REPORT 0194-1

DEVELOPMENT AND EVALUATION OF THE FAST SUBAREA FOCUSING PROCEDURE

FAST

FLEXIBLE ABBREVIATED STUDY TECHNIQUES
FOR SKETCH PLANNING AND SUBAREA FOCUSING

STATE DEPARTMENT
OF HIGHWAYS AND
PUBLIC TRANSPORTATION

TTI
TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

DEVELOPMENT AND EVALUATION

OF THE FAST SUBAREA FOCUSING PROCEDURE

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Flexible Abbreviated Study Techniques (FAST) Report Series

This report is one of a series of reports which documents the development and evaluation of the Flexible Abbreviated Study Techniques (FAST). FAST provides cost-effective analytical techniques for sketch planning and subarea focusing.

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INTRODUCTION

In urban transportation studies dealing with large urban areas, it is often desirable to consider alternatives which basically affect only a portion of the urban area. For example, in the Houston-Galveston Regional Transportation Study, it might be desirable to study and evaluate several alternatives within a portion of Harris County (i.e., a subarea of the Houston-Galveston eight-county area). The cost of rerunning the distribution and assignment models for the entire eight county area for each such alternative is, at best, impractical. As a result, interest has been focused on techniques whereby only a portion of the area might be studied and the alternatives examined at a reasonable cost.

Large vs Small Urban Areas

A subarea assignment technique is primarily applicable in large urban areas. Due to the relatively low cost associated with running the distribution and assignment models in small urban areas, it is expected that the potential cost savings from the use of a subarea assignment technique in small urban areas would be relatively small and probably not worth the trouble. In essence, the subarea assignment technique is primarily applicable to studies such as Houston-Galveston, San Antonio, Dallas-Fort Worth, and El Paso.

The Problem Matrix

In considering the problems which may be addressed by the subarea assignment technique, it was assumed that distribution and assignment models have been run for the entire urban area and that the analyst is interested in examining some specific alternatives for a few select subareas. In focusing on a specific subarea of the urban area, the analyst would be looking at alternatives which would involve transportation system changes and/or land use changes. The problem matrix shown in Figure I-1 generally describes the potential problematic situations (i.e., alternatives) which an analyst might wish to address on a subarea basis. It is important at the outset to delineate which of these eight problematic situations might be addressed using a subarea assignment technique.

A subarea assignment technique would be primarily applicable to problem situations involving either major changes in the transportation system or major land use changes or both (i.e., problems 1, 2, 3, 4, and 5 in Figure I-1). A subarea assignment technique generally would not be applicable to situations involving only minor land use and/or transportation system changes since the basic distribution and assignment models are not sufficiently sensitive to such minor changes to produce reliable data for evaluating such alternatives. Indeed, a manual adjustment process, performed by experienced analysts, would probably produce more reliable results at substantially less cost than could be obtained from computerized results. There may be, however, a few situations involving both minor land use changes and minor transportation system changes such that in combination they constitute a major change sufficient for evaluation using a subarea assignment technique. In other words, a subarea assignment technique might be applicable to few, if any, situations under problem 6 and not applicable to problems 7 and 8.

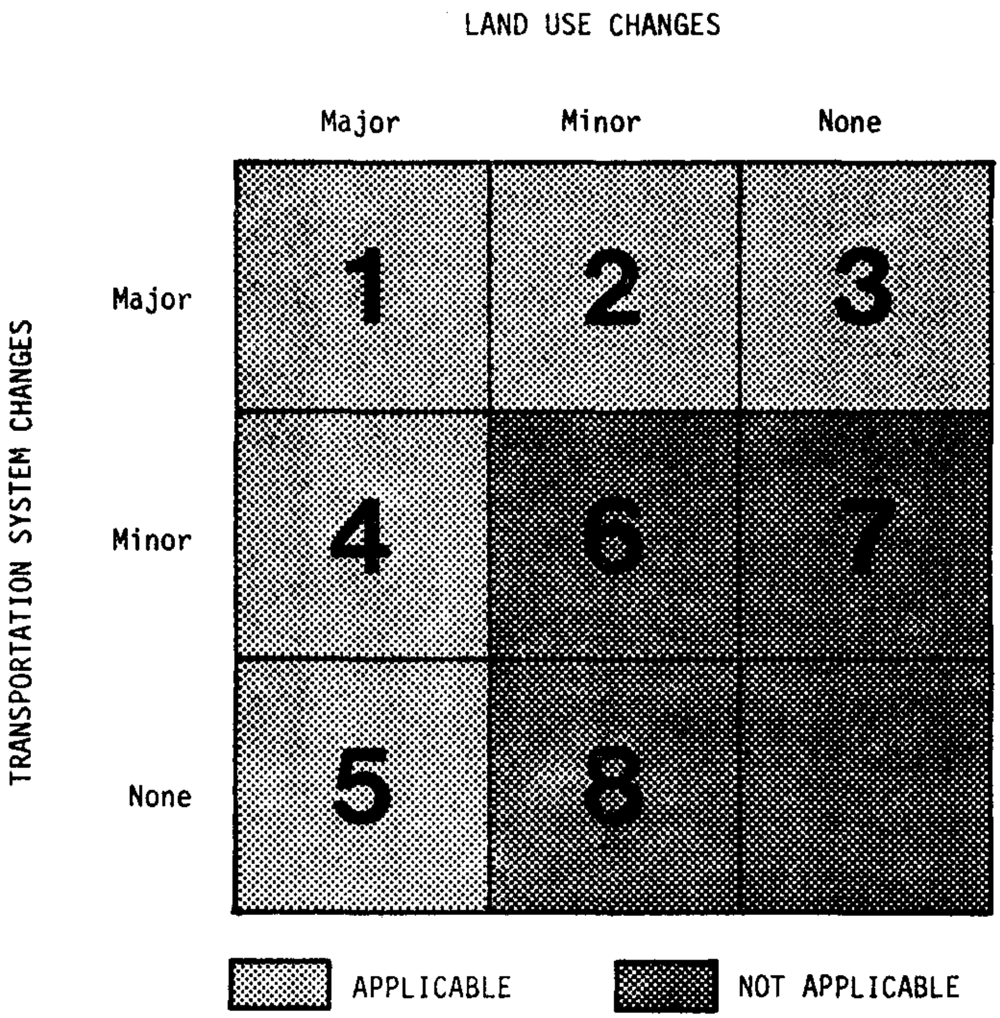


FIGURE I-1: PROBLEM MATRIX FOR SUBAREA ANALYSES

TECHNICAL APPROACH

Several alternative approaches for obtaining subarea assignments were examined in identifying the subarea assignment algorithm for implementation. The purpose of this section is to briefly describe the alternatives examined; provide a detailed description of the algorithm selected; identify some of the salient advantages of the FAST algorithm; and to briefly describe the study design for testing the FAST Subarea Focusing Procedure.

Subarea Windowing Approach

One of the subarea assignment approaches initially considered might be described as a "subarea windowing approach." Under this approach, the subarea would be identified and only those zones and network within the subarea would be carried forward in the subarea focusing procedure. In essence, the network and zones within the subarea would be "isolated" and treated as a small "stand-alone" study area. All traffic entering or leaving the subarea would be treated as "external" traffic relative to the subarea. It should be noted that in most applications, the subarea's "external" traffic would be predominantly composed of internal traffic relative to the larger study area. The implementation of such an approach would likely involve obtaining selected link assignments for each link crossing the subarea cordon. This information, together with the trip matrix for the entire urban area would then be processed to build a trip matrix for the subarea.

It was generally felt that this approach has several major inherent weaknesses. These include:

1. Since the trip matrix for the subarea is essentially a condensation of the trip matrix for the entire urban area, the technique, in essence, assumes that there will be no land use changes which will affect travel across the subarea cordon. In other words, such a technique could only be considered for situations in which the land use pattern remains relatively constant. In terms of the problem matrix described in Figure I-1, this technique basically attempts to address only problem situation number 3 (i.e., change in the transportation system with no land use changes.)

2. By holding the trip matrix essentially constant, the technique basically ignores the impact of the transportation system and its changes on the urban travel pattern (i.e., the trip distribution process). In other words, the changes in the transportation system would not alter the number of trips entering or leaving the subarea.

3. The technique basically only allows the rerouting of traffic (i.e., new minimum paths) within the subarea. By holding the trips entering or leaving the subarea at the subarea cordon line constant, the technique essentially assumes that this traffic continues to enter and/or exit at these points regardless of any transportation system changes. If the transportation system changes being considered are major improvements, it is quite possible and, indeed likely, that the volume of traffic passing through the subarea (i.e., trips with origins and destinations outside the subarea) would increase, and in some instances, this increase may well be substantial. Conversely, if the transportation system alternative being considered for a subarea offered a substantially lower level of service, it is quite likely that the volume of through traffic would decrease and, in some instances, this decrease may be substantial. In other words, the technique provides no opportunity for rerouting traffic either through or around the subarea.

4. The cost associated with obtaining selected link assignments for all links crossing the subarea cordon line is substantial and, in addition, would probably require rerunning the assignment for the entire urban area. In addition, the cost associated with building the subarea trip matrix would be substantial. In essence, unless more than one alternative, and possibly more than two, were being considered for the subarea, it probably would be less costly to simply make the proposed changes in the network for the entire urban area and simply rerun the assignment using the new network.

In view of these inherent weaknesses and limited scope of applicability, the subarea windowing approach was eliminated from further consideration.

Subarea Focusing With Revised Network

Another approach considered might be described as a "subarea focusing technique using a revised network and zone structure." Using this approach, the portion of the study area outside the subarea would be carried forward into the subarea analysis but at a substantially reduced level of detail. The consideration of a subarea within an areawide context would, of course, overcome many of the inherent weaknesses in the "subarea windowing approach." The use of this approach, however, involves the recoding of the network using a very sparse system and very large zones outside the subarea. A technique to automate the recoding of the network outside the subarea was studied when consideration was being given to this approach. While this approach has some conceptual appeal, it does require either manual or automated recoding of the network outside of the subarea which is expensive.

The FAST Subarea Focusing Assignment Technique

In considering the feasibility of implementing a subarea assignment technique, neither of the approaches initially studied were felt to be worthy of implementation. Nevertheless, the need for a subarea assignment technique remained apparent. The conceptual framework for an algorithm for the FAST subarea focusing assignment technique was, therefore, developed which would appear to overcome the basic inherent weaknesses in the previous approaches being considered and yet remain feasible for consideration and worthy of implementation and testing. The following describes the FAST algorithm for subarea assignments.

General Overview

The FAST algorithm for subarea assignments would incorporate both a trip distribution phase and a traffic assignment phase. The inclusion of the trip distribution phase is important for two reasons:

1. It allows the analyst to look at alternatives involving different land uses.
2. It provides a mechanism to account for the impact of transportation system changes on the urban travel pattern (i.e., the trip matrix).

The second important feature of the FAST algorighm is its use of a subarea focusing approach which allows the subarea to be studied within the context of the entire urban area. The FAST algorithm, however, will not require the recoding of the transportation system network. The means by which this is accomplished will become clearer as the algorithm is described in more detail. Nevertheless, at this point, it is important to note that, that by considering the subarea in detail and the remainder of the urban area at varying levels of grosser detail and at the same time including a trip distribution phase in the algorithm, the FAST algorithm basically overcomes the inherent weaknesses apparent in the previously proposed approaches.

Delineation of the Subarea and Rings

The first step in using the FAST algorithm would be, of course, to delineate the subarea of interest. This can be easily accomplished using a network map and simply drawing a subarea cordon line around the subarea of interest. The subarea would then be described for computer input by enumerating the zones contained within the subarea. Again, using the map, the analyst would next describe a ring (which will be referred to as a "transition ring") around the subarea as shown in Figure II-1. The width of this transition ring should probably be at least 2 to 3 miles. As with

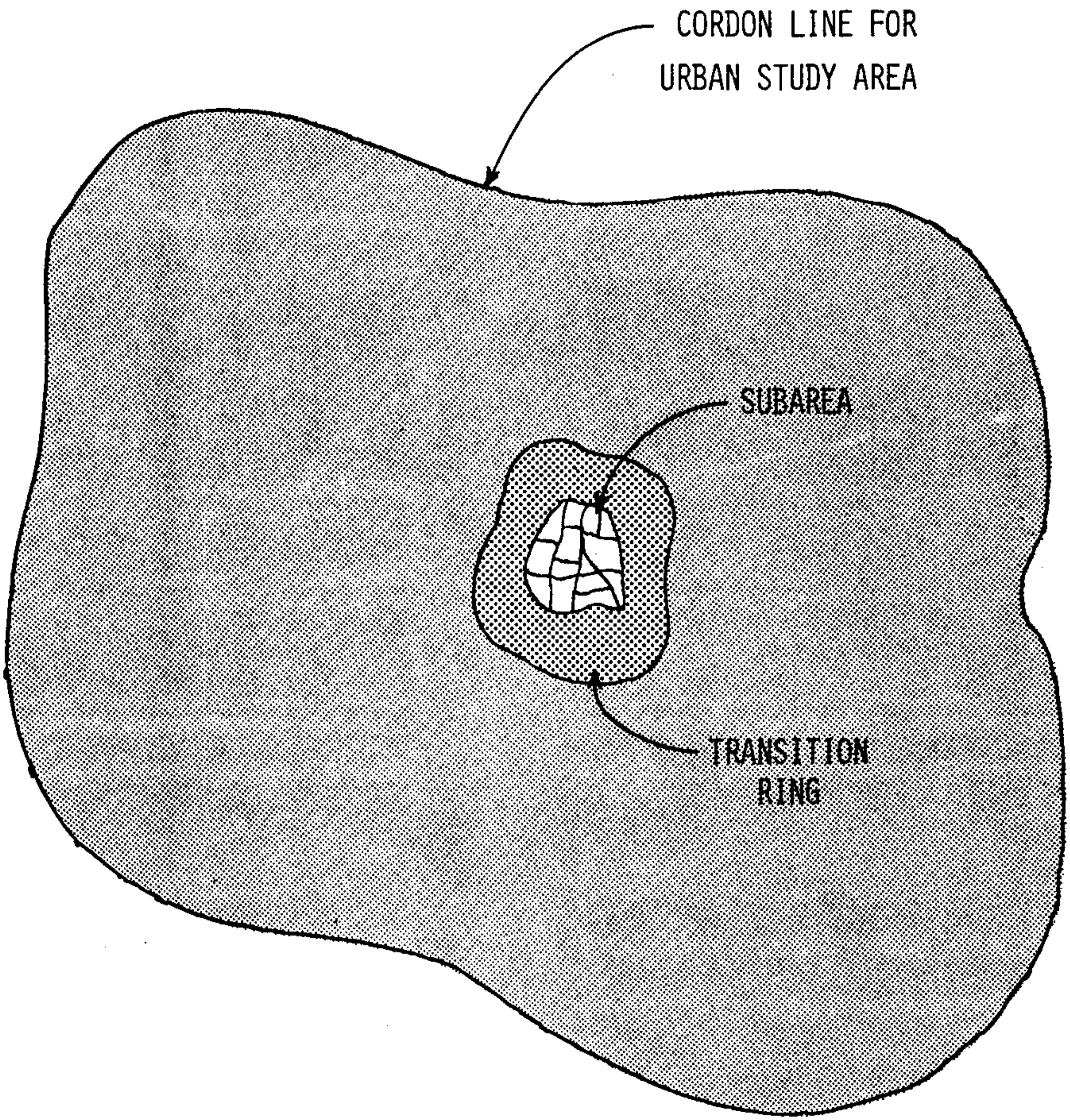


FIGURE II-1

SCHEMATIC OF SUBAREA AND TRANSITION
RING FOR AN URBAN AREA

the subarea, the transition ring would be described by simply enumerating the zones contained within the ring. At this point, we have delineated the subarea and the transition ring by simply drawing these on a map and enumerating the zones contained in each.

The next step basically involves describing the remainder of the urban area via a sector (or district) structure involving aggregations of the remaining zones in the urban area. In doing this, it is suggested that the size of the sectors should vary with the distance from the subarea (i.e., zones near the subarea and transition ring would probably be grouped into smaller sectors (or districts) while zones at substantial distances from the subarea would be grouped into larger sectors. Again, this may be accomplished using the network maps to delineate the sectors and simply enumerating the zones contained in each sector. In other words, the remainder of the urban area would be described by delineating, say, 50 to 75 sectors and enumerating the zones contained in each. A computer program was developed to assist the analyst in this task.

In describing each sector, the algorithm requires that a zone within the sector be delineated as the "sector centroid." This sector centroid concept is analogous to the zonal centroid concept currently used in urban transportation studies. This sector centroid should be the zone which represents the center of activity from the center of gravity point of view. The centroid of the selected zone would then serve as the centroid for the structure.

Transportation System Changes

As previously noted, a key feature of the FAST approach is that it does not require either the computerized or manual recoding of the network outside the study area. Instead, the procedure utilizes the already available network for the urban area. If the subarea alternative to be studied involves transportation system changes, the the already available network would simply be modified to reflect these changes. This revised network (i.e., the revised link data cards for the entire urban area) would then be input into the Assemble Network Program of the Large Network Package to obtain a new flexible record data set reflecting the system changes to be studied.

Land Use Changes

If the subarea alternative to be studied involves land use changes, the zonal productions and attractions by trip purpose for the zones in the subarea should be modified to reflect the new land uses. These revised production-attraction cards would then be inserted in the P-A deck for the entire urban area. Thus, the productions and attractions for the entire urban area would be input into the new subarea assignment procedure.

Build-Trees

At this point, the analyst is ready to build trees and skim trees. This is accomplished using a modified version of the Build Tree Program from the Texas Large Network Package. It requires as input:

1. The subarea description (i.e., an enumeration of the zones contained in the subarea).
2. The description of the transition ring (i.e., an enumeration of the zones contained within the transition ring).
3. The sector structure for the remainder of the urban area identifying the sector centroid for each sector (i.e., the zone within each sector which will represent the centroid for the sector).
4. The network (i.e., flexible record data set).

Using the information, the following trees would be built:

1. Trees for each zone in the subarea.
2. Trees for each zone in the transition ring.

3. Trees for each sector centroid.

In other words, only a subset of the trees for the urban area are built. For example, if the subarea assignment technique were to be applied in the Houston-Galveston Study such that:

a. the subarea contained 125 zones,

b. the transition ring contained 75 zones,

c. the remainder of the urban area was divided into 75 sectors,

d. assuming there are 25 external stations for the urban area,

there would be 300 trees built for subarea assignment (i.e., approximately 10% of the trees which would normally be built). These trees would, of course, describe the minimum paths for each of the 300 centroids (representing subarea and transition ring zones, sectors, and external stations). These trees may be skimmed to obtain the travel times for use in trip distribution. These trees would, of course, be saved for subsequent input into the Load Network Program.

Trip Distribution

As previously noted, one of the salient aspects of the FAST subarea focusing procedure is the provision of the option for interfacing a trip distribution phase in the subarea analysis process. This is, of course, an optional phase. If the changes in the subarea are felt to be of the nature which would not significantly change the travel patterns (i.e., trip matrix) within the subarea, the analyst may elect to simply "collapse" an available trip matrix modeled at the detailed zonal level. If minor land use changes are anticipated, the analyst may elect to simply use a Fratar growth factor technique to adjust an available trip matrix before it is collapsed. Finally, the analyst may elect to perform a new trip distribution at the subarea level of detail.

Assignment

The trees built during the "build trees" phase of the subarea assignment procedure would now be loaded using the trip matrix determined in the "trip distribution" phase of the subarea assignment procedure. Computationally, this requires a slightly modified version of the load routine from the Texas Large Network Package. Only the portion of the assignment results associated with the portion of the network within the subarea are valid for study and evaluation. Link assignments for links outside of the subarea being studied may be subject to substantial distortion and should not be considered in analyzing the assignment results. An option has, therefore, been provided to supress the printing of link assignments outside the subarea.

At this point, the analyst would have available to him a subarea assignment which he may use in evaluating the subarea alternative being studied. The computer costs associated with the development of the subarea assignment would be a fraction of the cost which would be associated with running the traditional distribution and assignment for the entire urban area. In the Houston-Galveston example previously described, the computer costs would be approximately 10% of the cost associated with running the traditional trip distribution and traffic assignments for the entire 3,000 zones.

User Perspective

An important criterion in the development and implementation of a subarea assignment technique is its ease of use. Therefore, the following summarizes (from the users point of view) the step-by-step procedure which would be required in applying the algorithm for subarea assignment.

1. *Delineation of the subarea, transition ring, and the sector structure:* this step basically involves simply enumerating the zones contained in subarea, the zones contained in the transition ring, the zones contained in each sector, and the zone within each sector which would be considered the sector centroid. This information would be keypunched into cards and assembled into a deck which, for convenience, will be referred to as the "Sector Structure Deck." To facilitate this activity, a program has been developed which assists the analyst in identifying the zones in each sector and outputs the "sector structure deck."

2. *Transportation system changes:* the transportation system changes to be considered under the subarea alternative being studied will require modifying the network of the urban area to reflect the proposed changes. The modified link data would then be input into the Assemble Network Program to produce a revised flexible record data set.

3. *Land use changes:* if land use changes are to be considered under the subarea alternative being studied, the production-attraction deck for the urban area would need to be modified to reflect the proposed land use changes.

4. *Computer runs:* at this point, the user would be ready to make the computer runs necessary to obtain the subarea assignment.

5. *Posting and assignment:* having completed the computer runs, the assignment results for those links contained in the subarea would be posted for analysis.

The FAST subarea focusing procedure, from a user point of view, is probably the simplest procedure which was considered for subarea assignments.

Study Design

It is obvious that no subarea assignment procedure will exactly replicate the assignment results which would be produced using the full distribution and assignment. The subarea assignment procedure should, however, reasonably replicate the assignment results from the full modeling process. There are, of course, two primary sources of variation which may affect the assignment results:

1. The urban travel pattern described by the trip table.

2. The assignment procedure itself.

In other words, there are basically two issues to be addressed by the preliminary tests. First, given the urban travel pattern (i.e., given the fully modeled trip table for the urban area), can be proposed assignment procedure reasonably replicate the assignment results in the subarea? Second, given that the proposed FAST subarea focusing procedure can reasonably replicate the detailed assignment results, can the urban travel pattern (i.e., the collapsed subarea assignment trip table) be modeled with sufficient accuracy to produce reasonable subarea assignment results?

To address these issues, a two-phase test procedure was utilized. The 1990 Houston-Galveston Regional Transportation Study (H-GRTS) was selected as the data base for this test. The subarea selected for study is located along the West Beltway of Houston. The subarea comprises 37 zones and the transition ring comprises 157 zones. The remaining 2,869 zones and external stations were grouped into 81 sectors. The following briefly outlines the two-phase preliminary test procedure being performed.

Phase I: The H-GRTS 90-90-3 trip table was collapsed from a 3063 zone trip table to a 275 zone trip table and a collapsed trip table assigned to the H-GRTS would 90-90-3 network. The Phase I subarea results then be compared to the 90-90-3 fully modeled assignment results. The analyses included a link-by-link comparison of the posted assignment results, comparison of subarea screenline and cutlines, comparison of the subarea vehicle miles and vehicle hours.

Phase II: Phase II would be initiated only if the results from Phase I continued to affirm the feasibility of a proposed FAST subarea assignment procedure. Phase II would investigate alternative trip distribution techniques for the modeling of the trip table. Based on the preliminary findings of Phase I, Phase II was performed.

The purpose of this report is to present the findings of both Phase I and Phase II of this study.

PHASE I

ASSIGNMENT EVALUATION

As specified in the study design (Phase I), the 1990 detailed 3,000 zone trip matrix was collapsed and a subarea assignment was performed using the FAST subarea assignment technique. To evaluate the FAST subarea assignment technique, the link volumes within the subarea were compared with those from the detailed 3,000 zone assignment results (i.e., the H-GRTS 90-90-3 assignment).

The portion of the H-GRTS network contained in the subarea selected is shown in Figure III-1. The node numbers, centroid numbers and centroid connectors were omitted for ease of review. Both the H-GRTS 90-90-3 assignment volumes and the subarea assignment volumes are posted on the network. As may be observed, the link volumes compare very favorably with the exception of those along the Southwest Freeway. The link volume differences observed along the Southwest Freeway were due to a sector structure problem which can be easily avoided in subsequent applications. A detailed discussion of this sector structure problem is presented in the chapter entitled "Sector and Ring Delineation."

Link Volume Differences

Inspection of Figure III-1 on a link-by-link basis indicates relatively small disparities between the existing assignment volumes and those obtained via the FAST subarea assignment technique. To illustrate the magnitude of the assignment differences, the subarea links were cross-classified by volume group (based on the 90-90-3 assignment) and the magnitude of the link volume differences observed between the two assignments (see Table III-1).

LEGEND

A - GESSNER
B - FONDREN-BLALOCK
C - MEMORIAL
D - RICHMOND
E - BELLAIRE BLVD

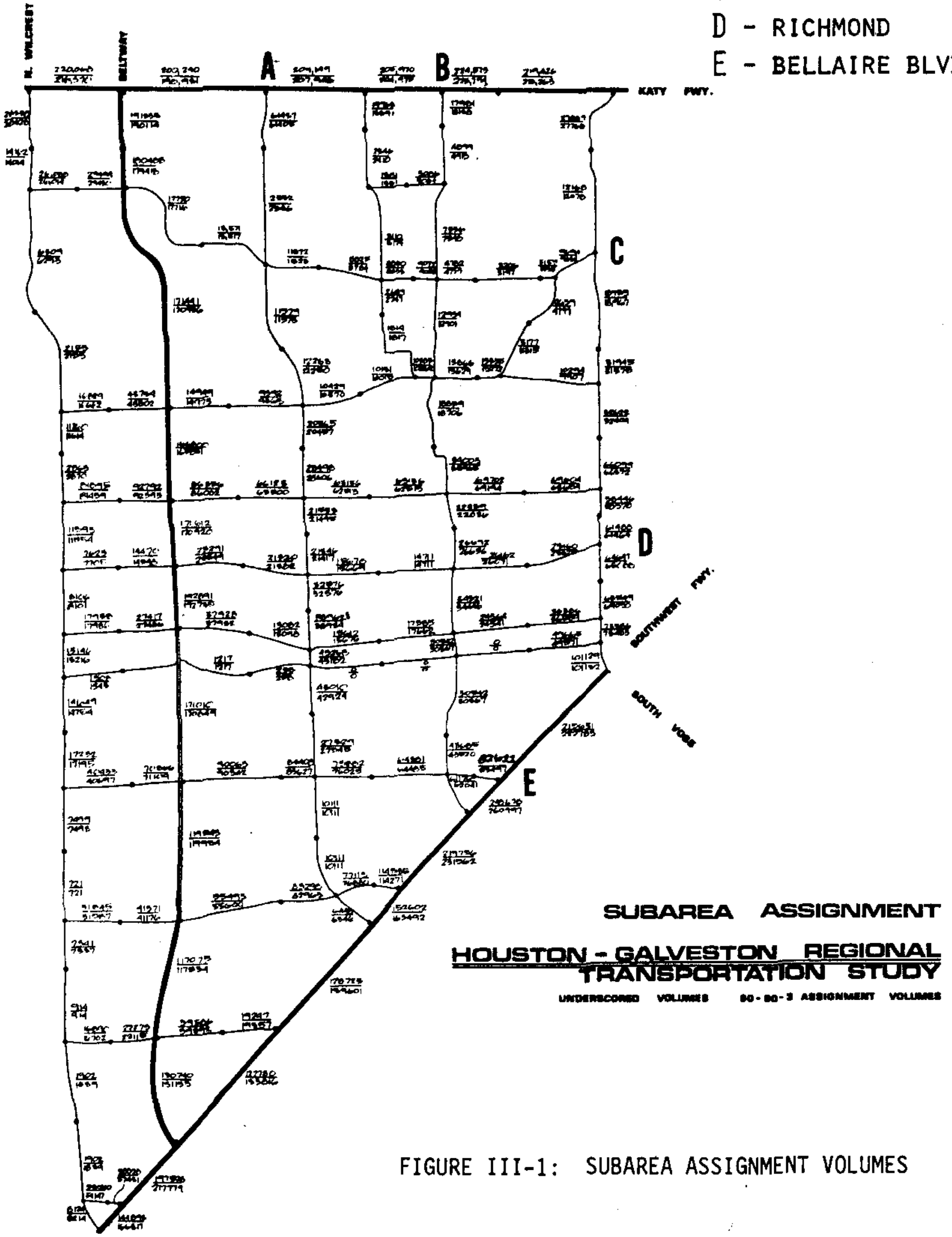


FIGURE III-1: SUBAREA ASSIGNMENT VOLUMES

TABLE III-1: DISTRIBUTION OF SUBAREA LINKS BY VOLUME GROUP AND THE MAGNITUDE OF THE VOLUME DIFFERENCE*

Volume Group (vpd)	ABSOLUTE VOLUME DIFFERENCE (vpd)					TOTALS
	0 to 250	251 to 500	501 to 1,00	1,001 to 1,500	3,001 to 3,500	
0 - 999	6					6
1,000 - 4,999	18					18
5,000 - 9,999	14					14
10,000 - 14,999	22	2				24
15,000 - 19,999	12					12
20,000 - 24,999	7	2				9
25,000 - 29,999	9					9
30,000 - 34,999	6	1	1			8
35,000 - 39,999	3	1				4
40,000 - 44,999	5	1	1			7
45,000 - 49,999	1					1
50,000 - 74,999	7	2	7	2		18
75,000 - 99,999	3	5	1			9
100,000 - 149,999	1	4				5
150,000 - 199,999	2		2	3		7
200,000 and above			1	4	1	6
TOTALS	116	18	13	9	1	157
PERCENT	73.9	11.5	8.3	5.7	0.6	100.0

* Excludes Southwest Freeway links.

As may be observed, 90 percent of the 157 links were within ±1,000 volume difference range and 99 percent were within the ±1,500 volume difference range. Only one link had a volume difference greater than 1,500 vpd. This link is located at the northwest corner of the subarea along the Katy Freeway and had a volume difference of -3,730 vpd representing a percent error of -1.7%. It is interesting to note for perspective, volume differences of 1,500 vpd or less suggest peak-hour differences of 150 vph or less (assuming a 0.10 peak-hour factor). In short, the magnitude of the link volume differences observed were not considered of sufficient magnitude to significantly affect any long-range planning decisions.

To illustrate the percent differences observed between the two assignments, the subarea links were also cross-classified by volume group and percent difference (see Table III-2). As may be observed, over 80% of the links had a percent difference of less than 2% and over 90% had a difference of less than 3%. It should be further noted that 25 of the 27 links with an assigned volume greater than 75,000 vpd (i.e., 92.6% of the higher volume links) had link volume differences of 1% or less and that all 27 links had differences of less than 2%. It is also interesting to note that none of the 157 links had volume differences exceeding 4% and that 5 links which had a 3 to 4 percent differences were very low volume links (i.e., less than 15,000 vpd). These data again illustrate that the assignment differences were hardly of sufficient magnitude to affect any long-range planning decisions relative to the subarea.

Major Routes

An evaluation of the major route differences provides an indication of the location and the realtive position of the individual link disparities

TABLE III-2: DISTRIBUTION OF SUBAREA LINKS BY VOLUME GROUP AND THE PERCENT VOLUME DIFFERENCE*

Volume Group (vpd)	ABSOLUTE PERCENT VOLUME DIFFERENCE				TOTALS
	0% to 1%	1% to 2%	2% to 3%	3% to 4%	
0 - 999	6				6
1,000 - 4,999	10		4	4	18
5,000 - 9,999	10	4			14
10,000 - 14,999	18	5		1	24
15,000 - 19,999	11	1			12
20,000 - 24,999	7	1	1		9
25,000 - 29,999	9				9
30,000 - 34,999	7	1			8
35,000 - 39,999	4				4
40,000 - 44,999	6	1			7
45,000 - 49,999	1				1
50,000 - 74,999	14	2	2		18
75,000 - 99,999	8	1			9
100,000 - 149,999	5				5
150,000 - 199,999	7				7
200,000 and above	5	1			6
TOTALS	128	17	7	5	157
PERCENT	81.5	10.8	4.5	3.2	100.0

* Excludes Southwest Freeway links.

with respect to the network, transition ring and sector structure. The summary of interior routes is provided in Table III-3 and a summary of peripheral routes bounding the subarea is provided in Table III-4. Appendix A provides a detailed breakdown of these routes.

The West Beltway constitutes the only high level facility completely enclosed by the subarea. The Southwest Freeway and Katy Freeway are along the periphery and serve as the north and south boundaries for the subarea.

The summary of six selected interior routes as outlined in Table III-3, indicates that the mean volume differences of all routes are well within ±1,000. Using a peak hour factor of 0.1, this suggests an average peak hour nondirectional difference of substantially less than 100 vehilces per hour. In addition, all average percent differences are within ±1% and the vehicle mile totals for each route show negligible differences between the two assignments (i.e., all are within ±1 percent).

The north two links of the West Beltway contain the largest volume difference of the six interior routes with values slightly over 1,000. These volume differences, however, represent percentage differences of approximately 0.6 percent. Again, using a peak hour factor of 0.1, these represent nondirectional peak hour volume differences of approximately 100 vehicles per hour.

The volume differences and percentage differences tend to decrease near the middle of the route. This trait is relatively consistent for all routes listed. Since the outermost links are proximal to the transition ring, a larger opportunity for error is present in these marginal links. This emphasizes and reinforces the need for and importance of a transition ring.

TABLE III-3: SUMMARY OF INTERIOR ROUTES

Route	Distance (Miles)	Number of Links	Average Volumes		Average Absolute Difference	Percent Absolute Differences	Vehicle Miles		Percent of Previous
			90-90-3	Subarea			90-90-3	Subarea	
Beltway 8	8.5	10	161,293	160,902	643	0.40	1,329,152	1,328,375	99.9%
Fondren-Blalock	5.8	13	25,129	24,990	166	0.66	133,382	132,647	99.4%
Gessner	6.9	16	24,486	24,466	44	0.18	138,472	138,373	99.9%
Richmond	4.2	8	18,302	18,048	131	0.71	78,168	78,645	100.6%
Bellaire Blvd.	3.8	8	71,104	71,478	374	0.52	275,353	276,450	100.4%
Memorial	4.8	12	12,366	12,343	46	0.37	64,005	63,890	99.8%

TABLE III-4: SUMMARY OF PERIPHERAL ROUTES

Route	Distance (Miles)	Number Of Links	Average Volumes		Average Absolute Difference	Percent Absolute Differences	Vehicle Miles		Percent of Previous
			90-90-3	Subarea			90-90-3	Subarea	
Southwest Freeway	6.25	8	178,824	192,106	13,281	7.40	1,085,870	1,159,619	106.8%
Katy Freeway	4.70	6	213,288	211,707	1,581	0.74	996,867	989,288	99.2%
N. Wilcrest	9.35	18	8,817	8,813	39	0.44	73,088	73,011	99.9%
S. Voss	4.72	12	51,443	51,463	202	0.39	193,747	193,775	100.0%

In contrast, Table III-4 summarizes the differences along the peripheral routes. In this instance, the Southwest Freeway shows a large difference relative to the interior routes and the other peripheral routes. The average of the percent difference for the interior routes is 0.47% while that of the peripheral routes is 2.2%. This is largely attributable to the average percent absolute difference (7.4%) of the Southwest Freeway segment. Except for the Southwest Freeway, all peripheral routes were within ±1%.

The primary source of the disparities observed along the Southwest Freeway, as will be discussed later, is due to a problem with the adjacent sector structure which can be easily avoided in future applications.

Corridor Intercepts

Five corridor intercepts were determined within the subarea; three intercepted the northbound/southbound thoroughfares and the remaining two intercepted eastbound-westbound thoroughfares. Figure III-2 shows the locations of the five corridor intercepts. A review of Table III-5 indicates the degree of "fit" between the two assignments relative to the five intercepts.

TABLE III-5: SUMMARY OF CORRIDOR INTERCEPTS

Corridor Intercept Number	Previous Assignment	Subarea Assignment	Percent of Previous Assignment
10	202,369	210,410	99.6
11	190,830	192,106	100.7
12	206,224	205,044	99.4
13	105,815	105,148	99.4
14	250,496	250,255	99.9

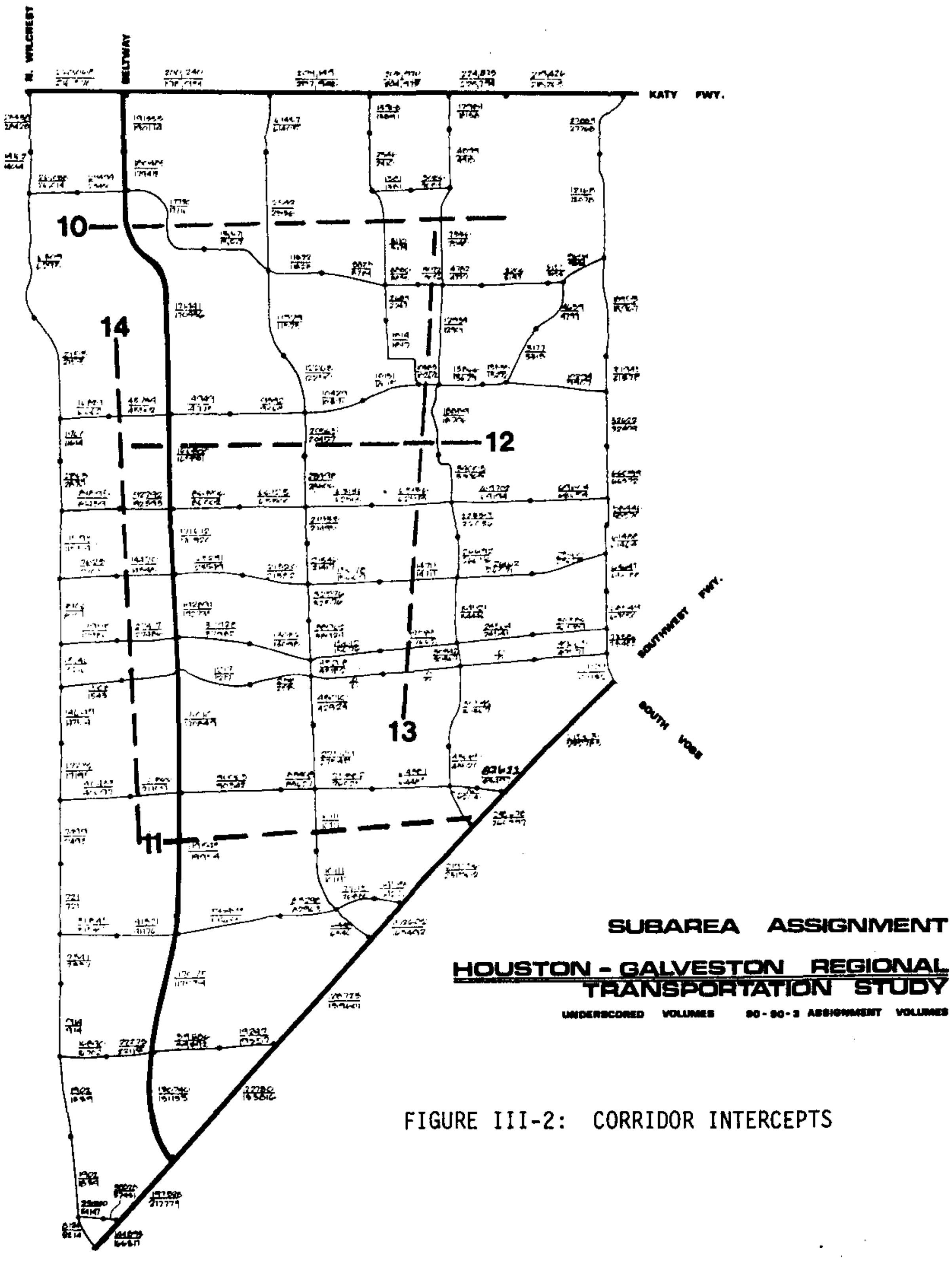


FIGURE III-2: CORRIDOR INTERCEPTS

The five corridor intercepts selected show an excellent comparison with the comparable 90-90-3 assignment volume totals. As may be seen, all intercepts were well within ±1%. Of particular interest is corridor intercept 11 situated near the Southwest Freeway. All four links along the intercept yielded excellent results. The impact of the sector problem which caused the Southwest Freeway disparities are not reflected in the interior of the subarea.

Corridor intercept 12, situated near the center of the subarea has an underestimation of -1,180, though this amounts to a 0.57% difference. Despite the evident tendency toward slight underestimation, the percent difference for all five corridor intercepts is well within ±1% and is thereby considered insignificant.

Subarea Screenlines

The two screenlines defined within the subarea network are shown in Figure III-3. The screenline volumes are outlined in Table III-6.

TABLE III-6: SCREENLINE SUMMARY

Screenline	Previous Assignment	Subarea Assignment	Percent of Previous Assignment
North/South	611,569	621,164	101.6
East/West	285,423	284,425	99.7
North/South (excluding Southwest Freeway)	488,789	487,348	99.7

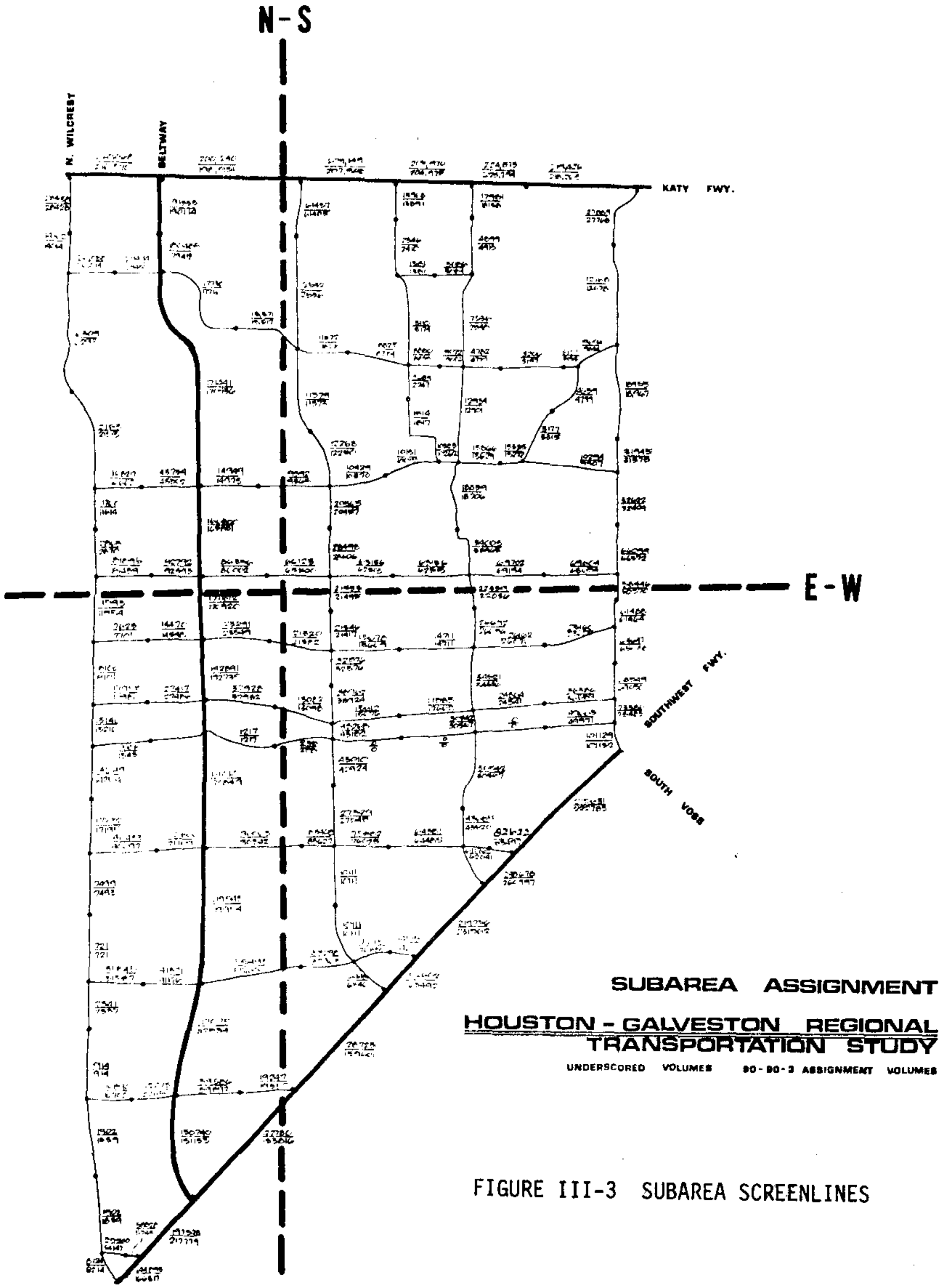


FIGURE III-3 SUBAREA SCREENLINES

An inspection of the detailed screenline data (Appendix C) yields the following observations:

1. The N-S screenline (11 links) has a volume difference of +9,595 which amounts to a percentage difference of 1.6%. This difference value is largely attributable to one link on the Southwest Freeway. With the Southwest Freeway link omitted, the volume difference would be reduced to -1,441 (or -0.29 percent) with an average absolute volume difference of 259 for the ten links.

2. The E-W screenline bisecting the subarea yielded a volume difference of -998 or -0.35%.

The screenline data again verifies the adequacy of the subarea assignment.

Vehicle Miles of Travel

The analysis of vehicle miles traveled within the subarea excluded the peripheral links. The peripheral routes as discussed earlier proved to have the greater source of percent difference.

The summary outlined in Table III-7 indicates a satisfactory comparison between the forecasted and subarea assignments. The greater relative difference appears to be located among the expressway/freeway links. Had the peripheral links been included, the impact of the volume difference characterizing the Southwest Freeway would have been reflected within the expressway/freeway links.

As an adjunct to the VMT analysis, an examination was made of vehicle hours traveled. Table III-8 summarizes the VHT for both assignments. Again, a satisfactory comparison is found between the respective assignments. The differences noted are reflective of the VMT analysis.

TABLE III-7: COMPARISON OF SUBAREA VEHICLE MILES OF TRAVEL*

	H-GRTS 90-90-3		SUBAREA ASSIGNMENT		ASSIGNMENT COMPARISONS	
	VMT	Percent of Total	VMT	Percent of Total	Difference	Percent of 90-90-3
TOTAL	5,117,705	100.0	5,178,512	100.0	+60,807	101.2
Functional Link Type:						
Expressway/ Freeway	3,413,890	66.7	3,477,283	67.1	+63,393	101.8
Principal Arterials	725,113	14.2	723,011	14.0	-2,102	99.7
Minor Arterials	898,098	17.5	897,548	17.3	-550	99.9
Collector Streets	80,607	1.6	80,670	1.6	+63	100.1

* Excludes intrazonal VMT

TABLE III-8: COMPARISON OF SUBAREA VEHICLE HOURS OF TRAVEL*

	H-GRTS 90-90-3		SUBAREA ASSIGNMENT		ASSIGNMENT COMPARISONS	
	VHT	Percent of Total	VHT	Percent of Total	Difference	Percent of 90-90-3
TOTAL	123,039	100.0	124,240	100.0	+1,201	100.2
Functional Link Type						
Expressway/ Freeway	67,957	55.2	69,231	55.7	+1,274	101.9
Principal Arterials	22,176	18.1	22,119	17.8	-57	99.7
Minor Arterials	29,948	14.3	29,930	24.1	-18	99.9
Collector Streets	2,957	2.4	2,961	2.4	+4	100.1

* Excludes intrazonal VMT

SECTOR AND RING DELINEATION

As noted in the assignment evaluation, the differences in the assigned volume on the Southwest Freeway were largely attributable to a sector structure problem. It is worthwhile, therefore, to briefly review some of the theoretical constructs which guide the delineation of the transition ring and sector structure. From this perspective, the sector structure problem, which caused the assigned volume differences on the Southwest Freeway, should become apparent. At the same time, it worthwhile to examine the assignments in the transition ring to determine the necessity of the ring.

Theoretical Constructs

The following reviews the procedures and rationale in the delineation of the subarea, transition ring, and sector structure for the FAST Subarea Focusing Assignment Technique.

Subarea

The first step in using the FAST Subarea Focusing Assignment Procedure is the delineation of the subarea of interest. This is easily accomplished by simply enumerating the zones contained in the subarea of interest. A zone-to-zone level of detail will, of course, be maintained within the subarea will remain the same as those that would have been obtained with the full assignment procedure. In essence, therefore, there can be no distortion of the assignment trips which both begin and end within the subarea of interest.

Transition Ring

The next step in using the FAST Subarea Focusing Assignment Procedure is the delineation of a transition ring which completely surrounds the subarea being studied. This again is accomplished by simply enumerating the zones contained within the transition ring. When using the FAST Subarea Focusing Assignment Procedure, it was initially recommended that the transition ring whould be at least five to seven miles in width. This loosely translates in terms of network minutes to approximately 10 to 14 network minutes in width. The width of the transition ring might vary depending on the type of facilities provided to traverse the transition ring. While it appears 2 to 4 mile transition ring would probably, in most instances, be adequate, a 5 to 7 mile transition ring should certainly be adequate and may be appropriate in many applications.

The transition ring basically acts as a buffer area surrounding the subarea to be studied. A zonal level of detail is maintained within the transition ring. This, of course, assures that there can be no distortion in the assignment of the following kinds of trips:

(a) trips with one trip end in the transition ring and the other trip end within the subarea

(b) trips with both trip ends within the transition ring but whose minimum path traverses some portion of the subarea

If a transition ring with minimum width of 10 minutes (i.e., approximately 5 miles) is used, this would imply that all trips of 10 minutes or less, assigned to the portion of the network within the subarea, would be completely free of distortion. If the average width of the subarea were, say, 10 minutes, this would suggest that a large portion of the 10 to 20 minute trips assigned to links in the subarea (i.e., the 10 to 20 minute trips with both trip ends either in the subarea or transition ring) would be free of distortion in the assignment process. The only trips in the 10 to 20 minute range assigned to links in the subarea portion of the network which might be subject to some distortion as to their minimum path would be those trips with a trip end outside of the subarea and transition ring. Therefore, under the conditions indicated, only a relatively small portion of the trips of 20 minute duration or less assigned to links within the subarea, are subject to any assignment distortion. A simple review of the trip length frequency distributions for the various urban areas in Texas would suggest that a majority of the urban trips are 10 minutes or less in duration and that a substantial majority of urban trips are of 20 minute duration or less. Although the trip length frequency of trips traversing one or more links within the subarea may differ from the trip length frequency for the urban area (depending on the location of the subarea and the urban form), it is still reasonably safe to assume that for most subareas the major portion of trips assigned to links within the subarea would be trips of 20 minute duration or less which are subject to limited or no distortion. It is also clear that freeway links are subject to somewhat greater distortion since they tend to attract a larger portion of the longer trips.

Sector Structure

The next step in using the FAST Subarea Focusing Assignment Procedure involves describing the remainder of the urban area (i.e., that portion of the urban area outside of the subarea and transition ring) in terms of a sector structure. It is suggested that the size of these sectors should vary with the distance from the subarea (i.e., zones near the subarea and transition ring would be grouped into smaller sectors than those zones at substantial distances which might be grouped into increasingly larger sectors). A computer program has been developed which partially automates the delineation of this sector structure.

Not only should the size of the sector vary with the distance from the subarea and transition ring, but the analysis of subarea assignment results for this application indicates that care must be exercised in the delineation of the sector and identification of the sector centroid relative to higher level facilities. For example, if a large sector is delineated such that it is bounded on the north, say, by the Southwest Freeway, and is bounded on the south, say, by the Bay City Freeway, then the location of the sector centroid can easily bias traffic originating in that sector toward one or the other of the two freeways. This can readily be avoided by simply subdividing the sector into two to four smaller sectors oriented toward the freeways. The manner in which this may be accomplished will become clear in the subsequent discussion of the Southwest Freeway assignment problem.

Since only trips with a trip end outside of the subarea and transition ring are subject to possible distortion due to the sector structure, the remainder of the discussion on the impact of the sector structure will be limited to the three types of trips which fall in this category.

1. Subarea External-local: internal trips (relative to the entire study area) which have an origin outside the subarea and transition ring but have a destination within the subarea or transition ring.

2. Subarea External-through: internal trips (relative to the entire study area) which have both origin and destination trip ends outside the subarea.

3. Study Area External Trips: trips with one or both trip ends at an external station of the entire study area.

First focusing on the "Subarea External-local" trips, what are the potential distortions to the sector structure for these trips? Subarea external-local trips associated with sectors near the transition ring (which are generally the smaller sectors) are subject to only limited distortion since their point of origin or destination outside the subarea has likely shifted only slightly. Indeed, the portion of the minimum path which traverses links within the subarea, in a large portion of the instances, may not have changed at all. Those whose minimum paths did change would have likely shifted only slightly. Subarea external local trips associated with sectors at greater distances from the transition ring may have their point of origin or destination shifted further since the sector size increases with the distance from the subarea. However, these trips represent a longer trip length and as the trip length increases, it is reasonable to expect that the number of trips involved would be generally decreasing. Trips associated with the more distant sectors are the longer trips which tend to gravitate toward the use of higher level facilities, thus, a shift of the external origin or destination of these trips may only impact the point at which these trips enter or leave a higher level facility outside of the subarea. Once a trip is on a higher level facility, its path within the subarea or transition ring will generally remain unchanged. In essence, with a carefully delineated sector structure, the subarea external local trips would generally be expected to be subject to minimal (if any) distortion relative to their assignment to links within the subarea.

The second type of trip to be discussed relative to potential distortions, are those internal trips with both a trip origin and trip destination outside of the subarea and transition ring (i.e., the "Subarea external-through trips). While these may account for a major portion of the urban travel, it is reasonable to expect that, in general, only a small portion of these trips would traverse the subarea. Indeed, with a 7 minute wide transition ring and a subarea with an average width of 10 minutes, the only trips of this nature that could traverse a portion of the subarea would be trips of 25 minute duration or greater. A brief review of trip length frequency distributions for urbanized areas in Texas would suggest that only a small portion of the urban trips have a trip duration of 30 minutes or more. Further, of those trips at these longer separations, only a portion would likely traverse a subarea being studied. Also, with the longer trips, they are again generally oriented to the higher level facilities so that the distortion may generally be their points of access and egress on the higher level facility which would generally lie outside of the subarea. Again, with a carefully defined sector structure, these trips would generally be subject to only limited distortion relative to their assignment to links within the subarea being studied.

The remaining type of trip to be discussed relative to potential distortions are the study area external trips. In applying the FAST methodology, each study area external station was treated as a separate sector. Hence, there will be no distortion of the paths for the study area external-through trips. The paths for external-local trips traversing the subarea and transition ring are subject to some possible distortion. Again, since these are generally longer trips oriented to higher level facilities, it is likely that the possible path distortions will be minimal in their impact on subarea assignment results.

At this point, it should be obvious as the reasons for the use of smaller sector sizes near the transition ring with the sector sizes gradually increasing with distance from the transition ring. In dealing with the larger sectors at greater distances, we are obviously only concerned with the longer trips as far as their impact on the links within the subarea. Since these longer trips are generally oriented toward the higher level facilities, it is important to delineate our sectors and sector centroids so that these trips would be biased toward the proper higher level facility.

Southwest Freeway Problem

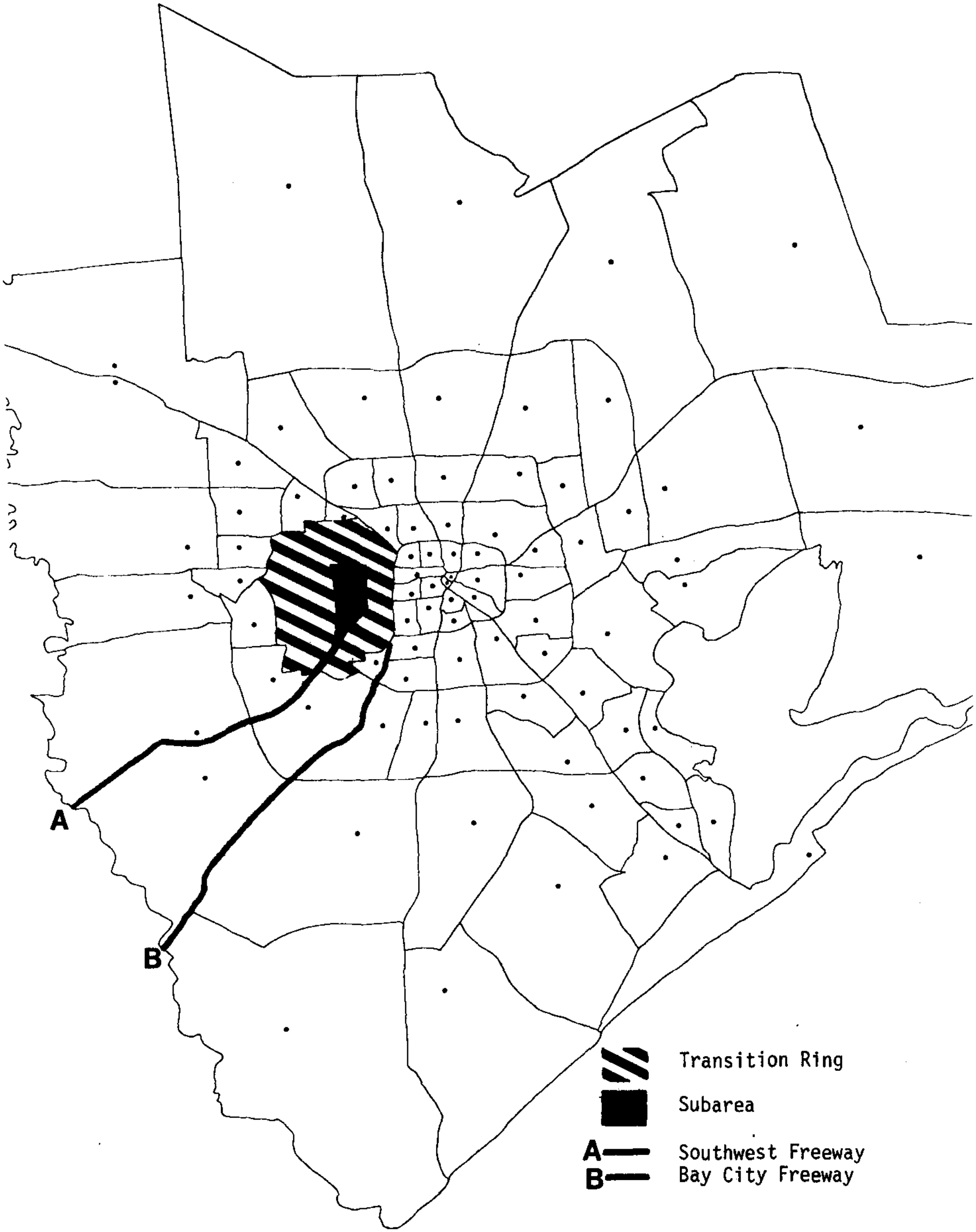
The subarea, transition ring, and sector structure used in the subarea assignment is shown graphically in Figure IV-1. The black dots within each sector represent the sector centroids. Both the Southwest Freeway and Bay City Freeway* are also shown in Figure IV-1.

The overassignment of Southwest Freeway links bounding the south edge of the subarea are largely due to the two sectors south and southeast of the subarea and transition ring, which are bounded on the north by the Southwest Freeway and on the south by the Bay City Freeway. Note that in both instances, the sector centroids are obviously oriented toward the Southwest Freeway, rather than the Bay City Freeway. As a result, all trips originating in these two sectors, which were destined either to zones in the subarea or transition ring or to zones contained in sectors north or northeast of the transition ring were generally assigned to the Southwest Freeway. In actuality, a large portion of these trips would likely have used the Bay City Freeway, largely as a result of the delineation of these two sectors and their designated sector centroids.

From an inspection of the sector structure south and southwest of the transition ring, it is obvious that the sector size did not gradually increase with distance from the transition ring. The second problem, as previously noted, is that the two sectors bounded on either side by the Southwest Freeway and the Bay City Freeway are obviously biased toward the Southwest Freeway. At the same time, one might argue that much of the sector structure delineation east of the transition ring is unnecessarily detailed. While this unnecessary detail does not have any adverse effect on the assignment results, it may unnecessarily increase the run times.

* A proposed facility subsequently deleted.

FIGURE IV-1



A
B
Transition Ring
Subarea
A Southwest Freeway
B Bay City Freeway

Transition Ring Analysis

The transition ring is obviously an expensive element in the FAST Subarea Focusing Assignment Procedure. The question must be raised as to its benefits. To address this issue, the assignment results in the transition ring must be examined. To facilitate this analysis, the transition ring was subdivided into two smaller rings: an inner ring containing 300 links and an outer ring containing 356 links.

The purpose of this analysis is to demonstrate the increasing degree of error in assignment volumes as the distance from the subarea increases. The transition ring acts as a buffer area and is considered necessary to the subarea assignment technique.

The transition ring should conceptually reflect the tendence toward greater error near the periphery. The distribution of percent differences and of the absolute volume differences was determined for both rings. Tables IV-1 through IV-4 summarizes the link differences observed in the inner and outer rings of the transition ring. Table IV-1 indicates that 52 percent of the inner ring links are found within the percent difference range of 0-2 percent compared to 27 percent for the outer ring over the same range. The inner ring contains 21 percent of the 300 links over a percent difference of 5 percent in contrast to 49 percent of the 356 outer links.

The summary of absolute volume differences by volume group for both inner and outer rings also supports the increasing degree of error with distance from the subarea. For example, in the inner ring 51 percent of the 300 links were within ±250, while in the outer ring only 31 percent of the links were within ±250.

TABLE IV-1: DISTRIBUTION OF INNER TRANSITION RING LINKS BY VOLUME GROUP AND PERCENT DIFFERENCES IN ASSIGNMENT VOLUMES

Volume Group	PERCENT VOLUME DIFFERENCE							TOTALS
	0 to 0.5%	0.5% to 1%	1% to 2%	2% to 3%	3% to 4%	4% to 5%	5% and above	
0	2							2
1 - 999				1	1	2	3	7
1,000 - 4,999	7	10	7	1	6	2	18	51
5,000 - 9,999	9	4	4	7	3	5	10	42
10,000 - 14,999	14	7	3	4	4	2	10	44
15,000 - 19,999	9	7	4	2	3	1	5	31
20,000 - 24,999	4	6	4	4		2	4	24
25,000 - 29,999	4	5	6	8			5	28
30,000 - 34,999	2	3	4	2			4	15
35,000 - 39,999	5	3	2	1	1	6	2	20
40,000 - 44,999	1		1	1		1		4
45,000 - 49,999	2		1				1	4
50,000 - 74,999	2	6		4				12
75,000 - 99,999	2	2						4
100,000 - 149,999	1		1	4				6
150,000 - 199,999				1			2	3
200,000 - plus	1		1	1				3
TOTALS	65	53	38	41	18	21	64	300
PERCENT	21.7	17.7	12.7	13.6	6.0	7.0	21.3	100.0

TABLE IV-2: DISTRIBUTION OF INNER TRANSITION RING LINKS BY VOLUME GROUP AND THE ABSOLUTE VOLUME DIFFERENCES

Volume Group	ABSOLUTE VOLUME DIFFERENCE RANGES (vpd)									TOTALS
	0 to 250	251 to 500	501 to 1000	1001 to 1500	1501 to 2000	2001 to 2500	2501 to 3000	3001 to 3500	>3500	
0	2									2
1 - 999	7									7
1,000 - 4,999	44	2	5							51
5,000 - 9,999	23	9	7	1			2			42
10,000 - 14,999	28	3	10			1			2	44
15,000 - 19,999	20	3	5						3	31
20,000 - 24,999	10	5	5	1	3					24
25,000 - 29,999	7	7	10	1				2	1	28
30,000 - 34,999	4	1	6		2	2				15
35,000 - 39,999	5	5	1		8				1	20
40,000 - 44,999	1		1	1	1					4
45,000 - 49,999	2		1						1	4
50,000 - 74,999		4	4	3	1					12
75,000 - 99,999		2	2							4
100,000 - 149,999		1				1	1	1	2	6
150,000 - 199,999				1		1			1	3
200,000 - plus			1						2	3
TOTALS	153	42	58	8	15	5	3	3	13	300
PERCENT	51.0	14.0	19.3	2.7	5.0	1.7	1.0	1.0	4.3	100.0

TABLE IV-3: DISTRIBUTION OF OUTER TRANSITION RING LINKS BY VOLUME GROUP AND PERCENT DIFFERENCES IN ASSIGNMENT VOLUMES

	PERCENT VOLUME DIFFERENCE							
Volume Group	0 to 0.5%	0.5% to 1%	1% to 2%	2% to 3%	3% to 4%	4% to 5%	5% and above	TOTALS
0	3							3
1 - 999	2		2	1	2		9	16
1,000 4,999	3	6	8	6	4	2	34	63
5,000 - 9,999	7	6	9	5	8	1	28	64
10,000 - 14,999	2		7	5	2	3	24	43
15,000 - 19,999	4	3	4	4	1	3	24	43
20,000 - 24,999	1	2	6	2	3	3	11	28
15,000 - 29,999	1	2	1			2	4	10
30,000 - 34,999					2	3	15	20
35,000 - 39,999	1	3		1			6	11
40,000 - 44,999	1	2	3	1	1		4	12
45,000 - 49,999							1	1
50,000 - 74,999						3	4	7
75,000 - 99,999						2		2
100,000 - 149,999	3	1	1	1	3		5	14
150,000 - 199,999				1	1		4	6
200,000 - plus	1	1	3	2	1	2	3	13
TOTALS	29	26	44	29	28	24	176	356
PERCENT	8.1	7.3	12.4	8.1	7.9	6.8	49.4	100.0

TABLE IV-4: DISTRIBUTION OF OUTER TRANSITION RING LINKS BY VOLUME GROUP AND THE ABSOLUTE VOLUME DIFFERENCES

Volume Group	ABSOLUTE VOLUME DIFFERENCE RANGES (vpd)									
	0 to 250	251 to 500	501 to 1000	1001 to 1500	1501 to 2000	2001 to 2500	2501 to 3000	3001 to 3500	>3500	TOTALS
0	3									3
1 - 999	13	2				1				16
1,000 - 4,999	31	13	12	2	5					63
5,000 - 9,999	34	6	9	4	4		4	2	1	64
10,000 - 14,999	9	6	10	3	2	3	1	5	4	43
15,000 - 19,999	11	4	6	2		1	2	9	8	43
20,000 - 24,999	3	6	6	5	1				7	28
25,000 - 29,999	2	1	1	3	1		1		1	10
30,000 - 34,999				3	5	2			10	20
35,000 - 39,999	1	3	1				2		4	11
40,000 - 44,999	2	2	3	1		3			1	12
45,000 - 49,999									1	1
50,000 - 74,999						1	2	1	3	7
75,000 - 99,999									2	2
100,000 - 149,999	1	2	1		1			1	8	14
150,000 - 199,999									6	6
200,000 - plus			1				1		11	13
TOTALS	110	45	50	23	19	11	13	18	67	356
PERCENT	30.9	12.6	14.0	6.5	5.3	3.1	3.7	5.1	18.8	100.0

This analysis is felt to substantiate the hypothesis of increasing error with distance from the subarea within the transition ring. Comparison of these with Tables III-1 and III-2 substantiate the need for the transition ring in the FAST Subarea Focusing Assignment Procedure.

PHASE I
CONCLUSIONS

With the exception of the subarea links along the Southwest Freeway, it was felt that the FAST Subarea Focusing Assignment Procedure yielded excellent results. It further appears that the problems observed relative to the Southwest Freeway can be easily avoided by a more careful delineation of the sector structure. In short, the results of the Phase I tests were felt to demonstrate the applicability of trip distribution modeling at this level of detail and its impact on subarea assignment results.

PHASE II
TRIP DISTRIBUTION EVALUATION

Since the Phase I study results demonstrated the feasibility of the FAST subarea focusing procedure, Phase II of the study was initiated. The basic objectives of Phase II were to delineate a trip distribution methodology for use in subarea focusing applications and to evaluate the feasibility of applying the proposed trip distribution methodology.

From a preliminary review of the problems associated with trip distribution modeling for subarea focusing applications, it was clear that the Atomistic Model (i.e., a spatially disaggregate trip distribution modeling technique being developed for sketch planning applications) was clearly the most promising for subarea focusing applications. From a trip distribution perspective, the use of sectors (i.e., effectively very large sketch planning type zones) to represent the portions of the urban area outside of the subarea and transition ring creates essentially the same problems as sketch planning zone structures.

Dimensioning the Problem

The basic objective in the development of the Atomistic Model (described in Report 0194-4) was to implement a trip distribution modeling technique which considers the travel opportunities in a zone to be spatially distributed (rather than the traditional centroid concept) thereby providing travel pattern estimates more consistent with basic travel theory when dealing with very large zones. From a practioner's perspective, the basic objectives of the Atomistic Model might be stated as follows:

1. to reduce the differences which will result from the use of a common trip length frequency objective when modeling at two significantly different levels of zonal detail (i.e., traditional zone sizes versus very large zones); and
2. to provide reasonable estimates of intrazonal trips without requiring the development of independent estimates of intrazonal travel.

Trip Length Frequency Problem

Previous research (Report 0194-3) has demonstrated that the trip length distribution of zonal interchange volumes changes as the level of zonal aggregation increases. At two significantly different levels of zonal detail (e.g., traditional size zones versus the very large zones such as the sectors in subarea focusing applications), the differences in the trip length frequency distributions are of sufficient magnitude to generally warrant the use of different trip length frequency distributions for the calibration of trip distribution models at the two levels of detail.

Where traditional large sample origin-destination data are available, the data may be reprocessed for the large zone structure to obtain these estimates. However, this reprocessing is costly and time-consuming; this conflicts with the low cost and quick response objectives of subarea focusing methodology.

To further complicate the problem, many urban transportation studies are using, or are considering the use of, very small sample origin-destination data (i.e., about 400 to 600 home interviews). Previous research has shown that these small sample sizes provide a reliable estimate of the mean trip length but provide a much less reliable estimate of the frequency distribution. However, given a good estimate of the mean trip length, a model may be utilized to estimate the frequency distribution for the traditional detailed zone structures. Since this model was calibrated using origin-destination data from Texas cities for traditional detailed zone structures, it would provide little guidance as to the shape of the frequency distribution.

Further, most urban transportation studies in Texas have completely abandoned the traditional origin-destination home interview survey and adopted a synthetic study approach. Such synthetic studies rely heavily on observed data from other similar areas. In areas using a synthetic study approach, there is obviously no survey data base to reprocess to estimate the trip length frequency distribution for the subarea focusing zone structure.

An alternative approach, for estimating the trip length frequency distribution for a subarea focusing application in an urban area utilizing either a small sample origin-destination survey or the synthetic approach, is to treat the existing detail modeled results at the traditional level of detail as "observed" data. The detailed trip tables may then be collapsed and the resulting trip length frequency distribution computed. Again, such processing would be costly and time consuming, thereby conflicting with the low cost and quick response objectives.

As a practical matter, it would be obviously highly desirable to utilize the same estimated trip length frequency distributions at both levels of zonal detail. By considering the travel opportunities within a zone to be spatially distributed (rather than the conventional centroid concept), it is reasonable to expect that the Atomistic Model will reduce the differences which might result from the use of a common trip length frequency objective when modeling at two significantly different levels of zonal detail using a conventional model (i.e., the Texas trip distribution model).

Intrazonal Problem

The estimation of intrazonal trips at multiple levels of zonal detail is another significant problem for subarea focusing applications. The use of conventional trip distribution models at traditional levels of zonal detail have required the transportation analyst to estimate the portion of trips expected to be intrazonal and, subsequently, controlling these trips in the trip distribution process. Again, to obtain a reasonable estimate of intrazonal travel for a subarea focusing zone structure would require either reprocessing origin-destination survey data (if available) or the collapsing of trip tables developed at the detailed level. Both approaches are costly and time consuming.

As a practical matter for subarea focusing applications, it would be obviously desirable to relax the control of intrazonal trips. By considering the travel opportunities within a zone to be spatially distributed (rather than the traditional centroid concept), it is reasonable to expect that, without requiring analyst intervention in the control of intrazonal trips, the Atomistic Model will provide a substantially better estimate of intrazonal travel than the conventional model (i.e., the Texas model).

Evaluation Approach

The trip distribution evaluation concentrated on the differences which would result from trip distribution modeling at the traditional level of zonal detail versus a subarea focusing zone structure (i.e., using sectors outside the subarea and transition ring). The same data base was used for the Phase II analysis as was used for the Phase I Assignment Analysis.

In order to simplify the analyses and minimize the study costs, the trip distributions were performed for a single trip purpose: total internal travel (i.e., home-based work + home-based nonwork + nonhome-based + truck & taxi). The conventional Texas Model was applied at the 3014 zone level and the resulting trip table was collapsed to the subarea level for assignment using the FAST subarea focusing procedure. The Atomistic Model was applied at the 317 zone level or subarea level (i.e., 229 zones in the subarea and transition ring and 88 sectors, or large zones, representing the remaining 2785 traditional zones) and the results assigned using the FAST subarea focusing procedure. The subsequent evaluations concentrated both on trip table differences and assignment differences resulting from trip distribution modeling at two significantly different levels of zone detail.

Trip Table Comparisons

Preliminary evaluation of the results found that some data problems existed in the definition of the centroid-areas for the disaggregate model. Most of these problems were associated with the 229 detailed zones which were judged not to have a significant effect on the results. The tendency to somewhat overstate the r-values for the zones within the subarea and transition ring (in appling the Atomistic Model) resulted in a slight overestimate of intra-subarea travel.

There were, however, problems observed in the delineation of the centroid-areas for some of the large zones (or sectors). A number of the large zones essentially contained a small city surrounded by a substantial amount of agricultural land. From a spatial model perspective, zones of this type do not pose a major problem since the small city would generally account for a major portion of the zone's trip ends. The assumption of a uniform distribution of trip ends within the centroid area suggests that, in these instances, the centroid area should be defined in terms of the small city rather than the zone's geographic boundaries. Unfortunately, the definition of the centroid-areas for the large zones in the Houston-Galveston application tended to focus on the geographic boundaries of the zones rather than the distribution of trip ends within the zone. In spite of these data problems (which were judged relatively minor), it was felt that the results were indicative of the Atomistic Model's capability in dealing with very large zones.

Intrazonal Estimates

The 3014 zone trip table results aggregated to the 317 zone level (i.e., the "collapsed" 317 zone trip table) provides the best available estimate of the desired intrazonal trips at the 317 zone level. The "collapsed" 317 zone trip table indicated that approximately 25.6 percent of the trips were intrazonal. The application of the disaggregate model at the 317 zone level yielded an intrazonal travel estimate of 26.4 percent of the trips. It was felt that these results tend to confirm the Atomistic Model's capability to provide a reasonable estimate of intrazonal trips.

Trip Length Frequency Results

Nonzero zonal interchange volumes were observed for spatial separations up to 120 network minutes. However, over 99 percent of the trips are accounted for by zone pairs having a spatial separation of 50 network minutes or less. The trip length frequency results presented, therefore, focus only on the zone pairs with a spatial separation of 50 network minutes or less. Figure VI-1 summarizes the trip length frequency results for the 3014 zone trip table and the "collapsed" 317 zone trip table. Since both trip length frequencies in Figure VI-1 represent the same travel data at two levels of zonal detail, their comparison provides additional insight into the potential

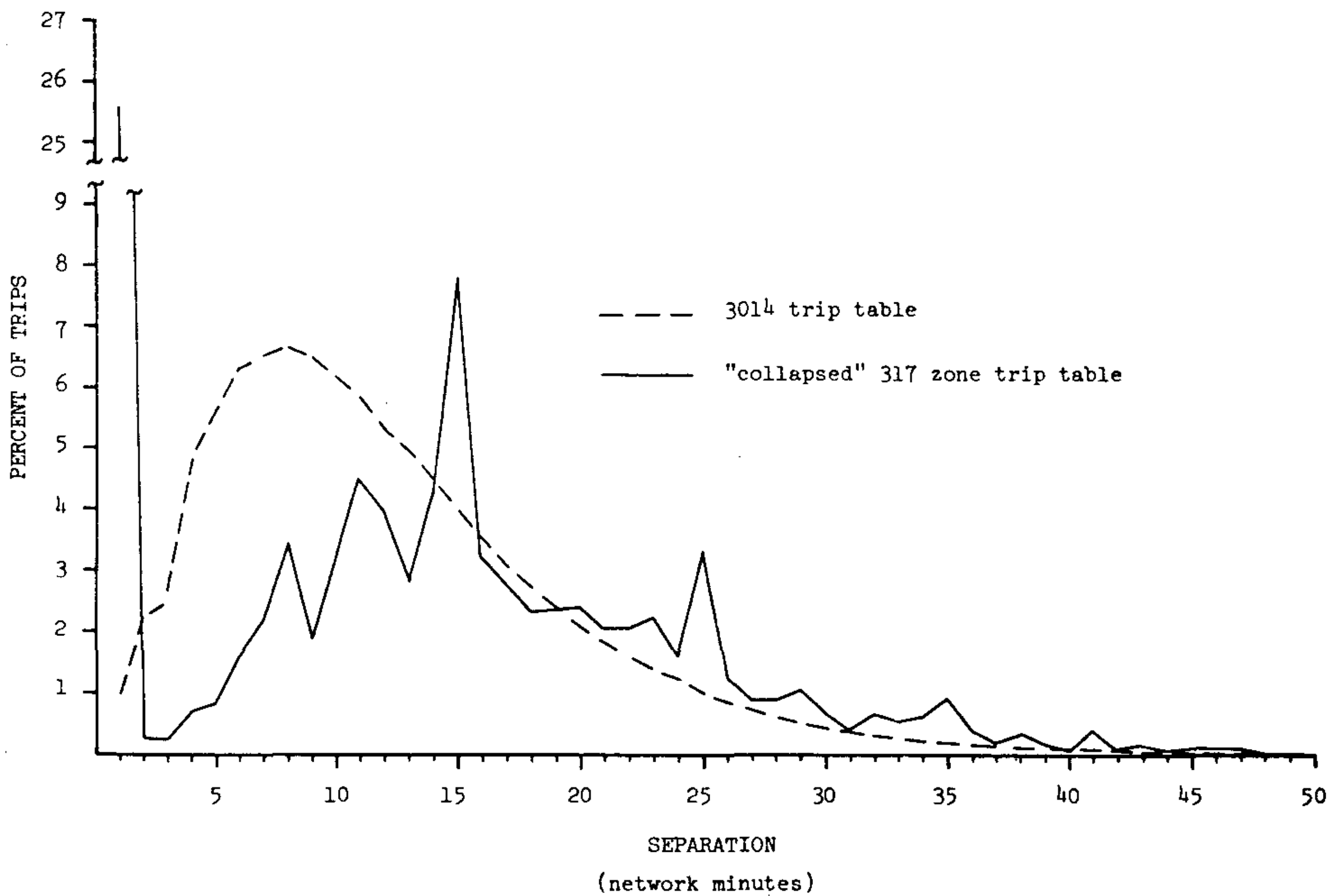


Figure VI-1: Trip length frequency for the Houston-Galveston 3014 zone trip table and the "collapsed" 317 zone trip table.

effects of zone size on the trip length frequency distribution of zonal interchange volumes. These data tend to confirm an earlier assertion that the use of very large zones would result in significant changes in the trip length frequency. The differences observed in the trip length frequency results shown in Figure IV-1 clearly suggest that the use of the conventional Texas model at the two levels of detail would require separate estimates of the desired trip length frequency at each level of detail.

The comparison of trip length frequency results from the application of the disaggregate model at two levels of detail is probably the more critical comparison. This comparison provides an indication of the basic capability of the Atomistic Model to reasonably account for changes in the trip length frequency distribution (due to the use of substantially larger zones) while continuing to use the trip length frequency estimates developed for detailed zone structures.

Figure IV-2 summarizes the disaggregate model trip length frequency results for the 317 zone "collapsed" trip table and the 317 zone modeled trip table. To fully appreciate the effectiveness of the Atomistic Model in accounting for changes in trip length frequency due to the use of larger zones, it must be emphasized that the trip length frequency input to the disaggregate model in the development of the 317 zone "modeled" trip table was essentially that shown in Figure VI-1 for the 3014 zone trip table and not the estimate from the "collapsed" 317 zone trip table with which it is compared.

In view of the zone sizes used, the differences in the trip length frequency results shown in Figure VI-2 were judged relatively modest. It was felt that these results tend to confirm the Atomistic Model's basic capability to reasonably account for changes in trip length frequency due

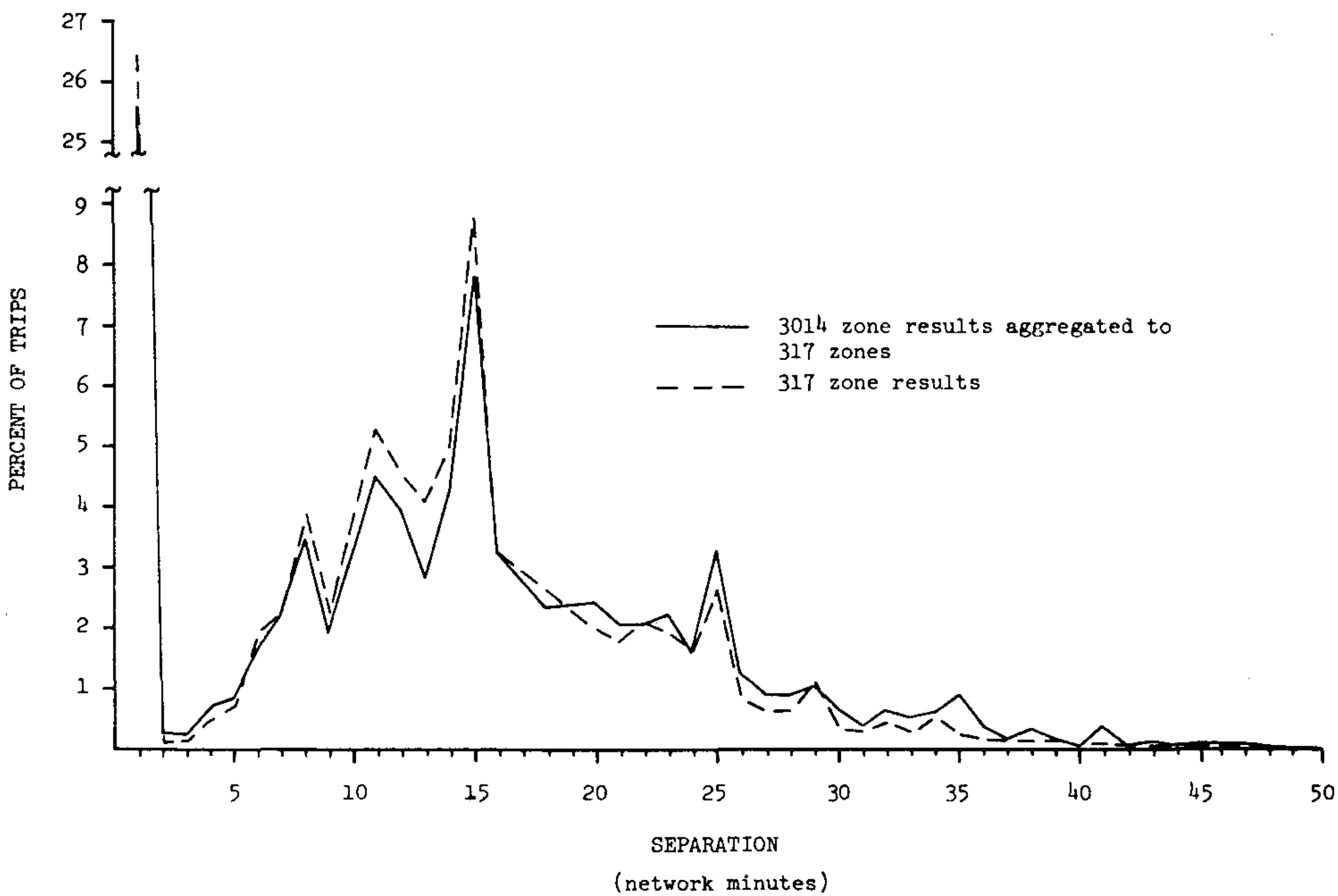


Figure VI-2: Comparison of the Houston-Galveston trip length frequency distributions at the 317 zone level resulting from the application of the disaggregate model at two levels of detail.

to the use of very large zones in subarea focusing applications while continuing to utilize the trip length frequency estimates for the traditional detailed zone structure as input to the modeling process.

Assignment Comparisons

The assignment comparisons also focused on the magnitude of the differences which resulted from trip distribution modeling at the two levels of zonal detail. It should be noted that the magnitude of the assignment differences observed would likely be significantly reduced with better delineation of the r-values for the centroid area model and with the use of multiple trip purposes rather than a single trip purpose. In spite of these problems, the differences observed in the assignment results were felt to be well within acceptable tolerances.

Subarea Screenlines and Corridor Intercepts

The Phase II analyses utilized the same subarea screenlines and corridor intercepts used in the Phase I analyses (see Figures III-2 and III-3). Table VI-1 summarizes the corridor intercept results. As may be observed, the corridor intercept volumes showed increases of from 2 to 7 percent with the use of the Atomistic Model at the subarea level. It was felt that the observed differences would be reduced with better delineation of the r-values for Atomistic's centroid area model.

The East-West Screenline (illustrated in Figure III-3) showed a 5 percent increase with the use of the Atomistic Model at the subarea level of detail and the North-South Screenline showed only a 2 percent increase. As with the corridor intercepts, the observed differences relative to the screenlines would likely be reduced with better delineation of r-values.

TABLE VI-1: COMPARISON OF SUBAREA CORRIDOR INTERCEPTS

Corridor Intercept Number*	Percent Change in Subarea Assignment Results Using the Atomistic Model at Subarea Level
10	+2%
11	+5%
12	+4%
13	+7%
14	+5%

*See Figure III-1

TABLE VI-2: COMPARISON OF SUBAREA VMT BY SELECTED ROUTES

Route	Percent Change in Subarea Assignment Results Using the Atomistic Model at Subarea Level
Beltway 8	+2%
Bellaire Blvd.	+5%
Memorial	+7%
Fondren-Blalock	+11%
Richmond	+5%
Gessner	+5%

Nevertheless, the observed differences for both screenlines and corridor intercepts were felt to be within the tolerances for a subarea focusing methodology.

Routes

Table VI-2 compares the vehicle miles of travel by specific routes within the subarea. In reviewing these results, it is important to note that the Beltway 8 (i.e., West Belt) is by far the highest volume facility traversing the subarea. Indeed, the subarea was delineated to study alternatives for Beltway 9. As can be seen from Table VI-2, Beltway 8 showed only a 2 percent increase while the lower volume facilities showed increases of from 5 to 11 percent. Again the differences were felt within reasonable tolerances and could likely be reduced with better r-values for the centroid area model.

Implementation

An interim implementation approach for subarea trip distribution was recommended which realizes some of the potential computational efficiencies, yet required no modification of existing computer programs. Under this approach, the sector trip productions and attractions would simply be aggregated to the sector centroid. Zones not serving as sector centroids would, therefore, have zero productions and attractions. In the Houston-Galveston example, this would mean that 2697 of the 2785 zones outside the subarea and transition ring would have zero productions and attractions. Unfortunately, this interim approach requires a full separation matrix and outputs a full trip table which must be collapsed.

As the usage of the subarea focusing capability increases, it will likely become worthwhile to develop a more computationally efficient version of the Atomistic Model specifically adapted to subarea focusing applications. Such a program would have the following attributes:

- it would accept a skim tree matrix built only for subarea zones, transition ring zones, and sector centroids; and
- it would output a collapsed trip table (i.e., eliminating the rows associated with zones outside the transition ring which do not serve as sector centroids).

A special version of the SWITCH routine will also be required in order to convert the resulting trip table from a production-attraction matrix to an origin-destination matrix. Other minor modifications will likely be required in the EDIT, ACCEPT, GET, and PACK routines. Due to the extensiveness of the proposed modifications, it is not recommended that they be initiated until usage warrants.

PHASE II

CONCLUSIONS

The trip distribution evaluations were felt to demonstrate the feasibility of using the Atomistic Model in subarea focusing applications. The two principal advantages realized in using the Atomistic Model are:

1) it allows the use of the same desired trip length frequency distribution when modeling at varying levels of zonal detail, and

2) it does not require the analyst to estimate the desired intrazonal trips and to subsequently control them in the trip distribution modeling process.

By considering the activities within a zone to be spatially distributed (rather than concentrated at a single theoretical point, i.e., the zone centroid), the Atomistic Model can be expected to yield travel pattern estimates more consistent with basic travel theory than the Texas Model when dealing with very large zones such as the sectors used in subarea focusing applications.

The problems observed in the delineation of the r-values for the centroid area models used by the Atomistic Model were felt to be the source of some of the differences observed in the Phase II analyses. It should be made clear that this was one of the very early applications of the Atomistic Model. As more experience is gained in the use of the Atomistic Model, it is reasonable to expect that such problems will be less likely to occur. In spite of this problem, the differences observed were felt to be within reasonable tolerances for a subarea focusing methodology.

In short, the results of the Phase I and II evaluations were felt to demonstrate the feasibility of the proposed FAST Subarea Focusing Technique.

Appendix A

Subarea Routes - Interior and Peripheral

INTERIOR ROUTE - BELTWAY 8

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
3619 - 3616	.45	191,333	190,114	-1219	86,100	85,551
3616 - 4420	.35	180,485	179,418	-1067	63,170	62,796
4420 - 4421	1.90	171,441	170,436	-1005	325,738	323,828
4421 - 4422	.65	166,800	165,881	-919	108,420	107,823
4422 - 4423	.50	171,612	170,970	-642	85,806	85,485
4423 - 4426	.50	192,891	192,735	-156	96,445	96,367
4426 - 4495	1.20	171,010	170,849	-161	205,212	205,019
4495 - 4494	1.05	119,543	119,954	+411	125,520	125,952
4494 - 4491	1.00	117,075	117,534	+459	117,075	117,534
4491 - 5013	.90	130,740	131,133	+393	117,666	118,020
	8.5				1,329,152	1,328,375

INTERIOR ROUTE - MEMORIAL

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
4438 - 4437	.35	26,088	26,014	-74	9,131	9,105
4437 - 4420	.40	29,494	29,430	-64	11,798	11,772
4420 - 4419	.85	17,750	17,716	-34	15,087	15,059
4419 - 4418	.60	13,571	13,517	-54	8,143	8,110
4418 - 4417	.35	11,872	11,828	-44	4,155	4,140
4417 - 4393	.50	8,825	8,784	-41	4,412	4,392
4393 - 4395	.20	8,880	8,833	-47	1,776	1,767
4395 - 4396	.20	9,072	9,052	-20	1,814	1,810
4396 - 4388	.30	4,782	4,777	-5	1,435	1,433
4388 - 4389	.50	3,206	3,197	-9	1,603	1,598
4389 - 4384	.15	5,155	5,135	-20	773	770
4384 - 4383	.40	9,694	9,834	+140	3,878	3,934
	4.8				64,005	63,890

INTERIOR ROUTE - FONDREN-BLALOCK

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
3652 - 3651	.30	17,981	18,138	+157	5,394	5,441
3651 - 4390	.45	4,899	4,913	+14	2,204	2,211
4390 - 4396	.75	7,536	7,548	+12	5,652	5,661
4396 - 4397	.77	12,934	12,901	+33	9,959	9,934
4397 - 4400	.55	18,859	18,706	-153	10,372	10,288
4400 - 4401	.35	34,003	33,965	-38	11,901	11,888
4401 - 4404	.30	22,239	22,036	-203	6,672	6,611
4404 - 4405	.30	26,692	26,656	-36	8,008	7,997
4405 - 4406	.50	34,521	34,446	-75	17,260	17,223
4406 - 4970	.25	30,542	30,367	-175	7,635	7,592
4970 - 4516	.60	30,542	30,367	-175	18,325	18,220
4516 - 4518	.30	43,685	43,520	-165	13,105	13,056
4518 - 4519	.40	42,238	41,312	-926	16,895	16,525
	5.82				133,382	132,647

INTERIOR ROUTE - GESSNER

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
3618 - 3617	.40	61,437	61,405	-32	24,575	24,562
3617 - 4418	1.00	2,532	2,536	+4	2,532	2,536
4418 - 4416	.80	11,579	11,573	-6	9,263	9,258
5516 - 4414	.50	12,268	12,250	-18	6,134	6,125
4414 - 4413	.35	20,565	20,457	-108	7,198	7,160
4413 - 4411	.35	28,498	28,606	+108	9,974	10,012
4411 - 4410	.30	21,533	21,495	-38	6,460	6,448
4410 - 4409	.30	21,346	21,417	+71	6,404	6,425
4409 - 4408	.30	32,576	32,576	0	9,773	9,773
4408 - 4498	.30	38,962	38,924	-38	11,689	11,677
4498 - 4972	.15	43,268	43,182	-86	6,490	6,477
4972 - 4499	.30	43,010	42,924	-86	12,903	12,877
4499 - 4500	.45	27,529	27,545	+16	12,388	12,395
4500 - 4501	.50	10,111	10,111	0	5,055	5,055
4501 - 5402	.50	10,111	10,111	0	5,055	5,055
4502 - 4512	.40	6,448	6,346	-102	2,579	2,538
	6.9				138,472	138,373

INTERIOR ROUTE - RICHMOND

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicles Miles 90-90-3	Vehicles Miles Subarea
4429 - 4430	.45	7,623	7,705	+82	3,430	3,467
4430 - 4423	.45	14,470	14,548	+78	6,511	6,547
4423 - 4424	.55	23,291	23,549	-258	12,810	12,952
4424 - 4409	.55	21,320	21,382	+62	11,726	11,760
4409 - 4403	.55	15,678	15,669	-9	8,623	8,618
4403 - 4405	.55	14,711	14,711	0	8,091	8,091
4405 - 4376	.50	26,162	26,071	-91	13,081	13,035
4376 - 4377	.60	23,160	23,625	+465	13,896	14,175
	4.2				78,168	78,645

INTERIOR ROUTE - BELLAIRE BLVD.

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	90-90-3	Subarea
4483 - 4484	.60	40,433	40,697	+264	24,260	24,418
4484 - 4495	.55	70,866	71,109	+243	38,976	39,110
4495 - 4496	.95	90,063	90,342	+279	85,560	85,825
4496 - 4500	.30	83,408	83,627	+219	25,022	25,088
4500 - 4515	.45	75,882	76,025	+143	34,147	34,211
4515 - 4518	.60	64,381	64,485	+104	38,629	38,691
4518 - 4517	.20	61,176	62,041	+865	12,235	12,408
4517 - 4520	.20	82,622	83,497	+875	16,524	16,699
	3.85				275,353	276,450

PERIPHERAL ROUTE - SOUTHWEST FREEWAY

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
5008 - 5012	.25	144,893	166,817	+21,917	36,223	41,704
5012 - 5013	.65	197,528	217,779	+20,279	128,393	141,556
5013 - 4503	1.40	122,780	133,816	+11,016	171,892	18,734
4503 - 4512	1.10	128,723	139,601	+10,901	141,595	153,561
4512 - 4513	.35	152,602	163,492	+10,892	53,411	57,222
4513 - 4519	.90	219,756	231,562	+11,762	197,780	208,406
4519 - 4520	.35	248,678	260,997	+12,297	87,037	91,349
4520 - 4546	1.25	215,631	222,783	+7,183	269,539	278,479
	6.25				1,085,870	991,011

PERIPHERAL ROUTE - N. WILCREST

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
3612 - 3615	.45	28,338	28,428	+90	12,752	12,793
3615 - 4438	.35	14,162	14,104	-58	4,957	4,936
4438 - 4436	1.0	6,309	6,293	-16	6,309	6,293
4436 - 4435	.8	2,153	2,153	0	1,722	1,722
4435 - 4433	.4	11,760	11,614	-146	4,704	4,646
4433 - 4432	.4	2,863	2,870	+7	1,145	1,148
4432 - 4429	.5	11,593	11,554	-39	5,796	5,777
4429 - 4428	.55	8,106	8,101	-5	4,458	4,455
4428 - 4480	.4	13,146	13,216	+70	5,258	5,286
4480 - 4482	.4	14,649	14,754	+105	5,860	5,902
4482 - 4483	.4	17,232	17,195	-37	6,893	6,878
4483 - 4485	.6	7,499	7,493	-6	4,499	4,496
4485 - 4486	.6	721	721	0	433	433
4486 - 5588	.4	7,341	7,337	-4	2,936	2,935
4488 - 4489	.5	914	914	0	457	457
4489 - 5005	.65	1,902	1,839	-63	1,236	1,195
5005 - 5007	.65	1,902	1,839	-63	1,236	1,195
5007 - 5008	.30	8,124	8,214	0	2,437	2,464
	9.35				73,088	73,011

PERIPHERAL ROUTE - KATY FREEWAY

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
3612 - 3619	.80	220,068	216,370	-3698	176,054	173,096
3619 - 3618	1.10	200,240	198,931	-1309	220,264	218,824
3618 - 3649	.80	209,149	207,908	-1241	167,319	166,326
3649 - 3652	.60	205,970	204,975	-995	123,582	122,985
3652 - 3653	.45	224,873	223,794	-1079	101,193	100,707
3653 - 3676	.95	219,426	218,263	-1163	208,455	207,350
	4.7				996,867	989,288

PERIPHERAL ROUTE - SOUTH VOSS

Links	Distance	90-90-3 Assignment	Subarea Assignment	Difference	Vehicle Miles 90-90-3	Vehicle Miles Subarea
3676 - 3677	.50	27,889	27,768	-121	13,944	13,884
3677 - 4383	.85	12,168	12,078	-90	10,343	10,266
4383 - 4382	.80	18,953	18,967	+14	15,162	15,174
4382 - 4381	.25	31,945	31,375	-570	7,986	7,844
4381 - 4380	.45	32,622	32,409	-213	14,680	14,584
4380 - 4378	.45	66,099	66,372	+273	29,744	29,867
4378 - 4964	.20	58,446	58,370	-76	11,689	11,674
4964 - 4377	.20	61,488	61,464	-24	12,298	12,293
4377 - 4965	.29	64,647	65,088	+441	18,748	18,875
4965 - 4374	.28	68,549	69,050	+501	19,194	19,334
4374 - 4547	.20	73,386	73,483	+97	14,677	14,697
4547 - 4546	.25	101,129	101,132	+3	25,282	25,283
	4.72				193,747	193,775

Appendix B

CORRIDOR INTERCEPTS

Corridor Intercept 10

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
4420 - 4421	171,441	170,436	-1005	99.4
4420 - 4419	17,750	17,716	-34	99.8
3617 - 4418	2,532	2,536	+4	100.1
4392 - 4393	3,110	3,174	+64	102.1
4390 - 4396	7,536	7,548	+12	100.1
	202,369	201,410	-959	99.5

Corridor Intercept 11

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
4516 - 4518	61,176	62,041	+865	101.4
4500 - 4501	10,111	10,111	0	100.0
4595 - 4494	119,543	119,954	+411	100.3
	190,830	192,106	+1276	100.7

Corridor Intercept 12

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
4421 - 4422	166,800	165,881	-919	99.4
4414 - 4413	20,565	20,457	-108	99.5
4397 - 4400	18,859	18,706	-153	99.2
	206,224	205,044	-1180	99.4

Corridor Intercept 13

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
4395 - 4396	9,072	9,052	-20	99.7
4398 - 4397	10,383	10,262	-121	99.8
4402 - 4401	63,136	62,513	-623	99.0
4403 - 4405	14,711	14,711	0	100.0
4407 - 4406	17,585	17,662	+77	100.4
4971 - 4970	0	0	0	0.0
	114,887	114,200	-687	99.4

Corridor Intercept 14

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
4434 - 4421	43,734	43,502	-232	99.5
4431 - 4422	92,792	92,393	-399	99.5
4430 - 4423	14,470	14,548	+78	100.5
4427 - 4426	27,417	27,486	+69	100.2
4481 - 4497	1,217	1,217	0	100.0
4484 - 4495	70,866	71,109	+243	100.3
	250,496	250,255	-241	99.9

Appendix C

SCREENLINES

Screenline - EW

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
4432 - 4429	11,593	11,554	-39	99.6
4422 - 4423	171,612	170,970	-642	99.6
4411 - 4410	21,533	21,495	-38	99.8
4401 - 4404	22,239	22,036	-203	99.1
4378 - 4964	58,446	58,370	-76	99.8
	285,423	284,425	-998	99.6

Screenline - NS

Links	90-90-3 Assignment	Subarea Assignment	Difference	Percent of Previous
3619 - 3618	200,240	198,931	-1309	99.3
4419 - 4418	13,571	13,517	-54	99.6
4415 - 4414	9,392	9,363	-29	99.7
4412 - 4411	66,123	65,500	-623	99.1
4424 - 4409	21,320	21,382	+62	100.3
4425 - 4498	13,082	13,098	+16	100.1
4497 - 4972	258	258	0	0
4495 - 4496	90,063	90,342	+279	100.3
4494 - 4493	55,493	55,600	+107	100.2
4492 - 4503	19,247	19,357	+110	100.6
5013 - 4503	122,780	133,816	+11,036	109
	611,569	621,164	+9595	101.6
Excluding the Southwest Freeway Link	488,789	487,348	-1441	99.7