THE EFFECT OF NETWORK DETAIL ON TRAFFIC ASSIGNMENT RESULTS

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SUMMARY

This research is concerned with ascertaining the value and effect of increased coded network detail on traffic assignment results. The Waco, Texas urban area (population of 132,000 during the O-D survey in 1964) was selected for use in the study, and three street system representations with greatly different degrees of detail were coded. The following table summarizes some of the prominent characteristics of the three networks:

	Normal-Detail Network[1]	Intermediate Network	Detailed Network[2]
Number of Centroids	221	670	1885
Total Number of Nodes	631	2400	7514
Number of Link Data Cards	916	4124	12352
Miles of Coded Network	195	372	645
Computer Processing Time (Minutes)[3]	2	49	275

Comparisons of traffic counts with the corresponding assigned volumes that resulted from each of three networks were analyzed with respect to screenline crossings, arterial streets, selected links, etc. Improved assignment results were not observed to accompany increased network detail. The networks with greater detail, however, presented extensive problems with respect to coding, data handling, adjustment and analysis.

[1] Commensurate with the network detail currently used in transportation studies.

[2] Comprised of block-by-block coding of the entire street system.

[3] Includes building network description, searching minimum paths, and loading minimum paths.

CONCLUSIONS

The following conclusions are based on the analysis of all-or-nothing assignments to three networks with different degrees of detail using the trip data from the Waco Urban Transportation Study.

1. It is concluded that the degree of network detail currently used in urban transportation planning studies is appropriate with the all-or-nothing assignment. There are no benefits, but several disadvantages, in the use of increased network detail.
2. Agreement between assigned link volumes and traffic counts on arterial and major collector street representations did not improve with increased network detail.
3. Assigned volumes across screenlines appeared to be virtually independent of network detail.
4. Coding and data handling problems became more numerous as network detail was increased.
5. Network analysis and adjustment became extremely difficult with increased detail. It was nearly impossible to anticipate the effect of link speed changes on assigned volumes in the detailed network.
6. Assigned volumes on pairs of one-way streets, coded individually, did not attain satisfactory agreement with traffic counts regardless of the degree of network detail. Coding a pair of one-way streets as a single two-way link is recommended.
7. Computer processing time became excessive as degree of network detail was increased.

INTRODUCTION

Computerized traffic assignment techniques have been used for several years by transportation engineers and planners to evaluate alternative urban transportation systems. Until recently, coded networks were restricted to 4000 nodes due to program and computer limitations. Since medium sized urban areas contain considerably more than 4,000 street intersections, only skeleton networks[1] could be used in urban transportation studies. It might be presumed that more realistic traffic assignments would result if additional coded network detail could be used.

This investigation was undertaken to evaluate the effect of the degree of coded network detail on traffic assignment results using the all-or-nothing assignment procedure. The study was facilitated through the recent development of the TEXAS-Large Systems Traffic Assignment Package which provided the capability of using coded networks of up to 16,000 nodes.

The Waco, Texas urban area was selected for use in the investigation since trip data were available from a recent origin-destination survey in which city blocks were coded as individual survey zones. This permitted use of an assignment network containing all existing streets. Also, the Waco area was considered representative of many medium size urban transportation study areas.

Three networks with substantially different degrees of detail

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[1] The term "skeleton network," as used throughout this discussion, is construed to indicate any assignment network that does not contain block-by-block representations of an entire urban street system.

were used; these are:

1. Normal-detail network - a skelton network of the detail normally used in urban transportation planning studies.

2. Detailed network - a network containing all existing streets at the time of the origin - destination survey.

3. Intermediate network - a network with detail between the extremes represented by the other two configurations.

TRAFFIC ASSIGNMENT NETWORKS

Freeways and major arterial streets are principally for traffic movement; conversely, the basic function of local streets is to provide access to abutting property. Traffic assignment is a technique for estimating future traffic volumes which are essential data in the planning of freeways and arterial streets. The inclusion of local street representations in assignment networks, however, appears superfluous since traffic volumes are not the criteria for providing local streets. These access facilities generally constitute 65-80% of the total urban street mileage, so their exclusion from the coded network results in considerable savings through reduced coding effort and computer time. However, if the addition of local streets in the coded network representation sufficiently improves the accuracy of traffic assignment on the major links, their inclusion would be warranted.

Conventionally, node maps for traffic assignment are drawn with freeway and arterial street representations in relative position with respect to actual ground locations. These are labeled with corresponding street names for convenience in referencing; consequently, the node maps appear similar to a normal street map and can be misleading. As a result, assigned volumes are sometimes misinterpreted as pertaining directly to physical street counterparts with the same name. Only a node map with explicit representations of all street segments could have a direct correspondence between the coded network and physical street system.

ZONE SIZE AND NETWORK DETAIL RELATIONSHIPS

The city block constitutes an appropriate traffic zone for a detailed coded network. Each centroid would be connected to loading points located roughly midblock on each encompassing street (wherever physically appropriate). Centroid connectors would then represent the driveways, alleys, etc. that intersect the street system. With single city blocks constituting traffic zones, very few intrazonal trips would be expected. People infrequently drive from one place in a city block to another location in the same block. Thus, it might be anticipated that traffic assignments to detailed networks would rather accurately reflect the actual traffic flow.

A traffic zone configuration of single city blocks is not applicable as such for use with skeleton networks. Each zone must be connected to the assignment network, yet without the provision of local street representations this task would be quite cumbersome. This extreme detail in zonal definition would also be inconsistent with the gross character of a skeleton network. In fact, the realism of the representation might be reduced since short trips between adjacent or nearby zones (city blocks) would have to be routed via the major links. The separation between these zones through the coded network would then greatly exceed the actual separation on the ground.

Thus, with the coded networks commonly used, several city blocks are appropriately aggregated to form a single zone. The zone centroid is connected to the network in a manner consistent with the physical treet system characteristics. Hence, centroid connections to the ssignment network represent the local streets.

Since some trips would be expected to travel between city blocks ggregated to a single zone, a number of intrazonal trips could result. herefore, many of the short trips that would be assigned to local treet representations in a detailed network would become intrazonal rips which are not assigned to a skeleton network. Trips between djacent zones would be assigned to the centroid connectors only. ther short trips that could use only local streets, however, would ave to be allocated to the corridor most closely paralleling their aths. Thus, there is a "trade-off" between the trips that are assigned o the major links and the degree of coded network detail. Due to nese characteristics, the street representations in skelton networks ust be recognized as "pseudo streets" in corridors of traffic move- ent. These links implicitly represent certain nearby parallel local reets in addition to the associated arterial.

AGREEMENT BETWEEN TRAFFIC COUNTS AND ASSIGNED VOLUMES

Since links in a detailed coded network can be considered to repre- ent their physical street counterparts, assigned volumes and traffic ounts should be in close agreement. Agreement between counted and signed volumes in skeleton networks might be poorer due to the rela- onship between network detail and the assigned trips. Other possible uses of disparity could be one or a combination of the following:

1. Under-reporting of trips - "minor" trips are easily over- looked by the respondent.
2. Traffic count error - traffic counts for 24-hour periods are made with automatic counters which may produce some error.

3. Sampling deficiencies - dwelling unit samples may not accurately reflect the true zone to zone movements.

4. Traffic circulation - assignments do not account for traffic circulation within commercial areas such as the CBD.

5. Impedance parameters - slight variation of impedance parameters can cause changes in routing of individual trips which may result in sizable variations in assigned volumes.

6. Centroid representations - as a consequence of using a centroid to represent all trip terminals within each zone, all trips interchanging between two zones are assigned to the same centroid connector rather than distributed among all feasible zone entry points; hence, contiguous links in the coded network may have abrupt changes in assigned volumes due to the centroid connector configuration.

STUDY OUTLINE

Objectives

The objective of this research was to determine the effect and value of increased detail in coded networks on traffic assignment results. Several measures were considered in the overall evaluation. The difference between assigned volumes and traffic counts was the primary basis for comparison. This was examined in conjunction with screenline crossings, traffic on arterial streets with and without parallel local facilities, traffic on oneway streets, and overall volume differences on major links.

Computer processing time was used as the principal measure of the increase in cost with increased network detail. The relative effort involved in the coding and in the analysis of each network was also noted as a subjective measure.

Procedures

The procedure followed in this investigation was to prepare the three networks of different degree of detail and assign the expanded

24-hour vehicle trips to each. A directional all-or-nothing assignment was used. However, the nondirectional assigned volumes were selected in order to maintain compatibility with 24-hour nondirectional traffic counts.

Link volumes were compared with traffic counts; where disagreement existed, link speeds were adjusted in order to alter the respective link travel time. The networks with the adjusted speeds were reassigned, and the new output evaluated; the process was repeated if necessary. This procedure is the same as that followed in practice for adjusting existing networks. The difference being that normally only one network, similar to the normal-detail network, would be employed.

Upon completion of the network assignments, the resulting assigned volumes were compared. The normal-detail network was considered to delineate the major traffic corridors; the additional detail included in the intermediate and detailed network was regarded as consisting primarily of local streets together with some collector streets. Only the links common to all three networks were used in the overall link volume comparisons. For the purpose of these comparisons the additional street representations in the intermediate and detailed networks were regarded as explicitly for the improvement of the assigned volumes to the major links.

CHARACTERISTICS OF THE STUDY AREA AND CODED NETWORK

The data used in this analysis were compiled by the Waco Urban Transportation Study. The study area covered 248 square miles, which included the city of Waco (47 square miles) and seven smaller incorporated places. According to the origin-destination survey, conducted during the winter and spring of 1963-64, there were 132,352 persons residing in 46,740 dwelling units within the boundaries of the study area.

The study area was subdivided into 2818 survey zones which ranged in size from a city block, in densely developed areas, to about 1000 acres, in the agricultural and open areas of the undeveloped fringe. There were 15 external stations on the external cordon at which trips entering and leaving the area were surveyed. No freeway facilities were in operation at the time of the survey (1). *

NORMAL-DETAIL NETWORK

The degree of detail in this network is comparable in all respects to that usually employed in urban transportation studies and has the least detail of the three networks used in this research. This network, without centroid connectors, is shown in Figure 1.

The 2818 survey zones were aggregated to form 206 internal traffic zones; thus, with the 15 external stations, there were a total of 221 centroids. A total of 916 link data cards, 142 of which represented one-way streets, were required to describe this network. The aggregation of survey zones into traffic zones resulted in 18,008 intrazonal trips and 268,200 interzonal trips.

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* Numbers in parentheses refer to references in the bibliography.

WACO NORMAL-DETAIL NETWORK

FIGURE 1

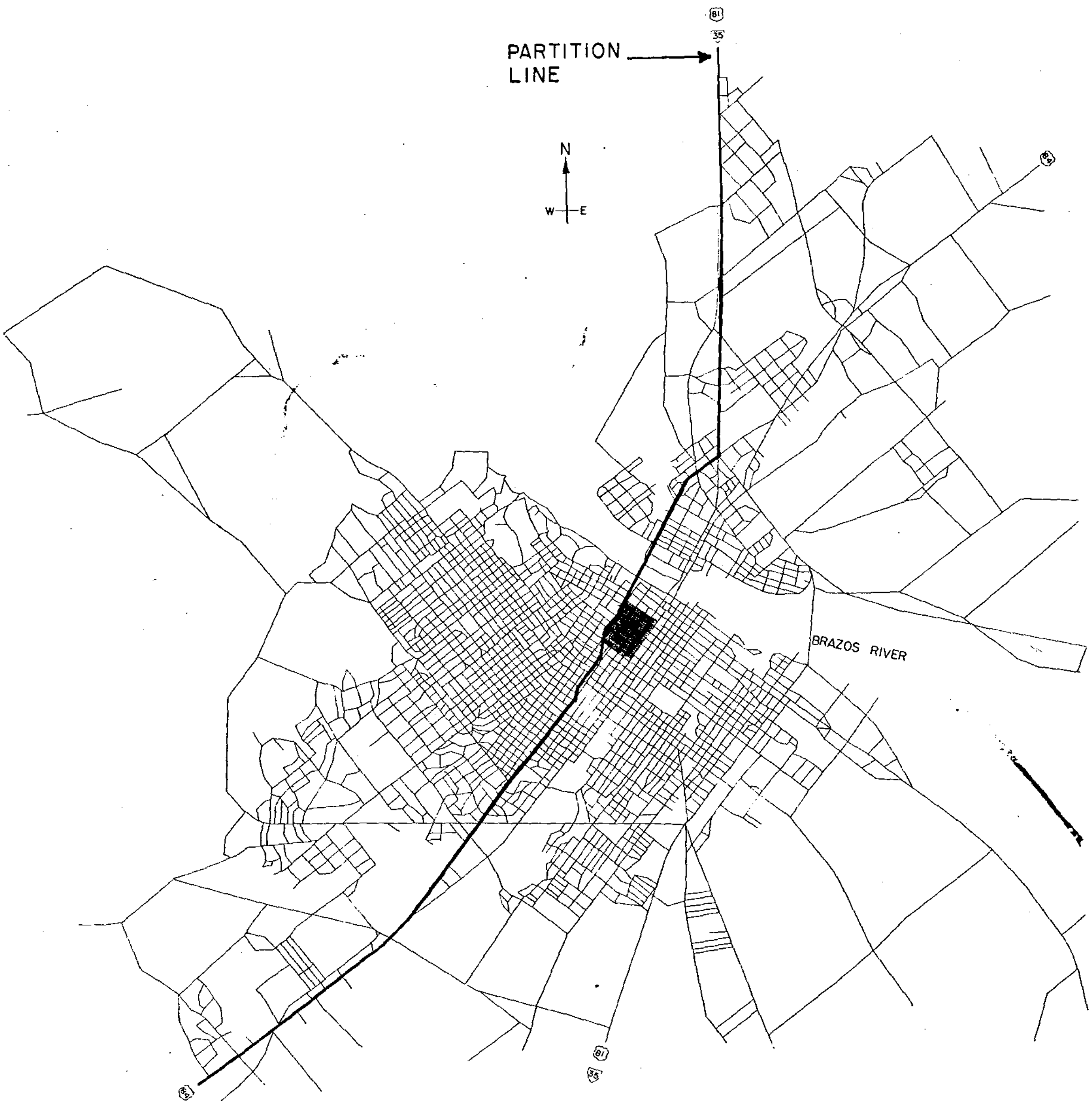
DETAILED NETWORK

In defining the detailed network, virtually every existing street in the study area was included. Coding of this network was done by the Planning Survey Division of the Texas Highway Department. Because of the degree of detail, it was necessary to use a node map consisting of 20 sheets each of which was 3.5 x 5.5 feet in size. A plot of the detailed network without the centroid connectors is shown in Figure 2.

The 2818 survey zones were aggregated to form 1870 internal traffic zones. Most of the aggregated zones were located in the fringe where there were very few trip ends; in the developed areas, each traffic zone corresponded to a survey zone. This aggregation resulted in 283,164 interzonal trips and only 3,044 intrazonal trips.

The detailed network contained 5,629 nodes (not including centroids), and its description required 12,352 link data cards, 380 of which represented one-way streets. Because the size of this network exceeded the maximum for processing it as a unit, it was necessary to divide the network into two subnets. The Brazos River was considered as a possible partition, but the network section south of the river appeared to exceed the capacity of a subnet. Therefore, the partition line was located along Waco Drive as shown in Figure 2.

Only one crossing of the partition line is permitted in order to reduce computer time in searching the minimum path between two centroids (2). Therefore, it was necessary to code Waco Drive into both subnets. In order to obtain the total link volume assigned to



WACO DETAILED NETWORK

FIGURE 2

Waco Drive it was necessary to sum the assigned volumes of the corresponding links in each subnet.

INTERMEDIATE NETWORK

The intermediate network was defined so that it would have a degree of detail about midway between the normal detail and detailed networks. The normal-detail network was first delineated on an extra copy of the detailed network maps in order to insure inclusion of all segments of this network in the intermediate network. Supplementary links were then added to represent additional streets on the basis of their location, importance, and traffic zone boundary suitability. A plot of the intermediate network without centroid connectors is shown in Figure 3.

In order to expedite preparation of the intermediate network, the coding from the detailed network was utilized. Link data cards representing the streets to be included in the network were merely selected from the detailed network deck and reproduced. This expediency necessitated the utilization of the two subnets for the intermediate network even though the total number of necessary nodes was less than the capacity of a single subnet. A total of 2,128 nodes were unnecessary since they had only two link connections. Due to the additional coding effort involved, these redundant nodes were not removed. It was estimated that the inclusion of the extra nodes would not significantly affect computer processing time comparisons.

A total of 655 internal traffic zones were used in the intermediate network; 277,312 interzonal trips and 8,896 intrazonal trips

WACO INTERMEDIATE NETWORK

FIGURE 3

resulted from this zone aggregation. The network contained 1730 effective nodes[1], excluding centroids; 4,124 link data cards, 236 of which represented one-way streets, were required for the network description.

SUMMARY OF CODED NETWORK CHARACTERISTICS

A summary of the pertinent data for the three networks is shown in Table 1. Figures 4, 5, and 6 illustrate the coding of the three networks for a selected section near downtown Waco. This particular section corresponds to the shaded area in the center of Figures 1, 2, and 3. Comparison of these figures illustrates the relative differences in detail of the three networks. In most instances, traffic zone boundaries were defined by surrounding network links, and centroids were connected to the networks in each major direction wherever this was reasonable.

TRAVEL COST

Level of service speed was used as the measure of travel impedance in the coded network. The speed and delay data collected by the Waco Urban Transportation Study, traffic volume data, and knowledge of the area were the basis for the level of service speed initially coded for each link. The standard deviation of the observed speed on each route was used to identify the range within which link speeds might be adjusted.

Centroid connectors were given a level of service speed of 15 mph. Likewise, a speed of 15 mph was initially designated for all local

[1]Effective nodes and link data cards are defined as those which are actually necessary to describe the network at the intermediate degree of detail; i.e., the 2,128 redundant nodes having only two link connections are not included.

streets in the detailed network. This speed was selected because the minimum speed on any arterial or collector street was 25 mph, and it was felt that it was necessary to have a substantially lower level-of-service on local streets in order to prevent overloading these facilities and underloading the arterials and collectors.

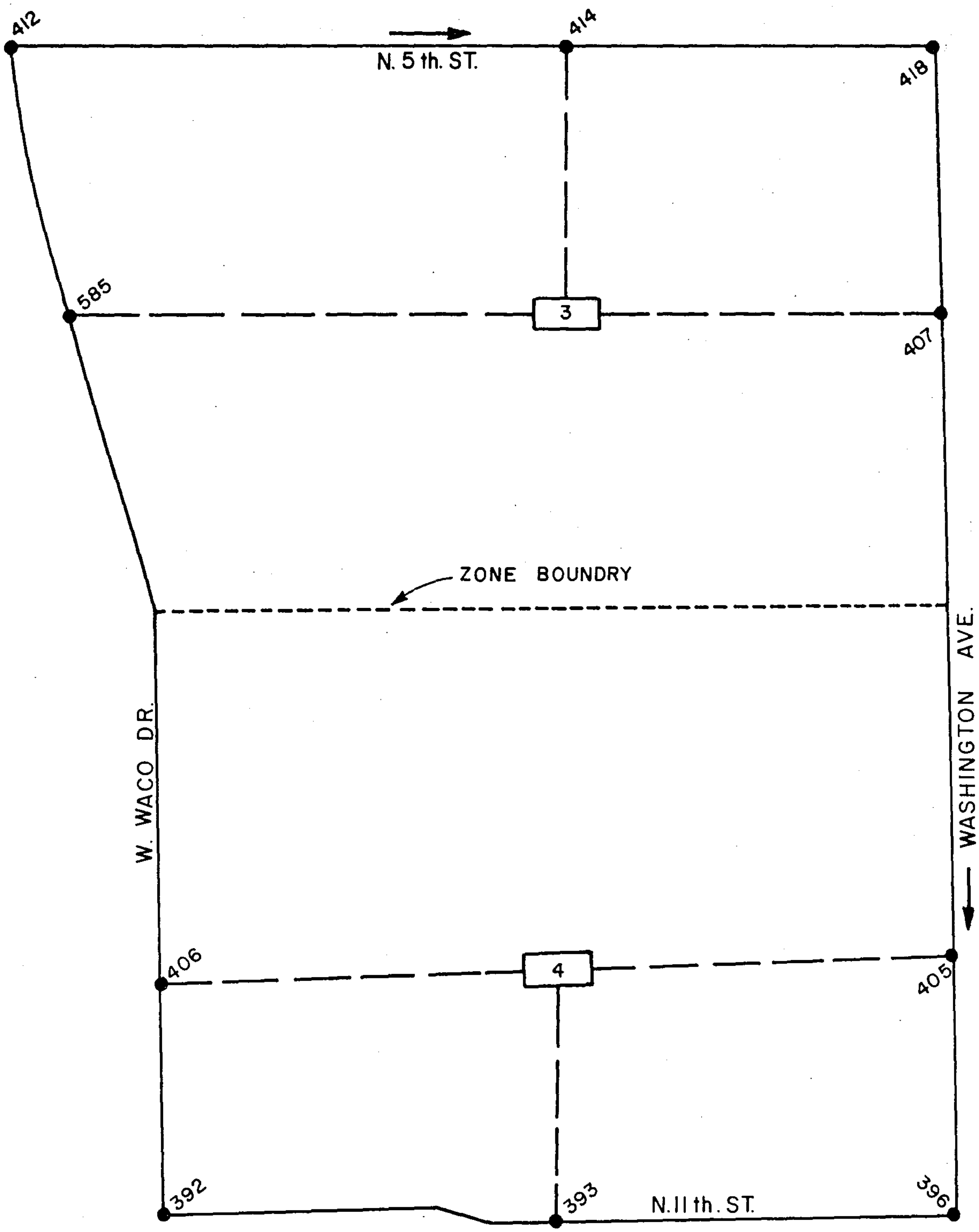
TABLE 1

SUMMARY OF NETWORK CHARACTERISTICS

	Normal-detail Network	Intermediate Network	Detailed Network
Number of Zones (Centroids)	221	670	1,885
Number of Non-Centroid Nodes	410	(3858)[1] 1730[2]	5,629
Total Number of Nodes	631	(4528) 2400	7,514
Total Number of Link Data Cards	916	(6252) 4124	12,352
Number of One-Way Link Cards (included in the above total)	142	(380) 236	380
Number of Intrazonal Trips	18,008	8896	3,044
Number of Interzonal Trips	268,200	277,312	283,164
Total Number of Trips	286,208	286,208	286,208
Intrazonal Trips	6.3%	3.1%	1.1%

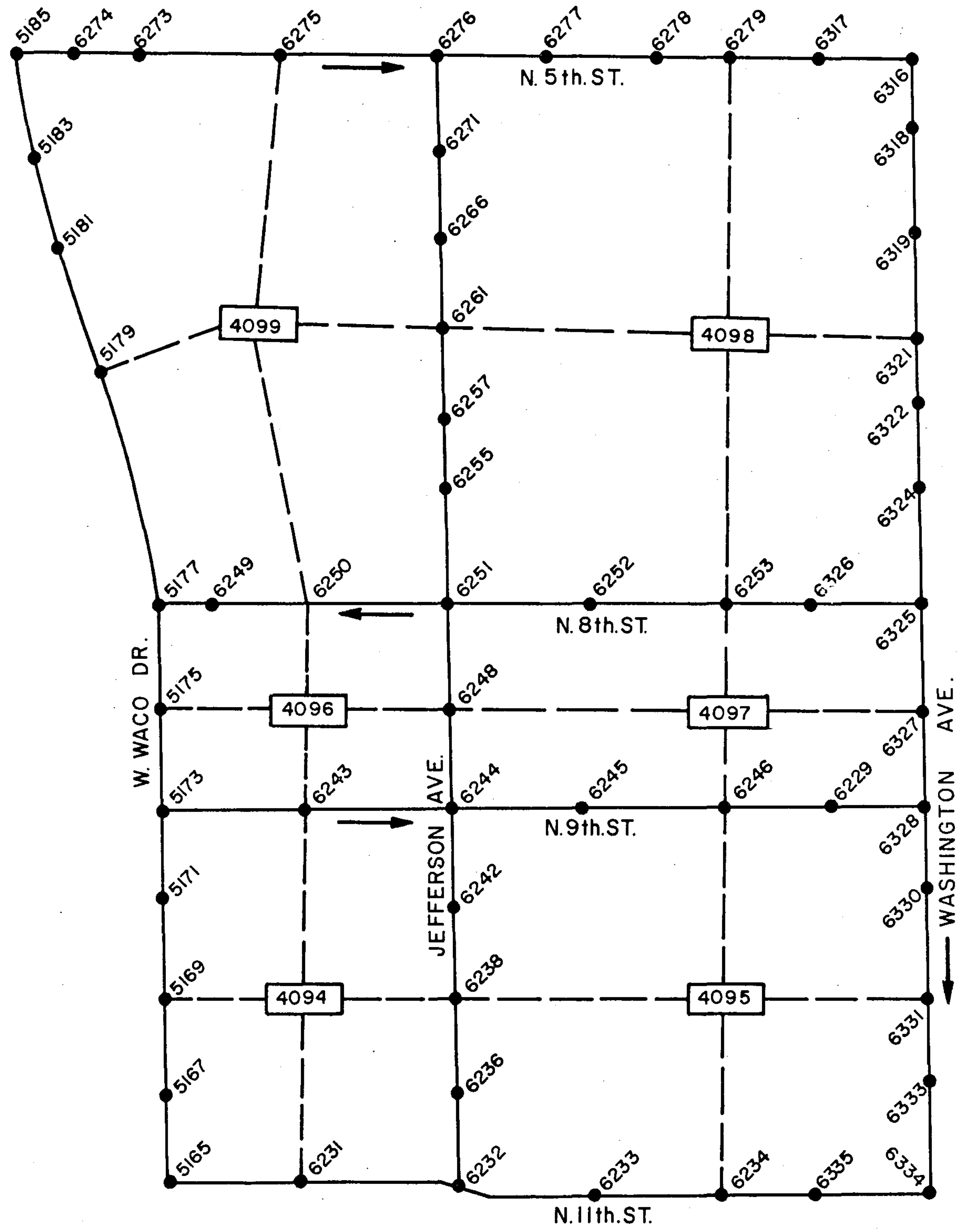
[1] The numbers in parentheses represent the number of nodes or link data cards in the intermediate network. Detailed network coding was used.

[2] These numbers indicate the number of nodes and links necessary to represent the intermediate network at the degree of detail to which it is coded.



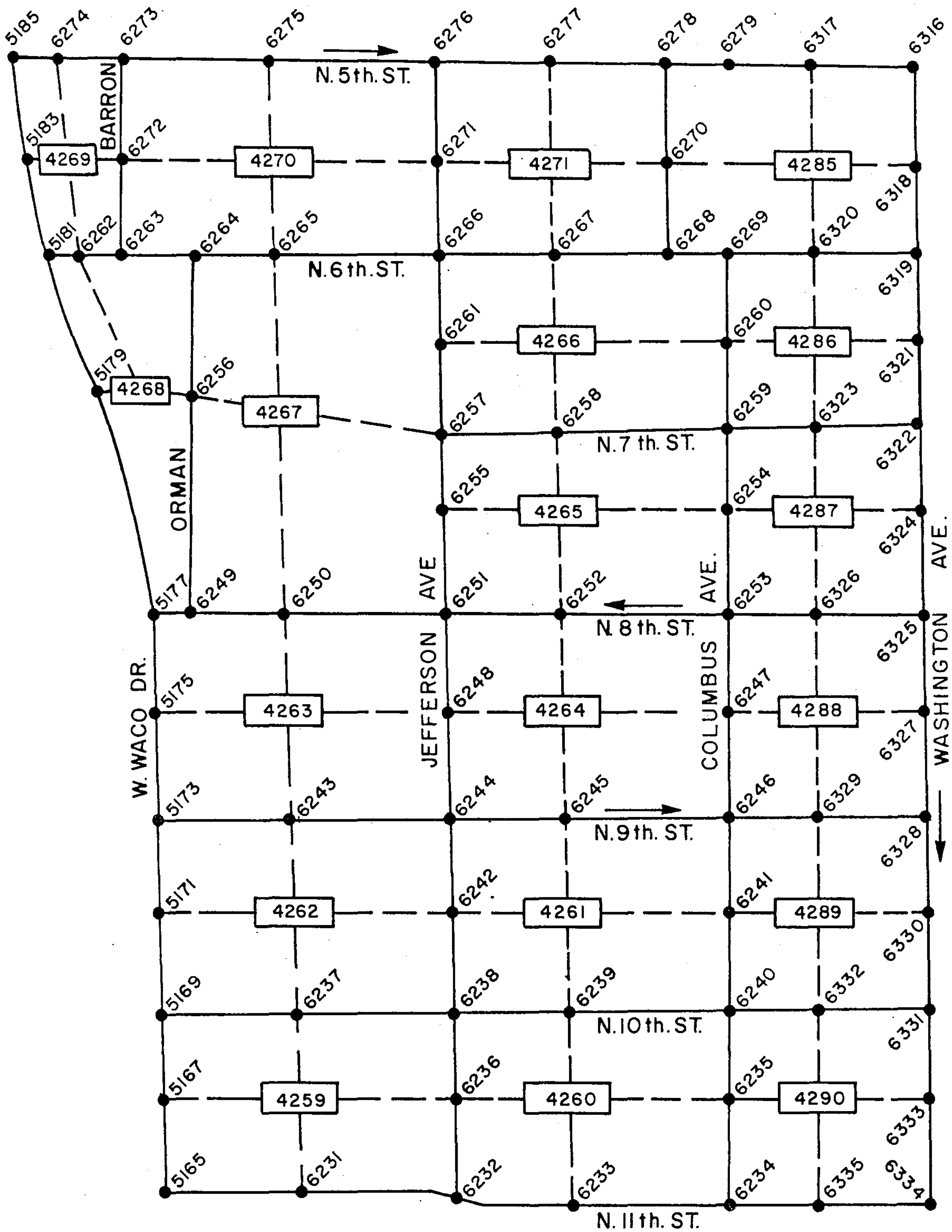
SAMPLE SECTION OF WACO NORMAL-DETAIL NETWORK

FIGURE 4



SAMPLE SECTION OF WACO INTERMEDIATE NETWORK

FIGURE 5



SAMPLE SECTION OF WACO DETAILED NETWORK

FIGURE 6

NETWORK ASSIGNMENT

DETAILED NETWORK

The initial assignment of the detailed network resulted in considerable disagreement between assigned volumes and ground counts. These discrepancies clearly indicated a need for speed adjustments. Therefore, it was decided to make a uniform speed change of 2 mph on each link which deviated from its corresponding ground count by more than 10 percent; speeds were decreased 2 mph on each link overassigned and increased 2 mph on each underassigned link. Approximately 2000 link data cards were revised after the first assignment.

After these changes had been made, trips were reassigned. The result of the second assignment was almost exactly identical to that of the first, and no significant improvement in agreement with ground counts was found.

The uniform speed change philosophy was again used in preparation for the third assignment. In addition, since the river crossings at La Salle Street and Washington Avenue were considerably underassigned and the links representing Waco Drive were overassigned, a zero turn penalty was used on the third assignment. It was believed that the turn penalties used in the previous assignments might have forced trips, which in reality would cross the river at either La Salle or Washington, to be assigned to Waco Drive.

Several test trees were examined to determine what effect, if any, resulted from the use of the zero turn penalty. No illogical routings were found; when the trees with a zero turn penalty were compared to trees with a turn penalty, only a few minor differences were observed.

The result of the third assignment was almost an exact duplication of the previous two assignments; this indicated the ineffectiveness of the uniform 2 mph speed change and the need for a modification in the adjustment procedure. Therefore, it was decided that speed changes of up to 5 mph would be used on selected links in making subsequent adjustments. Speed adjustments were made primarily on major routes which had the largest differences between assigned volumes and ground counts. The number of routes on which speeds were adjusted was held to a minimum since the effect of several changes in one particular area was too complex to anticipate. For example, in some instances links were given speed changes of 5 mph with little improvement in the agreement between assigned volumes and ground counts; however, when an additional speed change of 1 mph was made on these links, considerable "overcorrection" resulted.

The adjustment of the detailed network was terminated after nine trials because improvement in the assignments was not being effected.

The detailed network contained such a large number of links that posting the assigned volumes on the network maps was an enormous task! It was found to be unnecessary to post all of the assigned volumes since only those on links in the vicinity of ground counts were effectively used. However, substantial time was still consumed by the posting process.

After the assignments were posted it was difficult to obtain an overall picture of the agreement between assigned link volumes and ground counts due to the large size of the node map and number of sheets needed for it. Thus, a quantitative method of overall evaluation was sought.

Frequent use of root-mean-square difference calculations in data analysis suggested that it might be a suitable means of overall evaluation. This value was calculated for all links for which ground counts were available; the results are shown in Table 2.

It was hoped that the overall root-mean-square difference would decrease from assignment to assignment at a diminishing rate as successive adjustments improved the agreement between assigned volumes and ground counts. Then, when the root-mean-square for two consecutive assignments were approximately equal the network might be considered to be satisfactorily adjusted.

The results in Table 2 show a very small decrease in the overall root-mean-square difference between assignments 1 and 2; no significant change between the other assignments occurred. Likewise, the root-mean-square difference for each volume group showed a slight decrease from assignment 1 to 2, but displayed no meaningful pattern of change between the other assignments. However, assigned volumes on various individual links differed substantially from one assignment to another. Further, analysis of screenline crossing volumes (Figures 8, 9, and 10) revealed that in several instances an entire traffic corridor was shifted between successive assignments. Yet these changes were not reflected by changes in the root-mean-square differences. Since this measure proved to be very insensitive, calculation of root-mean-square differences was terminated after the seventh assignment.

INTERMEDIATE NETWORK

The values for the level of service speeds used in the initial assignment of the intermediate network were those resulting from the

TABLE 2

COMPARISON OF RMS DIFFERENCES FOR DETAILED NETWORK

Ground Count Volume Range	Number of Links	Asmt 1	Asmt 2	Asmt 3	Asmt 4	Asmt 5	Asmt 6	Asmt 7
0-1499	124	768	710	701	672	612	732	747
1500-4999	188	2056	1879	1811	1838	1838	1832	1833
5000-9999	127	3420	2932	2825	3060	3060	2890	2854
10000-14999	30	5059	3319	3424	3301	3301	4670	3154
15000-19999	18	5618	2578	2894	3348	3348	3856	3511
20000 & over	12	5860	5257	4815	5129	5129	4299	3749
overall	499	2866	2281	2225	2336	2330	2410	2203

$$\text{RMS difference} = \sqrt{\frac{\Sigma(\text{Assigned Volume} - \text{Counted Volume})^2}{N}}$$

where N = number of links compared

final assignment of the detailed network. The process of assignment and adjustment of the level of service speed parameter was then followed in attempting to obtain more reasonable agreement between assigned volumes and ground counts for the intermediate network. Five assignments were made to this network.

Since the degree of detail in the intermediate network was only one-third of that of the detailed network, it was anticipated that the intermediate network would be much easier to work with. However, the same difficulties in adjusting the network were encountered. The effects of speed changes were nearly impossible to predict; this made it necessary to resort to the procedure of changing speeds on only a few links in any one area of the network at a time, as was done in the detailed network adjustments. Also, the same difficulty in attaining realistic assigned volumes crossing the river at Waco Drive, La Salle Street and Washington Avenue was encountered.

NORMAL-DETAIL NETWORK

The normal-detail network presented the least difficulty in network adjustment. The effects of speed changes were readily anticipated, and as a result only three assignments were necessary in order to obtain satisfactory agreement of assigned volumes with ground counts.

ANALYSIS OF ASSIGNMENT RESULTS

Several techniques were used to compare the assignments to the three different coded networks for the Waco Study area. Screenline volumes were first examined to establish the agreement between traffic counts and the trip tables; then, they were analyzed with respect to corridor movements.

The assignment results for selected arterial streets were contrasted through the use of profile plots. Due to the difficulties encountered in obtaining agreement between assigned link volumes and ground counts on one-way streets, plots of representative one-way pairs were also made. Scatter diagrams of assigned and counted volume were plotted using individual links for which ground counts were available.

Additional network parameters were examined in attempting to explain the assignment results. These parameters included such measures as total network mileage, average network speed, relative frequency distributions of interzonal travel times, as well as some of the trip table properties. Consumption of computer time was established as a means of evaluating the relative "cost" of traffic assignment for each coded network.

SCREENLINE VOLUMES

The screenlines shown in Figure 7 were selected for use in analyzing corridor movements since they were considered to intersect the major corridors of traffic flow. The screenlines, of course, are the same for all three networks.

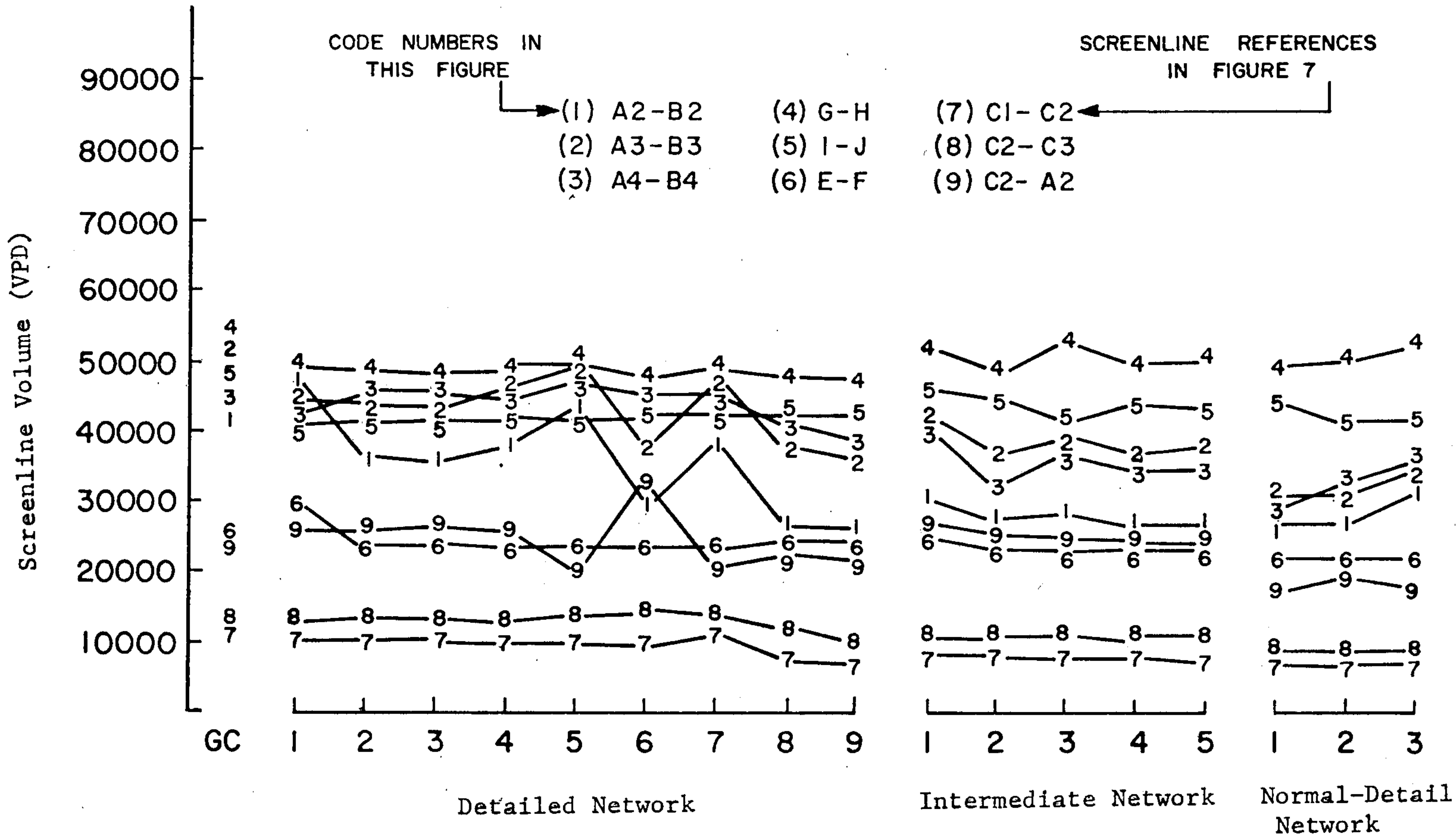
Adjustment of link speeds on the intermediate and normal-detail networks seems to have had relatively little effect on the assigned

SCREENLINE LOCATIONS

FIGURE 7

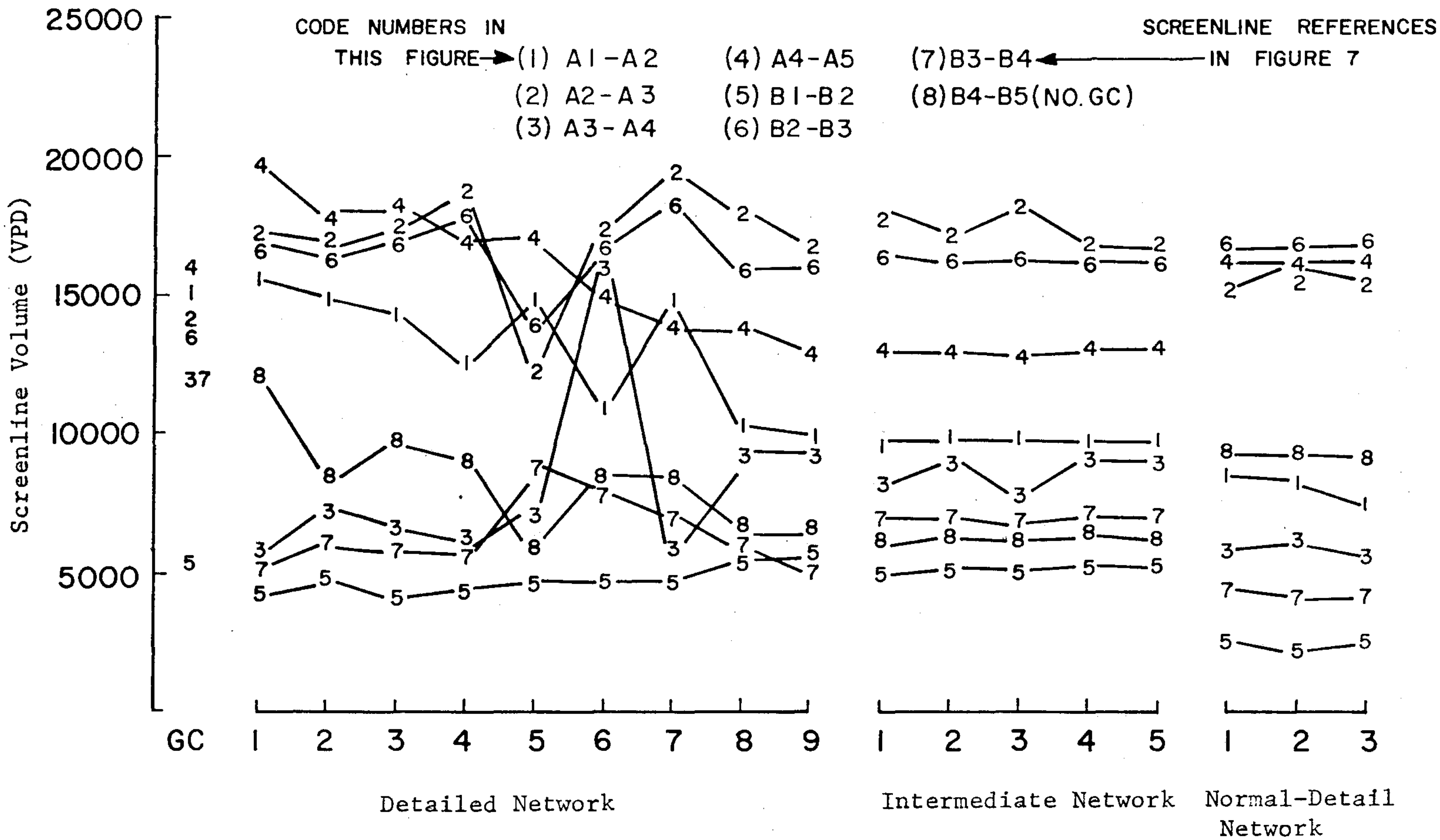
volume crossing a screenline. A pronounced shifting of traffic between corridors was observed between some assignments on the detailed network; this phenomenon was not found in the assignments to the other networks. This shifting is demonstrated by the pronounced change in screenline volume for successive assignments as shown in Figure 8,9, and 10. An example is the "jump" in the volume across screenline 3 between assignments 5, 6, and 7 in Figure 9. The screenline crossing volumes between the first assignments to the detailed network were reasonably stable, as would be expected since the uniform speed changes did not result in noticeable changes in assigned link volumes. The pronounced corridor shifting occurred in later assignments when the level-of-service speed adjustment scheme was altered and speed changes of larger magnitude were made on a limited number of selected links.

All three networks resulted in substantially similar screenline crossing volumes; this is somewhat surprising in view of the different network characteristics. Smaller screenline crossing volumes might be expected on networks with less detail since traffic zones are larger and fewer interzonal trips would be expected. However, as was shown in Table 1, the use of the lesser detailed networks (larger zones) resulted in a very small decrease in the proportion of interzonal trips. However, it may be noted that the assigned volumes crossing the screenlines are generally lower than the traffic count volumes. This suggests a possible deficiency in the number of trips reported in the origin-destination survey. A portion of the deficiency can be attributed to internal trips made by nonresidents of the study area after entering the study area; such trips become registered in traffic counts but are unsurveyed. Certain vehicle



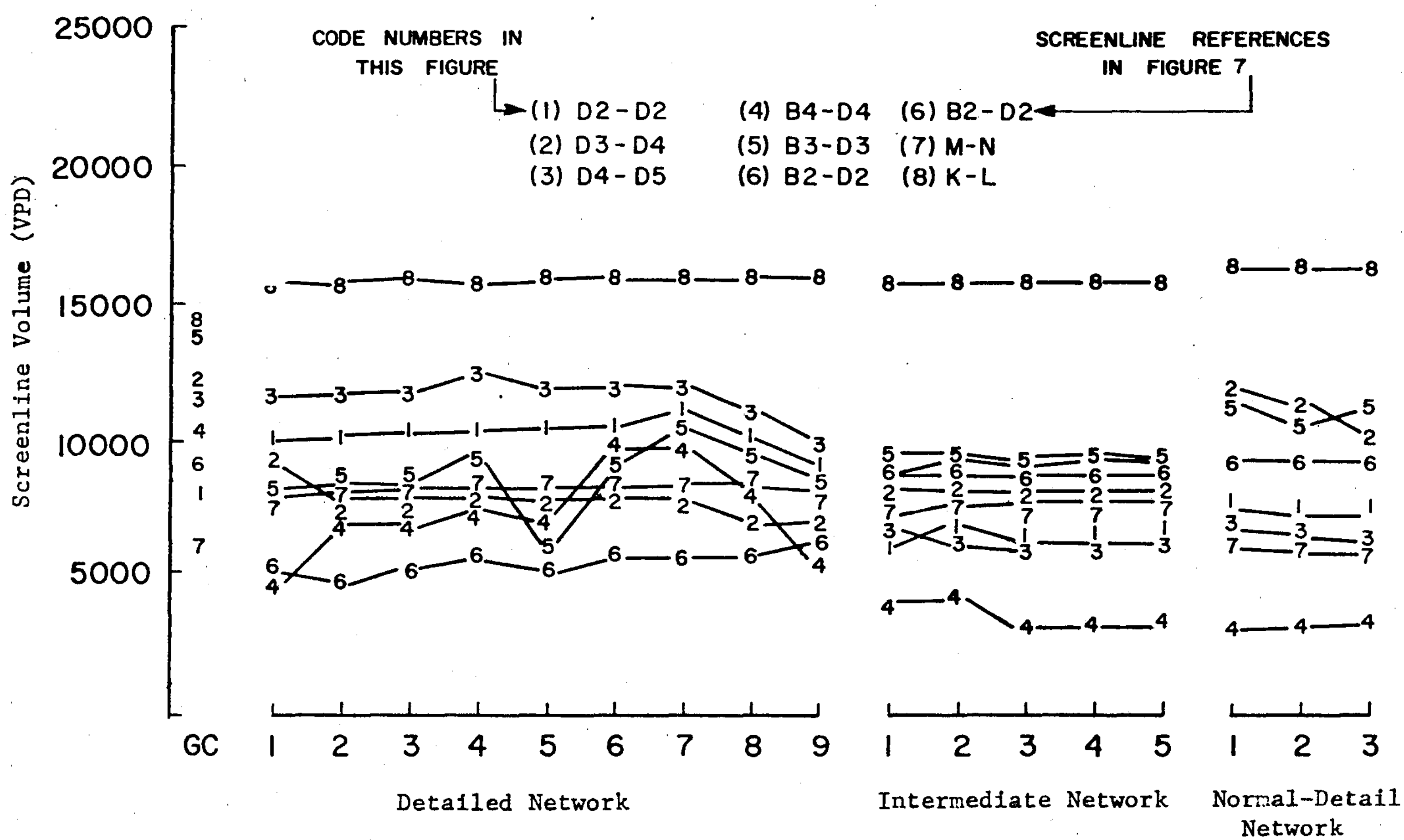
SCREENLINE VOLUMES, I

FIGURE 8



SCREENLINE VOLUMES, II

FIGURE 9



SCREENLINE VOLUMES, III

FIGURE 10

types (e.g., city owned vehicles) also escape being surveyed but contribute to traffic counts.

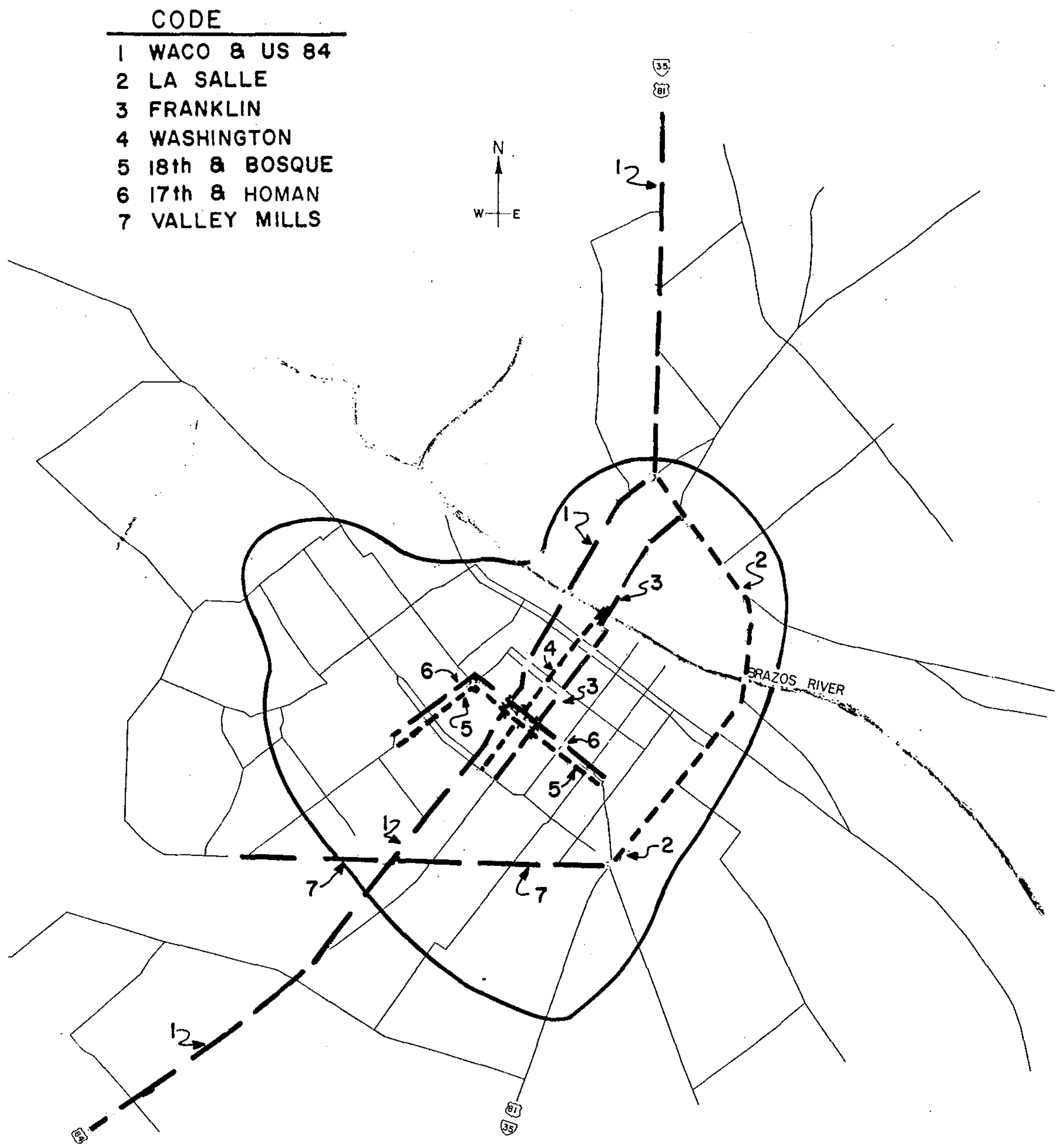
ARTERIAL STREET VOLUMES

Figure 11 displays several major streets for which volume profiles were plotted. The profiles show traffic counts and final assigned volumes for each of the three networks.

Waco Drive (U. S. 84) was the primary arterial through the study area. As shown in Figure 12, the assigned volumes from each of the three networks yield similar general patterns with the assigned volumes being generally lower than the traffic counts.

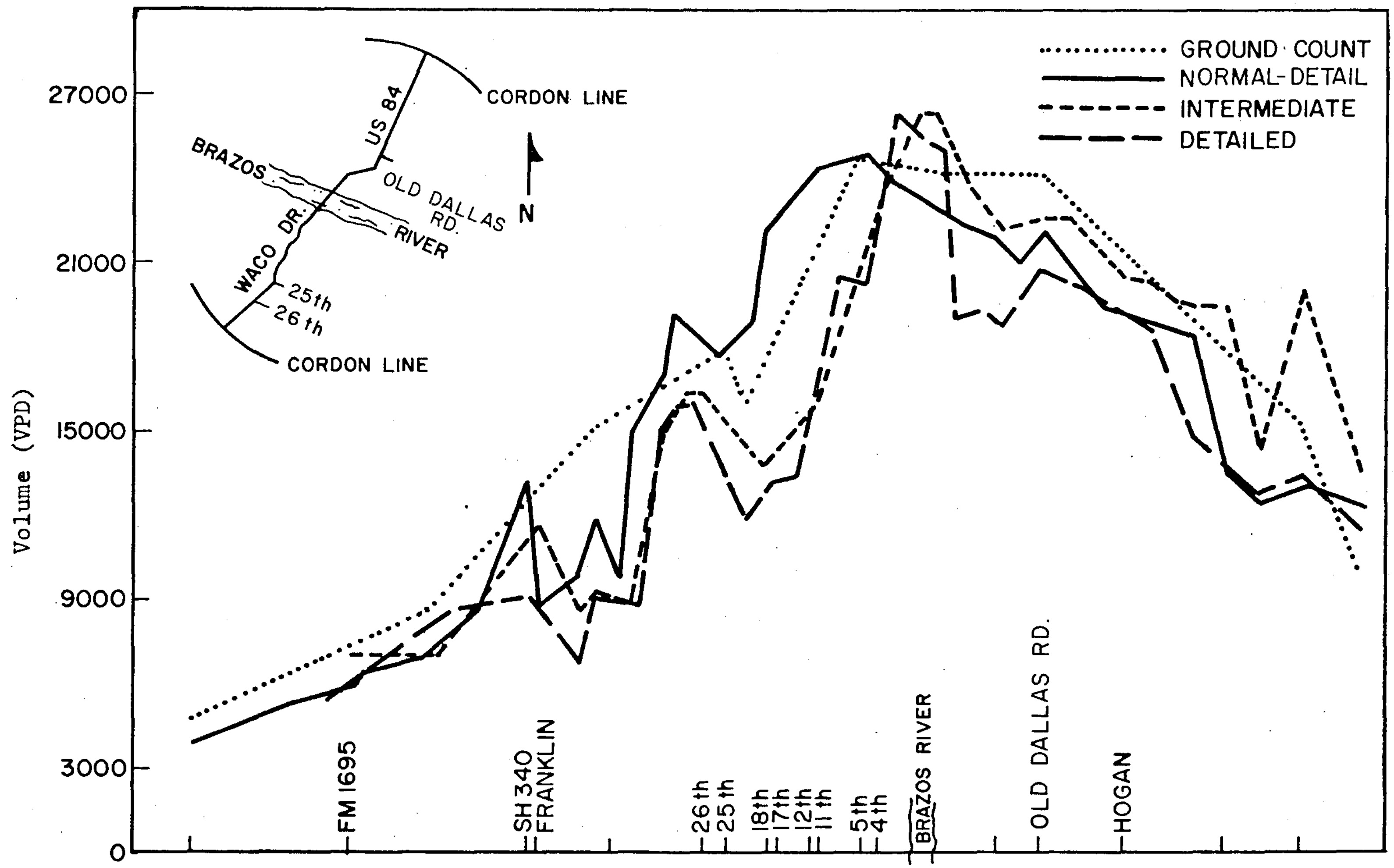
The La Salle Street volume profile, Figure 13, indicates that results from the assigned volumes of the intermediate and detailed networks are comparable. However, the profile of the normal-detail network assignment is somewhat higher; also, it is in closer agreement with the traffic counts. Traffic circulation, due to the many commercial establishments in the area, might be the cause of the large disparity between assignment volumes and traffic counts near the south end (between the circle and 5th Street) of this street.

The volume profiles for Franklin Avenue, which is one-way east bound, and Washington Avenue, which is one-way west bound, are presented in Figure 14 and 15, respectively. The Franklin Avenue volume profiles show that the assigned volumes of the intermediate and detailed networks are usually lower than that of the normal-detail network; again the assignment to the normal-detail network is in closer agreement with the ground counts. All the assignments on Washington Avenue were generally in closer agreement to the ground counts than were those on Franklin Avenue.



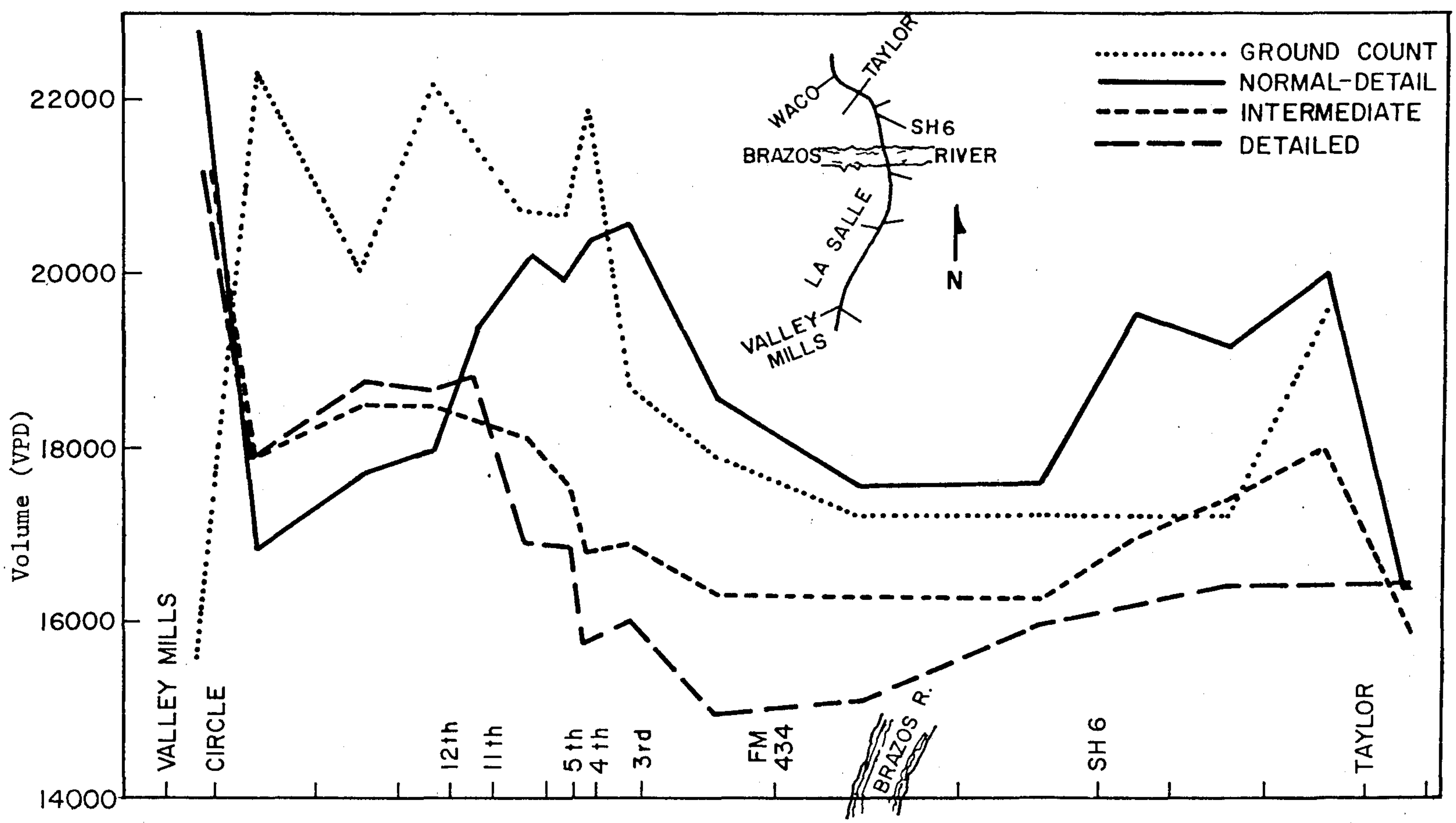
VOLUME PROFILE LOCATIONS

FIGURE 11



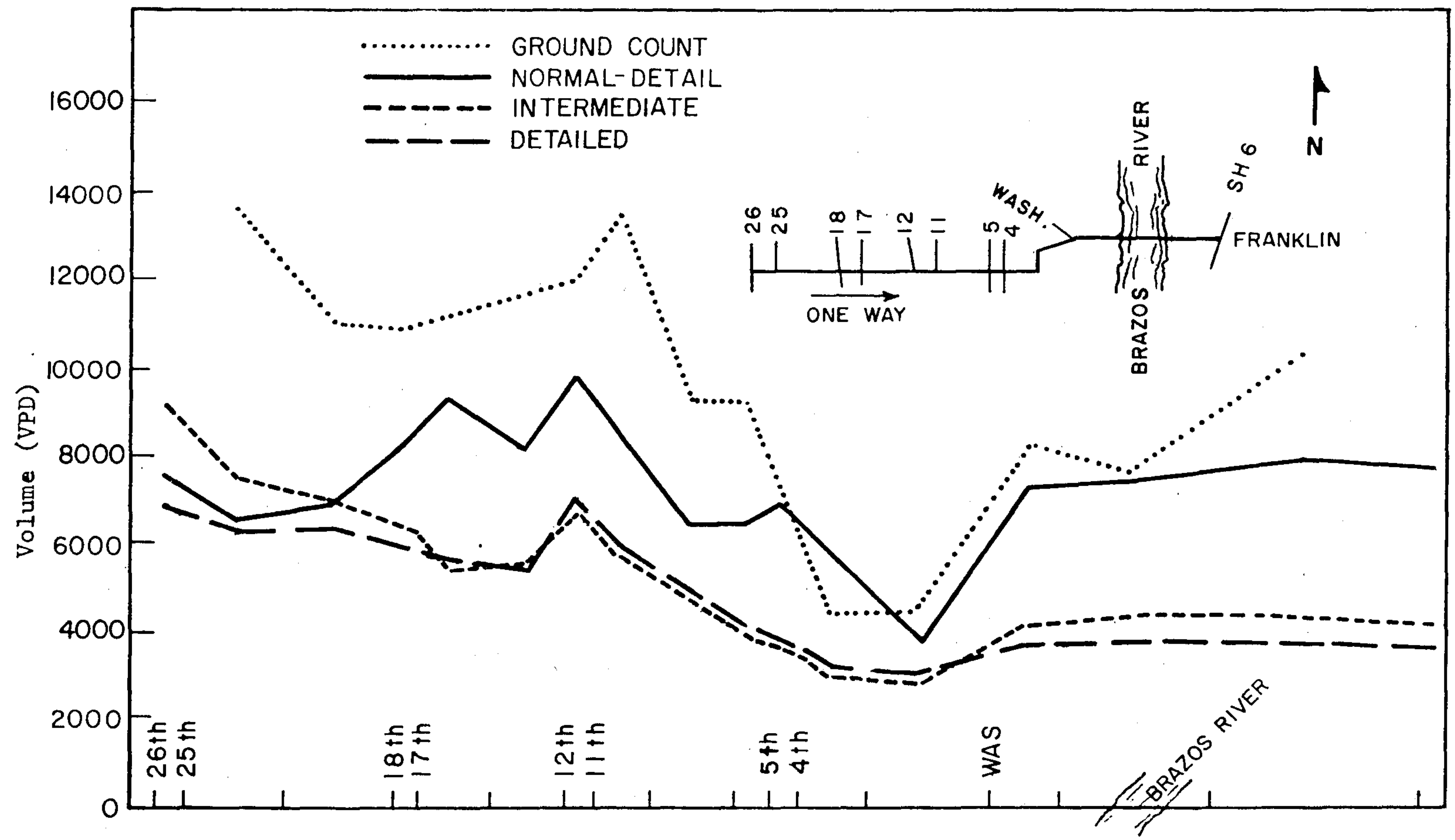
WACO DRIVE VOLUME PROFILE

FIGURE 12



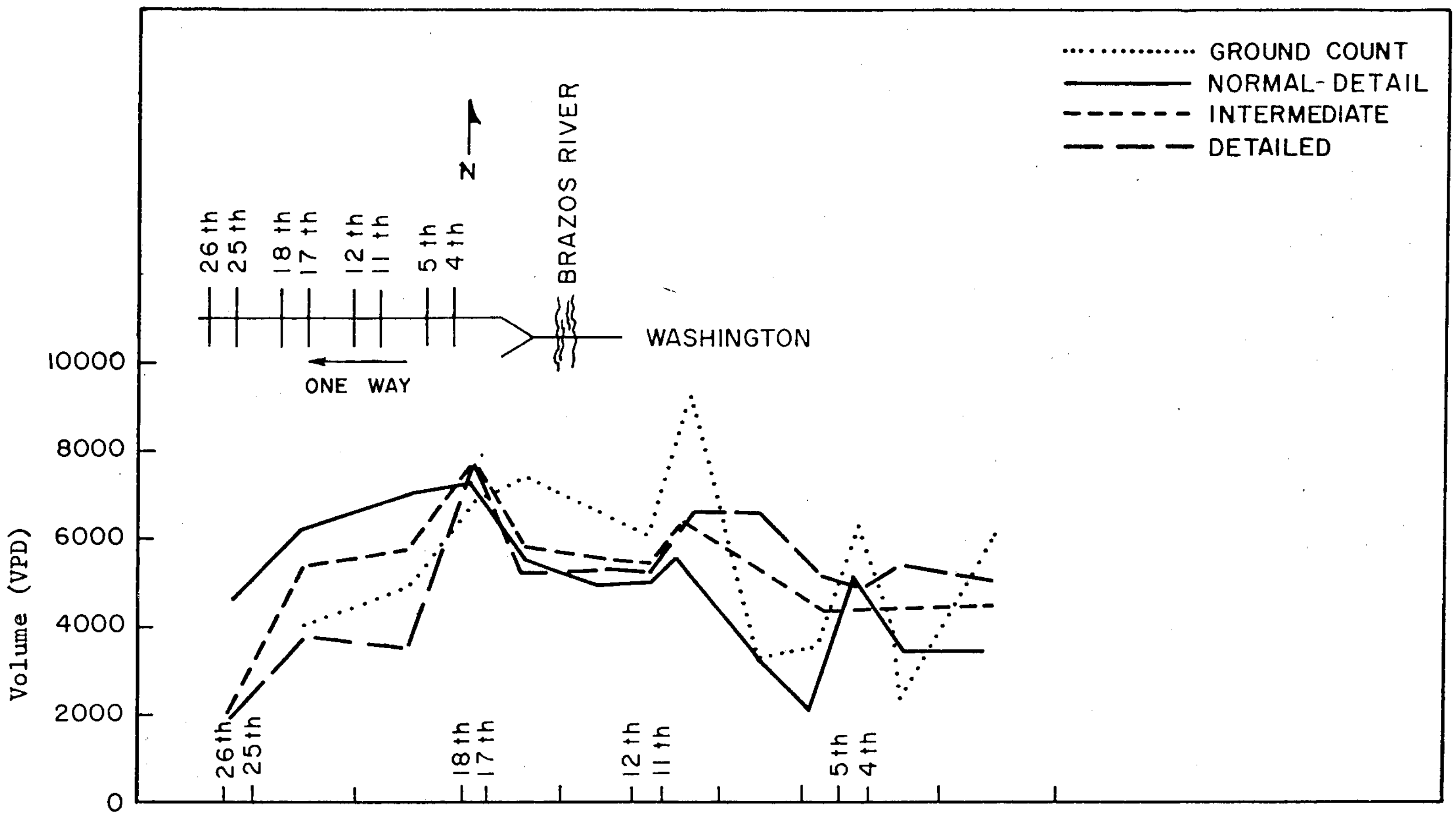
LASALLE STREET VOLUME PROFILE

FIGURE 13



FRANKLIN AVENUE VOLUME PROFILE

FIGURE 14



WASHINGTON AVENUE VOLUME PROFILE

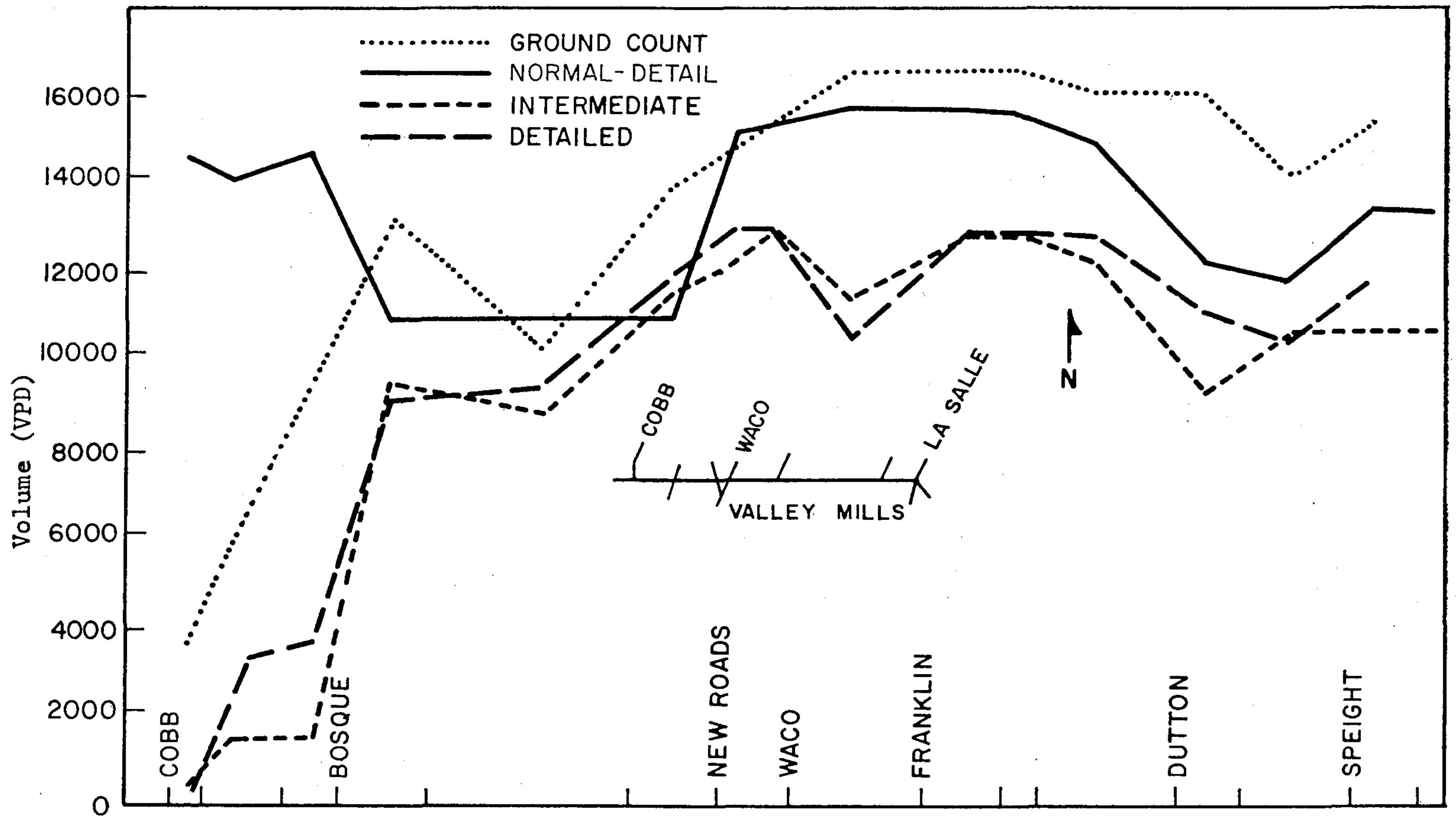
FIGURE 15

All of these routes (Waco, La Salle, Franklin, and Washington) are paralleled by other streets. Therefore, it might be thought that these links were generally underassigned in the intermediate and detailed networks due to the fact that traffic was being assigned to parallel facilities, which were not included in the description of the normal-detail network. However, the volume profile for Valley Mills Road, which does not have continuous parallel routes (Figure 16), shows the same tendency. Here again, the assigned volumes were usually lower than the ground counts, and the assignments to the normal-detail network in closest agreement with the ground counts.

Each street of a one-way pair was represented separately in all the networks. During the process of adjusting the network, it was difficult to attain reasonable agreement between assigned volumes and traffic counts on these one-way facilities. The volume profiles in Figures 17 and 18 (also Figures 14 and 15) reflect this problem. However, as shown in Figure 19, better agreement is not achieved when the volumes (assigned and counted) on each street of the pair are added together to obtain a non-directional total. This suggests problems with the directional trip table and/or the network simulation. Therefore, it appears that a representation of one-way pairs as a single two-way link for traffic assignment purposes is appropriate.

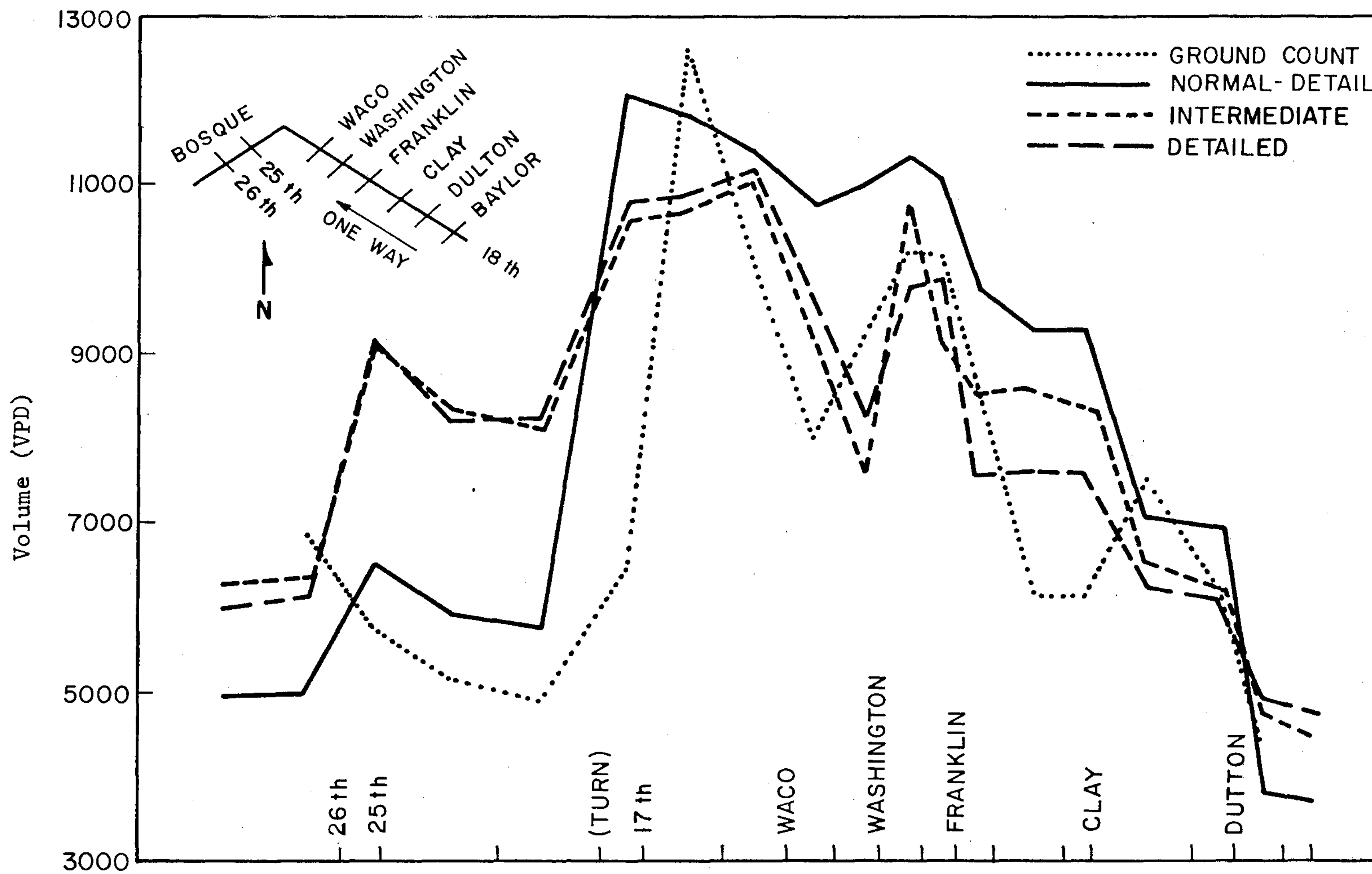
INDIVIDUAL LINK VOLUMES

Traffic counts were available for 250 of the 500 non-centroid connector links in the normal-detail network. Of these, 182 had traffic counts of over 500 vehicles per day and were located where the



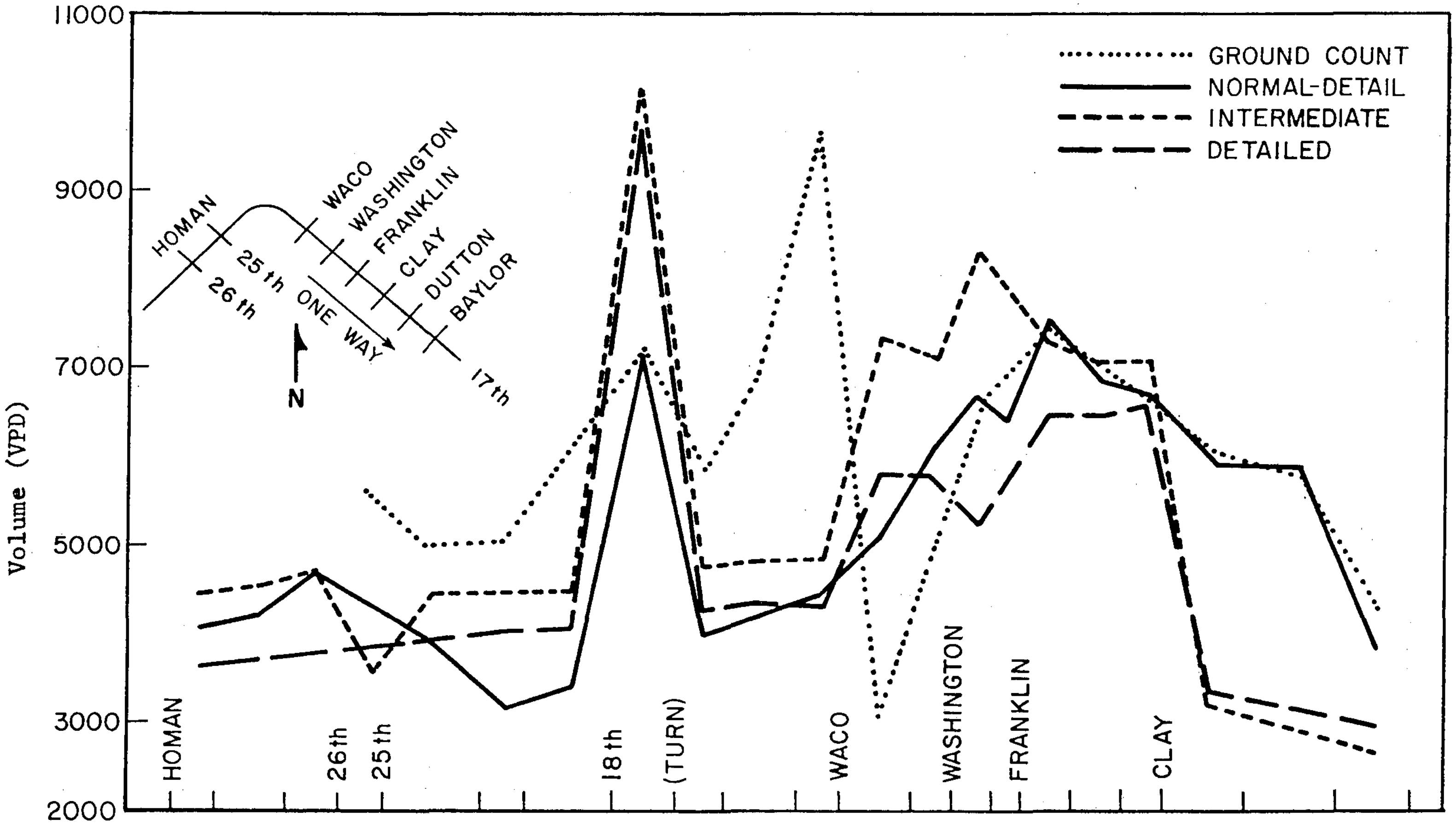
VALLEY MILLS ROAD VOLUME PROFILE

FIGURE 16



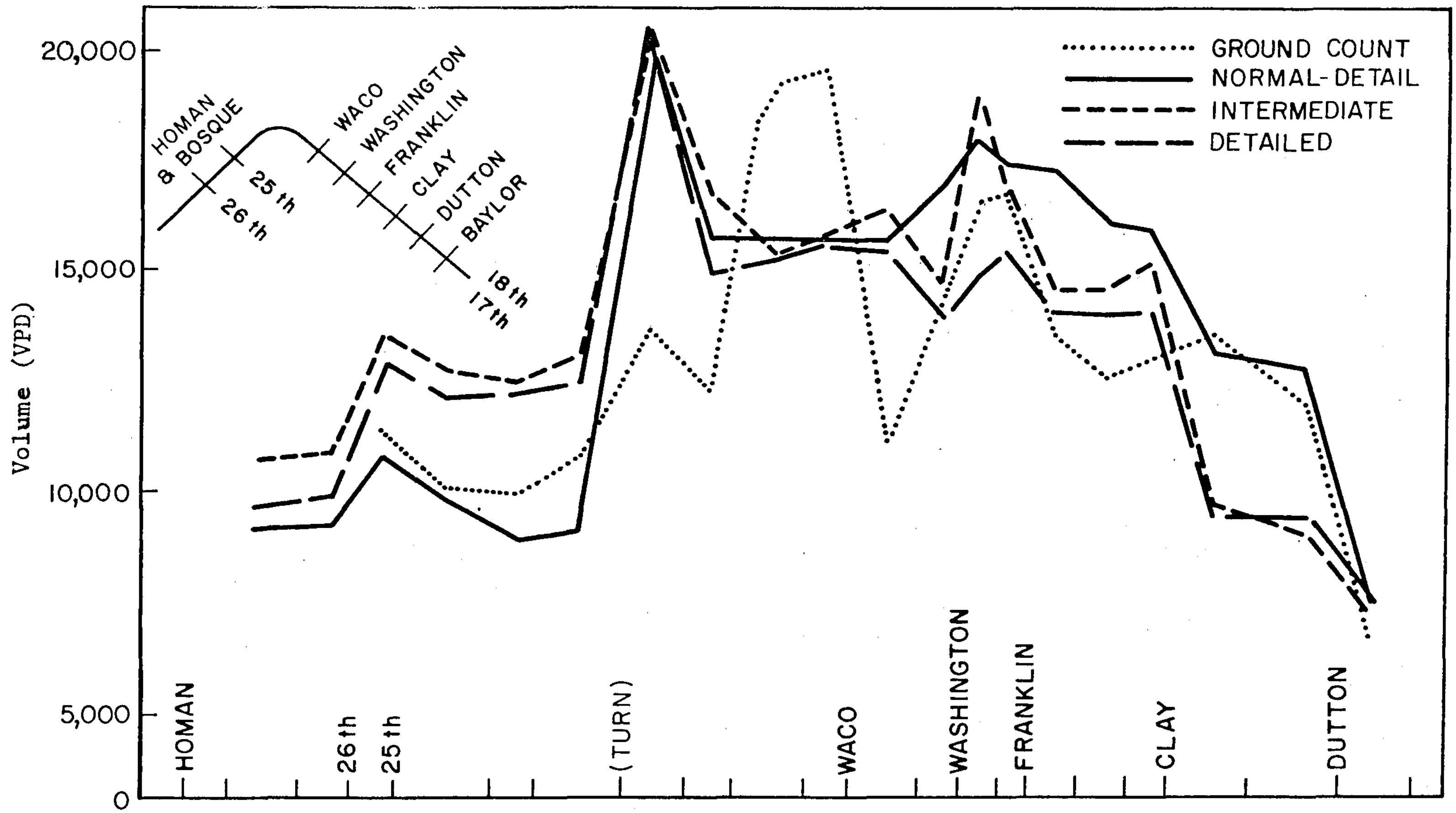
BOSQUE BOULEVARD AND 18TH STREET VOLUME PROFILE

FIGURE 17



HOMAN STREET AND 17TH STREET VOLUME PROFILE

FIGURE 18



PROFILE OF COMBINED VOLUMES ON ONE-WAY PAIRS

FIGURE 19

network configurations for the three levels of details were significantly different. Therefore, the assigned volumes and traffic counts on these 182 links were used as another basis for determining the effect of degree of network detail on the results of traffic assignment.

The root-mean-square difference[1] for the final assigned volumes on the 182 links for three possible network comparisons are as follows:

Intermediate vs. Detailed: RMS difference = 970 vpd

Normal-Detail vs. Detailed: RMS difference = 3010 vpd

Normal-Detail vs. Intermediate: RMS difference = 2830 vpd

From these values it was concluded that, as a whole, a relatively small difference exists between the intermediate and detailed networks, but a fairly large difference exists between the normal-detail network and the intermediate and detailed networks. This is commensurate with findings from the volume profiles.

The RMS difference was also applied to assist in the determination as to which network showed the best agreement with traffic counts. The outcome of this comparison is shown below:

Normal-Detail vs. Traffic Counts: RMS difference = 2520 vpd

Intermediate vs. Traffic Counts: RMS difference = 2360 vpd

Detailed vs. Traffic Counts: RMS difference = 2550 vpd

These values would indicate that little difference exists among

[1] For example, in comparing the intermediate and detailed networks

$$\text{RMS difference} = \sqrt{\frac{\Sigma(\text{link volume, intermediate} - \text{link volume, detailed})^2}{182}}$$

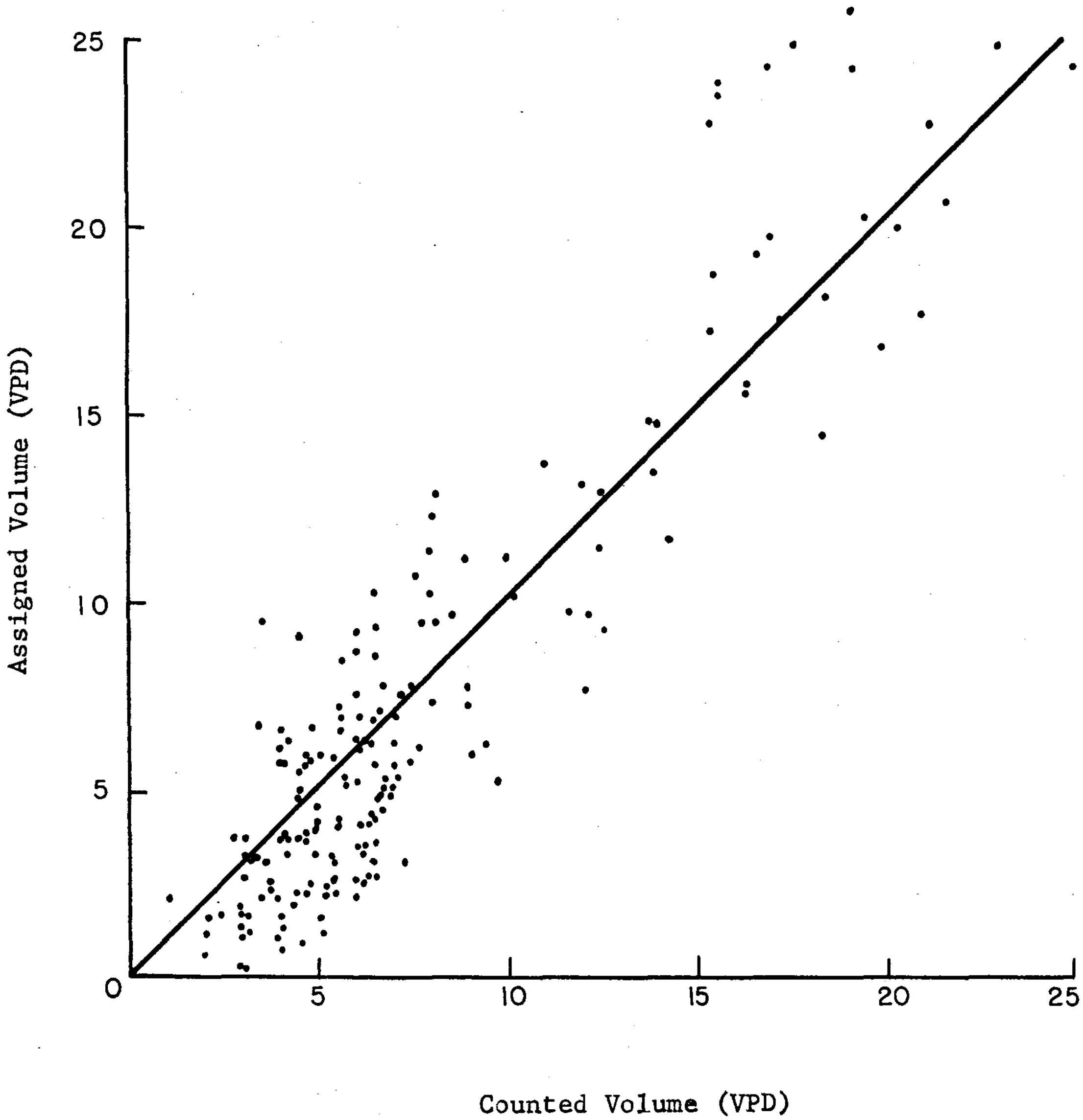
the three networks with respect to agreement between assigned link volumes and ground counts.

Another way of looking at the RMS difference would be to assume that each assigned volume for all 182 links deviated from the corresponding traffic count by a constant percentage. Then, the RMS difference of 2360 vpd for the intermediate network would mean that each assigned link volume differed by 24.5 percent from the corresponding traffic count. For the detailed network with a RMS difference of 2550, each link would differ by 26.5 percent.

The assigned link volumes were plotted against the traffic counts for each of the 182 links used in the comparison. The plots for the normal detail, intermediate, and detailed networks are shown in Figures 20,21, and 22, respectively. The normal-detail network has more overassigned links in the high volume range than either of the other two coded networks. In the middle volume range, the link volumes for the normal-detail network appear to be reasonably close to traffic counts, whereas the other networks are slightly underassigned. For low volumes, all three networks are generally underassigned. In comparing Figures 21 and 22, no significant difference can be noted between the intermediate and detailed networks.

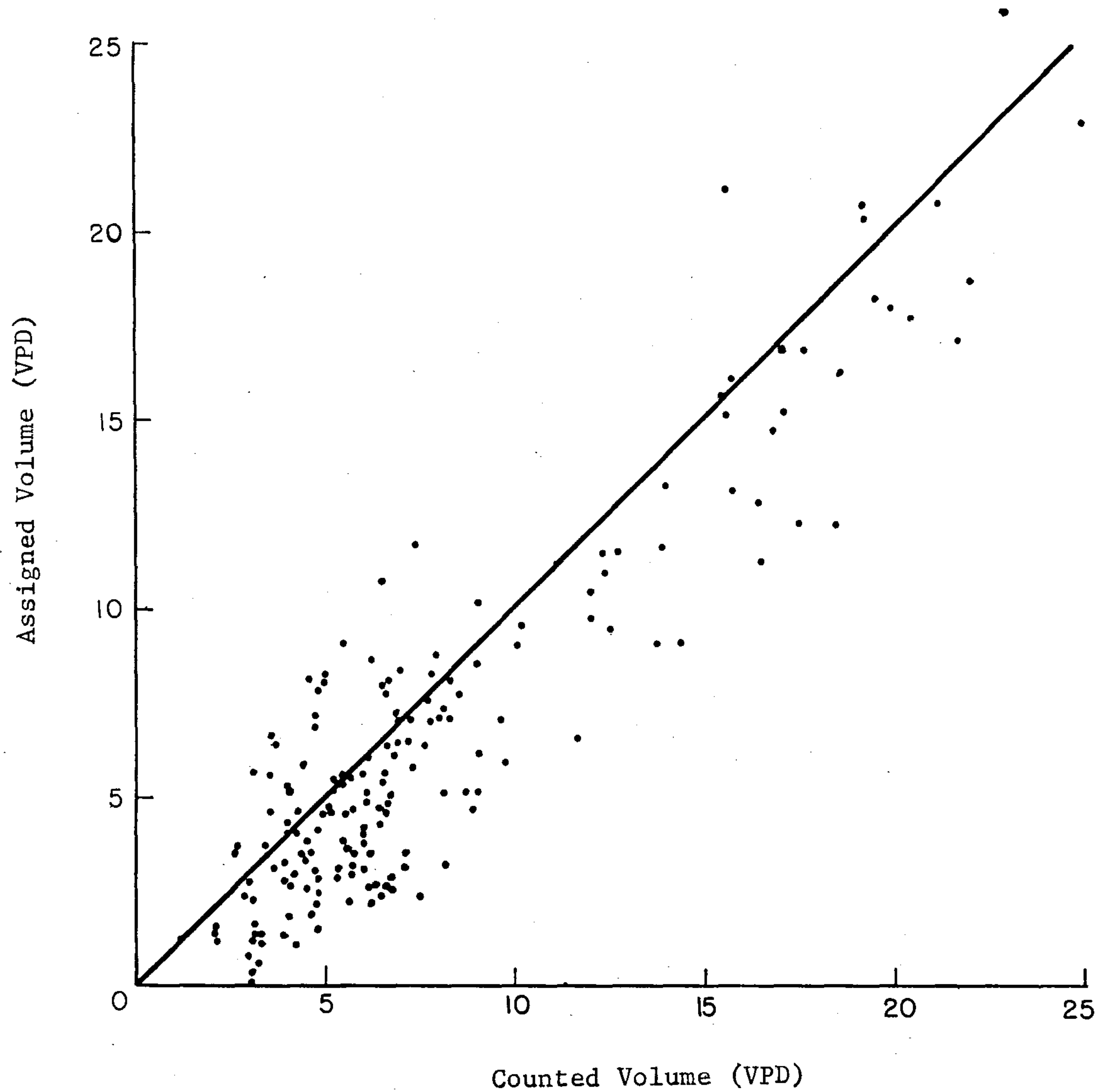
NETWORK PARAMETERS

Summary information for the three networks with different degrees of detail are shown in Table 3.



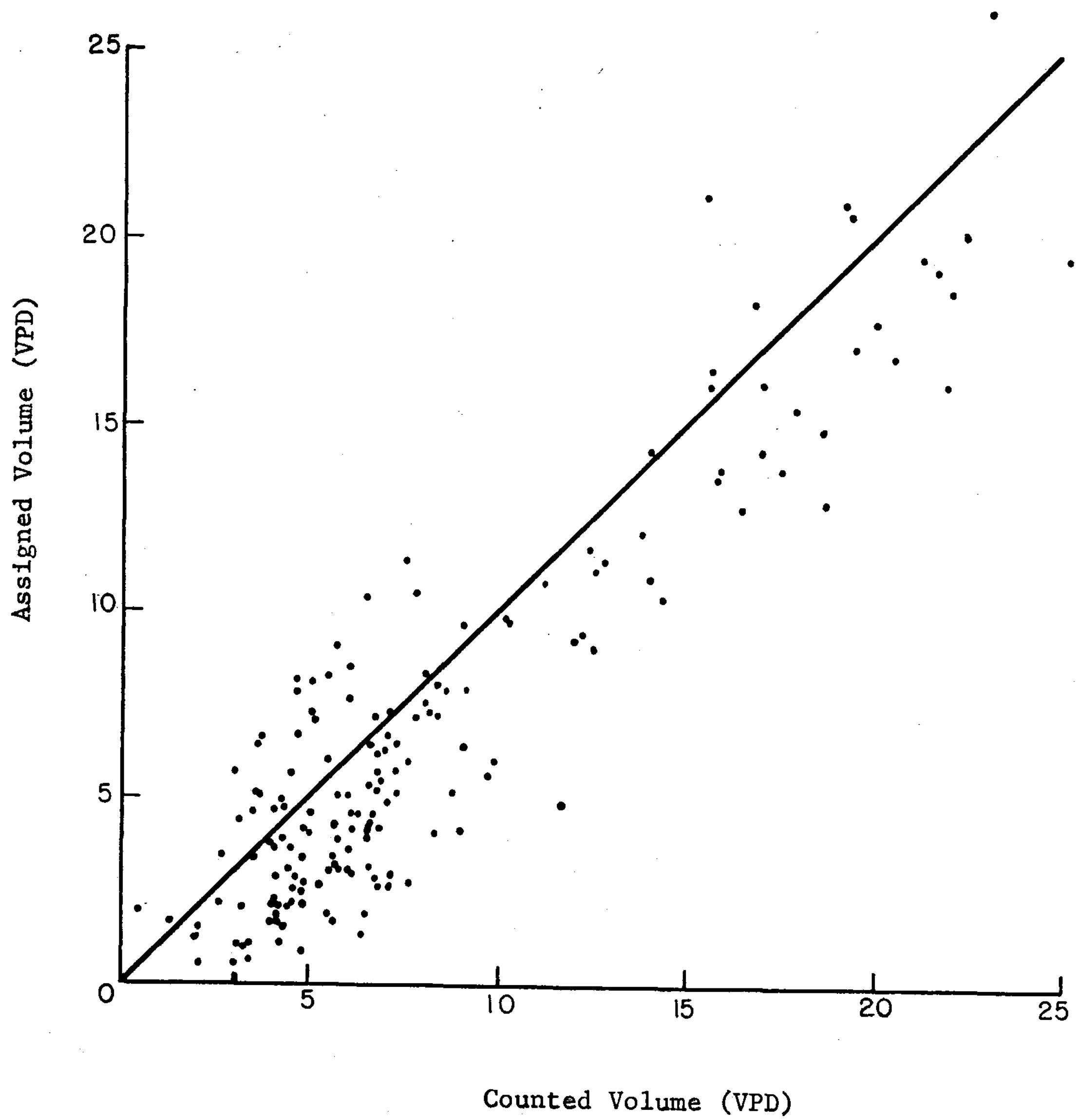
VOLUME ON SELECTED LINKS - NORMAL-DETAIL NETWORK

FIGURE 20



VOLUMES ON SELECTED LINKS - INTERMEDIATE NETWORK

FIGURE 21



VOLUMES ON SELECTED LINKS - DETAILED NETWORK

FIGURE 22

TABLE 3

OMPARISON OF DISTANCE AND SPEED PROPERTIES OF THE DIFFERENT NETWORKS

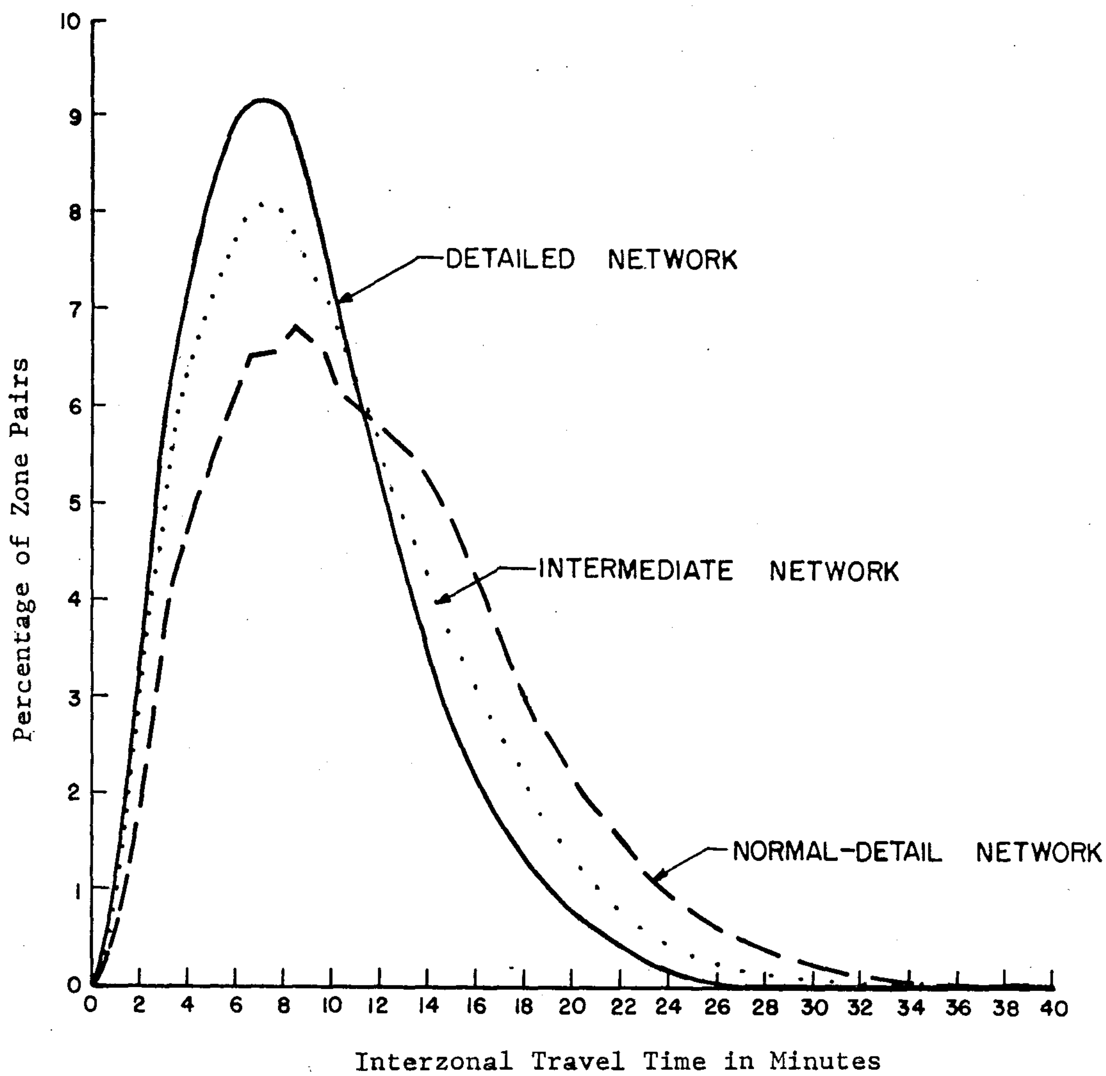
	Normal-Detail	Intermediate	Detailed
ummation of Link Distance (miles)	195	372	645
ileage as a Percentage of Detailed Network Mileage	30%	58%	100%
ummation of Centroid Con-nector Distance (miles)	111	234	341
etwork Average Speed, all noncentroid connector links (mph)	35.0	24.3	20.5

s indicated in Table 3, the normal-detail network contains about 30% s much distance as the detailed network while the intermediate net-ork contains 58% as much. Even though centroid connectors in networks th increased detail are shorter in length, the total centroid con-ctor distance increases since many more connectors are required. In ch of the three networks, the total centroid connector distance is out equal to half of the network distance.

The average speed for each network was calculated by dividing the mulative network mileage by the cumulative network travel time. As pected, network average speed decreases as network detail is increased. is is due to the addition of local streets which have relatively low eeds.

INTERZONAL TRAVEL TIME

Figure 23 shows the relative frequency distribution of interzonal avel times be pairs for each of the three coded networks.



RELATIVE FREQUENCY DISTRIBUTIONS OF INTERZONAL TRAVEL TIMES

FIGURE 23

The curve for the detailed network is the smoothest; this is to be expected since there are 3,551,340 pairs of zone combinations. There are only 448,230 pairs of zone combinations in the intermediate network, and 48,620 in the normal-detail network.

There are several possible causes for the three distributions to be dissimilar. With the small zones of the detailed network there is a larger number of zone pairs separated by short travel times than in the other networks. Therefore, the percentage of zones separated by short travel times would be expected to decrease with a decrease in network detail. The magnitude of the effect can be estimated by considering the zone relationships in two different networks. For the normal-detail and detailed networks with 206 and 1870 internal zones respectively, it could be said that, on the average, each zone in the normal-detail network corresponds to a cluster of about nine (1870÷206≐ 9) zones in the detailed network. Since each of the nine zones is connected to all of the remaining eight; a cluster of nine zones represents 72 (9 x 8 = 72) interzonal paths. For the entire 206 internal zones in the normal-detail network, there are about 15,000 (206 x 72 ≐ 15,000) interzonal connections in the detailed network which are eliminated by zone aggregation with the reduced detail of the normal-detail network. These 15,000 interzonal paths, which do not exist in the normal-detail network, represent short spatial separations in the detailed network and their effect would be concentrated near the origin of the curve (probably in the interval of from one to three minute separations).

Since local streets are not explicitly represented in the lesser detail networks, some zone pairs that would be most directly connected via the local street system would have to be routed via a corridor which would lengthen their time separation. This would have the effect of increasing the percentage of zone pairs separated by longer travel times in the intermediate and normal-detail networks.

However, it might be expected that the interzonal travel time frequency distributions should be essentially the same for the three different networks. As network detail is increased a more direct and therefore shorter routing between many of the zone pairs is likely to be provided, but the added links represent local streets which provide a lower level-of-service. As indicated by the summary of network average speeds (Table 3), the level-of-service speeds on these facilities were considerably lower than those on the arterial and major collector streets.

Since the three frequency distributions do not coincide, it must be concluded that the shorter routings made available through additional local street representations far outweigh the effect of the slower speeds on the additional facilities. However, it is possible that the level-of- service speeds on the local streets were not low enough.

In an attempt to establish a measure relating the interzonal travel time frequency distribution curves, the area common to each pair of curves was determined. Since the curves were plotted as a percentage of the total number of zone pair combinations in each network, the area under each individual curve is 100 percent.

The area common to each combination of networks is shown below:

Normal-Detail and Intermediate = 86.2%

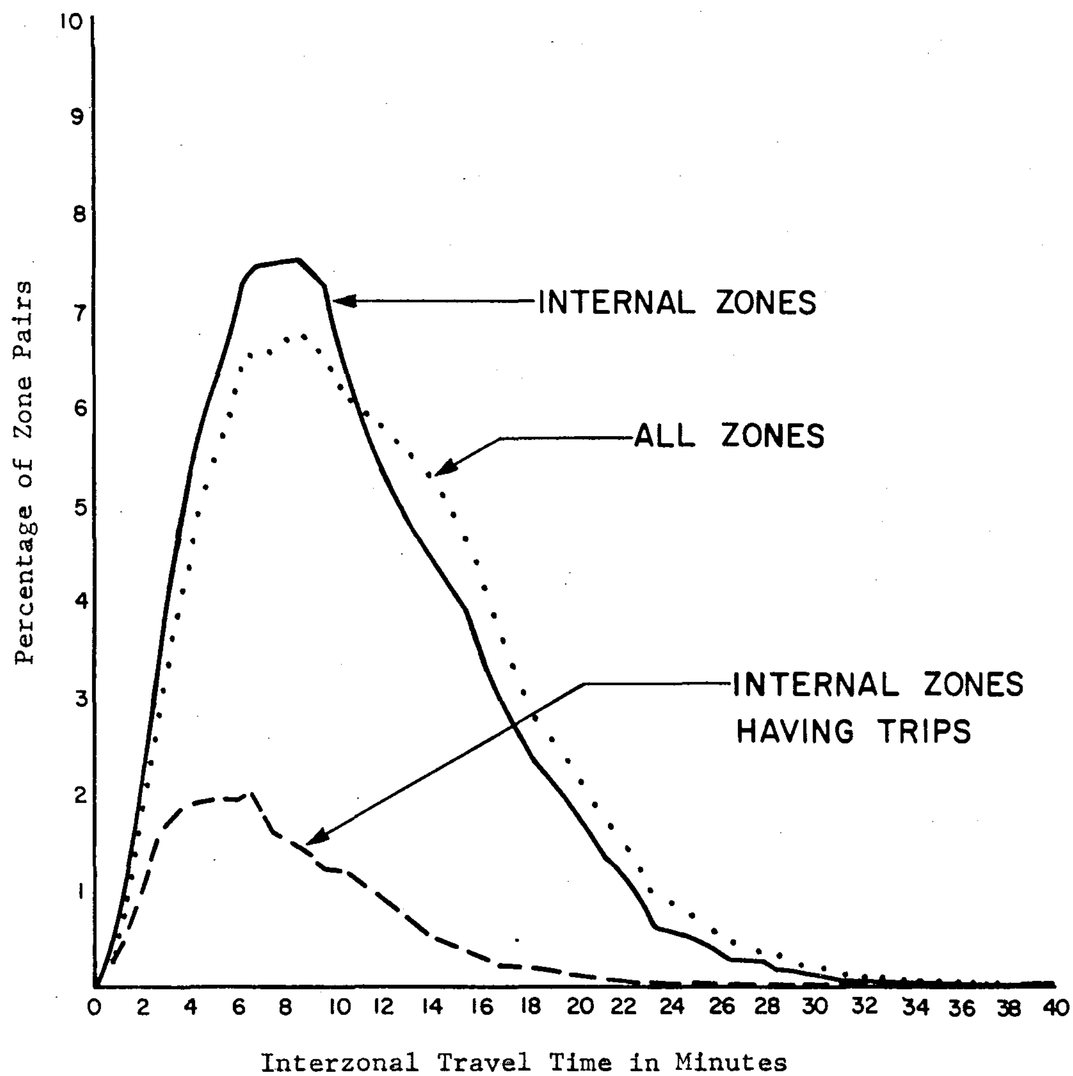
Detailed and Intermediate = 82.8%

Normal-Detail and Detailed = 75.5%

As expected, the normal-detail and detailed networks showed the greatest difference; however, the detailed and intermediate networks did not show the close agreement that would be anticipated from the previous findings.

The interzonal travel time distribution was also plotted using the internal zones only in the normal-detail network. This was done in order to gain insight into how the distribution behaved with the exclusion of interchanges between internal zones and external stations, and between external stations. The external stations have, on the average, the greatest separation from all other zones. Therefore, the percentage of long separations would be expected to decrease with the exclusion of interchanges to and between external stations as is shown in Figure 24. There were 15 external stations in all three networks. Hence, it would be expected that the effect of the external stations would be less pronounced in the interzonal travel time distributions of the more detailed networks since they have a significantly larger proportion of internal zones.

Having noted that somewhat different interzonal travel time frequency distributions resulted with each of the three networks, an obvious question is: "Is the trip length frequency distribution dependent upon network detail?" Unfortunately, the development of the computer programs for obtaining the trip length frequency distributions had not been completed at the time of this research so the question could not be answered directly. However, the trip table for each network was examined to discover the proportion of zone pairs without trip interchanges.



INTERZONAL TRAVEL TIME DISTRIBUTION FOR NORMAL-DETAIL
NETWORK INTERNAL ZONES

FIGURE 24

As the number of centroids in a network is increased, the size of the trip matrix increases as the square of the number of centroids. The detailed network contained approximately 8.5 times as many centroids as the normal-detail network and had a trip table which was about 73 times larger. However, the normal-detail network would not be expected to have trip interchanges between all zone combinations in the course of a 24-hour period; an even larger proportion of the detailed network trip matrix would be expected to contain no trips. This becomes obvious when it is recalled that there were 286,200 total trips in the study area as determined by the origin-destination survey. These 286,200 trips must be distributed between 3,553,000 zone pair combinations resulting with the 1885 zones in the detailed network. Due to the discrete nature of trips and the fact that some interchanges will consist of several trips, many zone pairs obviously cannot have a trip interchange. As seen in Table 4, about 99% of the total zone pairs in the detailed network were observed to have no trips. The actual number of zone pairs with observed trip interchanges is little more than doubled when comparing the normal-detail network with the detailed network.

If exactly one trip interchange existed between every possible zone pair in each network, the resulting trip length frequency distributions would be identical to the interzonal travel time relative frequency distributions shown in Figure 23. However, only about one percent of the zone pairs (36,385 zone pairs as shown in Table 4) of the detailed network had trip interchanges to contribute to the trip length frequency distribution.

TABLE 4

NUMBER OF ZONE PAIRS WITH AND WITHOUT TRIP INTERCHANGES

Interzonal Interchanges	Normal-Detail	Intermediate	Detailed
Number with trips	16,453	28,525	36,385
Number without trips	32,167	419,705	3,514,955
Total	48,620	448,230	3,551,340
Percentage with trips	34%	6%	1%
Intrazonal Interchanges	**Normal-Detail**	**Intermediate**	**Detailed**
Number with trips	171	238	192
Number without trips	50	432	1693
Total	221	670	1885
Percentage with trips	77%	36%	10%

Compared to the normal-detail network, this is slightly more than twice as many zone pairs with trip interchanges. Hence, it might be expected that any difference between trip length frequency distributions for these two networks would be smaller than the difference shown in Figure 23. However, as shown in Table 1 about 15,000 (18,008 - 3044 ≐ 15,000) trips contribute to the trip length frequency distribution of the normal-detail network, yet they not only contribute to that of the detailed network but their effect is concentrated on the portion of the curve adjacent to the origin. This should result in a noticeable increase in the percentage of short trips in the detailed network.

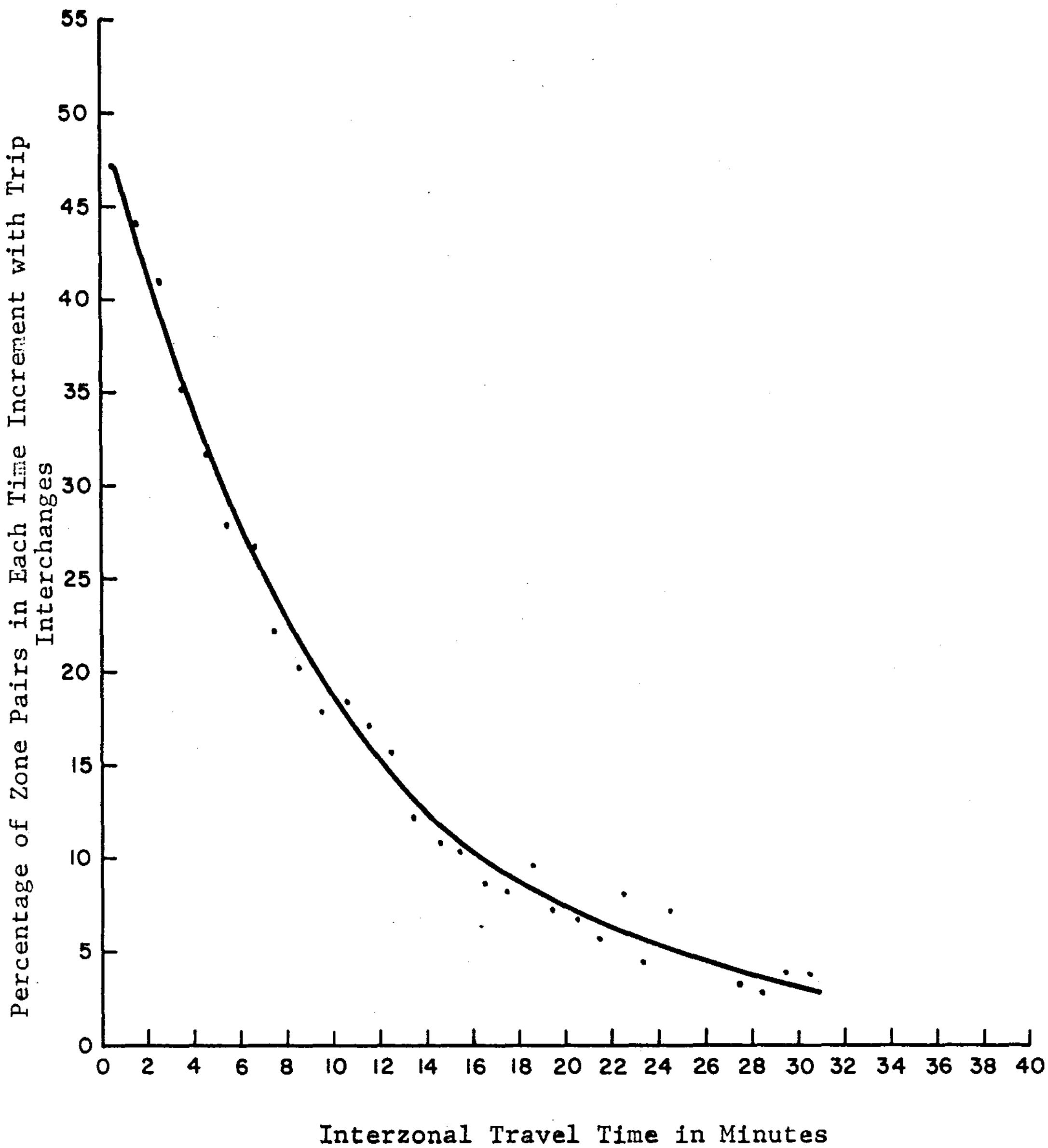
The relative frequency distribution of zone pairs that have one or more trip interchanges in the normal-detail network is also plotted in Figure 24. Only a moderate percentage of the total number of zone pairs are observed to have trip interchanges (about 34% as seen in Table 4). As shown in Figure 25, the proportion of the zone pairs with trips decreases rather smoothly as spatial separation is increased. While development of the capability for obtaining these data for the detailed and intermediate networks was not completed at the time of this study, it is expected that the curves for these networks would display a similar shape.

NETWORK PREPARATION, EVALUATION, AND COMPUTER COSTS

The relative time and effort involved in coding and adjusting the impedance parameters of each network has been discussed previously. To review rather briefly, the extreme detail of the detailed network caused a variety of problems. In order to have enough room to code node numbers and link parameters it was necessary to draw the network to such a scale that it had to be sectioned into twenty pieces. Matching the boundaries on each of the twenty sheets and checking to insure that all boundary connections were coded exactly once proved to be a troublesome task.

The twenty sheets of the detailed network posed an additional problem in the coding of node coordinates. Considerable difficulty was experienced in referencing the twenty sheets to a common base, and resulting errors, though modest in magnitude, created noticeable dislocation of some sections in the plotted network.

Simply locating a specific node in the detailed network was no small undertaking even though the sheet number on which it was located was known. Handling of the map sheets and the constant shifting from one sheet to another was a continual source of annoyance.



PERCENTAGE OF ZONE PAIRS WITH TRIPS IN EACH TIME INCREMENT
(INTERNAL ZONES OF NORMAL-DETAIL NETWORK)

FIGURE 25

It was very difficult to remember speed changes and assigned volumes; likewise it was hard to obtain an overall estimate of the agreement between assigned volumes and traffic counts. The overall change in assigned link volumes for successive assignments was nearly impossible to interpret. Further, in adjusting the network impedance parameters (level-of-service speed), it was nearly impossible to anticipate the effects of speed changes.

The problems associated with the intermediate network were identical and nearly of the same magitude as the detailed network. The normal-detail network, on the other hand, was coded on a single map and was quite easy to work with. The approximate effects of speed changes were relatively easy to ascertain. Also, a reasonably good evaluation of the overall agreement between assigned volumes and traffic counts could be determined by inspection of the values posted on a map.

As network detail was increased, computer time on the IBM 7094 increased very substantially. Average processing times for the three basic programs that were reiterated for each assignment with adjusted impedance parameters are shown in Table 5.

TABLE 5

IBM 7094 Computer Processing Times

	Network		
	Normal-Detail	Intermediate	Detailed
Build Network Description	0.5 min.	1.8 min.	2.6 min.
Build Trees	0.7	32	246
Load Network	1.8	15	26
Total	2.0	49+	275+

These data show that as network detail was increased, the basic assignment time increased from two minutes to over 4 1/2 hours. Such an increase, even though alarming, is to be expected. Assignment for the detailed network involves processing 73 times as many minimum paths as the normal-detail network and each minimum path involves considerably more links. There is an extensively larger number of alternative paths from which each minimum path must be selected in the detailed network. It is concluded that the degree of network detail presently used in traffic assignment is appropriate. No improvement is obtained in the assignment results with increased network detail using an all-or-nothing assignment. However, computer processing time, personnel time, and analysis problems increase substantially.

Bibliography

1. "Waco Urban Transportation Plan; Origin-Destination Survey," Volume 1, Texas Highway Department, 1964.

2. Stover, V. G. and Blumentritt, C. W., "User's Manual for Texas Large Systems Traffic Assignment Package," Research Report 60-6, Texas Transportation Institute, November 1966.