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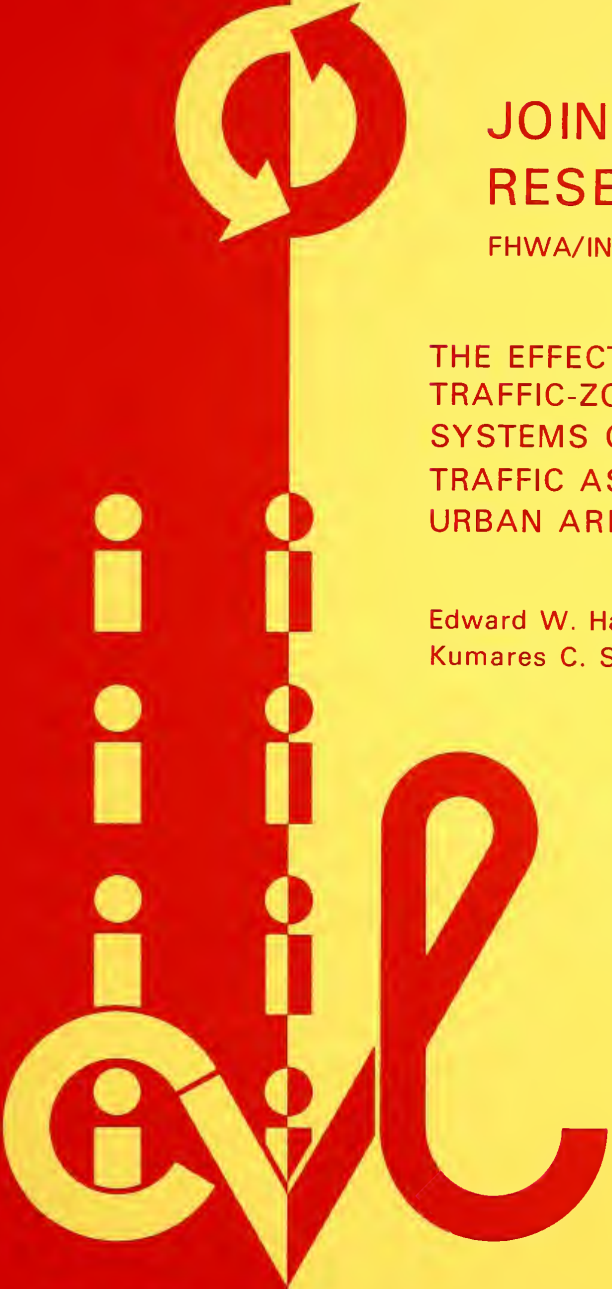

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-79/15

THE EFFECTS OF SIMPLIFYING TRAFFIC-ZONE AND STREET-NETWORK SYSTEMS ON THE ACCURACY OF TRAFFIC ASSIGNMENTS IN SMALL URBAN AREAS IN INDIANA

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PURDUE UNIVERSITY
INDIANA STATE HIGHWAY COMMISSION

Interim Report

THE EFFECTS OF SIMPLIFYING TRAFFIC-ZONE AND STREET-NETWORK SYSTEMS ON THE ACCURACY OF TRAFFIC ASSIGNMENTS IN SMALL URBAN AREAS IN INDIANA

TO: H. L. Michael, Director
Joint Highway Research Project

FROM: K. C. Sinha, Research Engineer
Joint Highway Research Project

September 5, 1979

Project: C-36-69L

File: 3-7-12

Attached is the third Interim Report on the HPR Part I Study titled "Use of Synthetic Demand Modelling Techniques in Transportation Planning for Small Urban Areas in Indiana". The title of this report is "The Effects of Simplifying Traffic-Zone and Street-Network Systems on the Accuracy of Traffic Assignments in Small Urban Areas in Indiana". The research has been conducted by Mr. Edward W. Hanscom, Graduate Instructor in Research on our staff under the direction of Prof. K. C. Sinha, Research Engineer.

The Report here is concerned with the evaluation of the role of traffic zone delineation and network configuration on the accuracy of traffic assignments in small urban areas. The findings provide recommendations that can be used by small urban areas in establishing zone boundaries in preparing network data.

This report is forwarded for review, comment and acceptance by the ISHC and FHWA as partial fulfillment of the objectives of the research.

Respectfully submitted,

K. C. Sinha

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Research Engineer

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Interim Report

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16. Abstract

As a part of a detailed study of synthetic travel demand modelling techniques that can be applied to small urban areas (population 50,000 to 250,000), this study concentrated solely on the traffic assignment phase of the modelling process. The study considered the effects of the following factors on the accuracy of traffic assignment: number of traffic zones, use of census tracts as traffic zones, complexity of the network configuration and method of traffic assignment. Transportation network and travel data from two small Indiana urban areas, Lafayette and Anderson, were used.

The results indicated that traffic zones, based upon census tract boundaries, and street nwtworks with less detail, can be used without significant reduction in assignment accuracy. For the small urban areas considered in the study 90 internal zones can provide acceptable accuracy in traffic assignment.

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Urban Transportation Planning; Traffic Assignment; Synthetic Demand Modelling.

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HIGHLIGHT SUMMARY

The costs of urban travel forecasting could be reduced if simple traffic-zone and street-network systems can be used without sacrificing accuracy in traffic assignments. This study considered simplification in the following forms: small numbers of traffic zones, use of census tracts as traffic zones, street networks with few low-volume links, and simple methods of traffic assignment. Transportation network and travel data from two small Indiana urban areas, Lafayette and Anderson, were used. Alternative traffic-zone and street-network systems were developed and tested for each city. Test results were compared by overall measures of traffic distribution and assignment accuracy, and by statistical analyses of network links stratified by volume group.

The results of the analyses show that some simplifications can be made without significant reductions in assignment accuracy for important network links. Traffic zones, based upon census tract boundaries, and street networks, with less detail, can be used. For the small urban areas considered in the study, 90 internal traffic zones can provide acceptable accuracy in traffic assignment.

INTRODUCTION

Conventional urban travel forecasting requires a considerable effort by a transportation planning staff in assembling a large data base. The data base includes inventories of land uses and transportation facilities and socio-economic and travel characteristics of tripmakers gathered through interviewing on a large scale. After this massive data-collecting effort, these data are coded to use in sophisticated, computerized, travel-forecasting models. After calibrating the models and making the initial land use and travel forecasts, supplementary data are gathered to periodically update these forecasts.

This conventional approach to travel forecasting, a major undertaking for any city, is especially burdensome for small urban areas, with populations 50,000 to 250,000. (1) To maintain the same level of accuracy in data, the per cent sampling rates for large-scale travel surveys must be higher in small cities than they are in large cities. (2) Therefore, travel surveys in smaller cities have a higher per capita cost in time, money, and manpower. Coding data for a detailed street network with many links, traffic zone centroids, and other nodes is laborious and time-consuming. The use of computerized modelling packages needed in the conventional approach requires computer facilities and specially trained personnel that few small planning staffs have on hand. Planners in small cities must rely on outside help to make the necessary computer runs for model calibrating and travel forecasting. This lack of an in-house computational capability slows the forecasting process even more. (1,3)

To summarize, conventional urban travel forecasting has two main shortcomings. When applied to a small city, it requires inordinate amounts of the city's resources to collect and code data. Secondly, the slow pace by which this approach proceeds from inventories and surveys to travel forecasts makes it ill-suited for quick-response planning. The first shortcoming has been recognized for many years, but the second shortcoming has grown in importance as the need for quick response planning has been recognized more recently. (3)

A simplified travel forecasting approach can ease some of the problems of travel forecasting in small cities. Better use of readily available data sources, such as the U.S. Census, will simplify data collection. (4,5,6) The use of fewer traffic zones to represent study areas will simplify the coding of land-use, network, and survey data and speed computing to the point where manual forecasting methods can substitute for computerized methods. (3) Also, the use of simplified street network representations that include fewer non-arterial streets will ease the coding and computational work-loads.

The danger of a simplified approach is oversimplification. If travel forecasting is oversimplified, the resulting traffic assignments may lack the accuracy needed for planning purposes.

Previous to this study, some research had been done on the effects of zone size on the accuracy of traffic assignments. Wildermuth and others used the 1964 network and travel data from Melbourne, Australia, as the study data. (7) They divided Melbourne into six different traffic zone systems with numbers of internal zones ranging from 40 to 607. Using the same street network each time, the researchers calibrated the gravity model and assigned the trips for the six zone systems. Then, they compared the accuracies of the trip distributions and traffic assignments with origin-destination survey data and ground counts. The researchers concluded that large zones, averaging as many as 30,000 trip ends each, can be used effectively in forecasting travel through transportation corridors.

In other research, Horowitz suggested that the appropriate number of zones to use in travel forecasting depends upon the number of network links being analyzed and the level of accuracy needed for a specific forecasting task. (8) The task may be predicting anything from area-wide vehicle-miles to local-level traffic movements to air pollution impacts in a transportation corridor. For each task and each network, achieving the desired level of accuracy requires the use of a minimum number of zones.

With respect to small urban areas, previous research has left several gaps in the knowledge of how the use of simplified zone and street systems affects the accuracy of traffic assignments. How would simplified systems affect accuracy in cities much smaller than Melbourne? How would the removal of less important links from the network, i.e., network reduction, affect the accuracy of assignments on more important links? Can the boundaries of census tracts be used as the boundaries of large traffic zones, or must the boundaries of traffic zones more closely follow the boundaries between differing land uses? Census tracts, which are very convenient land units for gathering socio-economic data, often do not contain one dominant land use. The purpose of this research has been to fill the gaps by answering these questions and providing guidelines for the future use of simplified zone and street systems in transportation planning in small urban areas.

DEVELOPMENT OF ZONE AND STREET SYSTEMS FOR STUDY

To build a framework for studying zone and street system simplification, the factors of interest first had to be identified. Average traffic zone size, inversely proportional to the total number of traffic zones, was an important factor to consider. Other major factors to study were the use of census tracts as traffic zones and the level of detail used in street networks. Another factor considered was the method of traffic assignment used, all-or-nothing or capacity restraint. Clearly, a statistical design of experimentation was needed to test these factors and the possible interactions among them. To do this, actual transportation network and travel data from small urban areas were gathered.

It should be noted that the zone size and the network complexity depend on the specific purpose of a transportation study and the method of analysis used. The present study concentrated on areawide long-range transportation planning and the zone and network configurations were developed accordingly. However, for subarea analysis, such as a corridor study, the zone delineation would involve using relatively fine analysis areas within the corridor of interest and relatively gross areas outside the areas of interest. The network details would also follow the same differentiation in such a subarea analysis.

Table 1. General Characteristics of Lafayette and Anderson Transportation Study Areas.

	Lafayette	Anderson
1970 population of Standard Metropolitan Statistical Area (SMSA)	109,000	138,000
Number of census tracts in SMSA	29	38
Year of network and travel data collection	1970	1971
Size of study area in square miles	165	80
Total daily vehicle-trips	339,000	301,000
Number of traffic zones		
Internal	111	169
External	17	44
Number of coded arterial and collector links	1000	1441

Urban Areas Studied

Urban areas used in this study met the following criteria. They had metropolitan areas with 50,000 to 250,000 people. Their transportation study areas contained no more than 250 traffic zones (internal plus external). Finally, their network and travel data were readily available with few preparations necessary. The last two criteria were needed because of temporal, fiscal, and computational limitations. Lafayette and Anderson, two Indiana urban areas meeting all the criteria, were chosen for the study. Table 1 provides general information on the two areas. The information comes from the Bureau of the Census (9), the

Greater Lafayette Area Transportation and Development Study (10,11,12), and the Anderson Urban Area Transportation Development Planning Process (13,14).

Alternative Traffic Zone Systems

For each urban area, alternative traffic zone systems were developed by substituting existing zones with smaller numbers of large zones. Only the internal zones were changed; all external zones were left intact.

As in the Melbourne study, larger zones were formed by combining whole existing zones into larger units. (7) Larger zones were made to average about twice the size of the next largest average zone size so that a good range of zone sizes could be tested. Only adjacent existing zones with similar land uses were combined into a larger zone. Zones containing special major trip generators, such as shopping centers, colleges, CBD's, and industrial plants were kept intact whenever possible. The numbers of vehicle-trip productions and attractions (P's and A's) for a new zone were computed simply by adding together the P's and A's of its component zones. Table 2 summarizes the alternative zone systems for Lafayette and Anderson.

New zone systems were also developed from census tracts. Because census tract boundaries always coincided with existing traffic zone boundaries, computing the P's and A's for Anderson census tracts was easy. However, Lafayette census tract boundaries rarely coincided with those of existing traffic zones. (9,10) This made computing P's and A's more difficult. A method used by Law apportioned P's and A's from old zones to new zones commensurately with old zones' areal

Table 2. Alternative Traffic Zone System Characteristics.

	Number of zones	Average trip-ends/zone in thousands	Average area/zone in sq. mi.
Lafayette Zone System			
L111 (Existing zones)	111	5.5	1.50
L55	55	11.2	3.04
L55C (Half census tracts)	55	11.2	3.04
L30	30	20.5	5.57
L30C (Census tracts)	30	20.5	5.57
Anderson Zone System			
A169 (Existing zones)	169	3.0	.47
A93	93	5.4	.86
A51	51	9.9	1.57
A28	28	18.0	2.86

contributions. (5) For example, if new Zone A is composed of all the area of zone 1, 40% of zone 2's area, and 30% of zone 3's, then the P's and A's of zone A are equal to the sum of zone 1's P's and A's, 40% of zone 2's and 30% of Zone 3's. This method was used in the present study for the two Lafayette zone systems made from census tracts. Appendix A shows how existing zones were apportioned to form new zones.

When a new zone system was created, the centroid-connecting links to the old zones were changed. Some were deleted, but others were renumbered for use in the new zone system. Only centroid connectors that were near the new zone centroid and collectively provided access to all nearby arterial and collector streets were chosen for the new zone. These criteria for selecting centroid connectors helped prevent distortions in assigned volumes due to the unavoidable elimination of some centroid connectors.

Terminal Time and Intrazonal Travel Time Estimations

New terminal times and intrazonal travel times were established for each new zone. The terminal time for a new zone was set as the terminal time predominant among the existing zones from which the new zone was formed. The following equation was developed to compute the intrazonal travel times for new zones:

$$ITT_{new} = \frac{\Sigma(ITT_z * p_z)}{\sqrt{\Sigma p_z}} \qquad z = 1,2,\ldots,n \qquad \text{(eq. 1)}$$

where: ITT_{new} = intrazonal travel time for new zone

ITT_z = intrazonal travel time for old zone

n = number of old zones within new zone

p_z = areal fraction of old zone z within new zone.

This method for estimating the intrazonal travel time (ITT) required the basic assumption that the ITT is directly proportional to the square root of the zone's area. Also, old zones were assumed to be equal in size. Because ITT's for the existing zones of both urban areas were available only in terms of whole minutes, ITT's for new zones were computed to the nearest whole minute. The assumptions made with respect to intrazonal travel times and areas of zones were reasonable and adequate for computing new ITT's with this level of accuracy.

The equation was derived in the following way. A weighted average ITT for the contributing old zones was:

$$\frac{\Sigma(\mathrm{ITT}_z * p_z)}{\Sigma p_z}$$

where the areal fraction (p_z) represented a weighting factor and the denominator represented a weighted total number of old zones. If each p_z was equal to one, then the denominator was simply the number of old zones comprising the new zone. This average ITT for old zones was converted to an ITT for the new zone by multiplying the average ITT by:

$$\sqrt{\Sigma p_z}$$

which took into account the larger area of the new zone. The net result of this multiplication was the right side of Equation 1.

The p_z's were equal to one, except when Lafayette traffic zones were aggregated into Lafayette census tracts. Returning to the earlier example of computing P's and A's shows how the method worked with Lafayette census tracts.

Given: New Zone A = 1.0(Zone 1) + .4(Zone 2) + .3(Zone 3)

$n = 3$ $p_1 = 1.0$ $ITT_1 = 1$ min.

$p_2 = .4$ $ITT_2 = 2$

$p_3 = .3$ $ITT_3 = 1$

Thus: $\Sigma p\text{'s} = 1.7$ $\Sigma(ITT*p)\text{'s} = 2.1$

$$ITT_{new} = \frac{2.1}{\sqrt{1.7}} = 1.6 \text{ or } 2 \text{ min.}$$

Alternative Network Systems

Two alternative street network systems were developed for each urban area. One alternative was the full, existing coded network for the urban area. The other alternative was a reduced version of the full network, with some minor links removed. All links on collector streets that carried less than 5000 vehicles per day were removed, since accurate volumes are difficult to assign to links in this volume group. (2) All links on arterial streets and high-volume collector streets were kept in the reduced networks, as well as in the full networks. This level of street network detail was a minimum level at which all important links would still be represented. Yet, the reduced networks, detailed at this minimum level, have more than 75% of the links in the full networks. (See Table 3.) For this reason, no street networks of intermediate detail were developed; the differences between an intermediate alternative network and the full and reduced networks would be very small.

Table 3. Alternative Street Network Characteristics.

	Lafayette	Anderson
One-way links in full network	1000	1441
One-way links in reduced network	870	1107
Percent reduction in links	13%	23%

PROCEDURES FOR DATA COLLECTION AND ANALYSIS

For both Lafayette and Anderson, each alternative traffic-zone system was tested with each alternative street network. This resulted in ten zone-network tests for Lafayette and eight for Anderson. Table 4 shows the layout of the eighteen tests. Each test included a gravity-model calibration, an all-or-nothing assignment, and a capacity restrained assignment. After all tests had been completed, the data resulting from the calibrations and assignments were analyzed.

Data Collection

Running the tests required street network data and travel survey data. The street network data, for building the full and reduced networks, included a listing of all links with each link's length, travel time, ground count, and capacity. Model calibrations and all-or-nothing assignments required the link lengths and travel times, but capacity-restrained assignments also required the ground counts and capacities. Travel survey data included vehicle-trip P's and A's for each zone, trip length distributions, and vehicle-trips interchanged between external-internal and external-external zone pairs. The trip length distributions and the P's and A's of internal zones were broken down into three trip purposes: home-based work (HBW), home-based other (HBO), and non-home-based (NHB). This breakdown is sufficient for planning in small cities. (1) The gravity model was calibrated for

Table 4. Layout of Zone-Network Tests.

Zone System	Full Network	Reduced Network
L111	x[*]	x
L55	x	x
L55C	x	x
L30	x	x
L30C	x	x
A169	x	x
A93	x	x
A51	x	x
A28	x	x

[*] Each "x" represents one test. Each test includes one gravity-model calibration and two traffic assignments.

internal trips only, since this study was concerned with effects of the size of internal zones. However, because assigned volumes would be compared with ground counts, externally produced trips were assigned with the internal trips.

Each test followed the same set of procedures. Figure 1 shows the sequence of activities in the testing process. These activities are described in the following paragraphs.

Preparation of Network and Travel Data

Preparing the link deck, determining terminal times (TT's) and intrazonal travel times (ITT's), and aggregating zonal data were the first three activities. The two street networks, full and reduced, were each represented by a link deck. The network to be tested determined the link deck to be prepared. Link deck preparation involved the removal of excess centroid connectors, and the renumbering of centroids for the test zone system. TT's and ITT's for the test zones were determined by the methods discussed in the previous chapter. Three types of zonal data were aggregated for the test zones: P's, A's, and external-internal trips.

Two more activities were done before the gravity model was calibrated. First, minimum path trees for the test zones were built from the prepared link deck. Then, the travel time matrix was built by using the minimum path trees, the TT's, and the ITT's.

Gravity Model Calibration

The next activities were calibrating the gravity model and building the combined trip table. The model calibrated in each test was

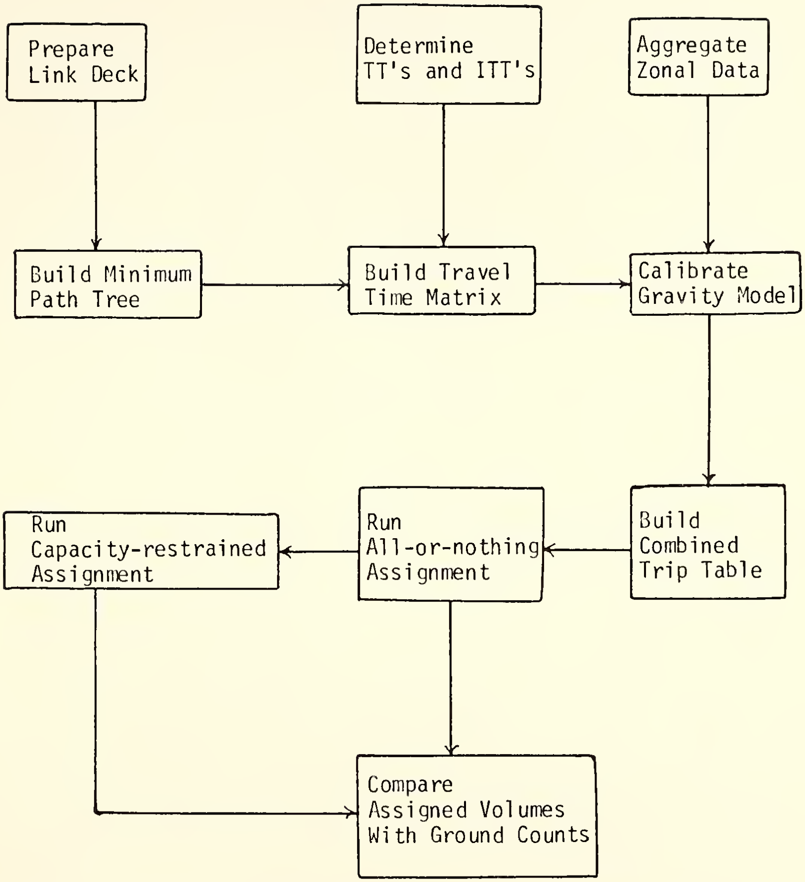

Figure 1. Sequence of Activities in Testing Process.

$$T_{ij} = P_i \frac{A_j F_{ij}}{\Sigma A_j F_{ij}} \qquad j = 1,2,\ldots,n \qquad \text{(eq. 2)}$$

where: $$F_{ij} = t_{ij}^{-\alpha} \qquad \text{(eq. 3)}$$

and: T_{ij} = trips produced in zone i and attracted to zone j

P_i = total trips produced in zone i

A_i = total trips attracted to zone j

F_{ij} = travel time factor from zone i to zone j

n = total number of zones

t_{ij} = travel time from zone i to zone j

α = alpha, travel time exponent.

This model contained no socio-economic adjustment factors (K factors). It was felt that without spot adjustments to the trip interchanges, calibrating would be more consistent from test to test. Using K factors could have biased the comparisons between tests. Alpha, the travel time exponent, was the only parameter in the F factor equation. Using alpha kept the equation simple and led to a well-calibrated model. The alphas for each trip purpose were determined to the nearest tenth (0.1).

Calibration produced trip tables for HBW, HBO, and NHB trips. These trip tables were added to a table of externally produced trips to create a combined trip table for traffic assignment.

Traffic Assignment

Trips were assigned by two methods: all-or-nothing and capacity restraint. The all-or-nothing assignment was run in the standard manner. The capacity-restrained assignment, an iterative process, began by assigning trips until a saturated link was found. A saturated link was a link in the network where the assigned 24-hr volume reached the link's 24-hr capacity. This capacity was assumed to be ten times the ultimate hourly capacity, because the one-directional 24-hr volumes on streets in small urban areas are typically ten times the one-directional peak-hr volumes. (15) After this first iteration, the remaining trips were assigned to the network in 10% increments until all trips had been assigned. As the iterations progressed, saturated links received large travel-time penalties, making these links unattractive for additional assigned volumes. Links over 50% saturated received smaller time penalties from the following equation (adapted from the FHWA formula (16)):

$$T = T_o + 0.15(V/0.75C)^4 \qquad \text{(eq. 4)}$$

where: T = new travel time

T_o = free flow travel time

V = assigned 24-hr volume

C = ultimate 24-hr capacity.

The final step was comparing traffic-assigned volumes with ground count volumes. This step produced the data from which most of the analyses would be based.

The computer package used in performing the activities in each test was the Purdue University NeTwork analysis package (PUNT). This package is a thoroughly modified and improved version of the TNET package developed at the Institute of Traffic and Transportation Engineering. (17) The PUNT package is well-suited for Purdue University's CDC computers.

Analyses of Data

The data from the test calibrations and assignments were analyzed by several methods. Both aggregate and stratified methods were used. Aggregate methods were used to evaluate overall model calibrations and traffic assignments. Stratified methods were used to study traffic assignments in more detail.

Aggregate Analyses

Alpha values and intrazonal trip measurements were used to compare the model calibrations and trip distributions of all tests. Alpha values were examined for their stability with changes in the zone system or street network. Intrazonal trips were measured as a percentage of all internal trips. The percentage of intrazonal trips could be expected to increase as zone size increased. This percentage should be kept down since intrazonal trips are not loaded on a network.

Total vehicle-miles traveled (VMT), on arterials and collectors, and overall percent root-mean-square error (%RMSE) were aggregate measures for comparing traffic assignments. Both measures have seen much use in past studies of traffic assignment. (2,7,18,19) The %RMSE approximates the percent standard deviation and is calculated by

$$\%\text{RMSE} = \frac{100\sqrt{\Sigma(A_i - G_i)^2 / n}}{\Sigma G_i / n} \qquad i = 1,2,\ldots n \qquad \text{(eq. 5)}$$

where:
A_i = assigned volume of link i
G_i = ground count volume on link i
n = number of links.

Volume Groups

To study traffic assignments at a detailed level, the total population of links in a street network was stratified into volume groups based on ground count volumes. For convenience in analysis, volume groups were designated by one-way volume ranges. Table 5 lists the five volume groups.

Links in the volume group of 0-2500 ADT were not studied in detail because of the large assignment errors associated with such links. However, low-volume links are less important to planners than higher-volume links. The reduced networks contained fewer low-volume links than the corresponding full networks did.

Volume groups 1 through 4 represented those links to which accurate assignments could generally be made. The ADT ranges for each group were set so that each volume group would contain a large number of links (over 100 links in most cases). For volume groups 1 through 4, corresponding full and reduced networks were identical in numbers of links. Table 6 shows the number of links in each volume group of the Lafayette and Anderson networks.

Statistical Analysis

Statistical analysis at the stratified level was conducted in two phases. In the first phase, the %RMSE's of volume groups in each assignment were analyzed for the main effects and certain interactions. In the second phase, Friedman rank sums were used to study the data at the link-by-link level. (20)

In the first phase of the stratified analysis, the primary interest lay with the main effects of the factors, while some interest lay

Table 5. Five Volume Groups for the Analyses.

Volume Group	One-way ADT Range
0	0 - 2500
1	2500 - 4000
2	4000 - 6000
3	6000 - 10000
4	10000 +

Table 6. Number of Links by Network and Volume Group.

Volume Group	Lafayette Networks Full	Lafayette Networks Reduced	Anderson Networks Full	Anderson Networks Reduced
0	360	230	829	395
1	195	195	241	241
2	213	213	222	222
3	158	158	125	125
4	74	74	24	24
Total Links	1000	870	1441	1107

with possible interactions between factors. These factors of interest were the number of traffic zones, the type of zone boundary (census or non-census), the type of street network (full or reduced), and the method of traffic assignment. Volume group was added to the list of factors because it is an important source of variation in %RMSE. (2) Two-way interactions were examined because some factors might have interacted in a way that affected assignment accuracy. For example, a significant interaction between the number of zones (zone size) and network type might suggest an optimum ratio between the numbers of zones and links. Three-way and higher interactions were assumed to be zero. Multiple-factor analyses of variance (ANOVA's) were run to indicate which factors and interactions had strong effects and which did not. Each observation in an ANOVA represented a %RMSE for one volume group in one traffic assignment. For Anderson, this meant 64 observations (4 volume groups x 4 zone systems x 2 networks x 2 assignment methods). The transformation of observed %RMSE's, as shown in Equation 6, was assumed to produce normally distributed variation in observations.

$$\text{Transform} = \log_e(\%\text{RMSE})^2 \qquad \text{(eq. 6)}$$

After the ANOVA's were run for each city, the results were compared to find common main effects and interactions.

For the second phase of stratified analysis, observations were the absolute differences between the assigned volumes and ground counts on individual links. Having large numbers of observations would improve the strength of any statistical findings. However, links on a network are not independent of each other and neither are their traffic volumes. Without independent observations, parametric statistical methods lack validity. For this reason, these data were analyzed by nonparametric methods using Friedman rank sums. (20)

Nonparametric rank sums analysis worked in the following manner. A factor such as number of zones was chosen for analysis. Each level of the factor represented a factor treatment as shown in Table 7. The levels of the other factors were kept constant. Observations on the same links were ranked in order of assignment accuracy, and the rank sums for each treatment were calculated. Multiple-comparison tests were run to find which treatments worked better than others. Treatments i and j were found to differ if:

$$|R_i - R_j| \geq q(\alpha, k, \infty)\sqrt{n(k)(k+1)/12} \qquad \text{(eq. 7)}$$

where: R_i = rank sum of treatment i

R_j = rank sum of treatment j

q = q statistic (from Table A.10., p. 330, Ref. 20)

k = number of treatments in the factor of interest

n = number of links in the volume group

α = level of significance

∞ = infinity, representing a large number of links

The results of an analysis, such as the one laid out in Table 7, would show how the number of zones affected assignment accuracy under a specific condition. By rerunning the analysis and changing the levels of the other factors, the effect of zones on accuracy would be shown in broader terms. Similar analyses were conducted for the other factors.

Table 7. Typical Layout for a Rank Sums Analysis.

	Number of Zones (4 Treatments)			
	169	93	51	28
Link	Observations and (Rankings)			
1	2015(1)	2596(3)	2239(2)	2964(4)
2	1986(2)	2802(4)	1934(1)	2095(3)
3	391(2)	802(4)	50(1)	506(3)
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
125	791(1)	979(2)	993(3)	1426(4)
Rank Sums	(294)	(284)	(323)	(349)

City: Anderson

Street Network: Full

Assignment Method: Capacity Restraint

Volume Group: 3 (6000 to 10000)

Observation = $|\text{assigned volume} - \text{ground count}|$

The nonparametric rank sums analyses were run for both Lafayette and Anderson. These results were compared, as were the results of the aggregate and other stratified analyses. General inferences, made from the data analyses of the two cities, are discussed in the next chapter.

ANALYSES OF TEST RESULTS

Upon completion of the 18 zone-network tests, the resulting data were analyzed to determine how the factors of interest affect the accuracy of traffic assignment. By using the methods described in the preceding chapter, relationships were found between factor simplification and assignment accuracy.

Effects of Factors on Alpha

As the data in Table 8 show, definite patterns appear in how zone and network factors affect values of the alpha parameter in gravity model calibration. Reducing the number of zones seemed to reduce the alphas for HBW trips, while the alphas of the other trip purposes were only slightly affected. Reducing the number of links in the network seemed to increase alphas for all trip purposes.

The effect of zones on HBW trip distribution can be explained this way. Commercial and industrial zones, which have large numbers of HBW attractions, rarely have large numbers of HBW productions. This forces HBW trips to be interzonal. Also, HBW attractions are concentrated within fewer zones than are attractions for other purposes. As zone sizes become larger, HBO and NHB trips are more inclined to become intrazonal. However, when HBW-attracting zones are aggregated into larger zones, HBW trips continue to be interzonal. The increasing restrictions on where HBW trips may be attracted diminish the importance

Table 8. Calibrated Alpha Values for All Zone-Network Combinations.

Trip Purpose	HBW		HBO		NHB	
Street Network	Full	Reduced	Full	Reduced	Full	Reduced
Zone System						
L111	1.7	1.8	2.7	2.8	2.5	2.6
L55	.9	1.1	2.1	2.3	1.8	2.1
L55C	.9	1.0	2.0	2.1	1.3	1.3
L30	1.1	1.1	2.9	2.9	2.5	2.6
L30C	.2	.4	1.9	2.0	1.0	1.1
A169	1.5	2.1	3.0	3.3	3.5	3.7
A93	1.2	1.8	2.9	3.1	3.3	3.6
A51	1.0	1.6	2.9	3.1	3.4	3.8
A28	.7	1.3	3.0	3.2	3.7	4.0

of travel time in HBW trip distribution. Relative to HBW trips, the restrictions on HBO and NHB trips are less severe; not only is the opportunity for intrazonal trips greater, those trips which remain interzonal have a larger selection of zones to which they may be attracted.

A reduced network increases alpha values in the following way. Removing some collector streets and centroid connectors (local streets) effectively increases the travel times between many pairs of zones. With a larger spread of travel times from any zone to all other zones, travel time becomes a more important factor in trip distribution. Larger alphas reflect the increased importance of travel time.

Alpha values were more variable for Lafayette than for Anderson. This occurrence may have been due to differences in the characteristics of the two cities, to differences in the accuracy of the data from the two cities, or to the use of very large zones in Lafayette. The 30-zone systems of Lafayette had an average zone size of 5.57 sq. mi., the largest zones being over 20 sq. mi. The largest zone in the 28-zone Anderson system was about 13 sq. mi. The variations in Lafayette alpha values, especially at the 30- and 55-zone levels, would affect assigned volumes. The effect on volumes would make study of zone boundary types more difficult. Zone and network factors have effects on the percentage of intrazonal trips. Table 9 shows the results. As expected, using larger zone sizes increased the percentage of intrazonal trips. For Lafayette the effects of zone size, zone boundary type, and street network were small. Intrazonal trips seem to increase when the network is reduced. Greater travel times between zones force more trips to be intrazonal.

Table 9. Percentages of Intrazonal Trips.

	Street Network	
Zone System	Full	Reduced
L11	4.7	4.5
L55	4.4	4.8
L55C	4.3	4.2
L30	6.0	6.1
L30C	4.9	5.0
A169	6.3	7.1
A93	7.8	9.3
A51	10.2	11.8
A28	12.4	14.1

The percentages of intrazonal trips in the 18 tests were small. In all tests, the percentage was never higher than the recommended maximum of 10-15%. (21)

Effects of Factors on VMT and %RMSE

The effects of zone and network factors on overall VMT appeared small. See Table 10. Total VMT in capacity-restrained assignments generally varied less than 5% with changes in zone size. Reducing network detail increased total VMT for both cities. A reduction in the number of network links increases the lengths of trips made on the network and reduces the number of alternate paths between zones. These actions work together in capacity restraint to increase congestion slightly and force trips to the more circuitous paths. The result is a higher overall VMT. Because the full Anderson network was reduced to a greater extent than the full Lafayette network (23% vs. 13%), increases in VMT were greater for Anderson.

Table 11 shows the overall %RMSE for each traffic assignment. Decreasing the number of zones tended to increase the %RMSE. Assigning traffic by capacity restraint always reduced the %RMSE. The use of capacity restraint reduced the effect of the number of zones on the %RMSE. Except for the cases of capacity-restrained assignments in Anderson, reduced networks showed lower %RMSE's. This was largely due to fewer links from volume group 0 being in the reduced networks. Assignment errors on such links tend to be high. As for the effect of zone boundary type on overall %RMSE, no real trend could be established.

Table 10. VMT[*] in Capacity-Restrained Assignments.

Zone System	Full	Reduced
L111	1086	1102
L55	1107	1080
L55C	1167	1191
L30	1030	1050
L30C	1076	1102
A169	990	1088
A93	995	1088
A51	1007	1092
A28	1010	1108

[*] VMT in thousands.

Table 11. Overall Percent Root-Mean-Square Errors.

	Zone System	Assignment Method All-or-Nothing	Capacity-Restraint
Full Network			
	L111	42.3	39.0
	L55	53.4	46.4
	L55C	60.4	47.4
	L30	63.2	52.0
	L30C	64.9	50.5
	A169	49.1	39.0
	A93	50.5	40.4
	A51	62.5	44.4
	A28	60.3	45.7
Reduced Network			
	L111	41.9	37.9
	L55	50.7	41.7
	L55C	52.8	46.1
	L30	62.6	47.3
	L30C	61.6	46.6
	A169	46.9	42.9
	A93	49.0	46.0
	A51	57.7	48.9
	A28	57.4	51.7

The %RMSE's for the Lafayette and Anderson traffic assignments compared favorably with those found in past studies. In a study of capacity restraint and traffic assignment accuracy, overall percent standard deviations for ten American cities ranged from 30.9% to 55.3%. (19) In the Melbourne study, %RMSE's for the six zone systems ranged from 47.4% to 84.5%. (7) Lafayette and Anderson %RMSE's, which approximate percent standard deviations, ranged from 37.9% to 52.0% for all capacity-restrained assignments. Of course, many of the assignments in this study were run with small numbers of zones and reduced street networks.

Stratified Analysis of %RMSE

In the stratified analyses of %RMSE, three ANOVA's were run at a .05 level of significance. Observations were the %RMSE's by volume group for every traffic assignment. Appendix B contains the observation tables and the ANOVA tables. The first ANOVA was run using four Lafayette zone systems and five factors (number of zones, zone boundary, street network, assignment method, and volume group). Zone system L111 was left out. The second ANOVA used all five Lafayette zone systems and four factors. By not including zone boundary as a factor, zone systems L55C and L30C became replications of L55 and L30, respectively. The third ANOVA used all four Anderson zone systems and four factors (number of zones, street network, assignment method, and volume group). Table 12 summarizes the results of the three ANOVA's.

The main effects of three factors were significant in all three ANOVA's: number of zones, assignment method, and volume group. Zone boundary, analyzed in the first ANOVA, was not a significant

Table 12. Summary of Analyses of Variance.

ANOVA	Lafayette (5-Factor)	Lafayette (4-Factor)	Anderson (4-Factor)
Significant			
Main Effects	Z,A,V	Z,A,V	Z,N,A,V
Interactions	ZB,AB,AV	ZA,NA,AV	AV
Insignificant			
Main Effects	N,B	N	
Interactions	ZN,ZA,ZV,BN,BV,NA,NV	ZN,ZV,NV	ZN,ZA,ZV,NA,NV

Z = Number of Zones

B = Zone Boundary

N = Street Network

A = Assignment method

V = Volume Group

Two-letter combinations = Two-way interactions factor. Street network was found to be significant in the Anderson ANOVA.

Of the two-way interactions, only the interaction between assignment method and volume group was significant in all three ANOVA's. This interaction can be explained by the observation that using capacity restraint improves accuracy in volume groups 1 and 2 more than in volume groups 3 and 4. Two interactions involving zone boundary were found significant in the 5-factor Lafayette ANOVA. However, a reasonable explanation for zone boundary interaction with either the number of zones or the assignment method is lacking. Because of this and the weakness of the main effect, boundary-type, interactions were not studied further.

The ANOVA showed that three factors, number of zones, assignment method, and volume group, had particularly significant main effects on the accuracy of traffic assignments. The main effects or zone boundary and street network were modest at most. Interactions between factors were few and generally inconsistent. The nonparametric, link-by-link analyses would describe the main effects more fully.

Nonparametric Analyses

The nonparametric analysis of zone boundary types confirmed what had been found in the preceding ANOVA. Table 13 shows that the type of zone boundary used had little effect at the 30 and 55 zone levels.

As Table 14 shows, the number of zones is an important factor in the accuracy of traffic assignments. For assigning traffic in Lafayette, 111 zones were slightly better than 55, and much better than

Table 13. Results of Nonparametric Analyses of Zone Boundary Types.

Assignment	Capacity Restraint								All-or-Nothing							
Street Network	Full				Reduced				Full				Reduced			
Volume Group	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Zone System Comparisons C:N																
L55C:L55	=	=	=	=	N	=	=	=	=	=	=	=	=	=	=	=
L30C:L30	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=

= : Both zone systems performed equally well.

C : Zone systems from census tracts performed better.

N : Zone systems not from census tracts performed better.

Pairwise comparisons were tested at a .05 level of significance.

Table 14. Results of Nonparametric Analyses of Number of Zones.

Assignment	Capacity Restraint								All-or-Nothing							
Network	Full				Reduced				Full				Reduced			
Volume Group	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Zone System Comparisons x:y																
L111:L55	x	=	=	=	=	=	x	=	x	=	=	=	=	x	=	=
L111:L30	x	x	x	=	x	x	x	=	x	x	x	x	x	x	x	x
L55:L30	=	x	=	=	=	x	=	=	x	x	x	=	x	x	x	=
L55C:L30C	=	=	=	=	x	=	=	=	x	=	=	=	x	=	=	=
A169:A93	x	=	=	=	=	=	=	=	x	=	=	=	=	=	=	=
A169:A51	x	x	=	=	x	=	=	=	x	x	=	=	x	x	x	x
A169:A28	x	=	x	=	x	x	=	=	x	x	=	=	x	x	x	=
A93:A51	=	=	=	x	=	=	=	=	x	x	x	x	x	x	x	x
A93:A28	x	=	x	=	x	=	=	=	x	x	=	=	x	x	x	=
A51:A28	x	=	=	=	x	=	=	=	=	=	=	y	=	=	=	y

= : Both zone systems performed equally well.

x : First zone system preformed better.

y: Second zone system performed better.

Pairwise comparisons were tested at a level of significance of .05.

30. Also, 55 zones appeared to be better than 30. For Anderson, 169 zones and 93 zone performed almost equally. 51 zones and 28 zones did not perform as well. In both cities accuracy differences between zone systems were less pronounced when capacity-restraint assignment substituted for all-or-nothing assignment. Accuracies on links in volume group 4 (10,000+ ADT) showed the least effect from the number of zones.

Using either a full or reduced street network made little difference in traffic assignment accuracy. Table 15 shows the results. For every zone system, assignment method, and volume group, the two networks performed almost equally.

Table 15 also shows the results of the assignment method analysis. The capacity-restrained assignment provided more accurate results than the all-or-nothing assignment. Capacity restraint appeared to have a very significant effect on assignment accuracy for volume groups 3 and 4 when a reduced network was used.

The results of all these analyses imply that several factors have effects on the accuracy of traffic assignments. Using fewer (and larger) zones tends to reduce the accuracy of traffic assignments. Capacity-restrained assignment is substantially more accurate than all-or-nothing assignment. Limited reduction in the detail of a street network will not materially affect the accuracy of traffic assignments on high volume streets. The boundaries of census tracts will serve as a basis for the boundaries of traffic zones without adverse effects on assignment accuracy. These implications are drawn from this study where two small urban areas were examined. However, the implications may also apply to larger urban areas.

Table 15. Results of Nonparametric Analyses of Street Networks and Assignment Methods.

Zone System			L111	L55	L55C	L30	L30C	A169	A93	A51	A28
Street Network	Assign. Method	Volume Group									
F:R	CR	1	F	=	=	=	=	F	=	=	=
"	"	2	=	=	=	=	=	=	=	=	=
"	"	3	=	=	=	=	=	=	=	=	=
"	"	4	=	=	=	=	R	=	=	=	=
"	AN	1	=	=	=	=	=	=	=	=	=
"	"	2	=	=	=	=	=	=	=	=	=
"	"	3	=	=	=	=	=	=	=	=	=
"	"	4	=	=	=	=	=	=	=	=	=
Full	CR:AN	1	CR	=	=	CR	CR	CR	CR	CR	CR
"	"	2	CR	CR	CR	CR	CR	=	=	CR	CR
"	"	3	=	=	CR	CR	CR	=	=	=	=
"	"	4	=	=	CR	=	=	CR	=	=	=
Reduced	"	1	=	=	=	CR	CR	CR	CR	CR	CR
"	"	2	CR	CR	CR	CR	CR	=	=	CR	CR
"	"	3	CR	CR	CR	CR	CR	=	=	=	=
"	"	4	CR	CR	CR	CR	CR	CR	CR	CR	=

= : Both treatments performed equally well.

F : Full street network performed better.

R : Reduced street network performed better.

CR : Capacity-restrained assignment performed better.

AN : All-or-Nothing assignment performed better.

Pairwise comparisons were tested at a level of significance of .05.

CONCLUSIONS

The purpose of this research has been to study the effects of reducing the number of traffic zones, and simplifying street networks on traffic assignment accuracy, and to propose guidelines for establishing zone systems and network configurations in emerging metropolitan areas. To study the various factors, actual transportation network and travel data from Lafayette and Anderson were used. Alternative zone and network systems were tested in factorially designed experiments. Then, the results of the tests were analyzed by aggregate measures and statistical stratified methods. The final results of the research are the guidelines for detail in zone systems and street networks, and the recommendations for further research.

Guidelines for Zone System and Network Development

Zone size is a significant factor in the accuracy of traffic assignments. The average zone size for a transportation study area should not exceed 3 sq. mi., and no zone should exceed 15 sq. mi. in area. Otherwise, gross instability in friction factor parameters may occur. Use of 90 internal zones is suggested for small urban areas such as Lafayette and Anderson in order to achieve acceptable overall accuracy levels. Use of more zones may increase accuracy slightly; use of fewer zones will likely decrease accuracy.

Census tract boundaries can be used successfully as a basis for establishing a traffic zone system. The inconsistencies that may occur between census tract boundaries and land use boundaries have little effect on traffic assignment accuracy. However, some census tracts in emerging small urban areas are large and would have to be broken into smaller units.

A reduced street network, comprised only of collectors with an ADT over 5000 and all higher-class streets and highways, should be adequate for planning purposes. Assignment accuracy on streets with an ADT over 5000 is equivalent to the accuracy achieved with a more detailed street network, incorporating low volume links.

Finally, capacity-restrained traffic assignment is suggested for assigning trips to accurately simulate ground counts. Not only is capacity-restrained assignment more accurate than all-or-nothing assignment, but capacity-restrained assignment also reduces the adverse impact that the use of a small number of zones can have on assignment accuracy.

Recommendations for Further Research

Because of resource constraints, this research effort was not able to examine urban areas with more than 250 zones total. Further research on such urban areas could include a wider range of zone sizes. Also, the effects of zone boundary type could be studied using smaller zones than those used in this study. Knowledge gained from such research would broaden understanding of zone systems and aid in the establishment of new systems.

Also suggested is a study of the costs of the urban transportation planning process as affected by city size, the level of detail in the coded network, the degree to which census data or borrowed data are used, the number of zones, and other factors. The costs take many forms: staffing, consulting, facilities, and computer utilization, to name a few. The results of such a study could be of great value to metropolitan planning organizations.

LIST OF REFERENCES

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(1) Grecco, W. L. et al., "Transportation Planning for Small Urban Areas", NCHRP Report 167, Transportation Research Board, 1976.

(2) Federal Highway Administration, "Traffic Assignment", August 1973.

(3) Sosslau, A. B. et al., "Travel Estimation Procedures for Quick Response to Urban Policy Issues", NCHRP Report 186, Transportation Research Board, 1978.

(4) Stuart, R. C. and Hauck, M. R., "The Census and Transportation Planning Survey of Evaluations and Recommendations as to the Usefulness of the 1970 Census Data in Urban Transportation Planning", preliminary draft of final report for Transportation Research Board, January 1976.

(5) Law, W. K., "Comparative Travel Patterns from Four Work Trip Data Sources", Joint Highway Research Project - Purdue University, Report 23, 1975.

(6) Fleet, C. R., "Applications and Uses of the Census Urban Transportation Planning Package", Special Report 145, Transportation Research Board, 1974, pp. 30-40.

(7) Wildermuth, B. R. et al., "Effect of Zone Size on Traffic Assignment and Trip Distribution", Highway Research Record 392, 1973, pp. 58-75.

(8) Horowitz, A. J., "The Evaluation of Transportation Model Random Error in Social and Environmental Indices", Environment and Planning, Vol. 9, 1977, pp. 385-394.

(9) Bureau of the Census, Census Tracts, Report PHC(1), 1970 Census of Population and Housing, U.S. Department of Commerce, 1972.

(10) Hattery, D. A. et al., "Trip Generation", Calibration of Traffic Forecasting Models, Purdue University, February 1977.

(11) Kambol, S. A. and Sinha, K. C., "Trip Distribution and Total Model Testing", Calibration of Traffic Forecasting Models, Purdue University, June 1977.

(12) Kambol, S. A. et al., "Base Year Traffic Assignment", Calibration of Traffic Forecasting Models, Purdue University, April 1977.

(13) Barton-Aschman Associates, "Existing Travel Characteristics," Anderson Urban Area Transportation Development Planning Process, February 1975.

(14) Barton-Aschman Associates, "Trip Generation Model Development", Anderson Urban Area Transportation Development Planning Process, June 1977.

(15) Sosslau, A. B. et al., "Quick-Response Urban Travel Estimation Techniques and Transferable Parameters", NCHRP Report 187, Transportation Research Board, 1978.

(16) Federal Highway Administration, "General Information, Planpac/Backpac", April 1977.

(17) Homburger, W. S., Traffic Estimation Computer Programs for Educational Purposes. The Institute of Transportation and Traffic Engineering, University of California, Berkeley, 1970.

(18) Huber, M. J. et al., "Comparative Analysis of Traffic Assignment Techniques with Actual Highway Use", NCHRP Report 58, Highway Research Board, 1968.

(19) Humphrey, T. F., "A Report on the Accuracy of Traffic Assignment When Using Capacity Restraint", Highway Research Record 191, 1967, pp. 53-75.

(20) Hollander, M. and Wolfe, D. A., "The Two-Way Layout", Nonparametric Statistical Methods, New York, N.Y.: John Wiley and Sons, Inc., 1974, pp. 138-151.

(21) Federal Highway Administration, "Urban Origin-Destination Surveys", 1973.

General References

Anderson, V. L. and McLean, R. A., Design of Experiments: A Realistic Approach, New York, N.Y.: Marcel Dekker, Inc., 1974.

Baerwold, J. E., ed., Transportation and Traffic Engineering Handbook, Englewood Cliffs, N. J.: Prentiss-Hall, Inc., 1976.

Dickey, J. W., Metropolitan Transportation Planning, Washington, D. C.: Scripta Book Company, 1975.

"Highway Capacity Manual", Special Report 87, Highway Research Board, 1965.

Hutchinson, B. G., Principles of Urban Transport Systems Planning, Washington, D.C.: Scripta Book Company, 1974.

Neter, J. and Wasserman, W., Applied Linear Statistical Models, Homewood, Ill.: Richard D. Irwin, Inc., 1974.

Paquette, R. J. et al., Transportation Engineering: Planning and Design, New York, N.Y.: The Ronald Press Company, 1972.

APPENDICES

Appendix A

Appendix A includes information regarding the alternative traffic-zone and Street-network systems developed for Lafayette and Anderson. The information consists of maps of the study areas and traffic-zone equivalency tables.

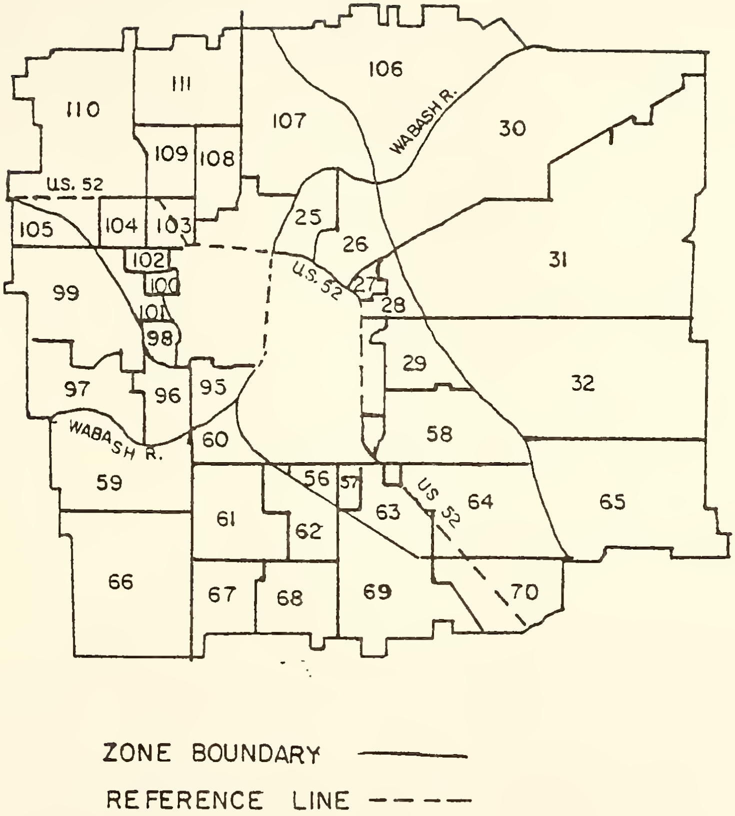


Figure A1. Traffic Zones of Total Lafayette Study Area.

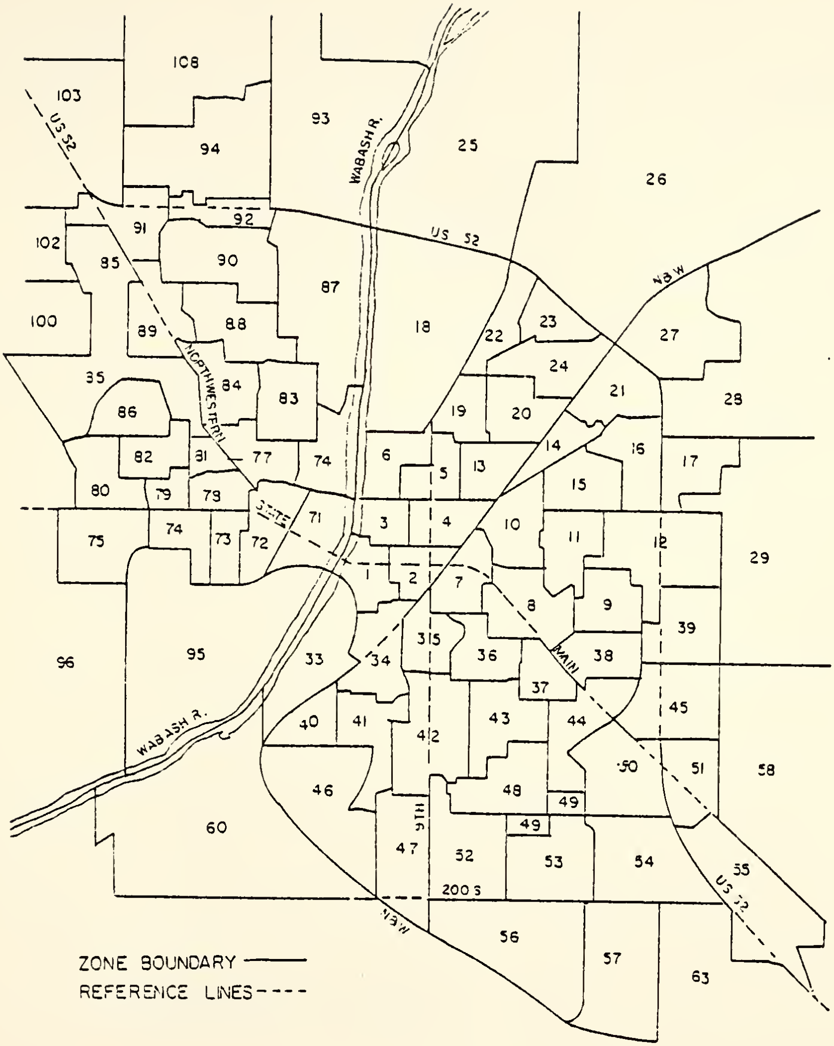


Figure A2. Traffic Zones of Urbanized Lafayette Area.

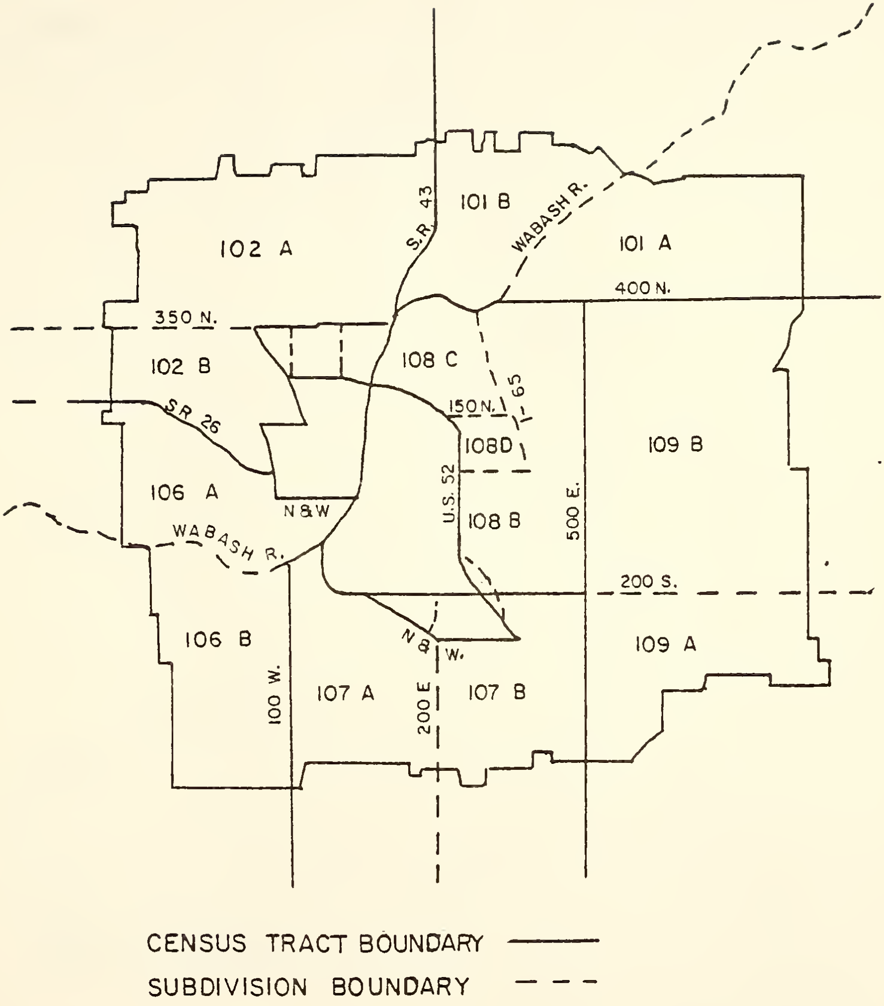


Figure A3. Census Tracts of Total Lafayette Study Area.

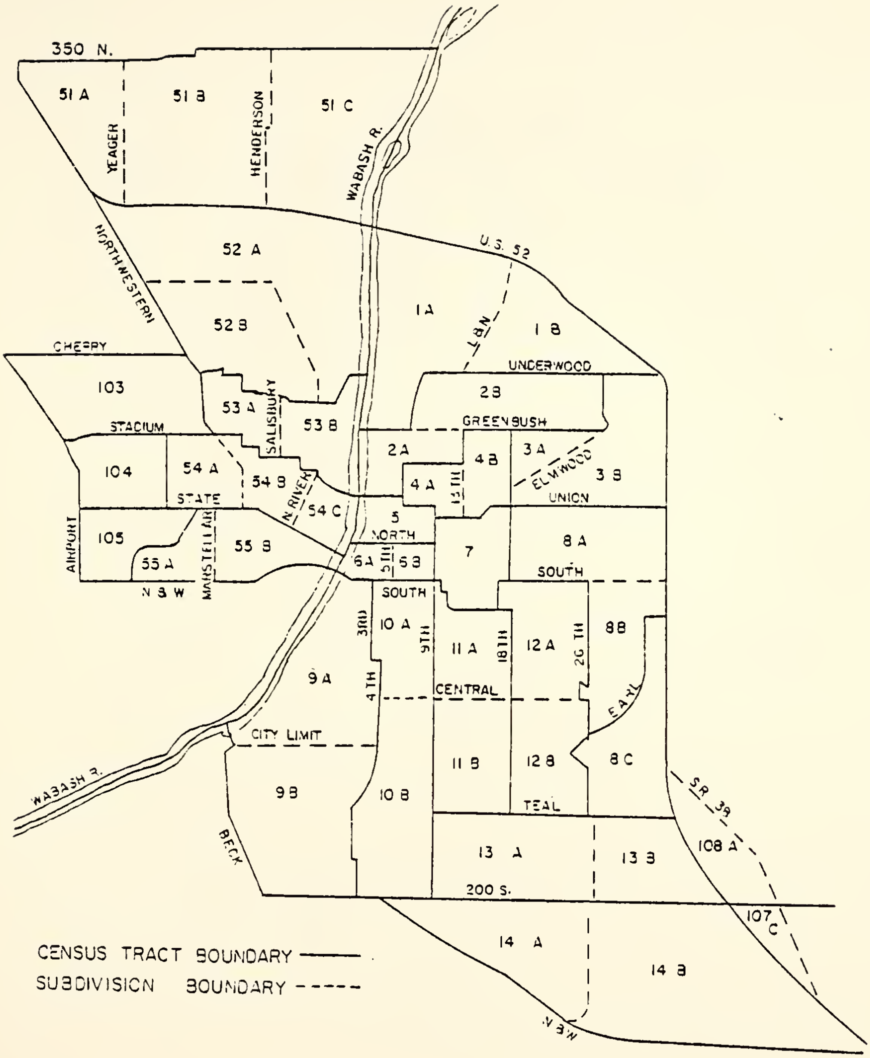


Figure A4. Census Tracts of Urbanized Lafayette Area.

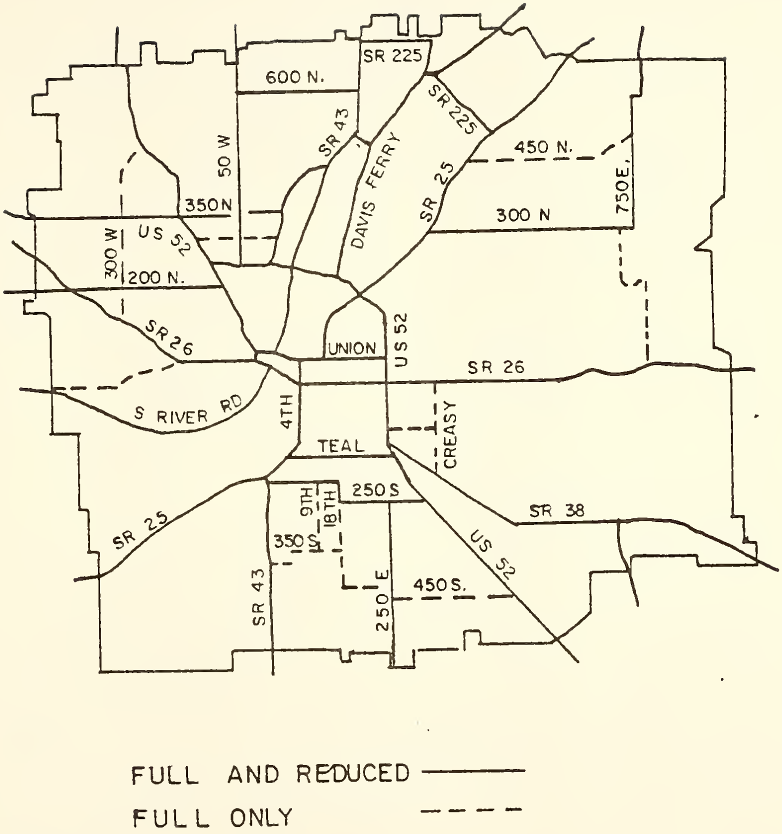


Figure A5. Full and Reduced Street Networks of Total Lafayette Study Area.

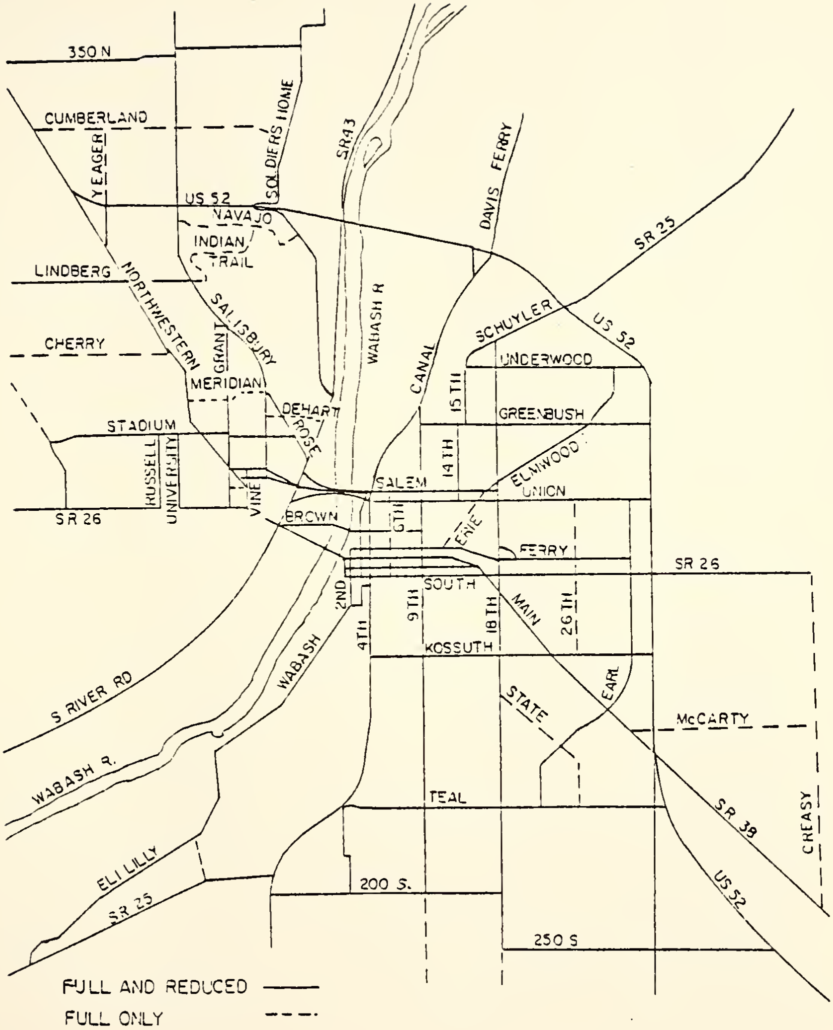


Figure A6. Full and Reduced Street Networks of Urbanized Lafayette Area.

Table A1. Zone-to-Zone Equivalencies for Lafayette Zone System L55.

L55 Zone	Existing Zones	L55 Zone	Existing Zones
1	1	29	52,53
2	2	30	54,57
3	3,5	31	55
4	4,13	32	56,62
5	6,18	33	59,60,66
6	7,8	34	61,67
7	9,38	35	63,64,70
8	10,11	36	68,69
9	12,17	37	71
10	14	38	72,77
11	15,16	39	73,74
12	19,20	40	75,80
13	21,28,29	41	76,87
14	22	42	78,81
15	23,24	43	79,82
16	25,26,27	44	83,84
17	30,31	45	85,86
18	32,65	46	88,89,90
19	33,40	47	91,92
20	34,41	48	93,94
21	35,36	49	95,98,97
22	37,44	50	98,99
23	39,45	51	100,101,102
24	42,43	52	103,104,105
25	46,47	53	106,107
26	48,49	54	108,111
27	50	55	109,110
28	51,58		

Table A2. Tract-to-Zone Equivalencies for Lafayette Zone System L55C.

L55C ZONE	Census tract (or part)	L55C Zone	Census tract (or part)
1	1A	29	51B
2	1B	30	51C
3	2A	31	52A
4	2B	32	52B
5	3A	33	53A
6	3B	34	53B
7	4A	35	54A
8	4B	36	54B
9	5	37	54C
10	6A	38	55A
11	6B	39	55B
12	7	40	101A
13	8A	41	101B
14	8B	42	102A
15	8C	43	102B
16	9A	44	103
17	9B	45	104
18	10A	46	105
19	10B	47	106A
20	11A	48	106B
21	11B	49	107A
22	12A	50	107C,108A
23	12B	51	108D
24	13A	52	108B
25	13B	53	109B
26	14A	54	107B,109A
27	14B	55	108C
28	51A		

Table A3. Zone-to-Zone Equivalencies for Lafayette Zone System L30.

L30 Zone	Existing Zones	L30 Zone	Existing Zones
1	1,2	16	52,53,56,57
2	3,4,5,6	17	62,67,68,69
3	7,8,10,11,36	18	63,64,70
4	12,17,39	19	71,72,76
5	13,14,19,20	20	73,74,75
6	18,22,23,24	21	78,81
7	15,16,21,28	22	79,80,82,86
8	9,37,38,44	23	77,83,84
9	33,34,40,41,35	24	85,89,100,102
10	42,43,46,47,48	25	87,88,90
11	45,50,51,49	26	91,92,93,94
12	29,31,32,58,65	27	95,96,97
13	54,55	28	98,99,101,105
14	25,26,27,30	29	103,104,109,110
15	59,60,61,66	30	106,107,108,111

Table A4. Tract-to-Zone Equivalencies for Lafayette Zone System L30C.

L30C Zone	Census tract (or part)	L30C Zone	Census tract (or part)
1	1	16	51
2	2	17	52
3	3	18	53
4	4	19	54A
5	5	20	54B,54C
6	6	21	55
7	7	22	101
8	8A,8B	23	102
9	8C	24	103,104
10	9	25	106
11	10	26	105
12	11	27	107A,107B
13	12	28	107C,108A
14	13	29	108C,108D
15	14	30	108B,109

Table A5. Zone-to-Tract Equivalencies for Lafayette.

Census tract (or part)	Existing Zones (or parts)
1A	(22),(23),.3(21),.8(24)
1B	.9(18)
2A	(6),.3(5)
2B	.2(14),.1(18),.9(19),.9(20),.3(21),.2(24)
3A	.2(13),.8(14)
3B	(15),(16),.3(10),.4(21)
4A	.2(4),.7(5)
4B	.2(4),.8(13),.1(19)
5	(3),.3(4)
6A	.7(1)
6B	.5(2)
7	.3(2),.3(4),.9(7),.1(8), .3(10)
8A	(50),.2(39),.4(45)
8B	.7(9),.1(12),.7(38)
8C	(11),.1(8),.2(9),.4(10).4(12)
9A	(33),(40),.1(1),.3(34),.5(41)
9B	.8(96),.4(60)
10A	.2(1),.2(2),.7(34),.6(35),.1(42)
10B	.5(41),.3(42),.2(46),.9(47)
11A	.1(7),.1(8),.4(35),.9(36).1(42),.2(43)
11B	.5(42),.5(43),.5(48),.1(52)
12A	(37),.7(8),.1(9),.1(36).3(38)
12B	.3(43),.6(44),.5(48),.5(49)
13A	(52),(53),.5(49)

Table A5. (continued)

Census tract (or part)	Existing Zones (or parts)
13B	(54)
14A	(56),.1(47)
14B	(57),.4(63)
51A	.5(103)
51B	(94),.2(91),.3(92)
52A	(87),(90),.6(91),.7(92)
52B	(88),.5(83),.4(84).5(89)
53A	.4(77),.2(83),.6(84)
53B	(76),.1(77),.3(83)
54A	(81),.9(78),.6(79),.3(82)
54B	.4(72),.5(77),.1(78)
54C	.7(71)
55A	.6(74),.1(95)
55B	(73),.3(71),.6(72)
101A	.8(106),.3(107)
101B	.8(30),.2(31)
102A	(100),(101),(102),(104),(105),.3(85),.5(89),.2(91),.6(98),.4(99),.5(103),.1(110)
102B	(109),(111),.1(93),.2(106),.7(107),.8(109),.9(110)
103	(86),.1(82),.7(85)
104	(80),.4(79),.6(82)
105	(75),.4(74)
106A	(96),(97),.9(95),.4(98),.5(99)
106B	(59),(66)

Table A5. (continued)

Census tract (or part)	Existing Zones (or parts)
107A	(61),(62),(67),(68),.6(60)
107B	(69),.6(63),.5(64),.4(70)
107C	.5(55)
108A	.3(51),.4(55)
108B	.5(12),.5(29),.1(32),.8(39),.6(45),.7(51),.1(55), .8(58)
108C	(25),(26),(27),.2(28),.2(30),.2(31)
108D	(17),.8(28),.5(29)
109A	.5(64),.8(65),.6(70)
109B	.6(31),.9(32),.2(58),.2(65)

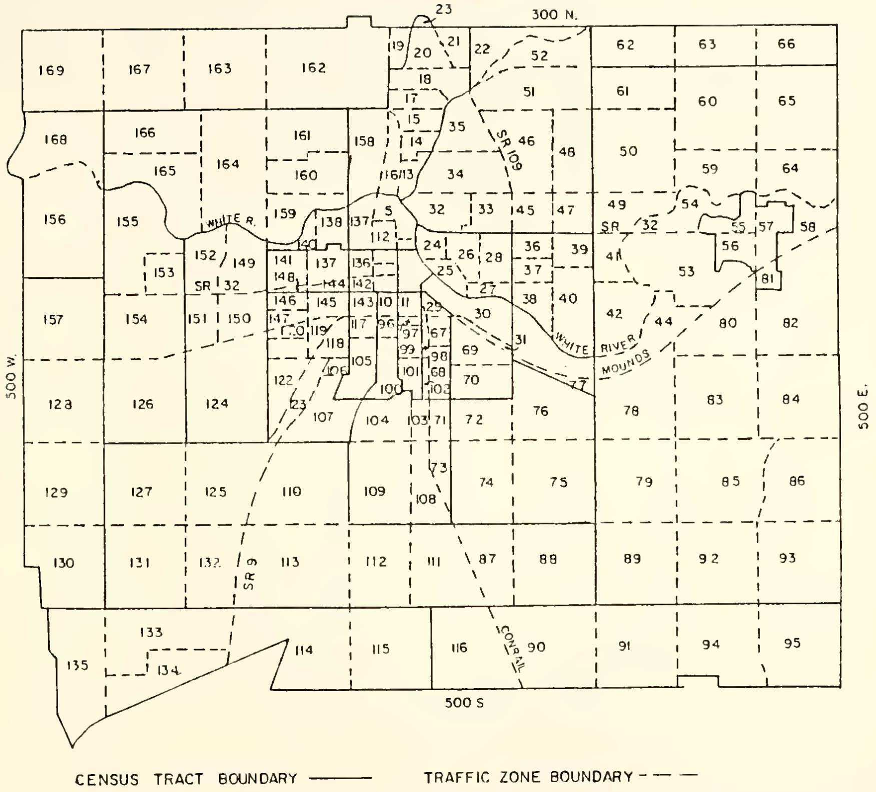
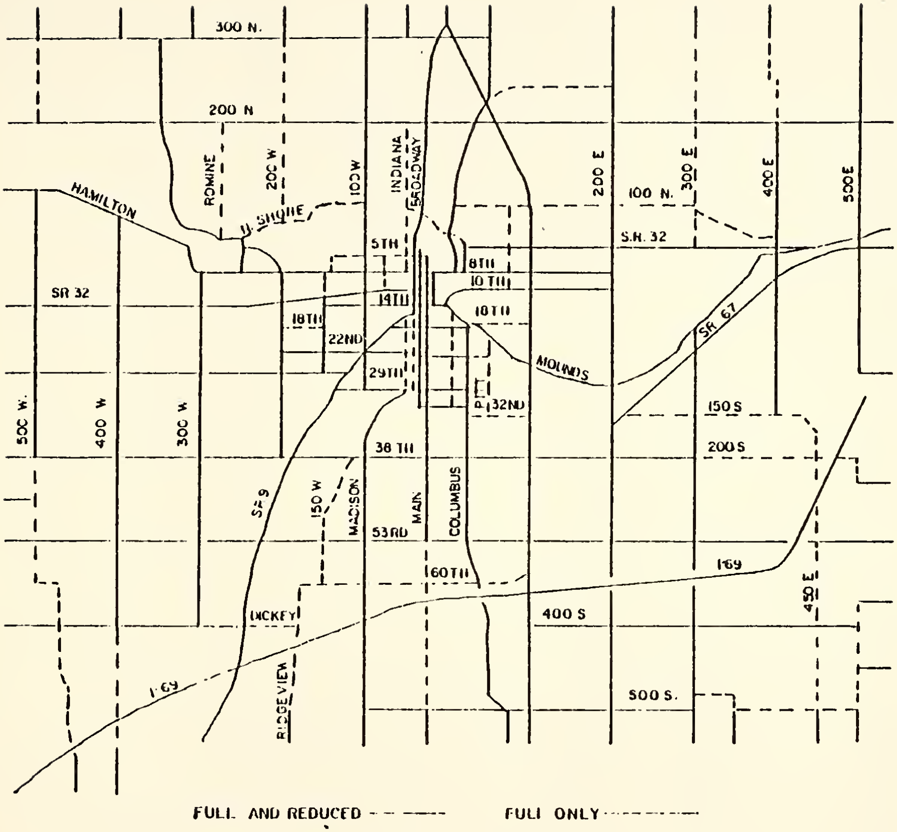


Figure A7. Traffic Zones and Census Tracts of Total Anderson Study Area.



Fibure A8. Full and Reduced Street Networks of Total Anderson Study Area.

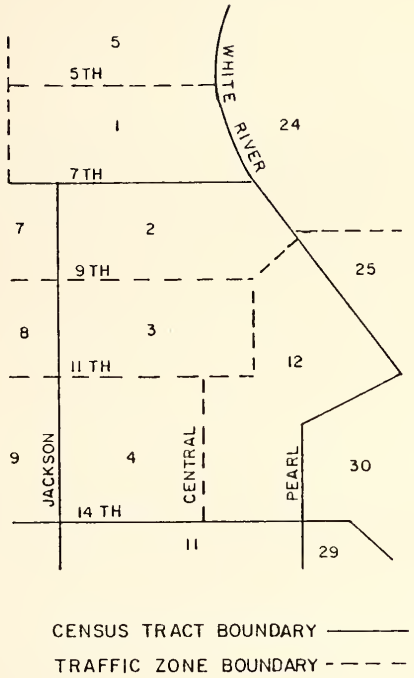


Figure A9. Traffic Zones and Census Tracts of Central Anderson Area.

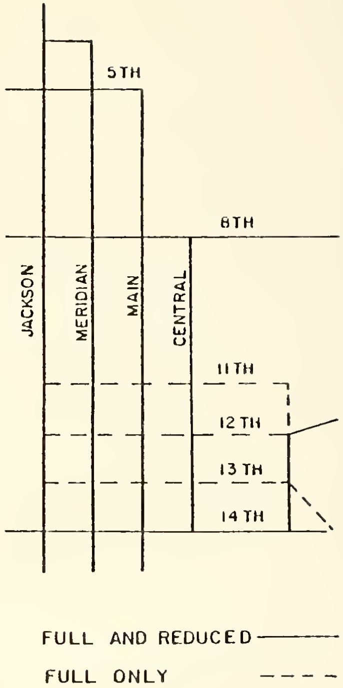


Figure A10. Full and Reduced Street Networks of Central Anderson Area.

Table A6. Zone-to-Zone Equivalencies for Anderson Zone System A93.

A93 Zone	Existing Zones	A93 Zone	Existing Zones
1	1,2	24	41,42
2	3,4	25	43
3	5	26	44
4	6,7	27	45,47
5	8,9	28	46,48
6	10,11	29	49,50
7	12	30	51,52
8	13,16	31	53,54
9	14,15	32	55,56
10	17,18	33	57,58
11	19,20,23	34	59,60
12	21,22	35	61,62
13	24,25	36	63,66
14	26	37	64,65
15	27,28	38	68
16	29,67	39	69,70
17	30,31	40	71,72
18	32	41	73,74
19	33	42	75
20	34,35	43	76,77
21	36,39	44	78
22	37,38	45	79,89
23	40	46	80,83

Table A6. (continued)

A93 Zone	Existing Zones	A93 Zone	Existing Zones
47	81,82	71	126,128
48	84,86	72	127,129
49	85,92	73	130,131
50	87,88	74	133,134,135
51	90,116	75	136,139
52	91,94	76	137,138
53	93,95	77	140
54	96,100	78	141,148
55	97,98,99	79	142,143
56	101,102	80	144,145
57	103,104	81	146,147
58	105,106	82	149,152
59	107	83	150,151
60	108,109	84	153,154
61	110	85	155
62	111,112	86	156,157
63	113,132	87	158
64	114,115	88	159
65	117	89	160,161
66	118	90	162,163
67	118,120	91	164,165
68	121,122	92	166,168
69	123	93	167,169
70	124,125		

Table A7. Zone-to-Zone Equivalencies for Anderson Zone System A51.

A51 Zone	Existing Zones	A51 Zone	Existing Zones
1	2,3,4,12	27	124,126
2	7,8,9,136,142	28	149,150,151,152
3	1,5,6	29	110,113
4	137,138,140	30	125,127,131,132
5	139,141,144,148	31	87,88,111,112
6	145,146,147	32	71,103,104
7	119,120,121,122	33	73,108,109
8	106,118	34	72,74
9	107,123	35	76,77
10	105,117,143	36	75
11	10,96,100	37	59,60,61,62,63,64,65,66
12	11,97,99,101	38	19,23,162
13	29,67,98	39	163,167,169
14	68,102	40	156,168
15	30,31	41	128,157
16	43	42	129,130
17	69,70	43	41,42,44,53
18	24,25,26,27,28	44	49,50,54
19	36,37,38,39,40	45	58,78,80,82,83,84
20	32,33,34,35	46	79,85,86,89,92,93
21	22,45,46,47,48,51,52	47	55,56,57,81
22	13,14,15,16,158	48	90,116
23	17,18,20,31	49	91,94,95
24	159,160,161	50	114,115
25	164,165,166	51	133,134,135
26	153,154,155		

Table A8. Zone-to-Zone Equivalencies for Anderson Zone System A28.

A28 Zone	Existing Zones
1	2,3,4,12
2	7,8,9,136,142
3	1,5,6,137,138,140
4	139,141,144,148
5	119,120,121,122, 145,146,147
6	106,107,118,123
7	105,117,143
8	10,96,100
9	11,97,99,101
10	29,67,68,98,102
11	30,31,43
12	69,70,76,77
13	24,25,26,27,28
14	36,37,38,39,40
15	22,32,33,34,35,45, 46,47,48,51,52
16	13,14,15,16,17,18, 20,21,158
17	159,160,161
18	19,23,156,162,163, 164,165,166,167,168, 169
19	153,154,155
20	124,126,128,129,120, 157
21	149,150,151,152
22	110,113,114,115,125,127 131,132,133,134,135
23	87,88,90,91,94,95, 111,112,116
24	71,73,103,104,108,109
25	72,74,75
26	49,50,54,59,60,61, 62,63,64,65,66
27	41,42,44,53,58,78, 79,80,82,83,84,85, 86,89,92,93
28	55,56,57,81

Appendix B

Appendix B contains tables showing observed %RMSE's for all traffic assignments. The %RMSE's are stratified by the following volume groups:

Volume Group	One-way ADT
1	2500 - 4000
2	4000 - 6000
3	6000 - 10000
4	10000+ .

Also in this appendix are ANOVA tables developed from the observed %RMSE's.

Table B1. Lafayette %RMSE's Stratified by Volume Group.

Zone System	Street Network	Assignment Method	Volume Group 1	2	3	4
L111	Full	All-or-Nothing	50.4	39.6	34.7	17.5
L55			64.8	45.2	46.7	22.2
L55C			71.2	53.0	51.6	26.8
L30			77.2	56.6	53.8	26.6
L30C			81.6	65.4	50.9	26.0
L111	Reduced	"	51.4	42.6	36.8	18.0
L55			64.2	44.2	47.3	24.3
L55C			68.9	54.4	52.2	26.4
L30			75.2	63.7	54.0	31.8
L30C			81.8	64.5	52.3	29.5
L111	Full	Capacity-Restrained	44.6	32.1	33.8	15.5
L55			54.1	33.6	43.4	16.8
L55C			53.1	33.4	45.0	15.2
L30			59.8	41.3	47.3	21.4
L30C			53.3	37.6	48.1	20.3
L111	Reduced	"	46.7	31.9	35.7	12.8
L55			50.0	33.2	42.0	15.2
L55C			55.8	35.2	45.1	14.6
L30			60.4	39.9	46.6	15.4
L30C			56.2	35.8	47.0	16.0

Table B2. Anderson %RMSE's Stratified by Volume Group.

Zone System	Street Network	Assignment Method	Volume Group			
			1	2	3	4
A169	Full	All-or-Nothing	51.2	34.3	23.2	23.4
A93			53.5	34.1	24.4	18.4
A51			63.1	41.7	30.5	25.8
A28			61.6	41.4	28.6	20.7
A169	Reduced	"	48.5	42.0	25.6	23.3
A93			49.6	40.9	29.7	25.6
A51			57.8	46.9	33.9	31.1
A28			56.4	48.0	31.7	26.0
A169	Full	Capacity-Restrained	35.5	29.0	21.4	17.7
A93			37.8	30.4	21.1	16.8
A51			40.4	32.0	24.1	19.9
A28			41.1	32.6	25.2	16.4
A169	Reduced	"	39.1	30.4	28.5	14.0
A93			42.7	32.6	26.6	16.2
A51			45.5	34.7	29.6	15.9
A28			50.8	36.9	27.5	21.3

Table B3. Five-way ANOVA of Lafayette Traffic Assignments.

Source of Variation	Sum of Squares	d.f.	Mean Square	F	$F_{.05}$
Number of Zones (Z)	.990	1	.990	55.34	4.12
Type of Zone Boundary (B)	.028	1	.028	1.55	4.12
Type of Network (N)	.015	1	.015	.82	4.12
Method of Assignment (A)	6.303	1	6.303	352.33	4.12
Volume Group (V)	43.760	3	14.587	815.39	2.88
Z x B	.153	1	.153	8.53	4.12
Z x N	.005	1	.005	.30	4.12
Z x A	.013	1	.013	.74	4.12
Z x V	.111	3	.037	2.06	2.88
B x N	.000	1	.000	.00	4.12
B x A	.090	1	.090	5.05	4.12
B x V	.039	3	.013	.73	2.88
N x A	.074	1	.074	4.11	4.12
N x V	.050	3	.017	.94	2.88
A x V	1.113	3	.371	20.74	2.88
Residual	.680	38	.018		
Total	53.423	63	.848		

Table B4. Four-way ANOVA of Lafayette Traffic Assignments.

Source of Variation	Sum of Squares	d.f.	Mean Square	F	$F_{.05}$
Number of Zones (Z)	4.668	2	2.334	120.89	3.18
Type of Network (N)	.008	1	.008	.42	4.03
Method of Assignment (A)	6.360	1	6.360	329.42	4.03
Volume Group (V)	54.700	3	18.233	944.37	2.79
Z x N	.014	2	.007	.36	3.18
Z x A	.338	2	.169	8.75	3.18
Z x V	.181	6	.030	1.57	2.28
N x A	.093	1	.093	4.80	4.03
N x V	.087	3	.029	1.50	2.79
A x V	1.219	3	.406	21.04	2.79
Residual	1.062	55	.019		
Total	68.730	79	.870		

Table B5. Four-way ANOVA of Anderson Traffic Assignments.

Source of Variation	Sum of Squares	d.f.	Mean Square	F	$F_{.05}$
Number of Zones (Z)	1.452	3	.484	10.63	2.90
Type of Network (N)	.446	1	.446	9.79	4.15
Method of Assignment (A)	4.116	1	4.116	90.42	4.15
Volume Group (V)	27.653	3	9.218	202.51	2.90
Z x N	.062	3	.021	.46	2.90
Z x A	.103	3	.034	.75	2.90
Z x V	.190	9	.021	.47	2.19
N x A	.016	1	.016	.35	4.15
N x V	.243	3	.081	1.78	2.90
A x V	.626	3	.209	4.58	2.90
Residual	1.502	33	.046		
Total	36.409	63	.578		

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