Technical Report Series

Estimating Vehicle Miles of Travel on Local Streets: Methodology and Results for the Fort Worth Case Study

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North Central Texas Council of Governments

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P.O. Drawer COG
Arlington, Texas 76011

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Abstract

TITLE: Estimating Vehicle Miles of Travel on Local Streets: Methodology and Results for the Fort Worth Case Study

AUTHORS: Tom K. Ryden
Senior Transportation Planning Engineer

John R. Hamburg
President, John Hamburg and Associates, Inc.

SUBJECT: A methodology to estimate vehicle miles of travel on local streets not normally maintained in a machine-readable highway data base.

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ABSTRACT: This technical report has been prepared to document the development to date of a workable and cost-effective methodology to estimate local street vehicle miles of travel (VMT). The methodology employs analysis of variance techniques on available link traffic counts, with applications of analytical geometry and network graph theory for estimates of local street mileage. This report is designed to supplement the procedures described in the report entitled Estimating Vehicle Miles of Travel for Non-Local Streets: Methodology and Results for the Fort Worth Case Study.

This report provides a discussion of alternative methodologies and documents the reasons for the procedure selected. The necessary steps to execute the procedure are outlined, along with a summary of available process results. This report serves as the final documentation on local street VMT procedures to be implemented in the North Central Texas Region.

Acknowledgements

This report is the result of a cooperative effort involving staff of the North Central Texas Council of Governments, John Hamburg and Associates, Inc., the State Department of Highways and Public Transportation, the City of Fort Worth, and the Federal Highway Administration Office of Highway Planning. Special thanks are in order for Mr. Arnold Breeden, who managed the collection of the local street count data base used in this report; Mr. Tom Foster and Ms. Victoria Hargis, who provided necessary technical support; and Mr. Michael Morris, who reviewed and commented in detail on this document.

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CHAPTER I

INTRODUCTION

This technical report has been prepared to document the development to date of a workable and cost-effective methodology to estimate local street vehicle miles of travel (VMT). The methodology employs analysis of variance techniques on available link traffic counts, with applications of analytical geometry and network graph theory, for estimates of local street mileage. This report is designed to supplement the procedures described in the report entitled Estimating Vehicle Miles of Travel for Non-Local Streets: Methodology and Results for the Fort Worth Case Study. The approach for local street VMT estimation described in the draft Guide to Urban Traffic Volume Counting[1] (hereafter referred to as the Guide) suggested that geographic areas be identified within the study area, a random sample of local street segments be taken, a count be taken for each selected link, and the mileage of all local streets be measured and then multiplied by the average volume per mile obtained from the sample of counts. This procedure is data-intensive, as it requires detailed knowledge of local street links. Also, a lack of available counts on local streets in the study area prohibits a rigid definition of geographic areas for stratified random sampling purposes.

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[1] Herbert Levinson and Adelbert Roark, Guide to Urban Traffic Volume Counting (draft), prepared for the Office of Highway Planning, Federal Highway Administration, U.S. Department of Transportation (October 1975).

In view of these problems, this report provides a discussion of alternative methodologies and documents the reasons for the procedure selected. The necessary steps to execute the procedure are outlined, along with a summary of available process results. This report serves as the final documentation on local street VMT procedures to be implemented in the North Central Texas Region.

Derivation of the alternative methodologies was provided by John Hamburg and Associates, Inc. (JHAI). The final methodology selected was the result of discussions by JHAI and the North Central Texas Council of Governments (NCTCOG). Data collection to support the selected methodology was provided by NCTCOG. A preliminary sample of 90 local street counts in the study area was provided by the Regional Planning Office of the State Department of Highways and Public Transportation (SDHPT).

The two major findings of the recommended approach relate to, first, a formula to estimate local street mileage based on nonlocal mileage, geographic area, and the number of city blocks in a given area and, second, the need for a sampling plan of local streets for the purpose of taking traffic counts. A comparison using 14 study area zones of calculated local street mileage versus actual measured mileage resulted in a difference of only 7 percent. Considering that local street mileage is the largest component of the highway system, accounting for 65 to 80 percent of the total, this level of error is reasonable. Concerning VMT, the preliminary sample of counts taken by the Regional Planning Office in three geographic areas did not reveal significant differences in either average values or dispersion from the average. Because local street VMT represents no more than 10 to 15 percent of total VMT in major urban areas, detailed strata definition for sampling is not recommended unless basic precision requirements cannot be satisfied.

The presentation which follows will demonstrate the need for local VMT estimates and the need for an alternative methodology from that proposed in the draft Guide. Candidate methodologies developed will be described, including the reasons for selecting the most appropriate methodology. Data collection to verify the usefulness of the selected procedure will then be discussed and the data collection to support the procedure will be outlined. Results will be summarized, sample sizes for counts will be presented, and an estimate of local street VMT will be calculated.

CHAPTER II

NEED FOR A LOCAL STREET VMT ESTIMATE

A small sample of local street traffic counts was taken in the study area. The volumes had a mean of 556 vehicles per day. When compared to mean daily volumes on study area freeway facilities which range from 29,000 to 76,000, depending on geographic area and number of lanes, the local street component may appear insignificant. The local street contribution is significant, however, due to the magnitude of local streets which exist in the study area.

The April 1969 report National Highway Functional Classification Study Manual[1] recommended guidelines on the extent of urban functional system mileage based on information obtained from urbanized areas across the nation. The local street system was found to contribute between 65 and 80 percent of total system mileage. A more recent survey of mileage, the National Highway Inventory and Performance Summary,[2] published in December 1977, indicates that the local street system contributes, on the average, 68 percent of the total system mileage in urban areas.

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[1] U.S. Department of Transportation, Federal Highway Administration, National Highway Functional Classification Study Manual (Washington, D.C., April 1969), p. 4.

[2] Clifford Comeau, National Highway Inventory and Performance Summary (Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, December 1977), pp. 1-5.

Due to this significant portion of local street mileage, local street VMT does contribute appreciably. A 1969 survey by the Institute of Transportation Engineers (ITE)[3] showed that local street VMT in urban areas ranged from 7 to 20 percent, depending on population size. The National Highway Inventory and Performance Summary[4] shows a local street VMT contribution of 14 percent as typical for urban areas.

In order to estimate the local street VMT in the study, the draft Guide[5] suggests that a simple random sampling approach be used because little prior information on local street counts is assumed to be available. Since accurate stratification requires previously recorded local street counts, a procedure of segmenting the study area into homogeneous groups is difficult to implement. As a result, the suggested methodology of the above-mentioned guide requires that local street links be uniform in length so as to minimize spatial variation, and counts be scheduled so as to obtain a representation of temporal variation when sampled. This requirement of constant link lengths greatly differs from the observed variation throughout an urban area.

The suggested approach assumes that knowledge of local street mileage and local street links exists. Because the local street mileage component is so large, a methodology to estimate mileage short of measuring each link should be incorporated in the

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[3] As reported in John Baerwald, ed., Transportation and Traffic Engineering Handbook, Fourth Edition (Arlington, Virginia: Institute of Traffic Engineers, 1976), p. 541.

[4] National Highway Inventory and Performance Summary, p. II-1.

[5] Levinson and Roark, Chapter 4.

VMT estimation procedure. Resources for this effort did not allow the creation of a data base of local street counts to examine spatial and temporal variance components of local street traffic volume behavior. A small data base does exist, however, in the study area. During April 1977, the Regional Planning Office of SDHPT took 90 traffic counts on local streets in three small areas inside the Fort Worth study area. Again, resources prohibited an investigation of temporal variation, as the counts were taken over a six-day period. The three areas selected represent a range of residential densities and income levels and thus allow a limited examination of spatial variance across geographic and socioeconomic stratifications.

The three areas are shown in Figure II-1. A summary of count statistics from each area is provided in Table II-1. There is very little difference between the means and standard deviations. A frequency distribution of all counts is given in Figure II-2. Frequency distributions of the counts taken in each area are provided in Figure II-3. From these data, it is apparent that a stratification by residential density and income level for spatial variation is not warranted. Designing a sample with a single stratification is recommended at this time. This will greatly simplify the sample design for local street VMT estimation although limiting its applicability to areawide local street VMT estimates only.

FIGURE II - 1

LOCAL STREET TRAFFIC COUNT AREAS

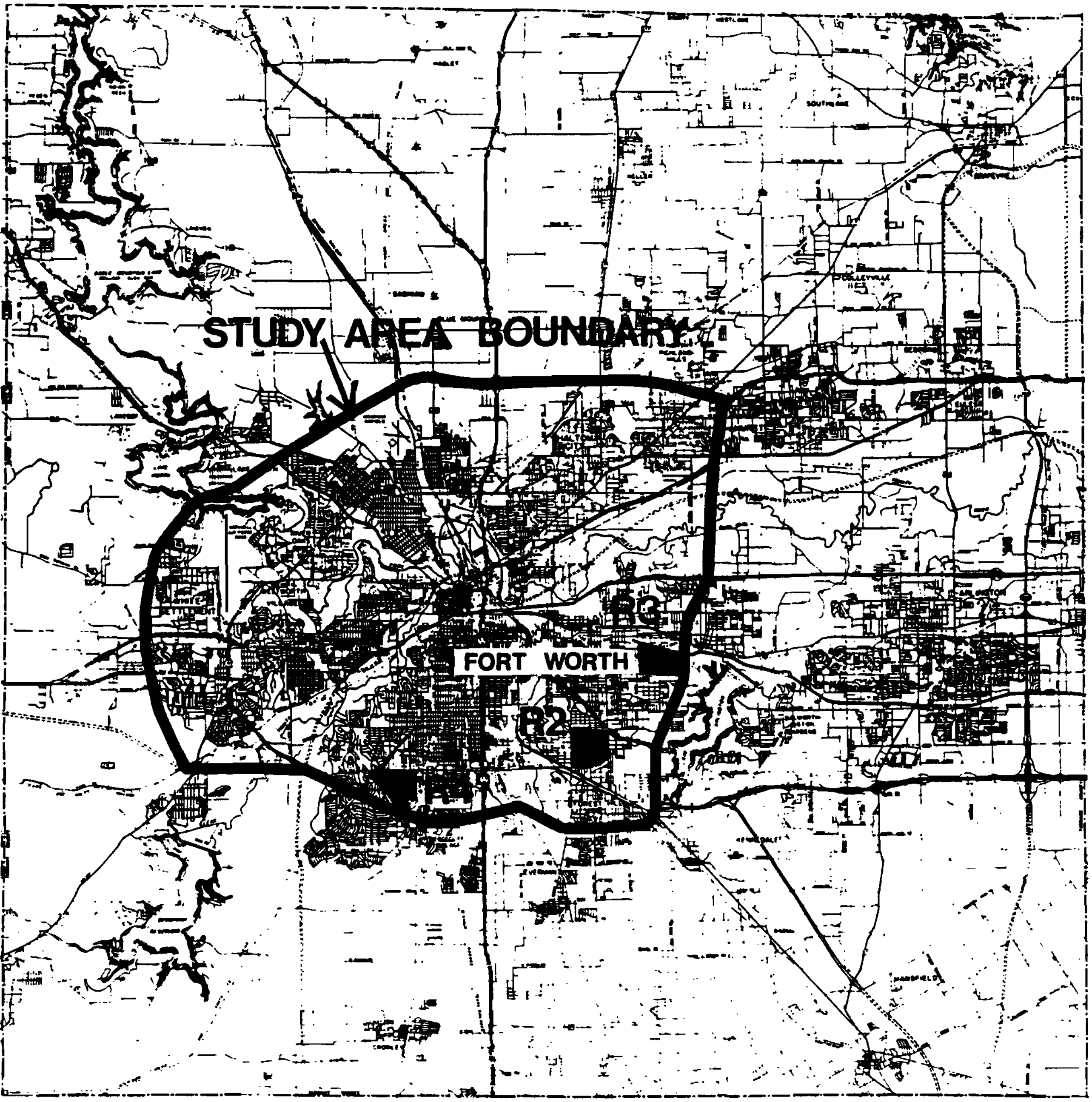


TABLE II-1

LOCAL STREET COUNT AREA SUMMARY STATISTICS

Test Area	Number of Counts	Mean	Standard Deviation	Coefficient of Variation[a]
R2	27	508	480	0.95
R3	32	533	471	0.88
R4	31	621	507	0.82
Mean Area	90	556	490	0.88

[a]The Coefficient of Variation measures the dispersion of values in relation to the mean. It is equal to the standard deviation divided by the mean. The values shown in the above table are all relatively large.

FIGURE II-2

TRAFFIC VOLUME FREQUENCY FOR ALL LOCAL STREET SAMPLES

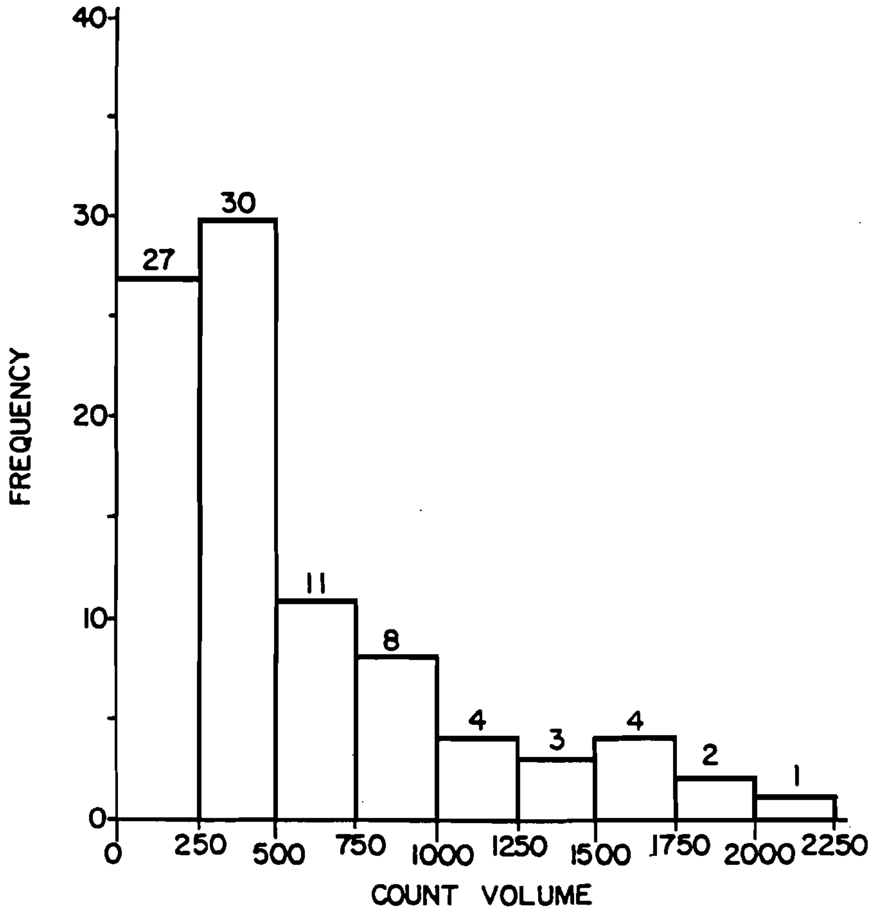
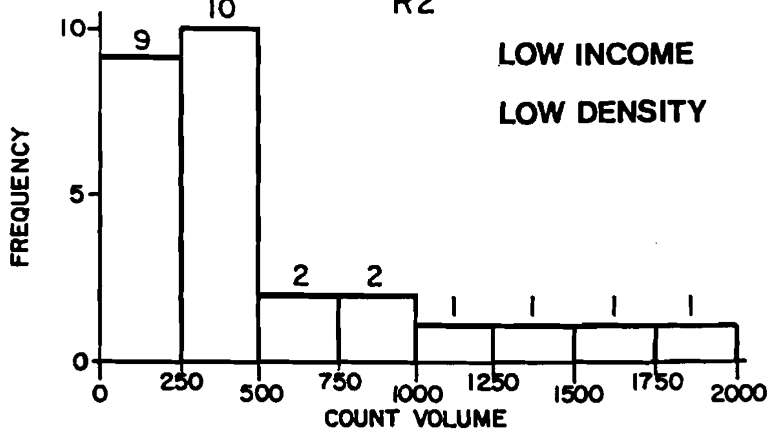


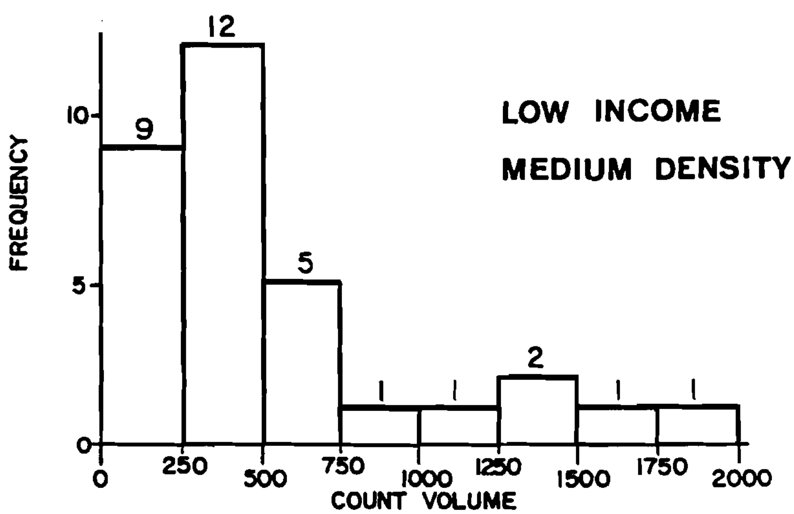
FIGURE II-3

INDIVIDUAL AREA TRAFFIC VOLUME FREQUENCIES

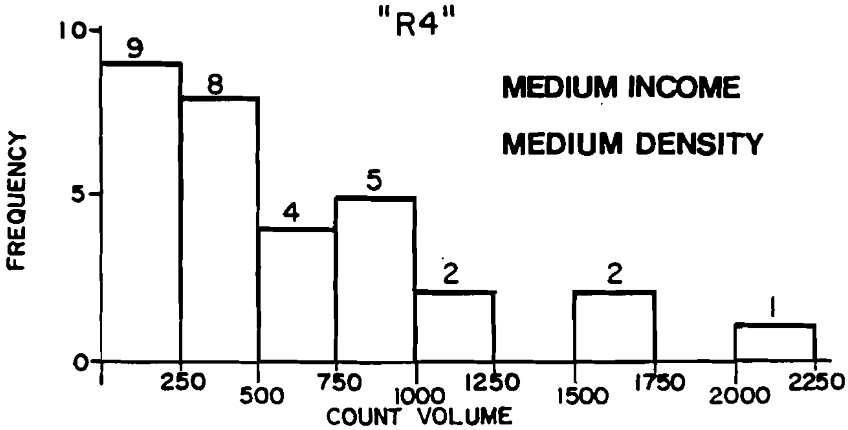
"R2"



"R3"



"R4"



CHAPTER III

CANDIDATE METHODOLOGIES

This chapter outlines a series of methodologies for estimating the mileage of local streets. For purposes of this study effort, a local street is any existing street segment which has not been functionally classified as either freeway, arterial, or collector. The traffic on these nonclassified streets consists of either through or local traffic. The volume of traffic on individual local streets may be affected by at least three factors. These include the following:

- the density of development along the local street
- length of local street (distance between bordering arterial/collector streets)
- congestion on the arterial/collector system

Obviously, the greater the density of development on a local street, the greater the volume of traffic which will use the local street to reach the activity sited on that street. Typically, this development is residential. Intensive nonresidential development traditionally has resulted in high traffic volumes which have the effect of shifting the street from local to the higher functional class of collector or arterial. The density of development can be expected to affect the local traffic component but will have no effect on the through component. Of course, one expects higher proportions of through travel to be associated with high-density development to the extent that congestion on arterials results in local streets being used for through travel.

The VMT to be expected on a local street link will be a function of the length of that link. Given the same development density, a mile-long local street link would be expected to have four times the VMT of a half-mile section (twice as many local trip origins and destinations and twice the average distance traveled). Length as used in this sense refers to the distance between the two arterial streets connected by the local street. The length of the local street affects the local street VMT and the through VMT, but the latter is only augmented by the length and probably at a decreasing rate since length would tend to discourage through travel.

Generally, we expect very little through traffic on a local street. This is because one expects to find faster alternative arterial routes. However, as congestion on the arterial system increases, the local streets may become a more attractive (i.e., faster) alternative route. One would expect that the local traffic component would not be affected by this factor.

The above discussion has considered individual local streets. However, one would rarely be concerned with the VMT on a specific local street in a planning sense. Typically, one is interested in determining the VMT on all of the local streets in a subregion or of an entire region. Therefore, it is not necessary to deal with individual local streets except as they represent the universe of local street segments from which a sample might be drawn and direct observations made. As the examination of the existing local street data base has shown, little variation in the aggregate exists in local street counts. Four potential schemes for estimating local street VMT are described below.

With the first method, a random sample of local street segments in each geographic area is drawn and a traffic count for each sample is taken. Next, the length of each sampled local street is measured, along with the length of all local streets in each area. Through multiplication of the total mileage of local streets in the subarea by the average count of vehicles from a sample of local street links in that subarea, VMT is estimated.

This is basically the approach recommended in the draft <u>Guide</u>, although with some significant differences with regard to link length treatment. This method requires a definition of the population of local streets including geographic location and length.

An alternative method is available which does not require that the entire population of local streets be identified. In this approach, the region would be subdivided into geographic areas -- say, 200. From among these 200 subareas, a random sample of subareas would be drawn. For each sample subarea, the total mileage of local streets would be measured. If the number of dwelling units and the land area of each subarea were known, these data might be correlated with the local street mileage to obtain an expression for estimating the local street mileage in the unsampled geographic areas. In the simplest form, miles of local street would be assumed to be a linear function of dwelling units in the geographic area.

For example, if we assume that the interior of a zone defined by bordering arterials/collectors is all residentially developed, we would expect local mileage to be a function of a number of residential buildings, the average frontage of each building, and the frequency of cross streets. From this, by assuming average dwelling units per structure, and assuming that blocks are rectangles with a length twice the width and structures facing the length,

$$M_L = \frac{1.42\,DF}{10{,}000\,R} \qquad (1)$$

where

M_L = mileage of local streets

D = number of dwelling units

F = frontage per structure in feet

R = dwellings per structure

For example, take a one-quarter square mile on the outskirts of a city such as Chicago. Blocks are typically 16 to the mile in length and are 8 to the mile in width. Frontages are 50 feet and structures are single-family. Assuming the streets bordering the one-quarter square mile area are arterials/collectors, this will give three half-mile cross-streets and seven half-mile frontage streets, or five miles of local streets. The above formula gives 4.8 miles of local streets. Perhaps a mechanism could be fashioned to obtain better estimates of total local streets than simply multiplying the local street mileage in the sampled areas by the sample interval and then adjusting for differences in the average size of sampled subareas and unsampled subareas.

Remaining, of course, is the estimation of local street VMT in the sampled subareas. This could be done on a sample basis as well and, in this regard, would be similar to the first process described.

The third approach would be to calibrate a model of local street VMT based on the knowledge of trip ends along a local street, the length of the local street, and an estimate of the ratio of through to local traffic using the local street.

If we define a local street as the linear collection of street segments connecting two arterial boundaries, then it is clear that the VMT for local streets should be easily calculated as the product of one-half the length of a local street times the volume of vehicular productions and attractions found along the local street. The through component of local street VMT would be the product of the number of through trips times the length of the local street. Alternatively, through local street VMT could be calculated by multiplying the volume of origins and destinations by a proportion representing through trips to local trips and multiplying this product by the length of the local street.

Symbolically:

$$\text{Local Street VMT} = T_L \times L/2 + T_L P_L L = T_L L\,(P_L + .5) \qquad (2)$$

where

T_L = local traffic = trip ends on local street

P_L = proportion of local traffic that is through traffic

L = length of local street.

This procedure requires the knowledge of the population of local street segments, the knowledge of trip ends by small areas, and a procedure or basis for estimating through travel on local streets. Counting through travel on a local street can be difficult, especially as the link increases beyond a single block. Ultimately, the DIME file could be utilized to define and give mileage counts for local street segments within a small area, and to obtain trip ends by that area, thus making the application of the algorithm trivial, given a through component estimate.

The fourth procedure is a variation of the second method discussed earlier. Assume that the study area is subdivided into a series of M zones and the central business district (CBD) excluded since local streets in the CBD will be treated as a separate stratum but similar to arterials. Select a sample of m zones randomly from the total of M zones. One could take a systematic sample from the M zones in random sequence. For each of the m sample zones, measure the mileage of local streets. This will be designated as D_i^L. Within each of the m zones, sample n_i links and take 24-hour traffic counts on each selected link. Ideally, we would want to randomize these counts by day of week as well as day within the counting period; however, resource constraints will not allow this. Calculate the vehicle miles of travel on local streets in each zone i. This Local Street VMT ($LVMT_i$) can be estimated as shown below:

$$LVMT_i = \frac{D_i^L \sum_{i=1}^{n_i} V_{ij}}{n_i} \qquad (3)$$

where

V_{ij} = a 24-hour count in zone i at location j

D_i^L = mileage of local streets in zone i

n_i = the number of counts in zone i.

Given the VMT in the sample zones, the question becomes how best to estimate the local street VMT for the region. Three alternatives are shown and briefly discussed below.

$$LVMT = \frac{M \sum_{i=1}^{m} LVMT_i}{m} \tag{4}$$

This equation can be seen to consist of the average local street VMT among the sampled zones (m) times the total number of zones (M). It is a standard way to expand the local VMT data, but it assumes that local street mileages within the sampled zones have the same distribution as all zones in the study area.

$$LVMT = \frac{M \sum_{i=1}^{m} LVMT_i \cdot A_i}{\sum_{i=1}^{m} A_i} \tag{5}$$

where

A_i = the area in a sample zone i

This formula seems more logical than formula 4, since it adjusts for differences in the area of the zones.

Yet another formula is:

$$LVMT = M \frac{\sum_{i=1}^{m} LVMT_i \cdot D_i^L}{\sum_{i=1}^{m} D_i^L} \qquad (6)$$

where

D_i^L = mileage of local streets in zone i.

The above equation is preferred since it accounts for variations in local street mileage within the zones.

These last three formulations all assume that there exists enough information to accurately define sample zones (m). From the results in Table II-1, it appears that it is very difficult even to define the variables which differentiate particular zonal areas. As a result of this lack of homogeneous sample zones as well as a lack of substantial data to investigate this further at this time, an alternative approach is presented below. This technique requires the need to calculate total local street mileage as a result. A formula for calculating this mileage based on dwelling units, dwellings per structure, and frontage per structure was given in the discussion on method 2. These data, however, may not easily be obtained, and an alternative is proposed as follows.

In this approach, we assumed that the miles of streets in a zone are a function of the number of city blocks and the area of the zone. Further, if we know the mileage of nonlocal streets in the zone, the local street mileage will be the difference between total mileage and arterial mileage. If we assume that blocks are bounded on all sides by streets and that blocks are square, it can be shown that the mileage of streets in a zone is equal to two times the square root of the product of the zone area and the number of blocks in the zone (note that intersections are counted twice in this approach). Therefore, the mileage of local streets in a zone should be:

$$D_i = 2\sqrt{A_i B_i} - D_i^A \tag{7}$$

where

B_i = the number of blocks in the zone

D_i^A = the nonlocal street mileage in the zone

A_i = the area of the zone.

It is assumed that the number of blocks for each of the zones can be obtained rather easily, either by using the census block statistics or by counting them. It is possible to obtain the nonlocal street mileage out of the available network files, and the area can be obtained from available zonal files. If local street mileage in the sample of zones is measured, and the area, number of blocks, and nonlocal street mileage is obtained, it becomes possible to calibrate empirically a formula assuming a functional relationship as specified in equation 7. Thus, for each of the zones not sampled, the local street mileage is estimated based on the number of blocks in the zone, the area of the zone, and the nonlocal mileage in the zone.

From the standpoint of data availability, resources, and simplicity, it was decided to adopt the final procedure described above. Subsequent chapters detail the assembly of information and results obtained from this methodology.

CHAPTER IV

LOCAL MILEAGE PROCESS CALIBRATION

In order to test the selected methodology described in the previous section, it was necessary to develop a step-by-step process which would allow a critical examination of the selected formula for estimating local street mileage. The generalized expression for the equation is as follows:

$$D_i = K(A_i B_i)^C - d_i \tag{8}$$

where

D_i = mileage of local streets in zone i

K, C = calibration constants

A_i = area of zone i

B_i = number of blocks in zone i

d_i = mileage of nonlocal streets in zone i.

In the previous discussion, values for the two calibration constants were given as K = 2 and C = 1/2. The assumption was that blocks were square and always bounded by streets. In reality, this is not the case. The following describes in detail how the calibration constants are determined and evaluated.

The first step involves taking a random sample of regional analysis areas, hereafter referred to as zones, by assigning each record of a machine-readable zone file in the study area a random number. In all, 14 zones were selected for further examination.

This represented a 20 percent sample of zones in the study area. The selected zones are shown in Figure IV-1. Next, for each zone, the boundaries are identified on 1" = 400' scale city plat maps which show all existing streets and indicate both blocks and property lots. The plat maps were used instead of DIME file maps for two reasons. First, the plat maps more clearly identified local streets and, second, the DIME file maps were being updated at the time of the calibration effort and were not available.

Once the zones are identified, nonlocal mileage links were identified using the NCTCOG Thoroughfare Information System[1] and the total nonlocal miles were accumulated for each zone. Next, the zone land area was obtained using the NCTCOG zone data information system. Measurements of local miles for each zone were then taken by technician staff. The area, number of blocks, nonlocal miles, and local miles measured are summarized in Table IV-1.

The functional form of the selected equation for computing local mileage is convenient in that by taking the logarithms of both sides, a linear expression results. In addition, the two calibration constants become the slope and the intercept of the transformed linear equation. In this way, by performing a linear regression on the data base, values for the constants can be obtained along with an analysis of variance on the constants. Figure IV-2 shows the regression line and data points from the transformed data base.

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[1] Terry Watson and William Parker, An Introduction to the North Central Texas Thoroughfare Information System, Technical Report No. 18 (Arlington, Texas: North Central Texas Council of Governments, January 1979).

FIGURE IV-1

SAMPLE ZONES FOR LOCAL MILEAGE CALIBRATION

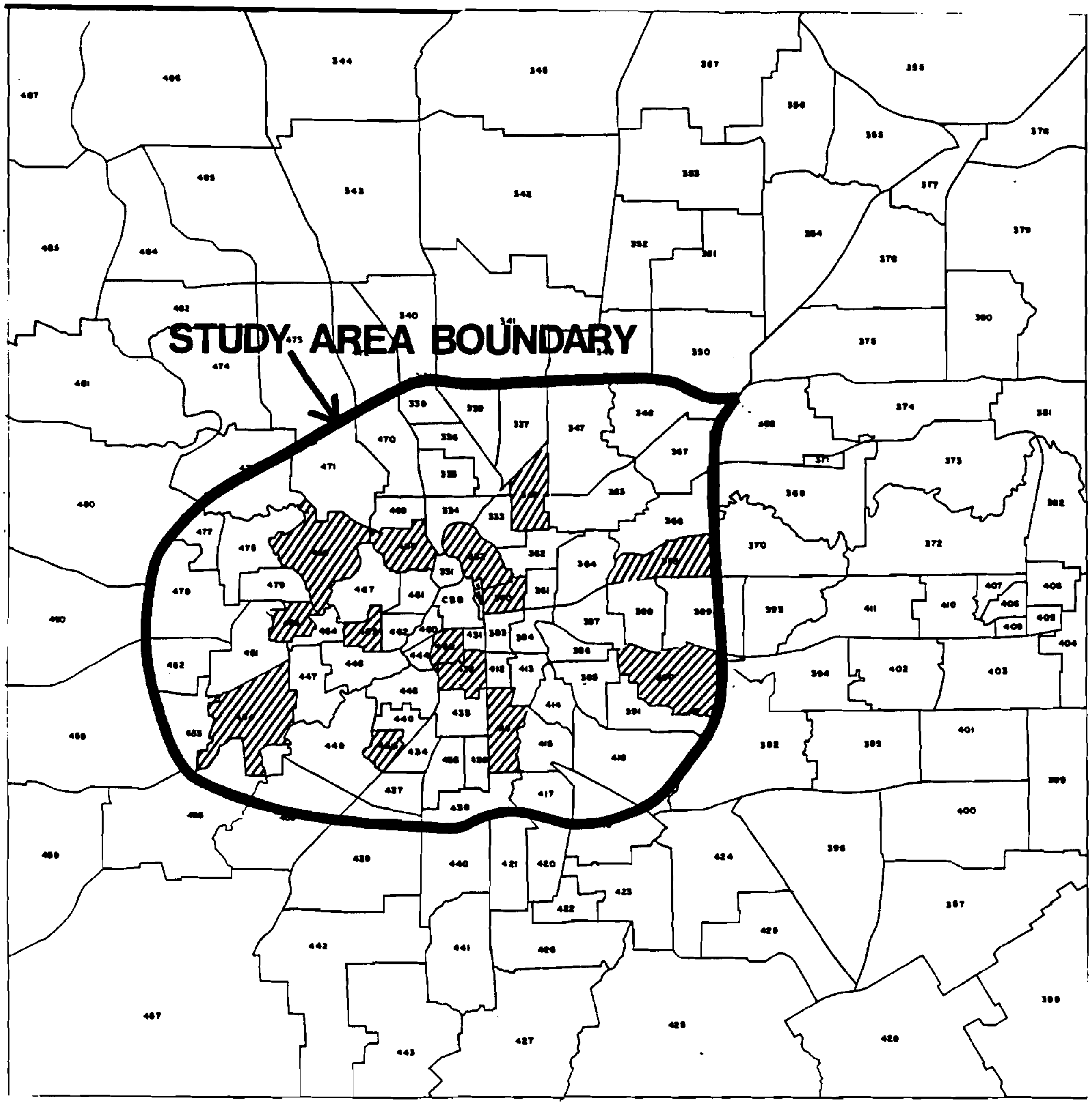


TABLE IV-1

LOCAL STREET MILEAGE EQUATION CALIBRATION DATA INPUT

Zone	Area (Square Miles)	Nonlocal Mileage	Blocks	Measured Local Mileage
332	2.062	12.80	119	14.17
346	1.857	5.49	121	23.35
360	0.975	7.49	79	8.19
365	2.571	11.01	47	12.43
390	3.011	24.33	193	33.65
416	2.229	9.80	159	26.67
430	0.857	7.32	164	16.34
432	1.376	7.21	224	24.16
450	0.825	3.59	65	10.58
454	4.712	14.88	209	43.17
463	0.877	3.69	106	16.89
465	1.056	3.45	34	7.33
466	4.211	12.17	187	43.95
468	1.896	6.14	129	22.04

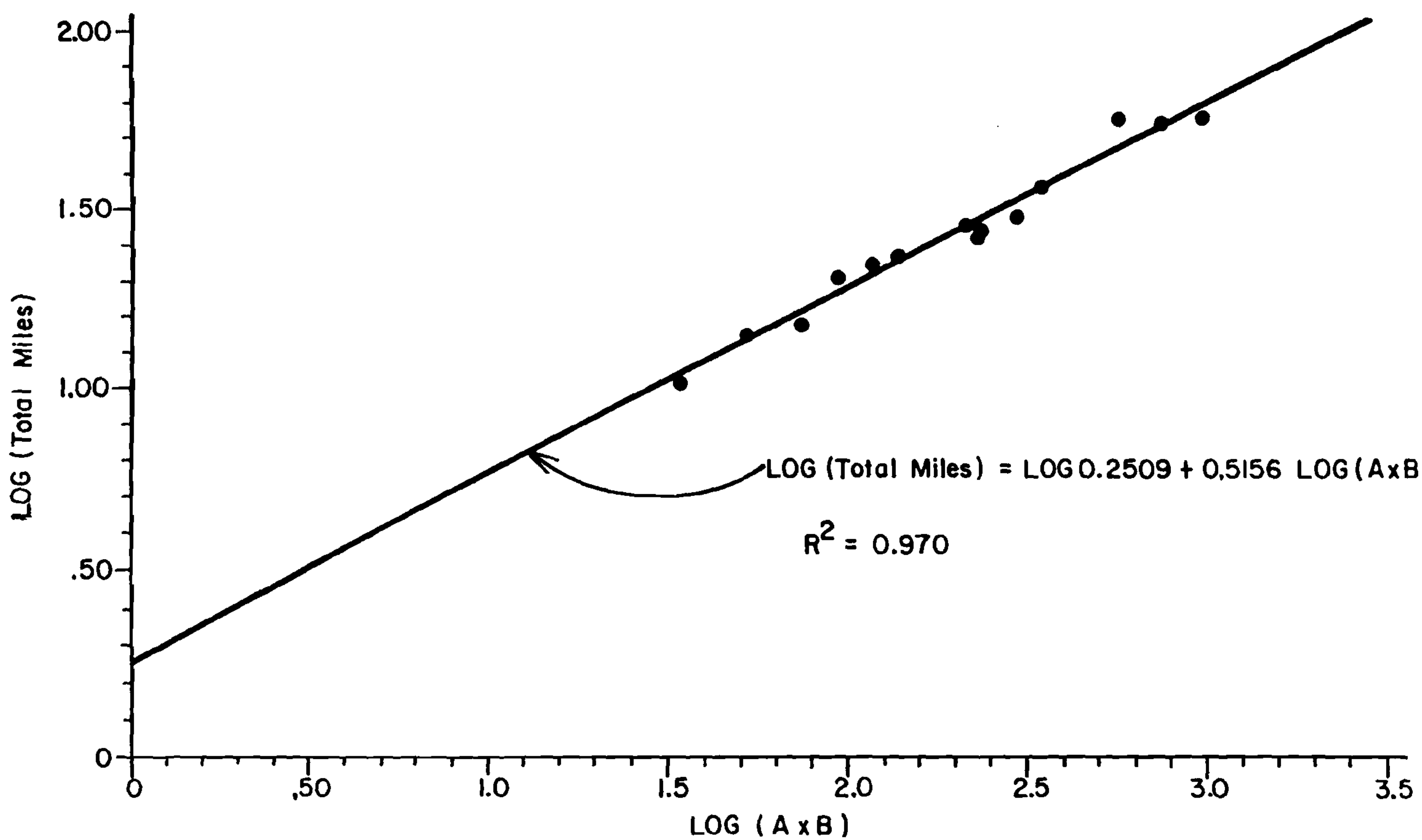
The degree of correlation is very good as $R^2 = 0.970$. The coefficient of (A*B) and the constant are both significant at $\alpha = .05$ where $t = 1.64$. By taking the antilog of the linear equation, K = 1.782 and C = 0.515. The equation to estimate local street mileage can now be expressed as follows:

$$D = 1.782(A \times B)^{.515} - d \qquad (9)$$

Recalling that the original equation assumed a value for K = 2 and C = 1/2, this would be true if all zones were square and the spacing of streets was equal in both directions. As is shown in Appendix A, if the zones are square but blocks are rectangular (unequal

FIGURE IV-2

LOCAL MILEAGE REGRESSION RESULTS



street spacing) then K=2.12 and C=1/2. In reality, blocks are not always square, rectangular, or, for that matter, equal in size or always bounded by streets. Railroad tracks and creeks often define blocks as well. Because of this, the value of K obtained in calibration can be explained. Given the good correlation of data, it is recommended that the above equation be utilized in estimating local street mileage.

CHAPTER V

LOCAL STREET VMT ESTIMATION

Obtaining an estimate of local street VMT consists of two general steps. First, mileage must be determined, then a sample of local streets must be selected for obtaining traffic counts to calculate an average volume. By multiplying the mileage by the average count, an estimate of local street VMT can be reported.

The results of the calibration process presented in Chapter IV revealed a workable and cost-effective approach to estimate local street miles making maximum use of existing NCTCOG thoroughfare and zone information systems. Three data items drive the procedure: zone area, number of blocks in a zone, and mileage of non-local streets. Only the number of blocks must be collected in the study area. Figure V-1 summarizes the data processing sequence developed to compute local street mileage estimates. Table V-1 shows the results of the data processing for each study area zone. The estimate of local streets sums to 1,456 miles. This compares to approximately 600 miles of nonlocal streets in the study area outside the central business district. Therefore, local streets account for 73 percent of the total estimated miles. This figure is within the range of local street percentage presented earlier in this paper.

Once the mileage estimate is obtained, sample size requirements for counts can be determined. Table II-1 summarizes pre-estimates of variance from the sample of counts taken by the Regional Planning Office of SDHPT.

FIGURE V-1

LOCAL STREET MILEAGE ESTIMATION DATA PROCESSING SEQUENCE

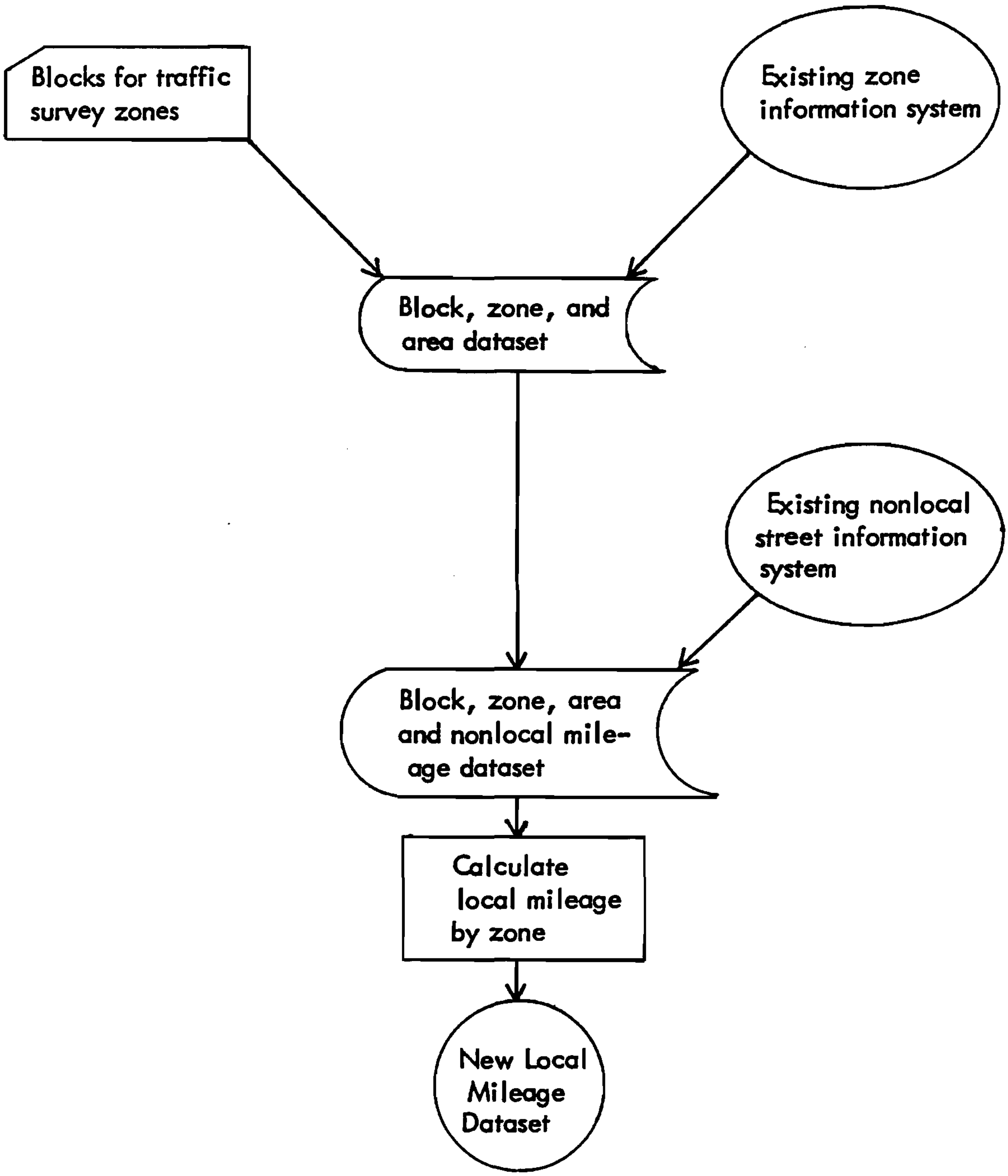


TABLE V-1

LOCAL MILEAGE AND SUPPORT DATA BY ZONE

Zone	Area	Nonlocal Mileage	Local Mileage	Blocks
346	1.85	5.49	24.48	121
347	6.90	18.90	81.09	362
362	1.62	8.96	19.86	128
383	1.04	9.60	15.52	151
386	1.36	6.81	21.99	152
387	2.16	10.30	25.51	148
388	2.56	10.04	25.49	123
412	0.68	4.56	10.22	80
416	2.22	9.80	27.85	159
430	0.85	7.32	16.39	164
431	0.61	5.59	10.86	111
432	1.37	7.21	27.90	224
433	1.70	7.59	27.62	182
435	1.60	6.32	31.22	220
436	0.92	3.90	14.24	89
449	1.15	8.38	11.23	83
450	0.82	3.59	11.05	65
451	3.42	13.49	39.77	207
461	1.18	4.85	15.90	91
462	0.86	5.03	1.39	12
463	0.87	3.69	15.59	106
476	2.77	---	---	5
331	0.64	1.43	9.68	48
332	2.06	12.80	18.52	119
333	1.37	6.38	14.19	77
334	1.72	4.41	18.95	79
335	1.72	4.51	34.12	217
336	2.07	4.48	22.87	90
337	2.99	11.90	4.71	23
338	2.39	8.68	2.46	13
339	1.35	2.36	2.84	5
348	4.09	17.34	34.03	161
359	0.19	1.04	2.84	19
361	0.74	3.42	6.35	32
363	3.65	22.74	19.29	121
364	2.85	4.75	12.48	26

TABLE V-1 (cont.)

Zone	Area	Nonlocal Mileage	Local Mileage	Blocks
365	2.57	11.01	10.97	47
366	3.61	5.32	11.24	19
367	3.10	12.08	31.25	151
384	0.94	6.98	11.45	90
385	2.10	9.95	32.16	211
389	1.60	9.59	12.95	79
390	3.01	24.33	23.88	193
391	1.88	4.04	27.59	133
413	1.09	5.62	16.48	112
414	1.09	5.78	9.91	56
415	1.90	7.18	19.46	93
417	2.05	8.79	-2.38	5
418	4.55	24.23	32.24	175
419	2.12	10.49	16.85	88
434	1.22	3.26	19.87	109
437	1.41	8.09	18.54	125
438	2.09	12.40	11.29	67
444	0.44	1.00	7.90	45
445	1.67	5.60	19.52	94
446	2.22	13.91	26.97	188
447	2.14	7.48	31.59	178
448	4.73	14.76	39.40	155
452	2.31	12.26	16.12	87
453	2.53	1.34	21.63	52
454	4.71	14.88	47.88	209
455	1.78	7.45	4.77	21
456	0.11	0.11	0.57	1
460	0.52	4.48	4.60	39
464	0.91	3.68	13.76	83
465	1.05	3.45	8.53	34
466	4.21	12.17	43.95	187
467	2.46	3.02	31.97	124
468	1.89	6.14	25.13	129
469	1.17	7.40	18.40	142
470	3.23	5.36	37.28	144
471	5.35	13.66	68.49	315
475	2.76	4.41	6.61	11
477	1.35	---	---	8
478	5.33	19.66	31.78	124
479	2.16	3.59	6.61	12

Given those statistics and using the standard sample equation, Table V-2 summarizes the required sample sizes for different levels of statistical confidence and precision. Through a meeting of local government staff, it was decided that for local streets a confidence of 68 percent and precision of 10 percent would be sufficient.

TABLE V-2

SAMPLE SIZE ESTIMATES FOR LOCAL STREET COUNTS

Alternative	Confidence	Precision	Sample Size
1	95%	$\pm$ 5%	1,239
2	95%	$\pm$10%	310
3	90%	$\pm$10%	198
4	68%	$\pm$10%	77
5	68%	$\pm$20%	19

Based on the information in Table V-2 and the decision on confidence and precision, a total of 77 sample links is required for traffic counts. A major obstacle arises in drawing this sample. An automated and machine-readable file of local street information does not currently exist for the study area. Given this problem, thought was given to a cluster sampling approach using zones as the sampling unit.

Another problem with estimating local street VMT in the study area is one of resources. NCTCOG does not have the staff or equipment to conduct traffic counts. The schedule developed to take sample counts, with the help of SDHPT, allowed only enough counts to satisfy nonlocal street requirements.[6] For purposes of obtaining an estimate, the mean 24-hour traffic count for a previous sample taken by SDHPT in the spring of 1977 was used. The mean value obtained was 556 vehicles. When multiplied by the 1,456 miles of local streets, an estimate of 809,536 vehicle miles traveled results.

Two sources of error exist with this estimate. The first is the error from the regression equation used to estimate mileage. The percent standard error is 13. In other words, the mileage estimate may be as low as 1,267 miles or as high as 1,645 miles. The second source of error comes from the assumed traffic count mean derived from the sample of traffic counts. The error of this estimate was found to be 10 percent. Since the error terms are additive, the total error is 23 percent. Thus, the VMT estimate for local streets could be as low as 638,400 and as high as 1,000,300. In relation to the magnitude of the non local street VMT estimate, this range represents a variation of only 2 percent.

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[6] Tom K. Ryden and John R. Hamburg, Estimating Vehicle Miles of Travel on Non-Local Streets: Methodology and Results for the Fort Worth Case Study, Technical Report No. 23 (Arlington, Texas: North Central Texas Council of Governments, Transportation and Energy Department, October 1979).

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The methodology as outlined in the draft Guide To Urban Traffic Volume Counting has two principal limitations from a practical standpoint. First, the methodology assumes that a database of local street links is readily available and each link can be defined as being uniform in length. Second, it is assumed that homogeneous groupings of local street volume counts exist, allowing stratification for sampling purposes. Unlike the database for non local streets, the availability of a detailed, up-to-date file of local streets in an urbanized area is rare, and historical information related to local street traffic counts and their variability -- both spatially and temporally -- does not exist.

The alternative methodology described in this report has demonstrated that:

- In the absence of a detailed local street mileage inventory, a credible estimate of total local miles can be obtained short of having to physically measure each local street. Only the total number of blocks must be counted.

- A statistical evaluation of potential strata variables including residential density and income level did not result in a set of useful descriptions for defining local street link count groupings. Due to limited available resources and a consideration of contribution of local street VMT to a total VMT estimate, it was recommended that a single stratum for local streets be employed.

As the methodology is expanded to the other areas of the North Central Texas region, it is recommended that equations be calibrated for local street mileage which are specific to geographic areas. It is also recommended that the investigation into variance components of local street counts continue since a definition of homogeneous groupings will help the overall precision of a local street VMT estimate.

APPENDIX A

DERIVATION AND DISCUSSION OF A FORMULA TO ESTIMATE LOCAL STREET MILEAGE

APPENDIX A

DERIVATION AND DISCUSSION OF A FORMULA TO ESTIMATE LOCAL STREET MILEAGE

It has been hypothesized that local street mileage can be estimated assuming a relationship exists between street miles in a zone, the area of a zone and the number of blocks in a zone expressed as follows:

$$D_L = 2\sqrt{AB} - D_A \qquad (10)$$

Where: D_L = Mileage of local roads in a zone

A = Area of zone

B = Number of blocks in zone

D_A = Non-local street mileage in zone.

This formula was derived as follows:

Let Z = Average spacing of local streets per mile in a zone

A = As above

B = As above

D = Mileage of streets in a zone.

Assuming that the zone is square, the number of streets per mile in one dimension is

$$\frac{\sqrt{A}}{Z}$$

and the mileage therefore in both dimensions is the sum of streets in each dimension multiplied by the average length ($\sqrt{A}$) or:

$$D = \left(\frac{\sqrt{A}}{Z} + \frac{\sqrt{A}}{Z} \right) \sqrt{A}$$

$$D = \frac{2A}{Z} \qquad (11)$$

The number of blocks in the zone is equal to:

$$B = \frac{\sqrt{A}}{Z} \cdot \frac{\sqrt{A}}{Z} = \frac{A}{Z^2} \qquad (12)$$

Solving for Z^2:

$$\frac{4A^2}{D^2} = \frac{A}{B} \qquad (13)$$

$$D^2 = \frac{4A^2B}{A} = 4\ AB$$

$$D = 2 \sqrt{AB}$$

This assumes that the zone is square and the spacing of streets is equal in both directions, i.e., square blocks of equal size.

A similar equation can be derived assuming a square area but rectangular blocks of equal size.

Let W = Width of block

L = Length of block

$$D = \frac{A}{W} + \frac{A}{L} \qquad (14)$$

$$B = \frac{A}{WL} \qquad (15)$$

Now if L = KW

$$D = \frac{A}{W} + \frac{A}{KW} = \frac{AK}{KW} + \frac{A}{KW} = \frac{A(K+1)}{KW} \qquad (16)$$

$$B = \frac{A}{KW^2} \tag{17}$$

$$W = \frac{A(K+1)}{DK} = \sqrt{\frac{A}{KB}} \tag{18}$$

$$D = \frac{A(K+1)}{K} \frac{\sqrt{KB}}{\sqrt{A}} = \frac{(K+1) \sqrt{KBA}}{K} \tag{19}$$

$$D = \frac{(K+1)\sqrt{BA}}{\sqrt{K}} \tag{20}$$

Moreover, it can be shown that the above is true for rectangular zones. Notice that for values of K falling between 1 and 2, the first equation is not bad. Generally, however, blocks tend to be twice as long as wide, so the equation might better be 2.12 $\sqrt{AB}$. Alternatively, one could calibrate based on a set of actual observations.

Another source of error in using this formulation is the assumption of equal block size. This is rarely the case. The impact of this assumption is to overestimate street mileage. Assume for example, a zone in which one-half of the area was given over to one block and the other half of the zone divided into several blocks. The mileage estimate for the zone treated as a whole would be equal to 2 $\sqrt{AB}$. The treatment of the two halves would be equal to:

$$2\sqrt{\frac{A}{2}} + 2\sqrt{\frac{A(B-1)}{2}} \tag{21}$$

and the ratio of the two treatments is:

$$\frac{\sqrt{2B}}{1 + \sqrt{B-1}} \tag{22}$$

The value of B is never less than 2 under the assumptions discussed here (one block in each half of the zone). The term (B-1) is the ratio of the block size. The ratio ranges from 1.0, for B = 2, to 1.414 as B approaches infinity. The assumption of equal-sized blocks overstates by a factor of about 10 percent when the ratio of block size is about 7.

Given limits of 1.0 and 1.1 for block size differences and a range of 2.0 to 2.12 (assuming blocks twice as long as wide), the multiplier of the square root of the product of the number of blocks and the area would be between 2.0 and 2.33. This suggests a possible contingency check for observations. Values outside this range are still possible as blocks are not always rectangular in shape and not always bounded by streets.

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