the network. The volumes may be either peak hour or 24 hour volumes. The process also gives turning movements at intersections. The volumes are developed from the accumulation of the O-D trip interchanges on each segment of the network.

METHODS OF ASSIGNMENT

Diversion

The early attempts at traffic assignment involved factoring of O-D travel information to represent future travel and the forecasting of the diversion of future travel from existing facilities to new facilities. Initially, the diversion was based on the judgment and intuition of the planner. Considerations were given to travel time, travel distance and cost via the different routes.

Through the work of Mr. Earl Campbell of the Highway Research Board, AASHO and various state highway departments, curves were developed which relate the percent usage of facility to the ratio of travel times between the new facility and competing facilities. A curve developed by Mr. Campbell for urban arterial highways is shown in Figure I-3. California developed curves which incorporate both time and distance savings as a factor in traffic diversion to a freeway as shown in Figure I-4.[3]

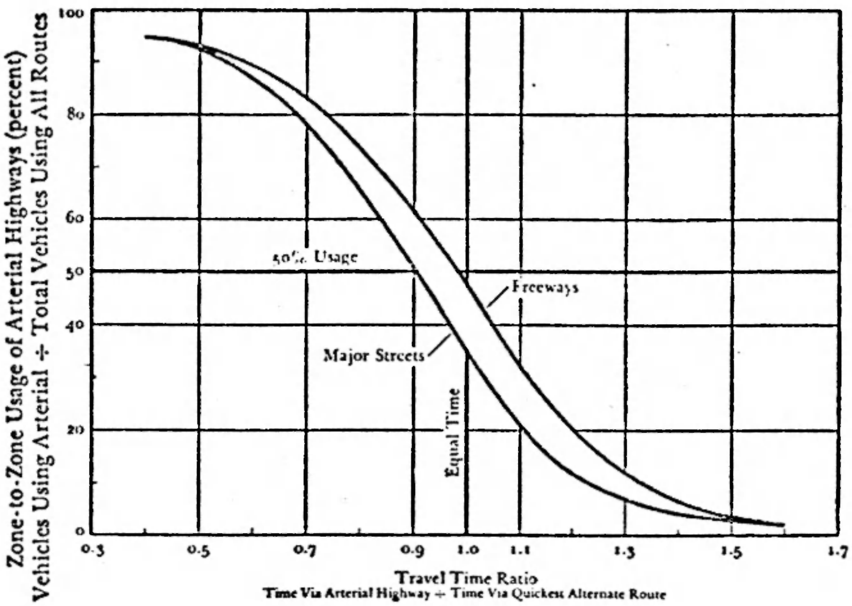


FIGURE I–3

Time Ratio Diversion Curves

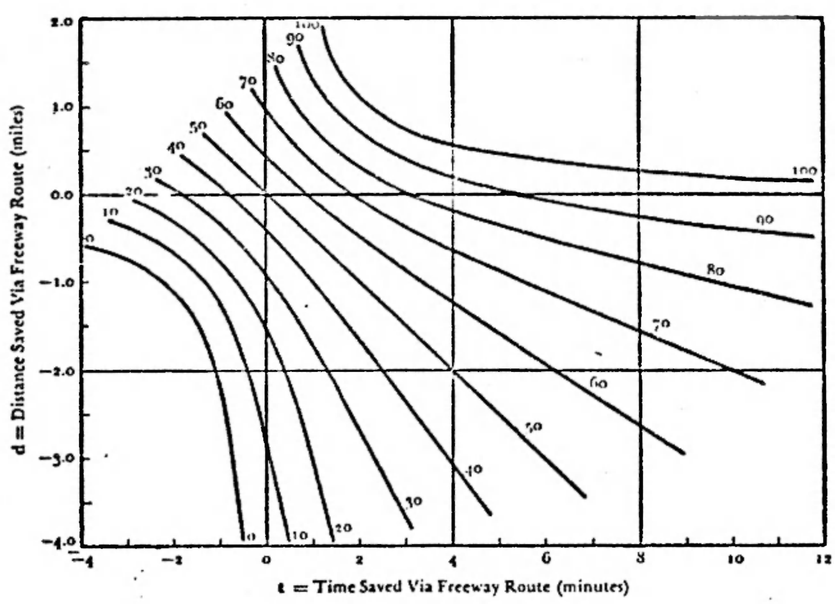


FIGURE I–4

California time and distance savings diversion curves

SOURCE: TRAFFIC ASSIGNMENT MANUAL

All or Nothing

The all or nothing technique assigns all of the trips between an O-D pair to the minimum route between them. The minimum route could be based on any of the network parameters such as travel time or distance. Initially, the technique of determining the minimum path involved the examination of every route between two points. The task becomes nearly impossible and very uneconomical with large networks. The development of algorithms for route selection of long distance phone calls by E. F. Moore gave impetus for development of a computerized technique for traffic assignment.[4] The algorithm, with modifications for traffic assignment, is known as Moore's algorithm. The algorithm does not require the examination of each possible route.

Capacity Restraint

The capacity restraint technique utilizes the all or nothing technique but attempts to divert trips from the minimum route to alternative routes. The technique uses the relationship between speed and volume on a highway. The speeds are reduced (travel times increased) on the individual links as the capacity on that link is exceeded. A typical formula for the speed adjustment is the one developed by the Federal Highway Administration:

where: $$T = T_0 \, [1+0.15 \, (V/C)^4] \qquad (1)$$

T = Balance travel time (at which the assigned volume (V) can travel on a highway segment).

T_0 = Free flow travel time; observed travel time (at Level of Service C) times 0.87.

V = Assigned volume

C = Capacity

Iterative techniques are generally used to get a diversion of assigned traffic. Network speeds are adjusted, using a restraint function such as equation (1), after each assignment and new minimum paths are computed before the assignment is repeated. Trips may use a different path during each assignment because of the speed adjustment. A diversion of the O-D movement between different paths may be obtained by the averaging of the successive assignments on each link. Research has indicated that reasonable assignments are obtained by the application of capacity restraint at least three times (four loadings) and using the average of four loadings.[5]

THE PROBLEM

The diversion techniques dealt with a single facility and existing competing routes. The technique was too time consuming and impractical for application to complete networks. The advent of the electronic computer reduced the tedious manual work but the diversion technique still involved high computer costs and sometimes gave unreasonable results.

The all or nothing technique assumes that the traveling public is able to discern the minimum path through the network for each O-D trip and will always travel those particular paths. It is obvious that all drivers do not take the same route between two points. The process often overassigns trips to a given facility resulting in unrealistic results.

The capacity restraint technique is widely used in traffic assignment today because it leads to some diversion of trips to multiple routes thus accounting for the fact that all drivers do not take the same route. Capacity restraint has reduced the overall error in traffic assignment and generally gives reasonable results when using iterative techniques but is not a true multipath technique.

PROBABILISTIC MULTIPATH TECHNIQUE

Attempts have been made in the last decade to develop a multipath assignment technique which would proportion traffic between O-D points in a more realistic manner. The most promising multipath technique was developed by Robert B. Dial of Alan M. Voorhees and Associates, Inc., under a U. S. Department of Transportation contract. Dial's model is operational and is available in the Federal Highway Administration's (FHWA) Urban Planning Battery of computer programs under the name of STOCH.[6] The model has five common-sense functional specifications:

1. All "reasonable" paths between two zones should have non-zero probability of use. All "unreasonable" paths should have zero probability of use. A "reasonable" path is defined as one which does not backtrack on itself, i.e., must get further from the origin as it progresses through the network.

2. All "reasonable" paths of equal length should have equal probability of use.

3. When there are two or more reasonable paths of unequal length, the shorter should have the higher probability of use.

4. The user should have some control over the path diversion probabilities.

5. The explicit enumeration of paths should not be necessary.[7]

The amount of path diversion is governed by the calculation of path probability. The formula for path probability is:

$$P = e^{(\theta \Delta t)} \qquad (2)$$

where:

e = Base of natural logarithms

θ = Diversion parameter (theta)

Δt = Difference between minimum time path time to the node and the time via another reasonable path.[8]

The parameter theta can be controlled by the user. As theta varies from zero to infinity the likelihood that the links forming the minimum path will be used increases. Large values of theta give results that are equivalent to an all or nothing assignment while a theta value of zero would give equal probability of use to all reasonable paths. The model calculates link probabilities and assigns link weights in a forward examination of the network as it proceeds toward the destination node and trips are assigned in a backward examination. The reader who wishes to further investigate the model theory should consult Dial's paper.[9] The process is best explained by a simple example:

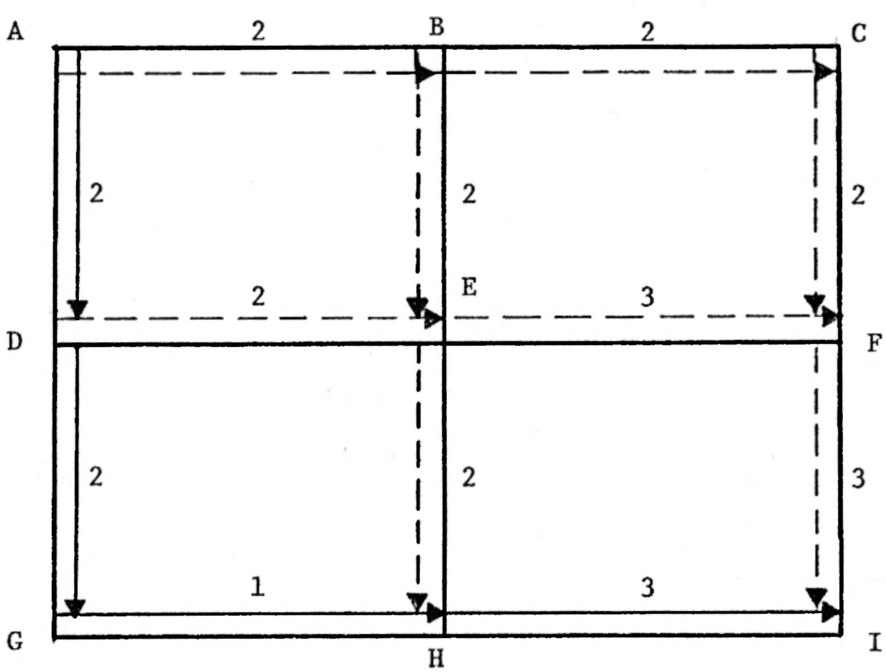
GIVEN: The following simple network with 100 trips desiring to travel from Node A to Node I.

X = Node

4 —— Impedance along the link in question

— — — — → Reasonable path

———→ Minimum path



Step 1. The program first calculates the minimum impedance to each node from origin node A.

Origin Node	Destination Node	Minimum Impedance
A	B	2
	C	4
	D	2
	E	4
	F	6
	G	4
	H	5
	I	8

Step 2. Determine the difference (Δt) between the minimum time path time to a node and the time via another reasonable path for each link by:

$$\Delta t_{ij} = t(j) - t(i) - t(i,j) \tag{3}$$

where: i and j represent the nodes of the origin and destination ends of the link, respectively.

$t(j)$ = minimum time to node j from the origin node A.

$t(i)$ = minimum time to node i from the origin node A.

$t(i,j)$ = time to traverse link i-j.

$\Delta t_{AB} = 2 - 0 - 2 = 0$

$\Delta t_{AD} = 2 - 0 - 2 = 0$

$\Delta t_{BC} = 4 - 2 - 2 = 0$

$\Delta t_{BE} = 4 - 2 - 2 = 0$

$\Delta t_{CF} = 6 - 4 - 2 = 0$

$\Delta t_{DG} = 4 - 2 - 2 = 0$

$\Delta t_{DE} = 4 - 2 - 2 = 0$

$\Delta t_{EF} = 6 - 4 - 3 = -1$

$\Delta t_{EH} = 5 - 4 - 2 = -1$

$\Delta t_{FI} = 8 - 6 - 3 = -1$

Step 2. (Continued)

$$\Delta t_{GH} = 5 - 4 - 1 = 0$$

$$\Delta t_{HI} = 8 - 5 - 3 = 0$$

Step 3. Compute the probability of each link receiving trips using equation (2) on page 8:

$$P_{ij} = e^{(\theta \Delta t)}$$

with $\theta = 0$

$$P_{AB} = e^{0} = 1$$

$$P_{AD} = e^{0} = 1$$

$$P_{BC} = e^{0} = 1$$

$$P_{BE} = e^{0} = 1$$

$$P_{CF} = e^{0} = 1$$

$$P_{DG} = e^{0} = 1$$

$$P_{DE} = e^{0} = 1$$

$$P_{EF} = e^{0} = 1$$

$$P_{EH} = e^{0} = 1$$

$$P_{FI} = e^{0} = 1$$

$$P_{GH} = e^{0} = 1$$

$$P_{HI} = e^{0} = 1$$

Therefore with $\theta = 0$, all reasonable paths receive an equal probability of receiving trips.

with $\theta = 1$

$$P_{AB} = e^{0} = 1$$

$$P_{AD} = e^{0} = 1$$

$$P_{BC} = e^{0} = 1$$

$$P_{BE} = e^{0} = 1$$

$$P_{CF} = e^{0} = 1$$

$$P_{DG} = e^{0} = 1$$

Step 3. (Continued)

$P_{DE} = e^{0} = 1$

$P_{EF} = e^{1(-1)} = 0.37$

$P_{EH} = e^{1(-1)} = 0.37$

$P_{FI} = e^{1(-1)} = 0.37$

$P_{GH} = e^{0} = 1$

$P_{HI} = e^{0} = 1$

Therefore as θ becomes large, the links on the minimum paths receive the highest probability of use.

Step 4. Using $\theta = 1.000$ (for this example), the effect of consecutive links in a path is found by calculating a link weight for each link by:

$$W_{ij} = P_{ij} \times \Sigma W_{i'j'} \qquad (4)$$

where: W_{ij} = link weight of link i-j.

P_{ij} = probability of link i-j receiving trips.

$W_{i'j'}$ = link weight of any link on the path entering the origin end of link i-j. If at beginning in the network, then $W_{ij} = P_{ij}$.

$W_{AB} - P_{AB}$

$W_{AB} = 1$

$W_{AD} = P_{AD}$

$W_{AD} = 1$

$W_{BE} = P_{BE} \times W_{AB}$

$W_{BE} = 1 \times 1 = 1$

$W_{DE} = P_{DE} \times W_{AD}$

$W_{DE} = 1 \times 1 = 1$

Step 4. (Continued)

$$W_{DG} = P_{DG} \times W_{AD}$$
$$W_{DG} = 1 \times 1 = 1$$

$$W_{GH} = P_{GH} \times W_{DG}$$
$$W_{GH} = 1 \times 1 = 1$$

$$W_{EH} = P_{EH} \times (W_{BE} + W_{DE})$$
$$W_{EH} = 0.37(1 + 1) = 0.74$$

$$W_{BC} = P_{BC} \times W_{AB}$$
$$W_{BC} = 1 \times 1 = 1$$

$$W_{CF} = P_{CF} \times W_{BC}$$
$$W_{CF} = 1 \times 1 = 1$$

$$W_{EF} = P_{EF} \times (W_{DE} + W_{BE})$$
$$W_{EF} = 0.37(1 + 1) = 0.74$$

$$W_{HI} = P_{HI} \times (W_{GH} + W_{EH})$$
$$W_{HI} = 1(1 + 0.74) = 1.74$$

$$W_{FI} = P_{FI} \times (W_{EF} + W_{CF})$$
$$W_{FI} = 0.37(0.74 + 1) = 0.64$$

Step 5. Beginning at the destination node of the assignment (Node I), the total number of trips at each node is proportioned to

Step 5. (Continued)

the corresponding links in relation to the link weights of the links entering the node by:

$$V_{ij} = V \times W_{ij}/\Sigma W_{i'j'} \tag{5}$$

where: V_{ij} = volume of trips assigned to link i-j.

V = volume of trips terminating at node j.

W_{ij} = link weight of link i-j.

$W_{i'j'}$ = link weight of any link having its destination at node j.

100 trips terminating at the destination node I.

$V_{HI} = 100 \times W_{HI}/(W_{HI} + W_{FI})$

$V_{HI} = 100 \times 1.74/1.74 + 0.64$

$V_{HI} = 73$

$V_{FI} = 100 \times W_{FI}/(W_{HI} + W_{FI})$

$V_{FI} = 100 \times 0.64/2.38$

$V_{Fl} = 27$

$V_{EF} = V_{FI} \times W_{EF}/(W_{EF} + W_{CF})$

$V_{EF} = 27 \times 0.74/1.74$

$V_{EF} = 11$

$V_{CF} = V_{FI} \times W_{CF}/(W_{CF} + W_{EF})$

$V_{CF} = 27 \times 1/1.74$

$V_{CF} = 16$

$V_{EH} = V_{HI} \times W_{EH}/(W_{EH} + W_{GH})$

$V_{EH} = 73 \times 0.74/1.74$

$V_{EH} = 31$

Step 5. (Continued)

$$V_{GH} = V_{HI} \times W_{GH}/(W_{GH} + W_{EH})$$

$$V_{GH} = 73 \times 1/1.74$$

$$V_{GH} = 42$$

$$V_{BC} = V_{CF} \times W_{BC}/W_{BC}$$

$$V_{BC} = 16$$

$$V_{BE} = (V_{EH} + V_{EF}) \times W_{BE}/(W_{BE} + W_{DE})$$

$$V_{BE} = 42 \times 1/(1 + 1)$$

$$V_{BE} = 21$$

$$V_{DE} = (V_{EH} + V_{EF}) \times W_{DE}/(W_{DE} + W_{BE})$$

$$V_{DE} = 42 \times 1/2$$

$$V_{DE} = 21$$

$$V_{AB} = (V_{BE} + V_{BC}) \times W_{AB}/W_{AB}$$

$$V_{AB} = 37$$

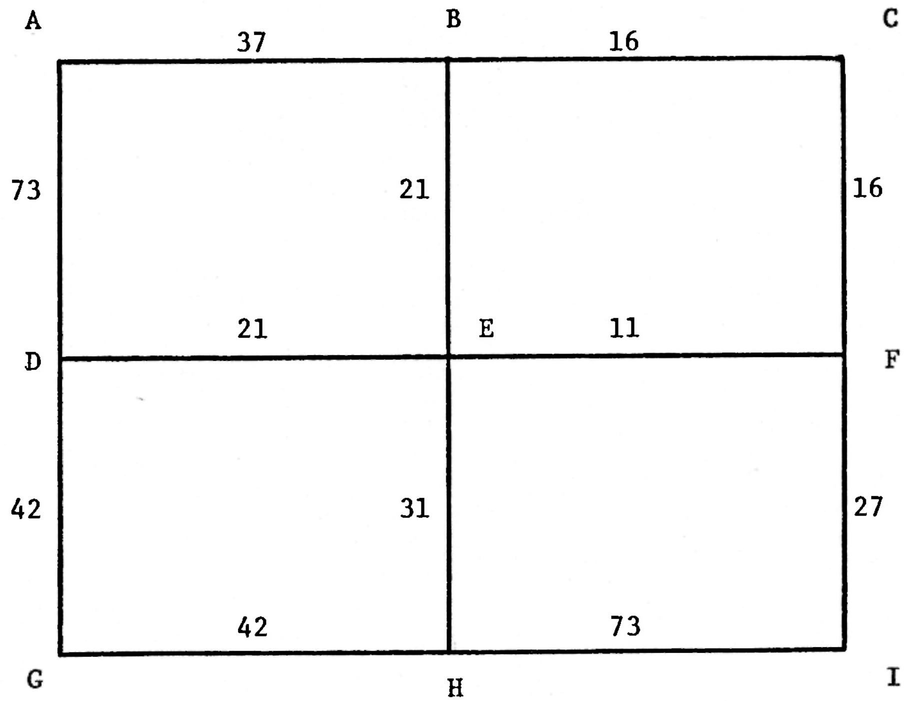
$$V_{DG} = V_{GH} \times W_{DG}/W_{DG}$$

$$V_{DG} = 42$$

$$V_{AD} = (V_{DG} + V_{DE}) \times W_{AD}/W_{AD}$$

$$V_{AD} = 73$$

The final volumes are shown as follows:



PROJECT DESCRIPTION

Little or no work has been done to evaluate this new multipath technique. This project utilized the multipath technique and compared it to the well known capacity restraint technique. The comparison was made by evaluating each technique's ability to simulate actual travel patterns. The multipath technique model STOCH was tested with various values of the diversion parameter, theta, until an optimum output was attained. The optimum output was that which best satisfied the evaluation techniques discussed in Chapter III.

CHAPTER II

SELECTION AND BACKGROUND OF THE STUDY AREA

The City of Lawrence, Kansas was selected for the testing of the multipath technique. Several criteria were involved in the selection of a city:

1. Availability of traffic assignment network.
2. Availability of a trip interchange matrix (trip table).
3. Prior use of capacity restraint technique.
4. Network size.
5. Availability of documentation on all procedures used.

The Kansas Highway Commission published a transportation study for the City of Lawrence in early 1972. In the preparation of this study, well documented trip tables and traffic assignments were developed. The network was small, consisting of only 110 zones (93 internal zones and 17 external stations). In addition, the capacity restraint process had been used in traffic assignment and all computer data files were readily available for testing of the multipath technique.

The computer programs used in the Lawrence Transportation Study came from two sources: (1) The FHWA Urban Planning Battery which contains a wide variety of programs for development of networks, trip tables, traffic assignment and evaluation. (2) The Planning and Development Department of the Kansas Highway Commission which has developed a number of programs to supplement the FHWA programs.[13]

Traffic Assignment Network

The inventory of the system as it existed in 1971 (See Figure II-1) was the basis for developing the traffic assignment network. Street widths, parking, speeds and travel times, facility types, PHV/ADT factors and area types were needed to describe each link in the system and compute link capacities. Traffic counts were also required for evaluation and calibration purposes. When the inventory was complete and zone boundaries selected, the information was coded onto link and node cards for input to the network building programs.

Trip Generation

Traditionally the O-D survey is used to determine the daily travel patterns of persons and vehicles in an urban area, however, the Lawrence Transportation Study was unique in that the travel patterns were synthetically developed.[11] Research and experience indicated that simulation of internal travel is feasible in smaller urban areas. A technical report: Development of Internal Travel-St. Cloud Metropolitan Area Transportation and Planning Study by Bather-Ringrose-Wolsfeld, Inc., in cooperation with the Minnesota Highway Department and the Federal Highway Administration, was used as a possible source for home based work, home based other and non-home based trip purpose trip generation equations and travel time factors (F-factors). The City of St. Cloud and the other cities in the report were all similar to Lawrence in size, population, geographic layout and travel patterns, thus leading to selection of the St. Cloud equations.[12]

The truck trip generation equations and the external local trip generation equations were developed from prior transportation studies in Lawrence and Hutchinson, Kansas. The external through trips were developed

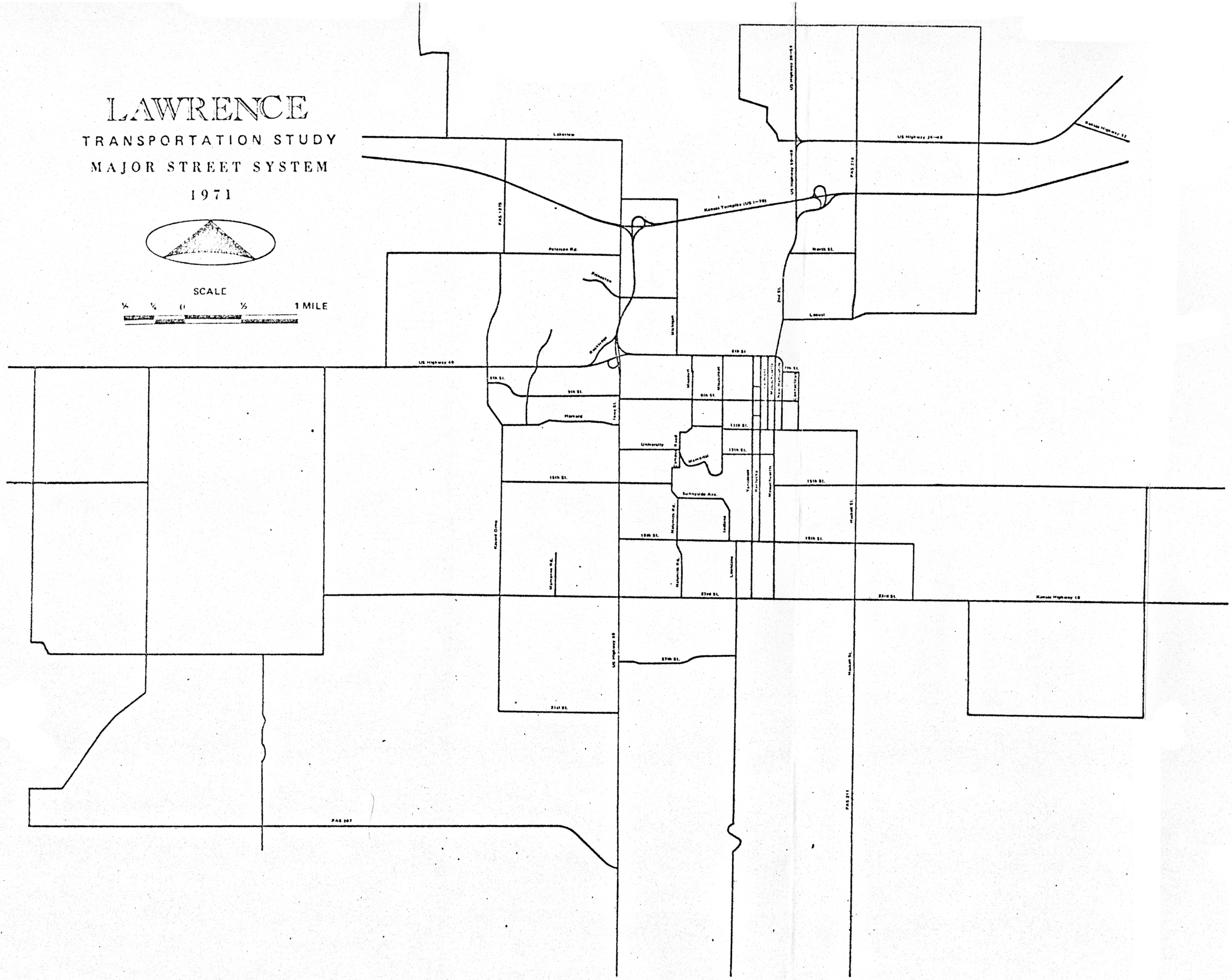

LAWRENCE
TRANSPORTATION STUDY
MAJOR STREET SYSTEM
1971
SCALE
1 MILE
Lakeview
FAS 1275
Peterson Rd.
Kansas Turnpike (US I-70)
US Highway 24-40
Kansas Highway 32
US Highway 59-40
FAS 216
North St.
Locust
2nd St.
Princeton
Rockledge
Michigan
6th St
US Highway 40
9th St.
Harvard
Iowa St.
11th St.
University
Campus Road
Memorial
13th St.
15th St.
Sunnyside Ave.
Tennessee
Kentucky
Massachusetts
Connecticut
7th St.
Haskell St.
Kasold Drive
19th St.
Naismith Rd.
Indiana
Louisiana
23rd St.
Kansas Highway 10
27th St.
31st St.
PAS 207
PAS 211

FIGURE II-1

by applying external zone growth factors to the trips developed in the 1964 Lawrence external O-D survey. The trip generation equations are shown in Appendix A.

The 1971 socio-economic data was obtained from the City of Lawrence and input to the generation equations to develop productions and attractions (P's & A's) for use in the trip distribution model with the exception of the zones comprising the Kansas University Campus. The campus was treated as a special trip generator to account for the high student population.

Trip Distribution

The gravity model was used for trip distribution resulting in 126,630 daily internal trips to be assigned to the network. The St. Cloud Report presented an equation to estimate the number of internal trips. The equation with a 95% confidence interval of ±5000 trips is:

$$\text{Trips} = 10{,}062 + 2.4\ (\text{population})$$

Using the 1971 population of Lawrence, the equation yields 127,120 ±5000 daily trips. The 126,630 internal trips from the gravity model is well within this range.

As a check on the validity of the F-factors, the trip length frequency distributions of Lawrence were compared to those in the St. Cloud Report. Average trip lengths and trip length frequency distributions of Lawrence were comparable to those in the St. Cloud Report thus confirming the validity of the F-factors.

The final check of the synthetically developed travel patterns in Lawrence involved a comparison of trips crossing the screenline and the actual ground counts. The screenlines in Lawrence were the Kansas River crossings on the Kansas Turnpike and U. S. 40 - U. S. 59 bridges and the railroad tracks in east Lawrence running along Haskell Street. The ground count along the RR screenline was 23,398 compared to a total of 23,525 from the gravity model. The total counts on the river crossings were 27,000 as compared to 27,268 from the gravity model. Both screenline crossings were virtually 100% in agreement with the ground counts thus confirming that the travel data reliably reflect the actual travel patterns of the City.

Traffic Assignment

The base year trip table developed in the gravity model was assigned to the 1971 Lawrence network using the capacity restraint technique. Since the volumes being assigned were ADT volumes, the capacity restraint program converts peak hour capacities to 24 hour capacities by use of the PHV/ADT factor contained in the network. The capacity restraint program used in the Lawrence Transportation Study was one developed by Mr. E. D. Landman of the Kansas Highway Commission. The theory of the program, called CAPRKANS, is contained in Appendix B. Four iterations of capacity restraint were applied as shown in Figure II-2.

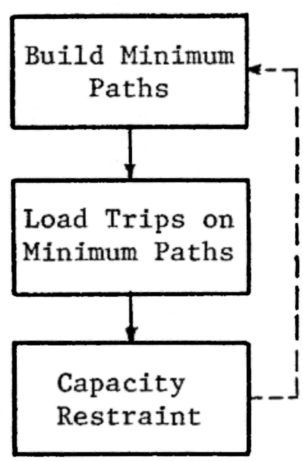


Figure II-2
The Iterative Process

The volumes of the four iterations were averaged to obtain the final assigned volume on each link.

CHAPTER III

METHODOLOGY AND EVALUATION TECHNIQUES

Application of STOCH

The STOCH program was used to assign the 1971 Lawrence trip table to the 1971 Lawrence network using travel time as impedance and with various values of the diversion parameter theta. The program has an option which allows travel time, distance or a combination of the two to be used as impedance, however, travel time was used for purposes of comparison to the capacity restraint technique. A copy of the program documentation is included in Appendix C and a listing of a typical set of control cards used in executing the program is given in Appendix D.

Several problems arose in the application of the program. The first problem resulted when a value of zero was coded for theta. The program internally defaulted to a theta value of 1.000 whenever a zero was coded, thus precluding use of that value of theta. An additional problem arose when the program was requested to output turning movements at intersections. The movements were correct but they were in such a format that the output dataset was incompatible with subsequent evaluation programs. If no turns were requested, the output was compatible with other programs resulting in all runs being made with no turns selected in output.

Six values of theta were used in making the programs runs. The six values are: 1.000, 0.2000, 0.015, 0.010, 0.005 and 0.001. The model was not responsive to change in values of theta over 1.000 as this was equivalent to an all or nothing assignment.

Evaluation Techniques

The evaluation of the capacity restraint and the multipath techniques of traffic assignment are based on their ability to duplicate reality. Reality consists of the most accurate travel information available. In this case, the 1971 Lawrence network contained ADT ground counts on each link of the system. These ground counts served as the basis for the evaluations which were made.

In evaluating the two assignment techniques, the following major checks were made:

1. Vehicle miles of travel (VMT) by facility type. Vehicle miles of travel are calculated by multiplying the count or assigned volume on a link times the length of the link and summing for some particular aggregation unit.

2. Visual analysis of results. The visual analysis involves comparison of ground counts to assigned volumes without conversion to VMT. The comparison is made on a link by link basis in the corridors of travel in the City.

In addition to these checks, the FHWA capacity restraint program (CAPRES) has been written to provide a variety of statistics which can be used in evaluation of the traffic assignment technique's ability to match ground counts.[14] Although not used to perform the capacity restraint function in Lawrence, the CAPRES program was used after each run of STOCH and after the averaging of the capacity restraint iterations to output evaluation statistics. Table III-1 shows the typical statistics which are output by the program. The columns are described as follows:

1. Counted Volume Group. This refers to ground counts stratified in the groupings shown.

2. Links. This refers to the total number of one-way links with counts within each volume group.

3. Average Count. Average count represents the average ground count for all links within the appropriate group. This is provided for relative comparative purposes only.

CAPRES OUTPUT STATISTICS FOR 1971 AVERAGE LOAD
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER	UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 -	BELOW	281	272	161	59.1	504	185.2	4.2	7.7	529	194.4
501 -	1,000	108	763	197	25.8	551	72.2	4.5	3.2	586	76.8
1,001 -	2,000	120	1,423	71	4.9	832	58.4	9.3	5.4	835	58.6
2,001 -	3,000	104	2,456	-147	-5.9	782	31.8	14.0	4.4	796	32.4
3,001 -	5,000	143	3,980	-324	-8.1	1,332	33.4	31.2	10.4	1,371	34.4
5,001 -	10,000	107	6,216	-587	-9.4	1,539	24.7	36.5	9.0	1,649	26.5
TOTAL -		863	2,108	-57	-2.7	973	46.1	100.0	40.1	974	46.2

VOLUME	1,770,514
COUNTS	1,819,712
PERCENT ERROR IN ASSIGNMENT	-2.7

TABLE III–1

4. Average Difference. This is the average of the difference between assigned and counted volumes within each group. This number is given for relative comparative purposes only.

5. Percent Difference. This is found by dividing the average difference (column 4) by the average count (column 3) and multiplying times 100 for each volume group.

6. Standard Deviation. The standard deviation is found by the following formula:

$$S.D. = \sqrt{\frac{\Sigma i(V_{gc} - V_{ta})^2 - \Sigma i(V_{gc} - V_{ta})^2/N}{N - 1}}$$

where: V_{gc} = ground count on Link L_i

V_{ta} = volume assigned to Link L_i

N = total number of links in aggregation unit

i = 1 through N

The standard deviation is computed to show that the average ground count differs from the average assigned volume by the average difference plus or minus the standard deviation two-thirds of the time.

7. Percent Standard Deviation. This is found by dividing the standard deviation (column 6) by the average ground count (column 3) and multiplying times 100 for each volume group.

8. Percent of Total. This percent represents the proportion of total volume within a volume group to the total of all volume in the network.

9. Weighted Error. This is computed by multiplying percent standard deviation (column 7) times the percent of total (column 8) and dividing by 100.

10. Root Mean Square. The RMS is computed for each volume group by the following formula:

$$RMS = \sqrt{\frac{\Sigma i(V_{gc} - V_{ta})^2}{N - 1}}$$

where: V_{gc} = ground count on Link L_i

V_{ta} = volume assigned to Link L_i

N = total number of links in aggregation unit

i = 1 through N

The RMS measures the deviation between the two distributions.

11. Percent Root Mean Square Error. This is computed dividing the RMS (column 10) by the average ground count (column 3) and multiplying times 100.

In addition to these statistics, the CAPRES program accumulates the ground counts that have been coded on the links and compares the total to the accumulations of volumes which have been assigned to these same links. The accumulated count and assigned volume comparisons are also shown in Table III-1. The percent error in assignment shown in Table III-1 represents the ratio of total assigned volume to total measured volume expressed as a percentage minus 100. The accumulated comparisons can be used as a gross indicator of the accuracy of assignment.

There is no one best test for the accuracy of the traffic assignment process. The evaluations must be made on the results as a whole. Generally, five of the above measures are most commonly used and will be weighted the most in this project.

1. Individual link checks by corridor.
2. Vehicle miles of travel (VMT).
3. Total weighted error.
4. Root mean square error (RMS).
5. Total counted volume compared to total assigned volume.

CHAPTER IV

ANALYSIS

Vehicle Miles of Travel

Table IV-1 illustrates the VMT by facility type computed with the 1971 ground counts, the capacity restraint load, and the loads for each of the theta values used in STOCH. The VMT totals using each of the assignments are slightly lower than the VMT total using the 1971 ground counts. This would indicate that there is a slight underestimation of trips for the study area using the synthetic techniques discussed in Chapter III. The higher VMT for the freeway facilities resulted from an overestimation of external travel when using the external zone growth factor techniques. This is obvious in looking at the ADT volume maps (Figure IV-1 through Figure IV-8). All of the assignments reflect a load of 11000 or more on the Kansas Turnpike while the counts range from 9450 to 10900.

A theta value of 0.005 gives a VMT total which most closely approximates the actual 1971 VMT total of 409,261. The total of 406,163 for theta of 0.005 is greater than the total of 399,409 for capacity restraint indicating that more diversion occurred in the STOCH assignment. In addition, the VMT for the collector facilities is much higher when using STOCH assignments than when using counts or the capacity restraint load. This indicates that there was a diversion of many trips to the collector facilities when using STOCH.

Total Volume Comparisons

The CAPRES output statistics for each of the assignments are shown in Table IV-2 through Table IV-8. Table IV-2 represents the statistics for the capacity restraint assignment and is designated as the 1971

LAWRENCE TRAFFIC ASSIGNMENT

VEHICLE MILE SUMMARIES

Facility Type	1971 Counts	Capacity Restraint	Theta = 1.000	Theta = 0.200	Theta = 0.015	Theta = 0.010	Theta = 0.005	Theta = 0.001
Freeway	58,622	69,088	69,251	69,115	68,651	68,610	68,570	68,651
Expressway	0	0	0	0	0	0	0	0
Arterial	298,085	271,648	260,394	261,426	265,797	267,331	269,254	265,797
Collector	23,946	28,829	34,270	34,161	37,582	38,065	38,548	37,582
Local	28,608	29,844	27,016	26,941	21,197	29,446	29,791	21,197
TOTAL	409,261	399,409	390,931	391,643	401,227	403,452	406,163	401,227

TABLE IV–1

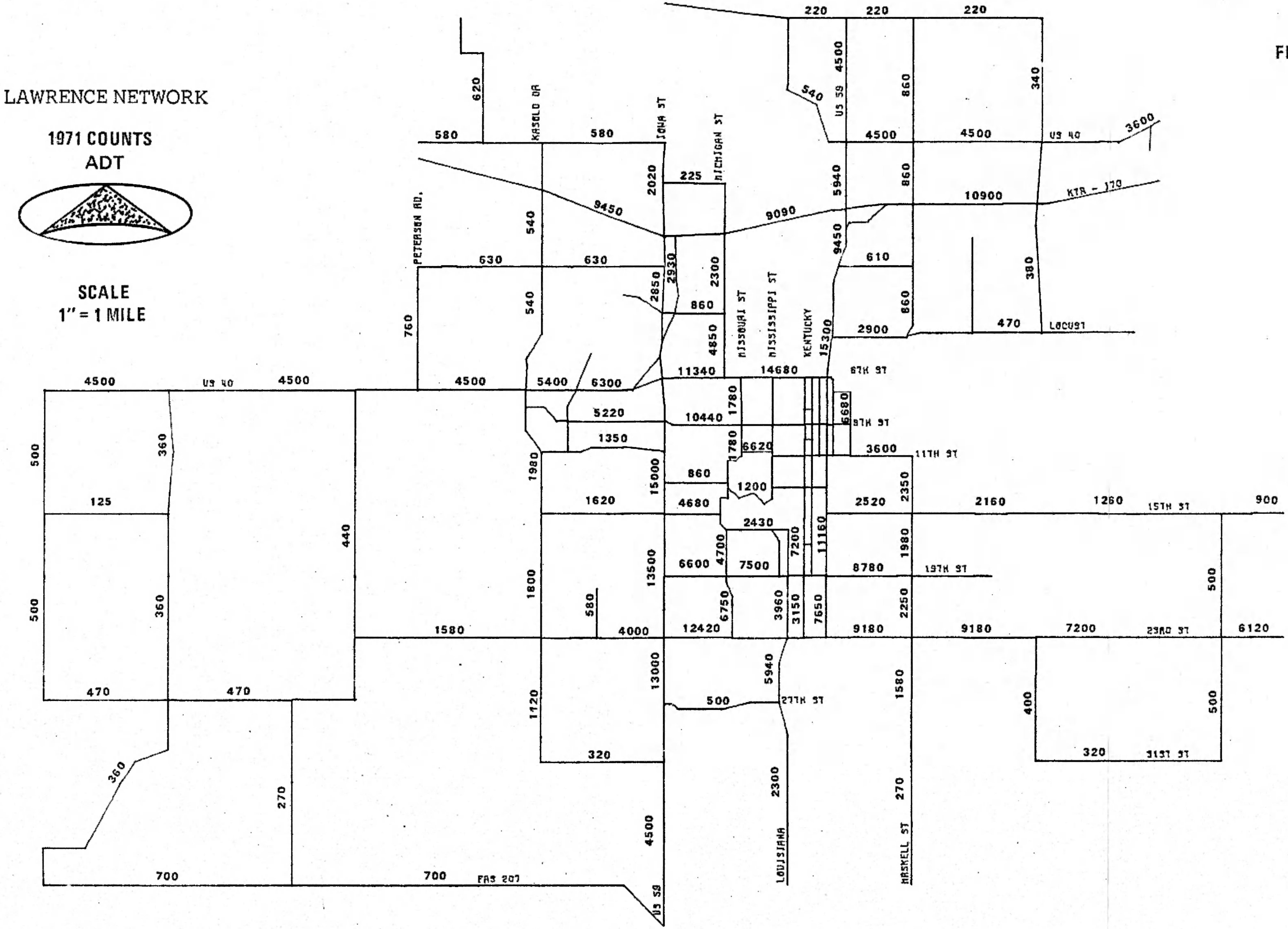

LAWRENCE NETWORK
1971 COUNTS
ADT
SCALE
1" = 1 MILE
PETERSON RD.
KASOLD DR
IOWA ST
MICHIGAN ST
MISSOURI ST
MISSISSIPPI ST
KENTUCKY
US 59
US 40
KTR - 170
LOCUST
6TH ST
9TH ST
11TH ST
15TH ST
19TH ST
23RD ST
27TH ST
31ST ST
FAS 207
LOUISIANA
HASKELL ST
220
220
220
4500
540
860
340
3600
620
580
580
4500
4500
2020
225
5940
860
10900
9450
9090
540
9450
610
630
630
2930
2300
2850
860
380
760
540
4850
860
2900
470
15300
4500
4500
4500
5400
6300
11340
14680
5220
10440
1780
6680
1350
1780
6620
3600
500
360
1980
15000
860
1200
2350
125
1620
4680
2520
2160
1260
900
2430
440
4700
7200
11160
1980
1800
13500
6600
7500
8780
500
500
360
580
6750
3960
3150
7650
2250
1580
4000
12420
9180
9180
7200
6120
13000
5940
1580
400
500
470
470
1120
500
320
320
360
270
2300
270
4500
700
700

FIGURE IV–1

FIGURE IV–2

LAWRENCE NETWORK

CAPACITY RESTRAINT

ADT

SCALE
1" = 1 MILE

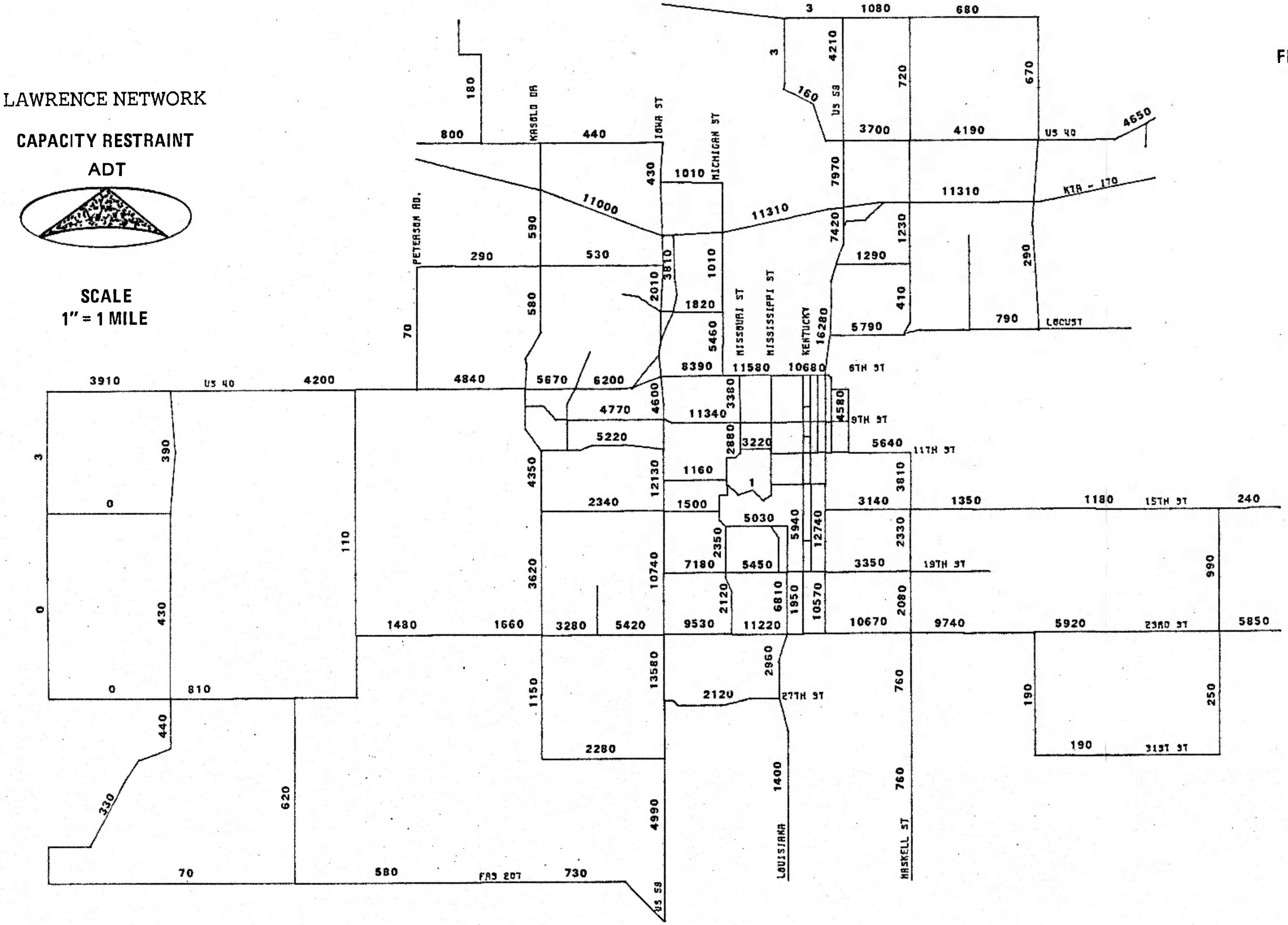


FIGURE IV-3

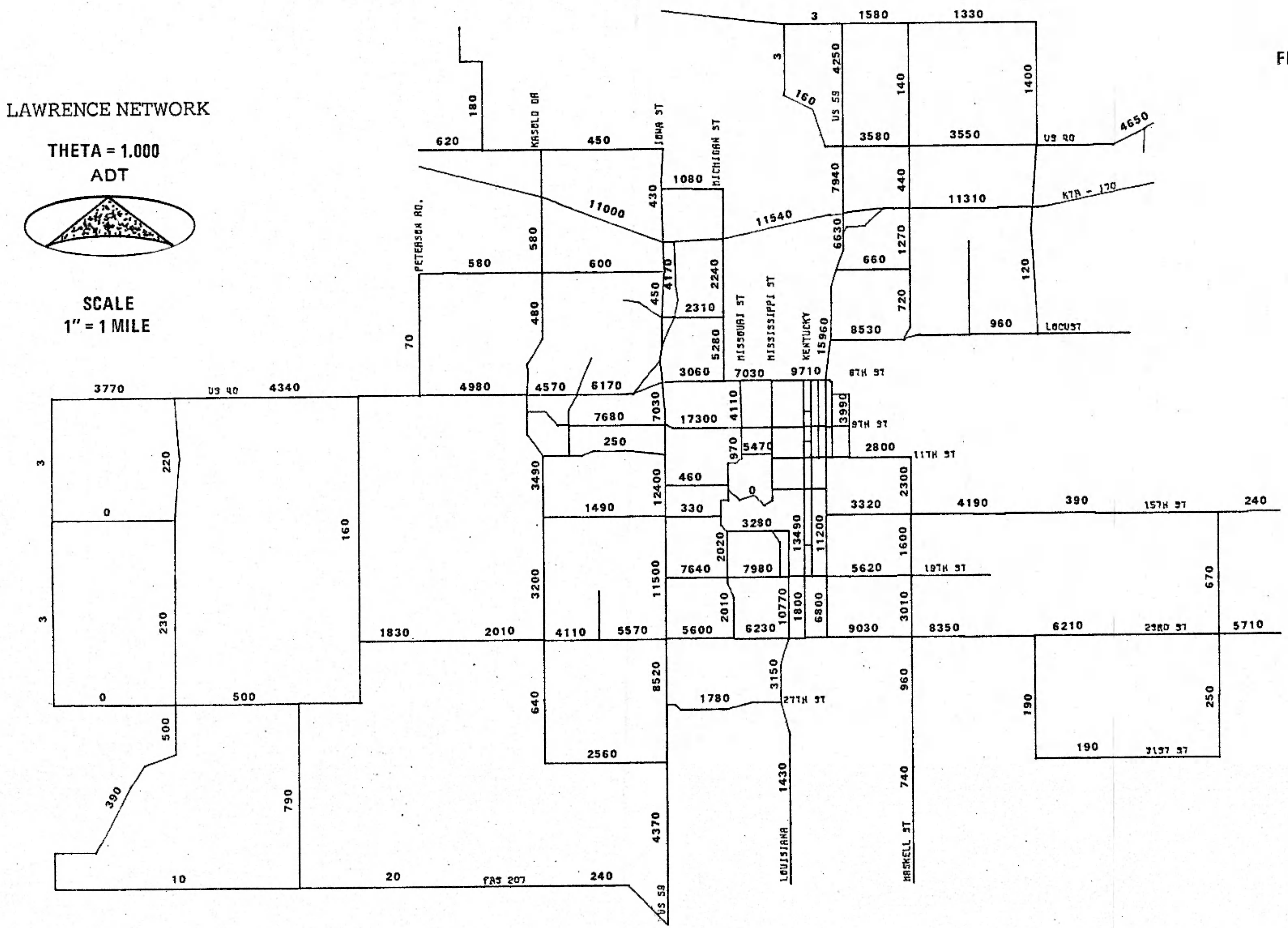

LAWRENCE NETWORK
THETA = 1.000
ADT
SCALE
1" = 1 MILE
US 40
PETERSON RD.
KASOLD DR
IOWA ST
MICHIGAN ST
US 59
K10 - 170
LOCUST
MISSOURI ST
MISSISSIPPI ST
KENTUCKY
6TH ST
9TH ST
11TH ST
15TH ST
19TH ST
23RD ST
27TH ST
31ST ST
FAS 207
LOUISIANA
HASKELL ST

FIGURE IV–4

LAWRENCE NETWORK

THETA = 0.200

ADT

SCALE
1" = 1 MILE

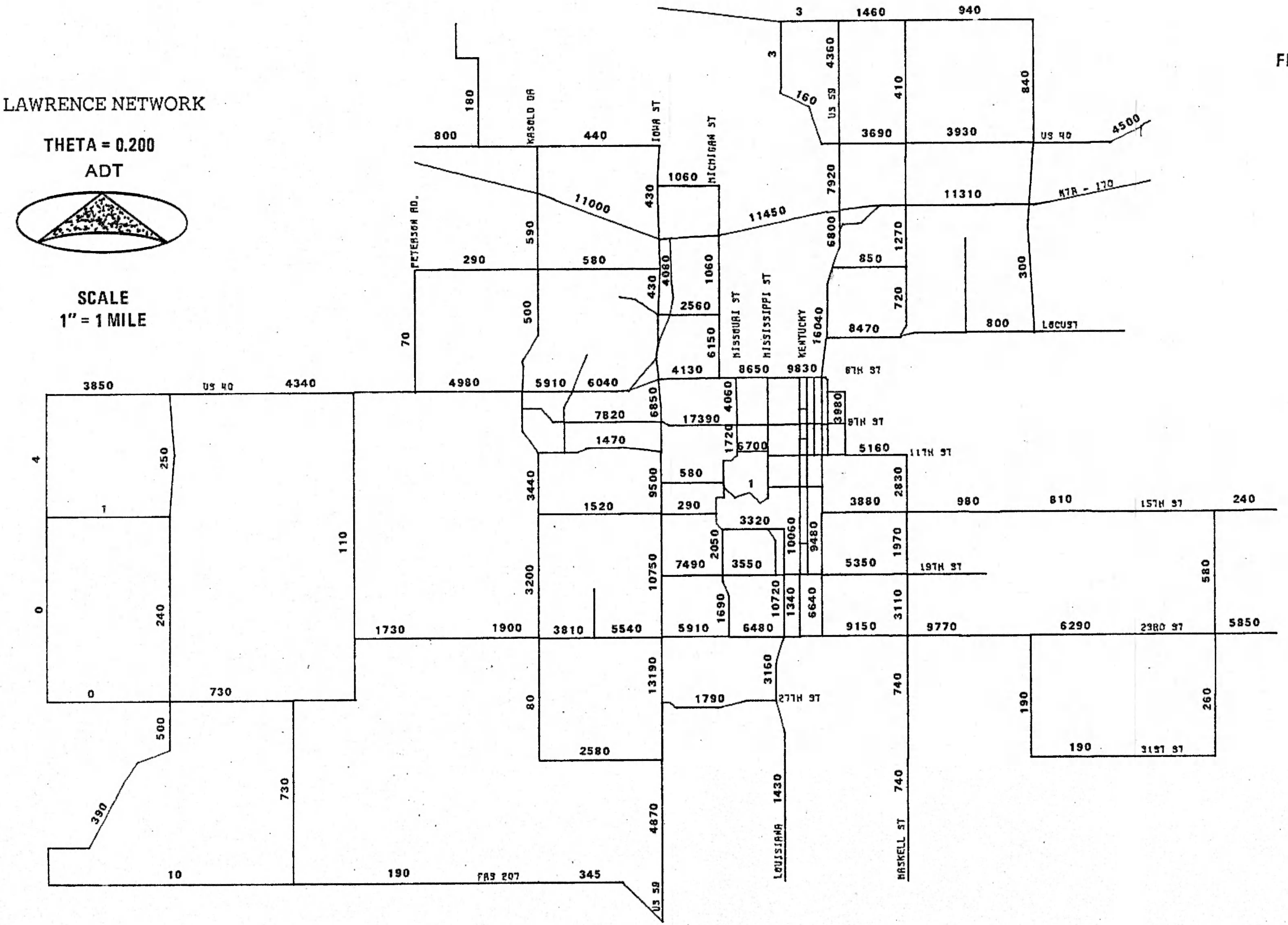
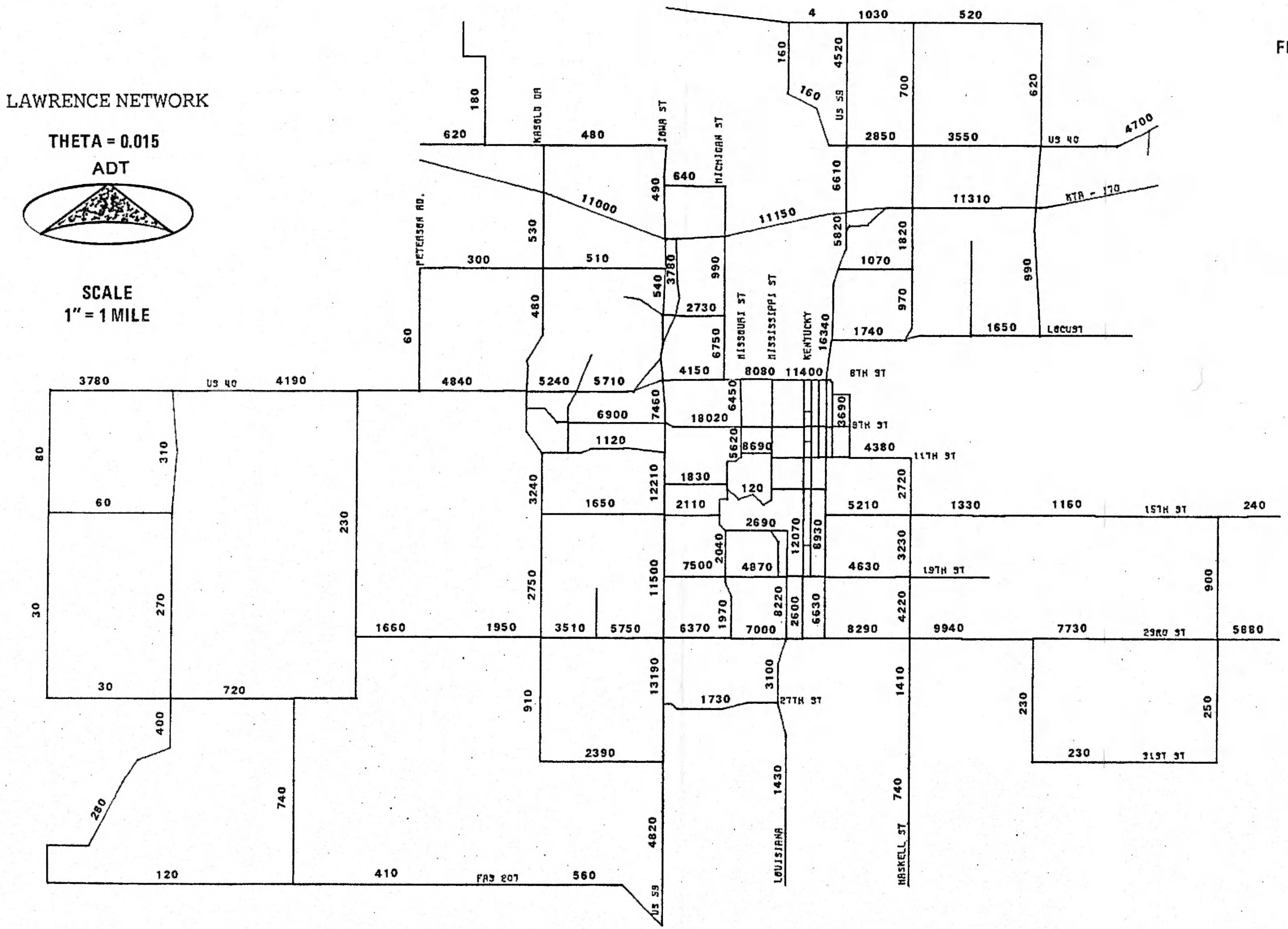


FIGURE IV–5



LAWRENCE NETWORK
THETA = 0.015
ADT
SCALE
1" = 1 MILE
US 40
US 59
KTA - 170
FAS 207
KASOLD DR
IOWA ST
MICHIGAN ST
PETERSON RD.
MISSOURI ST
MISSISSIPPI ST
KENTUCKY
LOUISIANA
HASKELL ST
LOCUST
6TH ST
9TH ST
11TH ST
15TH ST
19TH ST
23RD ST
27TH ST
31ST ST
4
1030
520
160
4520
160
700
620
180
620
480
490
640
2850
3550
4700
11000
11150
6610
11310
530
5820
1820
300
510
3780
990
1070
990
540
2730
970
480
60
6750
16340
1740
1650
3780
4190
4840
5240
5710
4150
8080
11400
6450
7460
6900
18020
3690
1120
5620
8690
4380
80
310
1830
120
3240
12210
2720
60
1650
2110
5210
1330
1160
240
230
2690
12070
8930
2040
3230
7500
4870
4630
11500
2750
900
30
270
8220
2600
6630
4220
1970
1660
1950
3510
5750
6370
7000
8290
9940
7730
5880
30
720
13190
3100
1410
910
1730
230
250
400
2390
230
280
740
1430
740
4820
120
410
560

FIGURE IV–6

LAWRENCE NETWORK

THETA = 0.010
ADT

SCALE
1" = 1 MILE

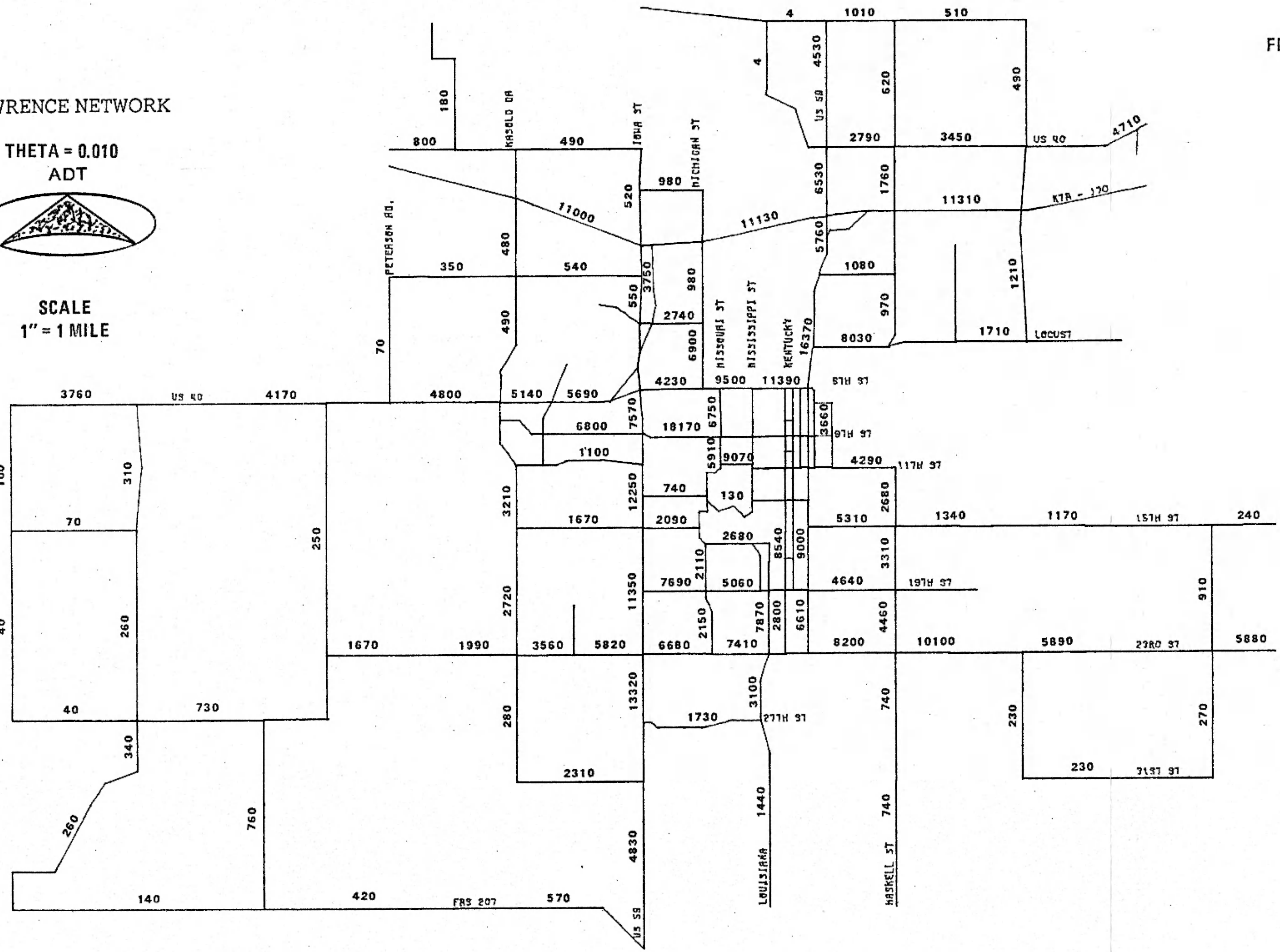


FIGURE IV–7

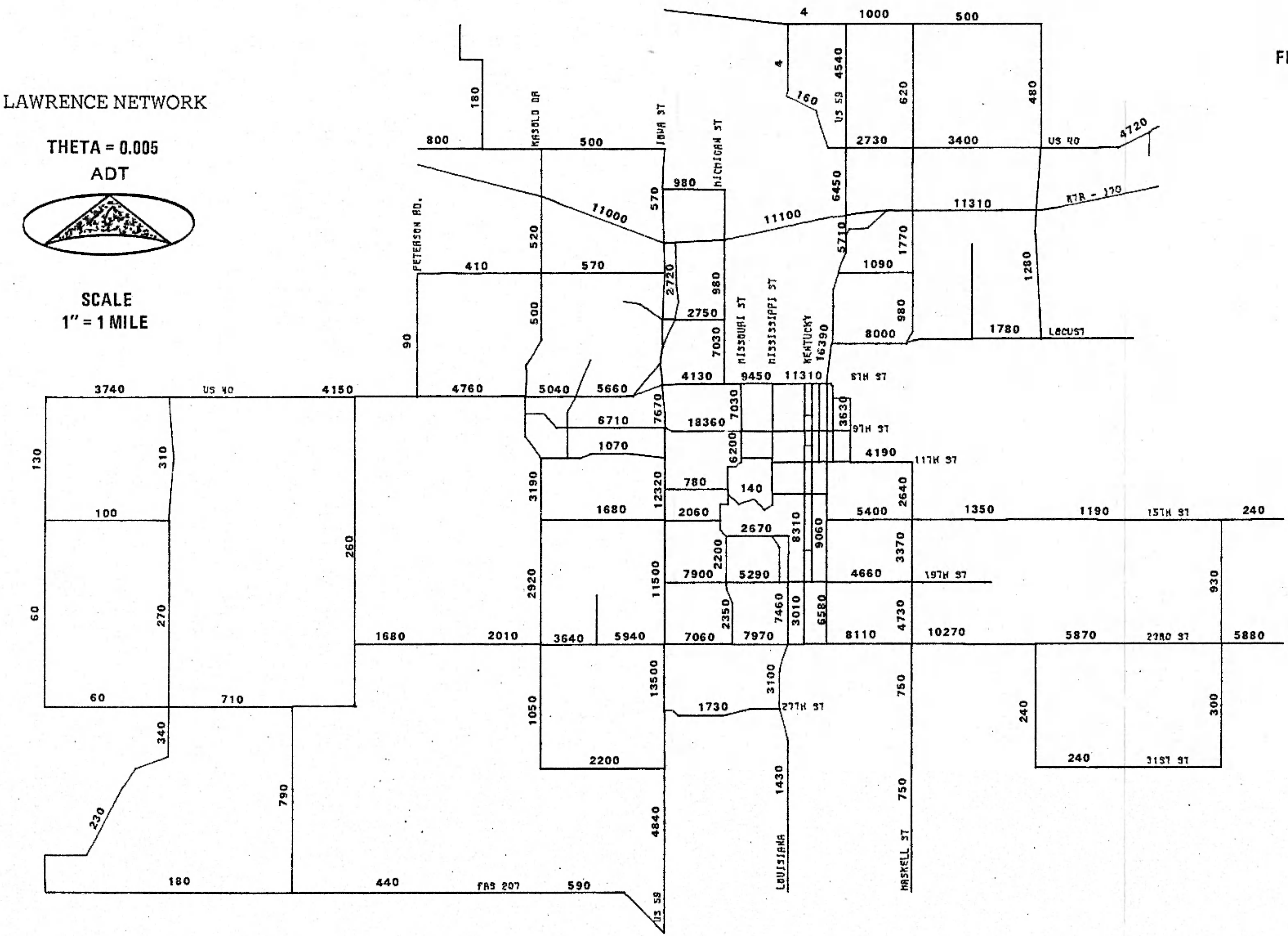
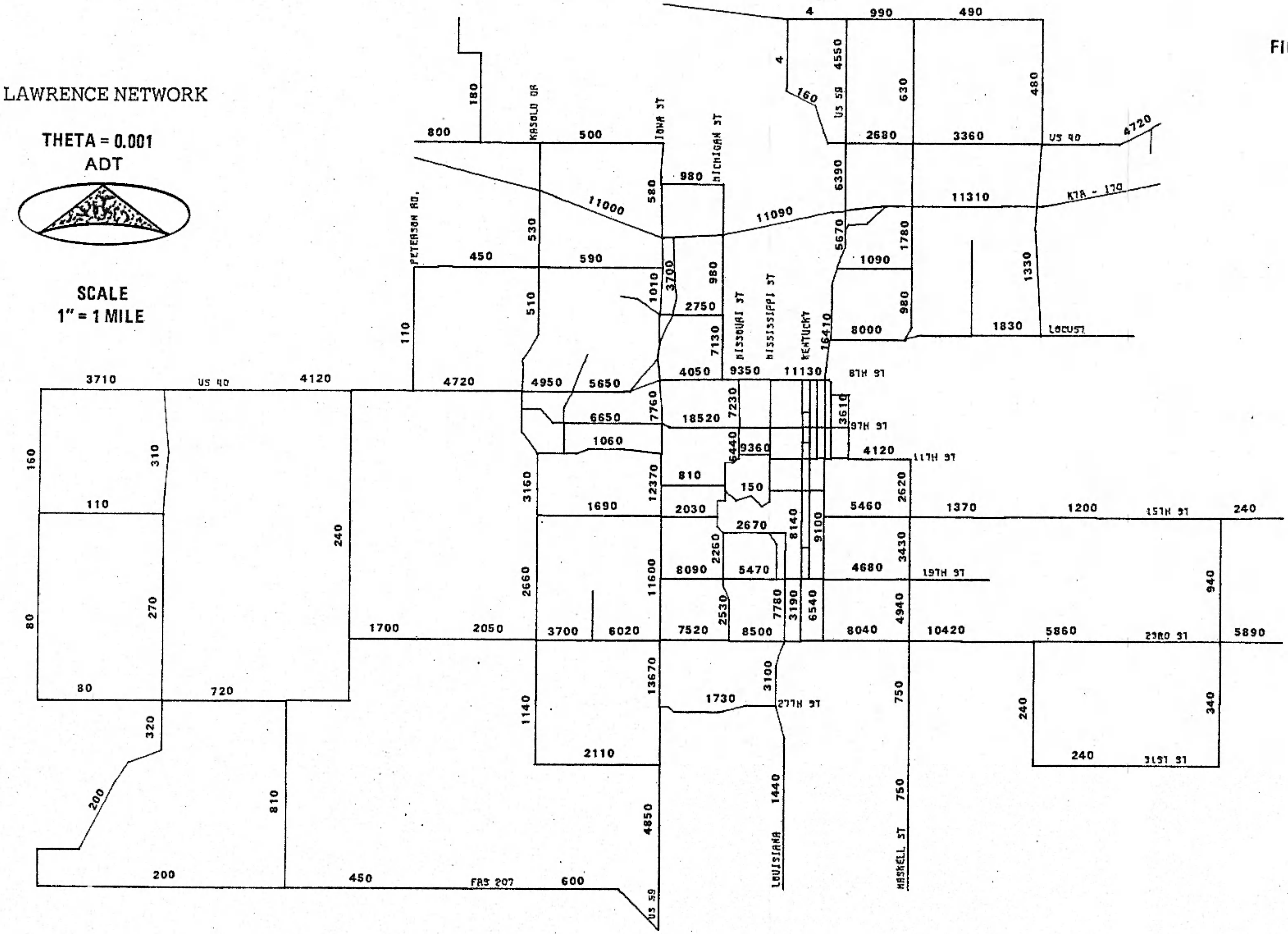

LAWRENCE NETWORK
THETA = 0.005
ADT
SCALE
1" = 1 MILE
US 40
PETERSON RD.
KASOLD DR
IOWA ST
MICHIGAN ST
MISSOURI ST
MISSISSIPPI ST
KENTUCKY
US 59
K10 - 170
LOCUST
8TH ST
9TH ST
11TH ST
15TH ST
19TH ST
23RD ST
27TH ST
31ST ST
FAS 207
LOUISIANA
HASKELL ST
4
1000
500
4540
620
480
160
4720
800
180
2730
3400
6450
980
570
11000
11100
11310
520
5710
1770
1280
410
570
2720
980
1090
500
2750
980
7030
16390
8000
1780
90
3740
4150
4760
5040
5660
4130
9450
11310
6710
7670
18360
7030
3630
1070
6200
4190
130
310
3190
12320
780
140
2640
100
1680
2060
5400
1350
1190
240
2670
8310
9060
260
2200
3370
2920
11500
7900
5290
4660
930
60
270
2350
7460
3010
6580
4730
1680
2010
3640
5940
7060
7970
8110
10270
5870
5880
13500
3100
750
60
710
1730
240
300
340
1050
2200
240
790
1430
750
230
4840
180
440
590

FIGURE IV-8


LAWRENCE NETWORK
THETA = 0.001
ADT
SCALE
1" = 1 MILE
4
990
490
4
4550
160
US 59
630
480
180
KASOLD DR
IOWA ST
MICHIGAN ST
800
500
2680
3360
US 40
4720
980
580
6390
11000
11090
11310
K10 - 170
PETERSON RD.
530
5670
1780
450
590
1090
1330
3700
1010
980
2750
MISSOURI ST
MISSISSIPPI ST
KENTUCKY
510
110
7130
16410
8000
980
1830
LOCUST
3710
US 40
4120
4720
4950
5650
4050
9350
11130
8TH ST
6650
7760
18520
7230
3610
9TH ST
1060
5440
9360
4120
11TH ST
160
310
810
150
3160
12370
2620
110
1690
2030
5460
1370
1200
15TH ST
240
2670
8140
9100
240
2260
3430
8090
5470
4680
19TH ST
11600
940
80
270
2660
2530
7780
3190
6540
4940
1700
2050
3700
6020
7520
8500
8040
10420
5860
23RD ST
5890
13670
3100
80
720
1730
27TH ST
750
240
340
1140
320
2110
240
31ST ST
200
810
1440
750
4850
LOUISIANA
HASKELL ST
200
450
FAS 207
600
US 59

CAPRES OUTPUT STATISTICS FOR 1971 AVERAGE LOAD
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER	UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 -	&BELOW	281	272	161	59.1	504	185.2	4.2	7.7	529	194.4
501 -	1,000	108	763	197	25.8	551	72.2	4.5	3.2	586	76.8
1,001 -	2,000	120	1,423	71	4.9	832	58.4	9.3	5.4	835	58.6
2,001 -	3,000	104	2,456	-147	-5.9	782	31.8	14.0	4.4	796	32.4
3,001 -	5,000	143	3,980	-324	-8.1	1,332	33.4	31.2	10.4	1,371	34.4
5,001 -	10,000	107	6,216	-587	-9.4	1,539	24.7	36.5	9.0	1,649	26.5
TOTAL -		863	2,108	-57	-2.7	973	46.1	100.0	40.1	974	46.2

VOLUME	1,770,514
COUNTS	1,819,712
PERCENT ERROR IN ASSIGNMENT	-2.7

TABLE IV–2

Average Load. Table IV-3 through Table IV-8 illustrate the statistics for the individual theta value assignments. The percent error in capacity restraint assignment is -2.7, indicating that the assigned volume accumulation is 2.7% less than the count accumulation. The accumulation comparisons for the STOCH assignments vary from a -3.7% at theta = 1.000 (all or nothing equivalent) to a +0.5% at theta = 0.001 (maximum diversion). A theta value of 0.005 gave a percent difference of 0.0% between total accumulated counts and total accumulated assigned volumes, however, this zero difference can only be interpreted as a gross indicator of the accuracy of assignment.

Total Weighted Error

The weighted error, shown in column nine of the statistics tables, is not a measure of the ability of the assignment process to match ground counts, but serves as a relative index of the error reduction in different or successive assignments. The weighted error for the STOCH assignments drops from 63.7 at theta = 1.000 to 58.5 at theta = 0.015 and then remains fairly constant indicating little error reduction with variation in the value of theta.

The first iteration of capacity restraint had a total weighted error of 50.5. The error was reduced to 40.1 as shown in Table IV-2, after averaging of the capacity restraint loads. This would indicate that the capacity restraint technique does reduce the overall error in assignment if average loads are used.

Average Difference

The average difference, shown in column four of Tables IV-2 through IV-8, reflects the difference between count and assigned volumes for each

CAPRES OUTPUT STATISTICS 1971 THETA=0.001
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER - UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 - &BELOW	281	272	236	86.7	618	227.2	4.2	9.5	661	243.0
501 - 1,000	108	763	235	30.7	878	115.0	4.5	5.1	910	119.2
1,001 - 2,000	120	1,423	472	33.1	1,336	93.8	9.3	8.7	1,418	99.6
2,001 - 3,000	104	2,456	-199	-8.1	1,007	41.0	14.0	5.7	1,027	41.8
3,001 - 5,000	143	3,980	-198	-4.9	2,047	51.4	31.2	16.0	2,056	51.6
5,001 - 10,000	107	6,216	-840	-13.5	2,456	39.5	36.5	14.4	2,597	41.7
TOTAL -	863	2,108	11	0.5	1,474	69.9	100.0	59.4	1,475	69.9

VOLUME 1,829,443

COUNTS 1,819,712

PERCENT ERROR IN ASSIGNMENT +0.5

TABLE IV–3

CAPRES OUTPUT STATISTICS 1971 THETA=0.005
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER	UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 -	&BELOW	281	272	230	84.5	608	223.5	4.2	9.3	650	238.9
501 -	1,000	108	763	223	29.2	866	113.4	4.5	5.1	894	117.1
1,001 -	2,000	120	1,423	451	31.6	1,331	93.5	9.3	8.6	1,406	98.8
2,001 -	3,000	104	2,456	-193	-7.8	1,006	40.9	14.0	5.7	1,025	41.7
3,001 -	5,000	143	3,980	-189	-4.7	2,051	51.5	31.2	16.0	2,059	51.7
5,001 -	10,000	107	6,216	-883	-14.2	2,430	39.0	36.5	14.2	2,587	41.6
TOTAL -		863	2,108	1	0.0	1,468	69.6	100.0	58.9	1,468	69.6

VOLUME	1,820,945
COUNTS	1,819,712
PERCENT ERROR IN ASSIGNMENT	+0.0

TABLE IV–4

CAPRES OUTPUT STATISTICS 1971 THETA=0.010
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER - UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 - &BELOW	281	272	222	81.6	596	219.1	4.2	9.2	637	234.1
501 - 1,000	108	763	207	27.1	849	111.2	4.5	5.0	874	114.5
1,001 - 2,000	120	1,423	428	30.0	1,335	93.8	9.3	8.7	1,403	98.5
2,001 - 3,000	104	2,456	-186	-7.5	1,011	41.1	14.0	5.7	1,028	41.8
3,001 - 5,000	143	3,980	-181	-4.5	2,062	51.8	31.2	16.1	2,070	52.0
5,001 - 10,000	107	6,216	-936	-15.0	2,409	38.7	36.5	14.1	2,586	41.6
TOTAL -	863	2,108	-10	-0.4	1,467	69.5	100.0	58.8	1,467	69.5

VOLUME	1,810,642
COUNTS	1,819,712
PERCENT ERROR IN ASSIGNMENT	-0.4

TABLE IV-5

CAPRES OUTPUT STATISTICS 1971 THETA=0.015
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER	UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 -	&BELOW	281	272	215	79.0	585	215.0	4.2	9.0	623	229.0
501 -	1,000	108	763	192	25.1	832	109.0	4.5	4.9	854	111.9
1,001 -	2,000	120	1,423	411	28.8	1,346	94.5	9.3	8.7	1,408	98.9
2,001 -	3,000	104	2,456	-180	-7.3	1,016	41.3	14.0	5.7	1,032	42.0
3,001 -	5,000	143	3,980	-175	-4.3	2,074	52.1	31.2	16.2	2,082	52.3
5,001 -	10,000	107	6,216	-980	-15.7	2,395	38.5	36.5	14.0	2,590	41.6
TOTAL -		863	2,108	-20	-0.9	1,468	69.6	100.0	58.5	1,468	69.6

VOLUME	1,801,643
COUNTS	1,819,712
PERCENT ERROR IN ASSIGNMENT	-0.9

TABLE IV-6

CAPRES OUTPUT STATISTICS 1971 THETA=0.200

STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP

USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER - UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 - & BELOW	281	272	131	48.1	473	173.8	4.2	7.2	491	180.5
501 - 1,000	108	763	69	9.0	778	101.9	4.5	4.5	781	102.3
1,001 - 2,000	120	1,423	418	29.3	1,644	115.5	9.3	10.7	1,697	119.2
2,001 - 3,000	104	2,456	-173	-7.0	1,044	42.5	14.0	5.9	1,058	43.0
3,001 - 5,000	143	3,980	-68	-1.7	2,295	57.6	31.2	17.9	2,296	57.6
5,001 - 10,000	107	6,216	-1,196	-19.2	2,563	41.2	36.5	15.0	2,831	45.5
TOTAL -	863	2,108	-70	-3.3	1,592	75.5	100.0	61.2	1,593	75.5

VOLUME 1,758,591

COUNTS 1,819,712

PERCENT ERROR IN ASSIGNMENT -3.3

TABLE IV–7

CAPRES OUTPUT STATISTICS 1971 THETA=1.000
STATISTICAL DATA STRATIFIED BY COUNTED VOLUME GROUP
USING RESTRAINING VOLUME

COUNTED VOLUME GROUP RANGE LOWER - UPPER	LINKS	AVERAGE COUNT	AVERAGE DIFFERENCE	PERCENT DIFFERENCE	STANDARD DEVIATION	PERCENT STANDARD DEVIATION	PERCENT OF TOTAL	WEIGHTED ERROR	ROOT MEAN SQUARE	PERCENT RMS
500 - &FFLOW	281	272	129	47.4	479	176.1	4.2	7.3	496	182.3
501 - 1,000	108	763	60	7.8	815	106.8	4.5	4.8	818	107.2
1,001 - 2,000	120	1,423	448	31.4	1,709	120.0	9.3	11.1	1,767	124.1
2,001 - 3,000	104	2,456	-325	-13.2	1,101	44.8	14.0	6.2	1,149	46.7
3,001 - 5,000	143	3,980	-10	-0.2	2,407	60.4	31.2	18.8	2,407	60.4
5,001 - 10,000	107	6,216	-1,207	-19.4	2,655	42.7	36.5	15.5	2,919	46.9
TOTAL -	863	2,108	-78	-3.7	1,658	78.6	100.0	63.7	1,660	78.7

VOLUME 1,751,987

COUNTS 1,819,712

PERCENT ERROR IN ASSIGNMENT -3.7

TABLE IV-8

volume group. The average total difference closely parallels the results of the total volume comparisons discussed on page 38. Generally the assignment techniques give the greatest differences in the high volume groups. The capacity restraint assignment had an average difference of -587 in the 5001 - 10000 volume group while the lowest average difference in this range for the STOCH technique was -840 at theta = 0.001. The least overall average difference resulted with a theta value of 0.005. The average difference in each volume group with this theta value was less than the capacity restraint average difference in each volume group with the exception of the 5001 - 10000 range.

Root Mean Square Error

The root mean square (RMS) error, shown in column ten of Tables IV-2 through IV-8, measures the deviation between assigned volumes and the ground counts. The capacity restraint technique gave an overall RMS error of 974 with the greatest error in the higher volume groups. The overall RMS error of the STOCH assignments varies from a high of 1660 with theta = 1.000 to a low of 1467 with theta = 0.010. The STOCH assignments, like the capacity restraint assignment, had high RMS error in the high volume groups. The RMS error results indicate that on a link by link basis the STOCH technique did not perform as well as did the capacity restraint technique in duplicating existing travel in Lawrence.

Corridor and Individual Link Checks

Individual link checks are the most stringent of the traffic assignment techniques. The assigned volume on each individual link is compared to the ground count on that particular link. The results of the comparison are generally expressed as a percentage. A positive percentage indicates an overloading of a link while a negative percentage indicates an underloading of a link.

Tables IV-9 and IV-10 show the volume-count link comparisons for the capacity restraint assignment and the STOCH assignments with theta values of 0.010 and 0.005. These two values of theta were chosen for link checks because they best satisfied the VMT and statistical comparisons. The volumes used in the comparisons came from Figures IV-1 through IV-8. Figure IV-1 shows the 1971 ground counts on the individual links and Figures IV-2 through IV-8 show the assigned volumes on the links. The volumes shown are typical volumes for each section as it was impossible to illustrate the volumes for every link in the network.

The count-volume comparisons indicate that both techniques under-assigned traffic on the major streets. The STOCH assignments were more accurate in the outlying areas than capacity restraint but were less accurate in the higher volume areas closer in on the network.

NORTH - SOUTH CORRIDOR

INDIVIDUAL LINK VOLUME CHECKS

Street	Capacity Restraint	Theta = 0.010	Theta = 0.005
Iowa St.			
6th - 9th	4600/12600 = -63%	7570/12600 = -40%	7670/12600 = -39%
11th - 15th	12130/15000 = -19%	12250/15000 = -18%	12320/15000 = -18%
15th - 23rd	10740/13500 = -20%	11350/13500 = -16%	11500/13500 = -15%
Kasold Drive			
11th - 15th	4350/1980 = +120%	3210/1980 = +62%	3190/1980 = +61%
15th - 23rd	3620/1800 = +101%	2720/1800 = +51%	2920/1800 = +62%
Haskell St.			
11th - 15th	3810/2350 = +62%	2680/2350 = +14%	2640/2350 = +12%
15th - 19th	2330/1980 = +18%	3310/1980 = +67%	3370/1980 = +70%
19th - 23rd	2080/2250 = -7%	4460/2250 = +98%	4730/2250 = +10%
US 40 - US 59 North			
River Br. - North St.	16280/15300 = +6%	16370/15300 = +7%	16390/15300 = +7%
North St. - KTA	7420/9450 = -21%	5760/9450 = -39%	5710/9450 = -39%
KTA - Jct. US 40 East	7970/5940 = +34%	6530/5940 = +10%	6450/5940 = +8%

TABLE IV-9

EAST - WEST CORRIDOR

INDIVIDUAL LINK VOLUME CHECKS

Street	Capacity Restraint	Theta = 0.010	Theta = 0.005
6th Street			
Kasold Dr. - Louisiana	$\frac{5670}{5400}$ = +5%	$\frac{5140}{5400}$ = -5%	$\frac{5040}{5400}$ = -7%
Lawrence Ave - Iowa	$\frac{6200}{6300}$ = -2%	$\frac{5690}{6300}$ = -10%	$\frac{5660}{6300}$ = -10%
Iowa - Michigan	$\frac{8390}{11340}$ = -26%	$\frac{4230}{11340}$ = -63%	$\frac{4130}{11340}$ = -64%
Michigan - Miss.	$\frac{11580}{14680}$ = -21%	$\frac{9500}{14680}$ = -35%	$\frac{9450}{14680}$ = -36%
Miss. - Kentucky	$\frac{10680}{14680}$ = -27%	$\frac{11390}{14680}$ = -22%	$\frac{11310}{14680}$ = -23%
9th Street			
Lawrence Ave. - Iowa	$\frac{4770}{5220}$ = -9%	$\frac{6800}{5220}$ = +30%	$\frac{6710}{5220}$ = +28%
Iowa - Missouri	$\frac{11340}{10440}$ = +9%	$\frac{18170}{10440}$ = +74%	$\frac{18360}{10440}$ = +76%
23rd Street			
Kasold Dr. - Marvonne	$\frac{3280}{4000}$ = -18%	$\frac{3560}{4000}$ = -11%	$\frac{3640}{4000}$ = -9%
Marvonne - Iowa	$\frac{5420}{4000}$ = +35%	$\frac{5820}{4000}$ = +46%	$\frac{5940}{4000}$ = +49%
Iowa - Naismith	$\frac{9530}{12420}$ = -23%	$\frac{6680}{12420}$ = -46%	$\frac{7080}{12420}$ = -43%
Naismith - Louisiana	$\frac{11220}{12420}$ = -10%	$\frac{7410}{12420}$ = -40%	$\frac{7970}{12420}$ = -36%
Mass. - Haskell	$\frac{10670}{9180}$ = +16%	$\frac{8200}{9180}$ = -11%	$\frac{8110}{9180}$ = -12%
Haskell - County Rd.	$\frac{9740}{9180}$ = +6%	$\frac{10100}{9180}$ = +10%	$\frac{10270}{9180}$ = +12%

TABLE IV-10

CHAPTER V

CONCLUSIONS

The STOCH model, when used as a "stand alone" traffic assignment technique in Lawrence, did not give better results than the capacity restraint technique. The best overall STOCH assignment results were obtained with a theta value of 0.005. The VMT comparisons, the percent error in assignment and the average difference for the overall assignment were more accurate with this STOCH assignment than with the capacity restraint assignment, however, the individual link volumes were more closely matched with the capacity restraint assignment. The greater accuracy of capacity restraint in duplicating individual link counts is indicated by an RMS error of 974 as compared to an RMS error of 1468 with the STOCH assignment.

Due to a general underestimation of trips with the synthetic procedures described in Chapter III, both assignments underassigned trips to the major facilities. The STOCH model was more inaccurate in this respect because of the high diversion of trips to other facilities with nearly all values of theta.

Suggestions for Additional Research

This has been one small test of the new multipath assignment technique. The results of this project do not call for immediate rejection of the technique rather they indicate that the model has a great deal of promise and deserves further testing.

An attempt should be made to use the model on a larger network. When using a small network such as Lawrence, there are many paths with little difference in length, thus resulting in large diversion over a wide range of theta values. The use of a larger network would provide larger differences in paths and lessen the diversion over a range of theta values.

The possibility of using the model in combination with capacity restraint should also be tested. The ADT trip table could be broken down into subtables by the time of day that the trip took place. A subtable would be assigned then capacity restraint applied and another subtable assigned using the revised speeds. Longer paths in the first iteration would become more attractive in successive iterations and have their share of assigned trips increase. The sum of the iteration loadings would be the final expected link volumes. This project has indicated that a theta value of approximately 0.005 would be an appropriate beginning value for these further tests.

FOOTNOTES

[1]U. S. Department of Transportation, Federal Highway Administration, Traffic Assignment. (Washington, D. C.: Government Printing Office, 1973), p. 1.

[2]Ibid. pp. 1-2.

[3]Ibid. pp. 28-34.

[4]Ibid. p. 7.

[5]Thomas F. Humphrey, "A Report on the Accuracy of Traffic Assignment When Using Capacity Restraint," Highway Research Record No. 191, (Washington, D. C.: Highway Research Board, 1967), pp. 53-56.

[6]U. S. Department of Transportation, Federal Highway Administration, Urban Transportation Planning Program Documentation. (Washington, D. C.: Government Printing Office, 1972), pp. 696-709.

[7]R. B. Dial, A Probabilistic Multipath Traffic Assignment Model Which Obviates Path Enumeration. (Springfield, Virginia: National Technical Information Service, 1971), pp. 15-16.

[8]Ibid. pp. 22-23.

[9]Ibid. pp. 15-35.

[10]State Highway Commission of Kansas, Planning and Development Department, Program Documentation Urban Transportation Planning. (Topeka, Kansas: 1973), pp. i-vii.

[11]State Highway Commission of Kansas, Planning and Development Department, Lawrence Area Transportation Study 1971. (Topeka, Kansas: 1972), pp. i-iii.

[12]Ibid. p. 2.

[13]Bather-Ringrose-Wolsfeld, Inc., Development of Internal Travel St. Cloud Metropolitan Area Transportation and Planning Study. (Rosseville, Minnesota: 1971), pp. 23-26.

[14]Urban Transportation Planning Program Documentation, pp. 181-208.

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1. Bather-Ringrose-Wodsfeld, Inc., Development of Internal Travel St. Cloud Metropolitan Area Transportation and Planning Study. Roseville, Minnesota, 1971.

2. Dial, R. B., A Probabilistic Multipath Traffic Assignment Model Which Obviates Path Enumeration. Springfield, Virginia: National Technical Information Service, 1971.

3. Humphrey, Thomas F., "A Report on the Accuracy of Traffic Assignment When Using Capacity Restraint," Highway Research Record No. 191. Washington, D. C.: Highway Research Board, 1967.

4. State Highway Commission of Kansas, Planning and Development Department, Lawrence Area Transportation Study 1971. Topeka, Kansas: 1972.

5. State Highway Commission of Kansas, Planning and Development Department, Program Documentation Urban Transportation Planning. Topeka, Kansas: 1973.

6. U. S. Department of Transportation, Federal Highway Administration, Traffic Assignment. Washington, D. C.: Government Printing Office, 1973.

7. U. S. Department of Transportation, Federal Highway Administration, Urban Transportation Planning Program Documentation. Washington, D. C.: Government Printing Office, 1972.

APPENDIX A

TRIP GENERATION EQUATIONS

TRIP GENERATION EQUATIONS

1. Home-Based Work Productions

   = -6.10 + .61 (Population)

2. Home-Based Work Attractions

   = 41.75 + 1.60 (Total Employment)

3. Home-Based Other Productions

   = .85 + 1.02 (Population)

4. Home-Based Other Attractions

   = 4.88 + .06 (Population + 10.91 (Retail Employment)*

5. Non-Home Based Productions

   = 33.24 + .29 (Population) + 6.06 (Retail Employment)

6. Non-Home Based Attractions

   = 33.24 + .29 (Population) + 6.06 (Retail Employment)

7. Truck Productions

   = 2.25 + .40 (Total Employment) + .12 (Population)

8. Truck Attractions

   = 2.64 + .40 (Total Employment) + .12 (Population)

9. External Local Attractions

   = 6.74 + 1.02 (Total Employment) + .10 (Population)

* SIC 50-59 which includes both wholesale and retail employment. For brevity, this group is referred to as retail employment.

APPENDIX B

CAPRKANS THEORY

HYUR008 (CAPRKANS)

Theory

The capacity restraint program reads in link capacities and loads from a traditional historical record and adjusts link speeds according to predetermined or user supplied volume-speed relationships and adds delay at intersections according to the volume-capacity relationship at the intersection approach. The program also allows the user to add a delay at all intersections regardless of the volume capacity relationship. No intersection delay time is added to freeway intersections. The observed speed coded in the link cards should approximate the operating speed for the first iteration since intersection delay is computed separately by the program.

The program contains the table of volume-speed curve slopes as shown in Table 1.

	CBD	Fringe	OBD	Residential	Rural
Freeway	0.019	0.019	0.019	0.019	0.030
Expressway	0.030	0.030	0.030	0.030	0.045
Arterial	0.045	0.030	0.030	0.045	0.060
Collector	0.060	0.045	0.045	0.060	0.067
Local	0.075	0.060	0.060	0.060	0.075

TABLE 1

An appropriate slope for each facility and area type is selected on a link basis. Using the observed speed and other information decoded from the link record a new speed is found by the following formula:

New Speed=Observed Speed + [(Load-Count) PHF ÷ NOL] (-Slope)

where: Load=Load being restrained.

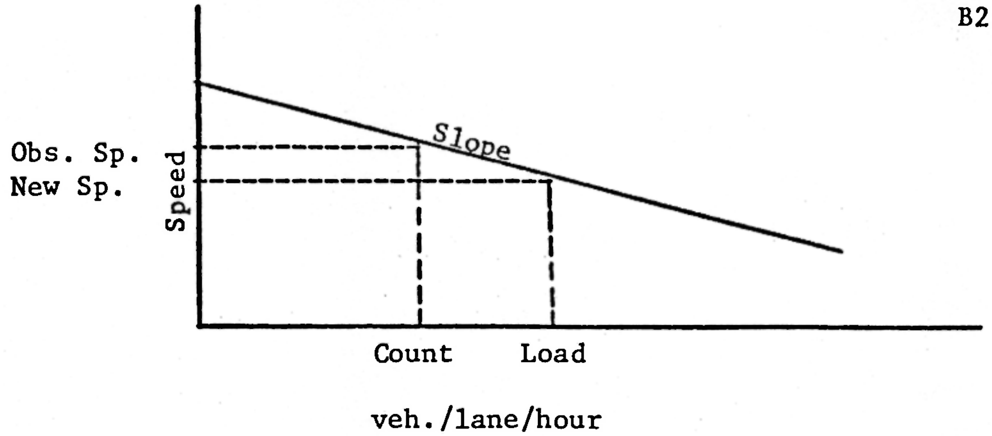
Count=Count coded in link record.

PHF=VPH/ADT

NOL=Number of lanes.

Observed Speed=Observed speed from input HR.

Slope=Slope selected from the table.



NOTE: The new speed could be greater than the observed speed if the load is less than the count. It is not necessary that the count always be coded but the new speed can only be less than the observed speed if it is not coded.

The assigned speed is now computed using the user supplied ratio from the parameter cards.

Assigned Speed=New Speed (Ratio) + Observed Speed (1-Ratio)

The new and assigned times are computed from the respective speeds.

New Time=(Distance)(60 min./hr.)(New Speed)

Assigned Time=(Distance)(60 min./hr.)(Assigned Speed)

The delay time is computed using the user supplied delay times in the parameter cards.

$$\text{Delay Time}=A/60\ \text{Sec./Min.} + (B/60\ \text{sec./min.})(\text{Load} \times \text{PHF} \div \text{Cap})^2$$

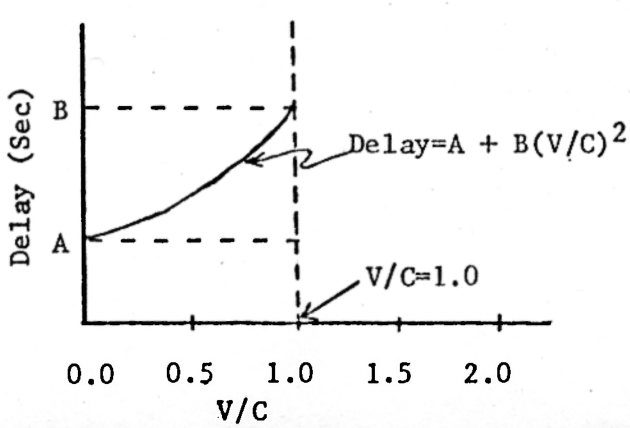
where: A=delay time in seconds for all real intersections.

B=delay time in seconds for volume at V/C=1.0

Load=load being restrained

PHF=VPH/ADT

Cap=Approach capacity of the intersection.



The delay time is also weighted using the user supplied ratio.

Delay Time = Delay Time (Ratio)

If the intersection is not a real intersection or is a freeway, no delay time is added. For all other intersections delay time is added to get a total time.

Total Time = Assigned Time + Delay Time

The four new words added to the HR contain the following:

A-B and B-A New Speed and New Time.

A-B and B-A Assigned Speed and Total Time.

APPENDIX C

STOCH DOCUMENTATION

STOCH

PROBABILISTIC MULTIPATH TRAFFIC ASSIGNMENT

A. Identification
Deck Name: STOCH
Written by: R. B. Dial, Alan M. Voorhees and Associates
Assembly date: May 1971

B. Purpose
STOCH reads a traditional historical record and trip table and performs a probabilistic multipath traffic assignment.* Using link impedances which are a user-specified linear combination of link times and distances, STOCH calculates all link volumes as well as turning volumes through user-selected nodes. Upon completing the loading process, the program prints a report that contains the link volumes for those links which were loaded and turning volumes through the user-selected nodes. The program optionally outputs an updated historical record and an "expected" travel impedance matrix.

This program can accommodate networks having up to 2000 centroids and 8000 nodes.

C. Components
This program is composed of the decks ST01-ST11, BPRJIN, AVDATE, PRTM, PARMF, SELCZZ, FLAG, AVGC, and routines from the FORTRAN library. Core required for the program is about 48K bytes. The program is coded entirely in FORTRAN IV(G).

D. Input-Output
The following datasets are used:

1. HRI — Input historical record

2. HRO** — Output historical record containing all input historical record data plus an additional five words at the end of each link record:

   (1) Impedance a-node to b-node.

   (2) Impedance b-node to a-node.

   (3) Turn volume 1, or all bits on indicating next two words are link volumes and not turn volumes.

*The theory and mechanics of the technique can be found in the report "A Probabilistic Mult-path Traffic Assignment Model Which Obviates Path Enumeration" (Available from the National Technical Information Service).

(more)

(4) Turn volume 2, or link volume a-node to b-node.

(5) Turn volume 2, or link volume b-node to a-node.

3. IMPEDO** Output expected travel impedance matrix ("skim bushes") in standard 2-byte impedance dataset format. The Job Control Language DCB parameter that the program defaults to for this dataset are as follows:

RECFM = V
LRECL = 2LCN+8
BLKSIZE = LRECL+4

Where LCN is the last centroid number.

4. SYSIN Standard "System Input" file containing program control cards.

5. DPNTAPE Standard "System Output" file destined for printer.

6. TRIPSI** Input Trip Table.

7. TEMP Scratch (sequential) dataset, used as repository for overflowing turn volumes. Not needed when region is large enough for saving all required turn volumes. The Job Control Language parameters to be punched on the DD card for this dataset are as follows:

```
DSN = TURNS,
UNIT = SYSDA,
SPACE = (TRK, (10,10),
DISP = (NEW, DELETE),
DCB = (RECFM=VBS, LRECL=2004,
BLKSIZE=2008)
```

E. Control cards
In addition to operating system job control cards, program control cards are required to specify program options and provide parameters. These cards must appear in the order given below:

		Number of cards which may be used
1.	Identification card	1
2.	Parameter card	1

**The presense of this dataset is dependent on user-selected options.

(more)

		Number of cards which may be used
3.	Options card	1
4.	Turn node range card	up to 3
5.	Origin range card	up to 3
6.	Destination range card	up to 3
7.	GO card	

E(1) Identification card (ID) - This card has "ID," punched in columns 1-3. The remaining columns contain any information the user wishes to use to identify the run. The information is printed as a heading to the link and turn volume report, and is written as a new comment record on the output historical record (if UPDATE is selected).

E(2) Parameter card (PAR) - This card has "PAR," in columns 1-4, followed by six numeric parameters separated by commas. These parameters, which must be provided in the sequence given, are:

a. TABLE — Trip table (purpose) number to be assigned.

b. THETA — Multipath diversion parameter. (Three assumed decimals.) When this parameter is large, e.g., 10000 (10.000), the effect is a loading of only the minimum paths, and when there is more than one minimum path between an origin-destination zone pair, each path receives the same number of trips. When THETA = 0, the effect is an ignoring of impedance, an all "reasonable" paths receive an equal number of trips. Recommended values for THETA are a subject of current research.

c. MAXC — Maximum link impedance (No assumed decimals.) The program scales all link impedances to 254ths of this value, except impedances greater than MAXC which are set to 254. If punched as 0, the program uses the highest calculated impedance as MAXC.

d. DC — Coefficient of distance (Three assumed decimals) in impedance calculation. When this parameter is zero, only link time is considered in the impedance calculation.

(more)

e. TC — Coefficient of time in impedance calculation. (Three assumed decimals.) A value must be specified if a coefficient of distance is not specified. Link impedances (before scaling) are calculated as DC times the link distance plus TC times the link time.

f. NWHRI — Number of words in the link record of the input historical record.

g. PRCNT — Percent of trip table to be assigned (three assumed decimals); a value of 90000 indicates that 90% of the trip table is to be assigned. If a number is not punched, 100% of the trip table will be assigned.

E(3) Option card (OPT) - This card has "OPT," in columns 1-4, followed by a series of "1s" and "0s" separated by commas. Currently 16 options exist, each of which is selected by punching a "1" in the appropriate field.

1. TEST — This option exists solely for program testing and demonstration. It eliminates the need to input a trip table dataset. When a 1 is punched, the program generates ten trips between all zones selected on the origin and destination range cards.

2. OBSERVED — This option selects the field of the historical record from which the link time is read. When a "1" is punched, the "observed travel time" is used. When "0" is punched, the time most recently appended to the record is used.

3-11. TRACE(1) . . . TRACE(9) — These nine fields yield "trace messages" for program diagnoses during testing for subroutines ST01-ST09. They should be all punched with a "0" for production runs. An explanation of the traces appears under item I Program Messages.

12. UPDATE — A "1" punched in this field causes STOCH to write an updated historical record as described above.

13. — Must be punched as "0".

14. SKIM — A "1" punched in this field causes STOCH to write the "expected travel impedance matrix."

15. A-O-N Currently a "0" must be punched for this field.

16. LOAD A "1" must be punched in this field to load the network.

E(4) Turn node range card (RANGET) - This card has "RANGET," punched in columns 1-7, followed by fields specifying individual node numbers or intervals of node number separated by commas. An interval of node numbers is given by the first node number in the interval followed by a dash and the last node number in the interval. For example, RANGET,75-100, 125-150 specifies that turn volumes are to be calculated for nodes 75 through 100, and nodes 125 through 150. STOCH calculates turning volumes through all nodes selected on the RANGET card. (Note: STOCH will <u>not</u> calculate turn volumes through centroids; therefore, centroids must not be included in any range(s) specified).

E(5) Origin range card (RANGEO) - This card has "RANGEO," punched in columns 1-7, followed by fields specifying individual centroid numbers or intervals of centroid number punched in the same format as the RANGET card. Only trips exiting from the selected centroids will be assigned. All other rows of the trip tables are ignored. If the expected travel impedance option has been specified, the matrix will only include rows for the selected origin zones.

E(6) Destination range card (RANGED) - This card contains "RANGED," in columns 1-7, followed by a sequence of destination centroids specified in the format of the RANGET card. Only trips ending at the selected centroids will be assigned. All other columns of the trip table will be ignored. The contents of this card have no effect on the expected travel impedance matrix.

E(7) GO card (GO) - This card has "GO" punched in columns 1-2, and must be the last program control card.

F. Core required
A rule of thumb for estimating the core required for a run of STOCH is CORE = 48K + 46 (highest node number).

G. Use of the program
The purpose of the program is to reduce the problems encountered with all-or-nothing assignment. The program is able to efficiently assign trips between a single O-D pair to more than a single path without use of an iterative procedure. Each of the "reasonable" paths between the O-D pair receives a fraction of the trips which is proportional to $e^{-(\theta \Delta t)}$

Where:

θ = the input dispersion parameter THETA

Δt = the difference between the total impedance of the given path and the minimum path impedance.

As can be seen, when θ = 0, all reasonable paths between an O-D pair become equally likely, and when θ is large, only the minimum paths have a significant likelihood of having trips assigned to them. A loading in the former case reveals a link's topological or positional importance, i.e., its proximity to the origin or destination centroid is revealed by the higher loading in the vicinity of either centroid. In the latter case, the loading is a demand assignment centroid with parallel, equal impedance paths being appropriately considered. Recommended values for THETA are a subject of present experimentation.

Link impedances are calculated as a linear combination of distance and time. Usually, time is the only factor of interest, and the coefficient of distance is zero. In this case, the time coefficient can be input as 10 (.01) to have the impedance measure be tenths of minutes or 1000 (1.0) for it to be hundredths of minutes. In the former case, the maximum time should be less than 25.4 and in the latter case than 2.54. In both cases the parameter MAXC is punched as 254. In this way, time and impedance become equivalent.

The program is capable of reading the historical record it outputs or one updated by the Capacity Restraint Program (CAPRES) and thus a reiterative assignment can be performed when STOCH is used in conjunction with CAPRES. For example, one may wish to stratify the trip table by intervals corresponding to the time of day the trip took place. A fraction of the total would thus be assigned and CAPRES used to recalculate the link times based on the estimated accumulated columes. Another fraction of the total trip table would then be assigned using the revised times, etc. In this way, secondary, longer paths in the first iteration would become more attractive as links on the shorter paths filled up, and their share of trips would increase. Upon completion, the sum of the incremental link loads would yield an estimate of the expected link volumes.

STOCH optionally calculates and outputs an "expected travel impedance" matrix. Written in the standard 2-byte impedance dataset format, each cell of the matrix contains the (integerized) statistical expectation of the impedance between its origin/destination pair. Expected travel impedance between a given O/D pair is defined as:

(more)

$$c = \sum t(P)\,\text{Prob}\,[P]$$

Where:

c = expected travel impedance between the given O/D pair

$t(P)$ = total impedance along path

Prob $[P]$ = probability that a trip between the given O/D pair uses path P

The user may opt to only output the expected travel impedance matrix. In this case the trip loading process is skipped, and the user should not input a trip table.

H. Program operation
This program has three distinct phases:

1. Input

2. Assignment

3. Output

Each is discussed separately below:

H(1) Input phase - In this phase the mainline routine after printing a sign-on message passes control to two subroutines. The first, ST01, reads and edits parameters and options from control cards and the historical record. Comments records on the historical dataset are read and listed. ST01 invokes the subroutines PARMF and SELCZZ for assistance in control card reading and interpretation. Upon return from ST01, the mainline routines passes control to ST02 via the core acquisition subroutine GETCOR.

ST02 reads the historical record, calculates impedances and tables a network description for use in subsequent phases of the program. ST02 also estimates the space required for saving turn volumes. Control is returned to the mainline routine which calls subroutine ST031 a mainline routine for the assignment phase.

H(2) Assignment phase - Subroutines ST031 calls subroutines BPRJIN, ST041, and ST051 once for each selected origin zones. BPRJIN reads rows of the trip table until the selected table number (parameter TABLE) is matched. The entire row of the trip table is returned to ST031, then zeros out the cells corresponding to unselected destination zones and calls ST041.

ST041 builds a "bush" of efficient links for the current origin zone and calculates measures for link usage probabilities. If skim option is selected, this routine ouputs a row of the expected travel impedance matrix.

(more)

ST051 assigns the trips returned by BPRJIN to the bush built by ST041. A table of link volumes for all links in the network are kept in core and appropriately incremented to account for the current origin zone's trips. For any turn volume that needs to be saved, ST051 calculates the volume and invokes subroutine ST09 to table the volume. ST09 saves turn volumes in a dynamic, list-structured array. Whenever the turn volume to be saved does not have an accummulating register presently in core, and all turn saving space is occupied, the contents of another turn's register are written on a scratch dataset, and its space is given to the current turn.

H(3) Output phase - This phase begins with ST031 calling ST07 to retrieve any turn volumes written on the scratch dataset. The amount of core available for turn saving is increased by the table space no longer used by subroutines ST041 and ST051. All turn volumes can now fit in core. ST07 reads in the turn volumes from the scratch dataset and calls ST09 to table them.

When ST07 returns control to ST031, the latter calls ST08 to print the link and turn volume report. ST08 involkes to calculate all volumes at a given node. ST101 in turn calls ST11 to adjust for any rounding error in turn volume calculation. ST08 prints nothing for any node at which there is no volume.

After the volume report is written, ST031 calls ST06 to update the historical record. ST06 also uses ST101 to obtain turn volumes. Also called is ST102, which returns volumes and impedances for a specified link. When updating is complete, control returns to the mainline routine which prints the signoff message and returns control to the operating system.

I. Program messages

STOCH prints many messages of varying severity. Listed below are the number, the severity code, the message, and its explanation for all messages produced by STOCH.

I = information message

W = warning message (abnormal condition encountered; STOCH keeps processing)

F = fatal message (will abort runs)

T = trace message (only printed if appropriate trace option selected)

Messages are grouped according to the issuing subroutine (CSECT).

<u>MAIN</u>

001 I START STOCH M01 AT TIME HH.MM.SS.
Displays hours, minutes, and second of time STOCH begins execution.

002 I END STOCH AT TIME HH.MM.SS.
Gives hour, minute, and second of the time STOCH HAS NORMAL TERMINATION.

003 F BETWEEN XXXXXXX AND XXXXXXX TOO FEW BYTES OF CORE AVAILABLE.

Tells how much additional core storage must be specified by JCL region parameters before STOCH can perform the assignment. The program can execute at the lower value, but it will run most efficiently at the upper value. At the upper value, all turn volumes can be saved in core storage; at the lower level, turns are written on the scratch dataset.

004 I REGION REQUIRED BETWEEN XXXXX AND XXXXK BYTES

Tells the total amount of core required to execute the program with the given input network configuration.

005 I ABNORMAL END AT TIME HH.MM.SS.

Gives hour, minute, and second of the time STOCH terminates due to an input parameter or data error.

006 F NOT ENOUGH CORE AVAILABLE

JCL region parameter is too small as specified. Program is unable to initiate processing. Increase its value to at least 48K plus 46 times the highest node number and rerun the job.

SUBROUTINE STO1

102 W HIGHEST CENTROID PARAMETER GREATHER THAN 2000

Too many zones in system or a parameter error.

103 W HIGHEST NODE PARAMETER GREATER THAN 8000

Too many nodes in system or parameter error. To minutes running time, the highest node number in the network should be a small as possible. In any event it cannot be larger than 8000.

104 W TRIP TABLE PARAMETER IMPROPERLY STATED --1 SUBSTITUTED

Something is wrong with the parameter that states which trip table of a merged file to assign.

111 I HRI COMMENT

This message is followed by the image of a comment record read from the input historical record file.

(more)

SUBROUTINE ST02

201 T ST02 ENTERED, ENTRY COUNT XX

This trace (2) message tells that subroutine ST02 was entered

202 T LP BITS=XXXX, ANODE=XXXXX, BNODE=XXXXX,XXXXX,XXXXX,XXXXX, TURN PENALTY =XXXXXXX

This trace (2) message displays the contents of an intersection record read from the input historical record.

203 T BNODE=XXXXX, DIST=XXXXX, TIME=XXXXX

This trace (2) message displays the partial contents of a link record read from the input historical record. The value equated to BNODE is the decimal equivalent of the first two bytes of word 3 of the link record, i.e., 4 times the node number plus the leg number.

204 T MAX COST=XXXX, SCALE FACTOR=XXXX.XXX .....

This trace (2) message giveSthe maximum link impedance to be used to scale calculated link impedance to integers between 1 and 254. Each link impedance is multiplied by the value equated to scale factor, and the result rounded to the nearest integral value.

206 W UNABLE TO FIND REVERSE OF LINK XXXXX TO XXXXX

Something is wrong with the contents of the input historical record file.

208 T LINK A=XXXXXX, IND=XXXXX, DATA=XXXX XXXX XXXX

This trace (2) message displays contents of network description tables (INDEX AND N2) built in core storage.

209 W END OF FILE ON HRI REACHED AT NODE XXXXX

Indicates that no links are connected to this node or nodes with higher numbers.

250 W UNABLE TO RELEASE CORE

Indicates a programing error encountered in attempting to release unused core storage through the routine PUTCOR.

(more)

299 I ACTUAL NUMBER OF LINKS IN THE NETWORK

This is an actual count of the number of links in the network as opposed to the number of links message that appears in the converted run parameter information (MESSAGE NUMBER 110). The number in MESSAGE 110 is just 4 times the number of zones.

SUBROUTINE ST03

301 I ASSIGNMENT BEGINNING AT TIME HH.MM.SS.

Indicates that parameters and networks has been read and tabled, and STOCH is beginning to load trips and/or skim bushes at the specified (wall clock) time.

302 I XXXXXXXXX TRIPS ASSIGNED, OUT OF TOTAL OF XXXXXXXXX TO BE ASSIGNED

Printed upon completion of assignment process. Both trip counts include intrazonal trips

303 W READ CHECK ON TRIP TABLES WHILE LOOKING FOR ZONE XXXX-- RECORD SKIPPED

Something wrong with indicated record of input trip table.

304 W EARLY EOF ON TRIP TABLE -- LOOKING FOR ZONE XXXX

Some rows missing from input trip table.

311 I END ASSIGNMENT AT TIME HH.MM.SS.

Gives (wall clock) time when all trips have been loaded.

BROUTINE ST04

401 T Network

ANODE BNODE BITS TAB TBA

Trace (4) message giving presence bits, and impedances for each link. Presence bits equal 1 for a one-way link B-to-A, 2 for a one-way link A-to-B, and 3 for a two-way link. Under the heading TAB is the scaled link cost from A to B, and under TBA is the reverse impedance.

402 T I=XXXX P(I)=XXXXX U(I)=XXXXXXX.XXXXXX

Trace (4) message giving the impedance over the shortest path to each node. The value equated to I is a node number and P(I) is equal to the impedance. The first value equated to I is the home node, and its P(I) should always be zero.

(more)

The nodes are listed in topological order with respect to the home node. Thus the ANODE of any "efficient" link would appear before its BNODE. The values equated to U(I) are meaningless at this time and are intended for use in future versions of the program.

403 T SKIM TREES XXXX

XXXX XXXX XXXX XXXX XXXX XXXX XXXX XXXX XXXX ...

Trace (4) message showing the home node, node number and expected travel impedance to each node.

SUBROUTINE ST06

601 T ST06 ENTERED, ENTRY COUNT=XX

Trace (6) message printed when the historical record update routine is entered.

602 W UNABLE TO FIND BNODE IN NLIST XXXXXX

Error condition stating that internal network description doesn't match the network being updated.

603 W END OF FILE ON HRI AT NODE XXXXXX

Indicates end of the input historical record as encountered during updating phase.

604 I HISTORICAL RECORD UPDATE COMPLETED

Volumes have been added to all link records of the historical record.

606 I NEW COMMENT RECORD

Displays contents of a comment record added to the historical record file.

607 T HRI COMMENT

Trace (6) message displaying contents of new comment record written on output historical record file.

608 T NEW HRI PARAMETER RECORD -
XXXXXXXXX XXXXXXXXX XXXXXXXXX ....

Trace (6) message giving a hexadecimal display of the contents of the parameter record of the output historical record.

609 T HRI INTERSECTION RECORD - XXXXX....XXXXXXXXXX.....

Trace(6) message giving a hexadecimal displays of the contents of an intersection records the output historical record.

610 T NEW COMMENT RECD -

Trace (6) message showing comment record added to output historical record.

611 T UPDATED LINK RECORD

XXXXXXXXX XXXXXXXXX XXXXXXXXX XXXXXXXXX XXXXXXXXX

Trace (6) message displaying contents of output link record in hexidecimal.

612 I LENGTH OF OUTPUT LINK RECORD IS XXXX.
This message gives the number of words in the link record output on the updated historical record. It should always be five larger than the NWHRI parameter input to STOCH.

SUBROUTINE ST07

701 I XXXXXX BLOCKS OF XXXXXX, TURNS WRITTEN ON SCRATCH DATASET

Tells how many turn volume records have overflowed onto the scratch dataset. These records are subsequently read back in an included in the calculated turn volumes. Their number (and the computer running time) may be reduced by increasing the JCL region parameter. If region parameter is set to higher value given in message 004, then no turn volumes are output on the scratch data set; all turn volumes are written in core.

SUBROUTINE ST09

901 T TURNS=XXXXXXXX

A trace (9) turn message specifies the maximum number of turn volumes STOCH might have to save. It is a function of the network configuration, and is usually an overestimate, as it assumes all links are two-way.

SUBROUTINE ST10

1001 W UNABLE TO FIND LINK XXXX,XXXX

An error condition encountered in attempting to fetch a link or turn volume. Indicates a program error related to tabling the network in core or reading it from the historical record file.

SUBROUTINE BPRJIN

1210 T TRIP TABLE RECORD: NZ=XXXX,FLAG=XXX,LTABLE=XXX,NZONE=XXXXX

A trace (6) message displaying contents of input trip table record. NZ is equated to the number of words in the record, FLAG the FLAG BYTE, LTABLE the TABLE number and NZONE the origin zone. The remaining fields are the contents of the remaining NZ-1 words. All values are given in hexadecimal.

1250 I TRIP TABLE COMMENT:

Displays the contents of a comment record read from the input trip table.

J. Sample set-up

```
X              X     LOCATION OF COLUMNS 1, 16, AND 72 MARKED          X

//P30RZ495  JOB  3330,'RALPH W ZYMMER',MSGLEVEL=1    STOCH RUN
//JOBLIB DD DSNAME=PLANPAC,DISP=(SHR,PASS),VOLUME=SER=UPDLIB,UNIT=SYSDA
//STOCHA EXEC PGM=STOCH
//HRI DD DSNAME=HRINPUT,VOLUME=SER=TAPEIN,DISP=(OLD,KEEP),             X
//              DCB=DEN=3,UNIT=(2400-4,,DEFER),LABEL=(1,SL)
//HRO DD UNIT=(2400-4,,DEFER),VOLUME=SER=TAPOUT,DISP=(NEW,PASS),       X
//              DSNAME=HROUTPUT,DCB=(RECFM=VB,LRECL=2004,BLKSIZE=2008)
//IMPEDO DD VOLUME=SER=IMPEDT,DISP=(NEW,KEEP),UNIT=(2400-4,,DEFER),    X
//              LABEL=(1,SL),DSNAME=IMPEDO.FILE
//TRIPSI DD DISP=(OLD,KEEP),LABEL=(1,SL),UNIT=(2400-4,,DEFER),         X
//              VOLUME=SER=TRPTAP,DCB=DEN=3,DSNAME=TRIPS.OUT
//TEMP DD DUMMY
//SYSABEND  DD  SYSOUT=A
//DPNTAPE   DD  SYSOUT=A
//SYSIN  DD  *
ID, THETA CALIBRATION, THETA=1000,  FROM ALL ZONES TO ALL ZONES, FROG HOLL
PAR,5,1000,254,0,1000,17,100
OPT,0,1,0,0,0,0,0,0,0,0,0,1,0,1,0,1
RANGEO,1-314
RANGED,1-314
RANGET,400-600
GO
/* END OF DECK
```

SAMPLE SET-UP ILLUSTRATING OPTIONS FOR ALL OUTPUTS.

(end)

APPENDIX D

CONTROL CARD LISTING

D1

```
//STEP1 EXEC PGM=STOCH,TIME=60
//STEPLIB DD DSNAME=HY.PL.UR.PLANPK72,DISP=SHR
//HRI   DD DISP=(OLD,KEEP),
//            UNIT=2314,
//           DSN=HY.PL.UR.P8060219.CAPXYNOD,
//              VOL=SER=D00003
//HRO      DD    DISP=(OLD,KEEP),
//            SPACE=(6447,(40,20),RLSE),
//              DCB=(RECFM=VB,LRECL=2004,BLKSIZE=2008),
//             DSN=HY.PL.UR.P8060101.STOCH100,
//              UNIT=2314,
//              VOL=SER=D00003
//TRIPSI DD DISP=(OLD,KEEP),
//        DSN=HY.PL.UR.P8066113,
//              UNIT=(2400,,DEFER),
//              LABEL=(1,SL,,IN),
//           VOL=SER=T02944
//TEMP  DD      DISP=(NEW,DELETE),
//              DSNAME=TURNS,
//              SPACE=(TRK,(10,10)),                                 X
//              DCB=(RECFM=VBS,LRECL=2004,BLKSIZE=2008),
//              UNIT=SYSDA
//DPNTAPE  DD SYSOUT=A
//SYSIN DD *
ID,LAWRENCE 1971 WITH THETA=1.000
PAR,1,01000,000,0000,1000,19
OPT,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,1
RANGEO,1-110
RANGED,1-110
GO
/*
```

APPENDIX E

DEFINITIONS

DEFINITIONS

ARTERIAL STREET: A street which provides for through traffic movement between and around areas and across the city with minimum direct access to abutting property; subject to necessary control of entrances, exits, and curb uses.

ATTRACTION: The pull or attracting power of a zone, usually measured in terms of number of trip ends.

AVERAGE DAILY TRAFFIC (ADT): The average number of vehicles passing a specified point during a 24 hour period.

CAPACITY: The maximum number of vehicles which can pass over a given section of a lane or a roadway in one or both directions during a given time period under prevailing roadway and traffic conditions.

COLLECTOR STREET: A street that provides access to abutting properties and also serves traffic between arterials and local streets.

CORDON LINE: An imaginary line enclosing a study area.

COUNT: The actual number of vehicles passing a specified point during a stated time period as determined by human or mechanical tabulation.

DESTINATION: The terminus of a trip.

EXPRESSWAY: A divided arterial highway for through traffic with full or partial control of access.

EXTERNAL: An adjective indicating outside of the study area.

EXTERNAL TRIPS: Those trips which cross the cordon line.

GRAVITY MODEL: A mathematical formula that distributes trips between zones proportional to the attraction of the destination and inversely proportional to some function of the separation between the zones.

HOME BASED TRIPS: Trips with either end at the residence (home).

INTERNAL: An adjective indicating inside of the study area.

LINK: A section of street or highway identified by the nodes at its ends.

LOADING (THE NETWORK): The computer process of accumulating loads upon each link in the network as trips from a triptable matrix are assigned to their associated routes.

LEVEL OF SERVICE: A qualitative measure of the effect on traffic of a number of factors such as speed and travel time, traffic interruption, freedom to maneuver, safety, driving comfort, convenience and operating cost.

DEFINITIONS (Cont'd)

IMPEDANCE: The resistance to travel such as time or distance between each pair of zones in the network.

IMPEDANCE SUMMATION: The accumulation of time, distance or some other resistance to travel between two zones.

MINIMUM PATH: The route of travel between two points which has the least accumulation of impedance.

LOCAL STREET: A street that is primarily for access to adjoining land and serves business, industrial or residential traffic movements.

NETWORK: The collection of links and nodes by which the major components of the street system within the study area are defined to the computer.

NODE: A numbered, identifiable point in a network at the junction of two or more links.

NONHOME BASED TRIPS: Trips with neither end at the residence (home).

ORIGIN: The point at which a trip commences.

ORIGIN AND DESTINATION (O&D) DATA: A collection of data indicating the true origins and destinations of trips.

PEAK HOUR VOLUME (PHV): The highest number of vehicles passing a specified point during any hour of the day.

PHV/ADT: The factor used to convert hourly traffic or capacity to daily capacity and vice-versa.

PRODUCTION: The generating power of a zone, usually measured in terms of number of trip ends.

PURPOSE: The reason for making a given trip. In the travel surveys, a purpose is usually associated with each trip end. For analysis, a single trip purpose is determined based on the two trip end purposes.

TRAVEL TIME FACTORS (F-FACTORS): A set of numbers, one for each travel time increment, indicating the effects of travel time upon number of trips. Used in the gravity model.

TRIP: A one-directional movement which begins at the origin and ends at the destination.

TRIP END: Either a trip origin or a trip destination.

TRIPTABLE: A matrix in computer-readable format showing how the trips are distributed between each pair of zones.

DEFINITIONS (Cont'd)

VEHICLE: Auto, taxi, truck, or bus.

ZONE: A portion of the study area which is delineated as such for the purpose of facilitating land use and traffic analyses.

MULTIPATH TECHNIQUE: A traffic assignment technique which attempts to proportion traffic among alternate routes between a pair of zones in a realistic manner.

LOADS (LINK OR NETWORK): The volume assigned on an individual link or the collection of volumes assigned on all links in a network as a result of loading the network.