research project (5). Again, one must be careful not to automatically attribute any changes in occupancy to the carpool program.

One aim of future research in the area of variations in automobile occupancy should be to verify whether the results of this study apply in other metropolitan areas. Since nearly all of the factors that relate to levels of ride sharing can vary from one city to another, occupancy rates and their variability over time and at different sites may also be significantly different. Since analysis of automobile occupancy is a relatively new field of research, ongoing projects will be needed before the complex interactions among the variables can be better understood and explained. This will then enable engineers, planners, and policy makers to work together to address transportation problems in metropolitan areas.

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Georgia's Evaluation of Federal Highway Administration Procedures for Estimating Urban Vehicle Miles of Travel

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The once relatively obscure statistic of vehicle miles of travel has taken on a much higher profile with the advent of air quality standards and energy policies. It is probable that federal agencies such as the U.S. Departments of Transportation and Energy and the Environmental Protection Agency will use statistics on vehicle miles of travel in establishing future national transportation policies. In late 1977, recognizing the need for a uniform method of calculating estimations of vehicle miles of travel, the Georgia Department of Transportation contracted with the Federal Highway Administration to test the draft procedural manual, Guide to Urban Traffic Volume Counting. This paper outlines Georgia's testing procedures and presents a comparison between procedures in the Guide and the current method of calculating vehicle miles of travel. Statistical tests are reported, and the advantages and disadvantages of each methodology are evaluated.

This paper presents the approach taken by the Georgia Department of Transportation (GDOT) in evaluating the procedures described in the Guide to Urban Traffic Volume Counting, which outlines a methodology for estimating vehicle miles of travel. GDOT has for a number of years provided a statewide estimate of vehicle miles of travel. This statistic is based on traffic information collected by Georgia's coverage count program. In GDOT's testing of the procedures, data were collected as prescribed and were then compared with the data collected in the coverage count program.

This paper covers the experience gained in the project and recommends procedural modifications based on this experience (since the basis of the research is the determination of vehicle miles of travel, no SI equivalents are given except in certain general references to distance).

BACKGROUND

In Georgia, traffic data collection and reporting are primarily the responsibility of GDOT. This applies to both rural and urban areas. However, some local governments do collect a limited amount of data, primarily for traffic engineering applications and to supplement annual traffic data provided to them by the coverage count program of GDOT.

GDOT currently operates 61 continuous-count and 96 seasonal-control stations throughout the state that provide trends and factors used in expanding 24-h coverage counts to estimates of average daily traffic.

Figure 1. Map of study area.

Approximately 25 000 of these 24-h coverage counts are collected annually on all highways classed functionally above the local system. In addition, a random 5 percent sample of local county roads and city streets is obtained in counties scheduled for reinventory of physical road characteristics. Vehicle miles of travel are estimated for each county and urban area and then totaled to provide a statewide estimate.

URBAN STUDY AREA

Selection

All major Georgia cities were considered for the testing of this procedure; by a subjective process, Savannah was selected. The following considerations were used in this process:

1. Coordination with local planning agencies,
2. Availability of historical traffic data,
3. Availability of up-to-date inventory data on road characteristics,
4. Availability of current functional classification information on the city street network, and
5. Availability of a current and adequately detailed set of base maps.

The data available from GDOT and the Chatham County-Savannah Metro Planning Commission were sufficient for conducting the study. More current information was available for the Savannah area than for any other areas of comparable size in Georgia.

Description

Planning data for the Savannah urban area are assembled according to "planning districts". There are 12 districts in the surrounding county and 1 district that includes the incorporated city limits of Savannah. These districts encompass the planning commission's geographical area of responsibility.

The research guidelines recommend using a minimum of geographic subareas. A compromise was reached by aggregating the planning districts into eight subareas that did not violate the boundaries of the local planning districts or reflect any significant differences in potential traffic patterns (see Figure 1).

Savannah is not a typical city inasmuch as there are distinct areas of land use that generate different types of traffic. Some examples of the ways in which these diverse travel patterns are generated that were considered in subdividing the study area are as follows:

1. The suburb of Savannah Beach generates a significant amount of seasonal tourist traffic.
2. The metropolitan area adjacent to the Savannah River, one of the larger coastal ports in the southeastern region, generates a substantial amount of long-range, freight-hauling truck traffic. The area is a major overland distribution center.
3. The suburban area to the northwest is almost exclusively a heavy industrial district that generates freight movement and work-related trips.
4. The northern portion of the incorporated city contains many historical landmarks that generate tourist traffic and the central business district (CBD), which generates shopping and work-related trips. This portion of the incorporated city is bordered on the south by Victory Drive, a major east-west arterial.
5. The southern and southeastern portions of the area are primarily marshland, but they contain an expanding residential district.

DEFINITION OF STREET NETWORK

Base Maps

The base maps provided by the Chatham County-Savannah Metro Planning Commission were up to date and detailed. GDOT personnel had recently completed a physical inventory of the street network in the area. With these two sources of data, the street network could be defined.

Road Definition

The definition of a public road as outlined in the Georgia Transportation Code was applied to this research in identifying the street network. This definition concurs with that used by the Federal Highway Administration (FHWA). By identifying the public road network, private facilities were eliminated. Consideration was given to those private facilities that are open to public use; however, because they can be closed to the public at the discretion of the owner, they were not included in the street network in this research. The various definitions of road type that were used (with the exception of private roads) are given in the following table:

Road Type	Definition
State route	All routes designated on the state highway system by resolution of the GDOT Transportation Board
County road	All roads designated by the county to be on the county road system
Public road	Any new road in a county that has not been declared a county road by the county
City street	All routes inside incorporated areas that are not designated as state routes or county or private roads
Access road	Roads (maintained by the state) primarily located parallel to Interstate roads that provide local access to other roads
Private road	Roads that can be closed to the public at the discretion of the owner

Functional Classification

The approved functional classification system, which was developed in cooperation with local governmental agencies, GDOT, and FHWA, was used for this project. Each facility was classified as a freeway, arterial, collector, or local street.

Link Definition

A link was defined primarily as a section of road that represents a homogeneous traffic volume. The secondary consideration was that the length of the link be uniform within each functional classification. An effort was made to conform to the allowable variations in link lengths set forth in the FHWA Guide.

The following guidelines were used in assigning links throughout the street network of the study area:

1. Freeways are primarily divided at interchanges or where full control of access is terminated.
2. Arterials and collectors are divided at major intersections that affect traffic flow within a 0.62-km (1-mile) distance; otherwise, they are divided at minor intersections.
3. Arterials and collectors are divided at lane transitions; e.g., a link node is placed at a location where a facility marks the end of a two-lane section and the beginning of a four-lane section.
4. Locals are divided at intersecting streets and at major changes in type of surface.
5. All streets are divided at locations where significant changes in traffic flow occur and in a manner to conform to the recommended link lengths prescribed in the FHWA Guide.
6. Half nodes are used where intersecting streets do not define link nodes—i.e., to prevent more link breaks than necessary on streets with homogeneous volumes.
7. One-way loops around city parks are treated as a part of the link on major approaching streets.
8. Divided streets with a median are considered to be one link.

NETWORK ASSIGNMENT

Historic Traffic Data

GDOT's coverage count program is primarily focused on the state highway system and on selected major off-state-system streets. In the Chatham County-Savannah area, the entire freeway and arterial system, a majority of the collector systems, and approximately 5 percent of the local road system are counted annually.

Each street was stratified by volume according to its functional classification. The traffic volume data used for stratification were obtained in the last quarter of 1976. Since historic traffic data were available for freeway, arterial, and collector systems, stratified random sampling methods could be used in determining the sample size for these groups. For collector streets where no previous traffic volumes were available, the mean lane capacities suggested in the FHWA Guide were used for volume stratification. Simple random sampling methods were used for the local system because of the lack of available historic data.

Link Numbering Scheme

The numbering scheme for link identification (ID) identifies the geographic subarea, facility type, volume stratum, specific location, and mileage of each link in the study network. Numeric codes are used to identify facility type and selected ranges of traffic volume for each functional classification. Because of the length of these code numbers, a decision was made to use a smaller 5-digit number, referred to as the "map link ID". The map link ID was used on the base maps and incorporates the geographical area number in the leftmost digit, and the remaining 4 digits are the unique link digits from the 10-digit number. A table of equivalence was then developed to include the link ID, map link ID, the "traffic section ID number" used by GDOT in its coverage count program, and available 1976 annual average daily traffic volumes.

A file containing the link network data was compiled on a computer. The file was then sorted by geographic area, functional classification, and traffic volume. Summaries of the link file were developed and aggregated into 32 subpopulations.

ESTIMATION OF SAMPLE SIZE

The calculations of sample size outlined here use the standard probability sampling theory described in the FHWA Guide. Reliance on the proper identification of links and their summaries was necessary for the application of these techniques.

In identifying methods of sample selection, the cost and accuracy of field use of such methods were assessed. Statistical parameters were selected to allow a 68 percent confidence level with desired ranges for relative error.

Two basic techniques were used in determining the sample size for each subpopulation. Simple random sampling was used for the collector and arterial systems. Stratified random sampling was considered for the freeway system but, because of the small number of freeway links, a 100 percent sampling was done. The sample calculations resulted in mileages that were converted to links by dividing the average link lengths for each subpopulation.

Simple Random Sampling

Because of a relatively large group population and an inability to further stratify local links by traffic volume (caused by the lack of historical data), a simple random sampling technique was used for determining sample size for the local street system. Accounting for a finite population correction factor, the following formula was used to determine the sample size for each geographic area from which to collect local traffic data:

$$n = Z^2(C_s^2 + C_t^2)/[e^2 + (C_s^2/N)Z^2] \quad (1)$$

where

- n = sample size, i.e., number of miles (to the hundredth) of roadway to count;
- Z = normal variate = 1.0 for 68 percent confidence level and 2.0 for 95 percent confidence;
- C_s = spatial coefficient of variation;
- C_t = temporal coefficient of variation;
- e = relative error = $E/\bar{x}$, where E = absolute error in mean vehicle miles per mile and $\bar{x}$ = mean vehicle miles of travel per mile; and
- N = number of miles in a road class, i.e., local street mileage for a given geographic subarea.

In maintaining a 68 percent confidence level, a normal variate of 1.0 and a relative error of 15 percent were assumed. Through a review of a case study conducted in Tulsa, Oklahoma, and other sources, values of 60 percent for the spatial coefficient of variation and 30 percent for the temporal coefficient were chosen. These parameters were held constant while the value of N was variable. As given in the summary Table 1, 124.93 miles of the local system were selected for sampling from a total system mileage of 645.12. Table 2 illustrates the sample selection computations made for the local network described above by using Equation 1, where Z = 1.0, C_s = 0.60, C_t = 0.30, and e = 0.15.

Table 1. Summary of sampled links and mileages.

System	Links Total	Links Sampled	Mileage Total	Mileage Sampled
Freeway	30	30	48.12	48.12
Arterial	355	129	175.16	77.96
Collector	218	107	113.68	65.03
Local	2006	665	645.12	124.93
Total	3609	931	982.08	316.04

Stratified Random Sampling

Since historic traffic data were available for the arterial and collector systems, stratified random sampling was used for these groups. These data allowed the links to be further grouped into volume strata, which permitted narrower strata, lower variance, and hence lower sample size. Again, the finite population correction factor was considered as the following formula was used for computing sample size for each subpopulation within these systems:

$$n = \Sigma(W_h S_h)^2/[(E^2/Z^2) + (1/N)(\Sigma W_h S_h^2)] \quad (2)$$

where

- W_h = weight of stratum h;
- S_h = composite standard deviation of vehicle miles per mile in stratum h = $\sqrt{S_s^2 + S_t^2}$, where S_s^2 = spatial variance and S_t^2 = temporal variance;
- E = absolute error in average vehicle miles per mile = relative error x (total vehicle miles ÷ total miles of roadway);
- Z = normal variate; and
- N = total miles of streets.

In maintaining a 68 percent confidence level, a normal variate of 1.0 and a relative error of 5 percent were used for both arterial and collector systems. E was computed for geographic subareas by multiplying the 1976 average annual daily traffic (AADT) for an area by the relative error e.

The spatial standard deviation S_s was assumed to be 30 percent of the range of each volume stratum. The temporal standard deviation S_t was computed from the product of the mean strata volume and the temporal coefficient of variation C_t. The suggested C_t values listed in the FHWA Guide were applied to the appropriate strata for this study.

Once the required mileage was computed for each stratum, the required links were determined by dividing the average strata link mileage into the sampled mileage. Table 3 gives an example of the procedure for stratified random sampling computation for arterials and collectors in one area by using Equation 2, where Z = 1 and E = 0.05.

One-Hundred Percent Sampling

Consideration was given to using the stratified random

Table 2. Sample-size computations by simple random sampling.

Area	N	Links	Miles Per Link	N Miles	N Links	Equivalent Percentage of Sample	Numeric Range Beginning Number	Numeric Range Ending Number
Areawide	645.12	3006	0.215	19.52	91	-[a]	-[a]	-[a]
1	161.20	800	0.202	18.19	90	11.25	249	1048
2	118.62	657	0.181	17.62	98	14.92	1124	1780
3	89.55	408	0.219	16.97	77	18.87	1827	2234
4	26.50	106	0.250	12.47	50	47.17	2249	2354
5	94.02	440	0.214	17.09	80	18.18	2423	2862
6	39.07	163	0.240	14.19	59	36.20	2909	3071
7	66.33	189	0.351	16.11	46	24.34	3114	3302
8	49.83	243	0.205	15.14	74	30.45	3367	3609
Total	645.12	3006	0.215	147.30	665	22.12		

[a] Use sample computations by area.

Table 3. Sample-size computations for area 1 by stratified random sampling.

Volume Range (vehicles/ day)	Mean Volume (vehicles/ day)	N_h	W_h	No. of Links	C_t	S_t	S_s	S_h	W_hS_h	$W_hS_h^2$ × 10^3	Links in Sample
Arterials											
0-5000	2 500	6.59	0.144	27	0.20	500	1500	1581	227.56	360	7
5000-10 000	7 500	22.29	0.487	86	0.14	1050	1500	1831	891.70	1633	23
10 000-15 000	12 500	9.81	0.214	32	0.12	1500	1500	2121	453.89	963	10
15 000-20 000	17 500	2.48	0.054	11	0.10	1750	1500	2305	124.47	287	3
20 000-35 000	27 500	4.61	0.101	14	0.09	2475	4500	5136	518.74	2664	5
Total[a]		45.78	1.000	170					2216.36	5907	48
Collectors											
0-2500	1 250	6.84	0.404	35	0.20	250	750	791	319.96	253	12
2500-5000	3 750	3.27	0.193	13	0.14	525	750	915	176.94	162	6
5000-7500	6 250	4.00	0.237	14	0.12	750	750	1061	250.98	266	7
7500-10 000	8 750	2.03	0.120	9	0.10	875	750	1152	138.30	159	4
10 000-20 000	15 000	0.77	0.046	2	0.09	1350	3000	3290	149.81	493	1
Total[b]		16.91	1.000	73					1035.99	1333	30

[a] Average miles per link = 0.269, average daily traffic = 10 110, absolute error E = 506, and miles in sample = 12.758.
[b] Average miles per link = 0.232, average daily traffic = 5539, absolute error E = 277, and miles in sample = 6.898.

sampling technique for the freeway system in determining sample size, but a review of the link summaries, which revealed a small number of links per stratum, made the applicability of this methodology questionable. To maintain a recommended minimum sample size and the desired statistical reliability, a decision was made to sample 100 percent of this system.

SAMPLE SELECTION

Once the sample size for each subpopulation was determined, count locations were selected by using a computer program that generated random numbers. Each subpopulation represented a universe. The computer program was then given the varying number of samples desired. Randomly selected samples were identified, and a file of these records was created.

The data collection phase of the study covered 261 weekdays over a 12-month period. By using another computer program, a series of randomly generated numbers between 1 and 261 were selected to equal the total number of samples for each subpopulation. These numbers were then added to the selected sample file in order of their selection. Except for only minor modifications, this method of using random spatial and temporal selection of counting stations followed the statistical theories presented in the FHWA Guide. This obviated the necessity to factor the results obtained from the count stations.

DATA COLLECTION

The actual collection of sample traffic data began the week of December 15, 1977. Nondirectional hourly counts over a 24-h period within each selected link constituted a sample unit.

The collection of field data was assigned as an additional duty to an area traffic recorder. In most cases in this study, the traffic counters were set out on a weekly basis and hourly recorders were used. The sample day required was then obtained from an hourly paper-tape printout. The area recorder is assigned on a permanent basis to an area that includes the Chatham County-Savannah area; using these personnel therefore seemed to be the only satisfactory solution. A review of the work schedule indicated that fewer than 30 machines would be required for any given week and that this could easily be managed for a one-year period. Because of the spatial randomness of the samples, there was a wide dispersement throughout the area on an average setout and pickup schedule. The required travel for each schedule often exceeded 200 miles.

Prior to the assignment, the area recorder was instructed on how the machines were to be set and was provided with the following information:

1. A calendar schedule that indicated the actual calendar date, the weekday number (1 to 261), and the number of sets required on any given day;
2. A computer printout of selected samples that indicated the day to count, the exact location description, the weekday to count, and the proper area map to use;
3. A set of area maps that showed each selected sample on the appropriate map and each link number; and
4. An operation schedule that indicated the number of sets and pickups for each day during the project.

With this information, the area recorder was able to satisfactorily and expeditiously perform the assigned task. However, there were a greater number of machine failures than anticipated. These were attributed to several local situations that existed in the area at the time of the project but were in no way related to the project. During this time, there was an upheaval in property assessments for tax purposes, and annexation of unincorporated areas of Chatham County into Savannah was being considered. This situation resulted in acts of vandalism that were intended to abort counting activity on a given street. When residents adjacent to count sites were informed of the purpose of the traffic data, resets were usually obtained. It was decided that resets would be made the week after the occurrence of a failure, which worked very satisfactorily.

In addition to this method of collecting data, an alternate method was used in which the data collected from the annual coverage count program were used in estimating vehicle miles of travel (VMT). These traffic data are collected annually for 24-h periods and factored to account for temporal variations. A 5 percent random sample based on the number of local county roads and city streets were counted to estimate local VMT as in previous estimations.

DATA ANALYSIS

Once link volumes were obtained from selected sample locations throughout the study area, computations of VMT were made. The variability in VMT was then determined by first computing the data variance by each subpopulation and then the standard deviation from the mean VMT. This procedure is discussed in detail below.

Estimation of Vehicle Miles of Travel

The first step in calculating VMT was to simply multiply the 24-h traffic volume by corresponding link length. This was done for each sampled link in a given stratum by using the following formula:

$$vmt_{hj} = ADT \times l_{hj} \qquad (3)$$

where

vmt_{hj} = vehicle miles of travel for sample link j in stratum h,
ADT = average daily traffic, and
l_{hj} = sample link mileage in stratum h for sample j.

Since only a sample of the link network was counted, the VMT computed for these samples must be expanded to represent total VMT for a given stratum. In order to make this expansion, the rate of VMT per mile was determined by stratum by using the sample population. This rate was determined by using the following equation:

$$R_h = (\Sigma vmt_{hj}/\Sigma l_{hj}) = (vmt_h/l_h) \qquad (4)$$

where

R_h = rate of VMT per mile for stratum h;
vmt_h = total sample VMT in stratum h, and
l_h = total mileage of the links sampled in stratum h.

Once this rate was established, total VMT for a given stratum was obtained by using the expansion equation

$$VMT_h = R_h \times L_h \qquad (5)$$

where VMT_h = total VMT for stratum h and L_h = total link mileage in stratum h.

Variability

To evaluate the estimates generated by this project, some statistical measure must be developed. Since the measurements outlined in the FHWA Guide assumed uniform link length, the prescribed evaluation was not applicable to this effort. Thus, the standard procedure for obtaining variance and standard deviation was applied.

The variance of mean VMT per mile for each stratum was first obtained by using the following formula:

$$S_h^2 = \Sigma(ADT_{hj} - \overline{VMT}_h)^2/(n - 1) \qquad (6)$$

where

S_h^2 = variance of VMT per mile in stratum h,
$\overline{ADT}_{hj}$ = average daily traffic of link j in stratum h,
$\overline{VMT}_h$ = mean VMT per mile in stratum h (i.e., the weighted average ADT for stratum h), and
n = total samples in stratum h.

The overall variance by highway functional classification was then computed by using

$$S_c^2 = (\overline{VMT}_{hc} - \overline{VMT}_c)^2/N_c \qquad (7)$$

where

S_c^2 = variance of VMT per mile of functional classification c,
$\overline{VMT}_{hc}$ = mean VMT per mile in stratum h that falls in functional classification c,
$\overline{VMT}_c$ = mean VMT per mile in functional classification c (i.e., the mean of the h strata containing functional classification c), and
N_c = number of strata that contain functional classification c.

The variance for the entire study area can be computed similarly; however, because of the wide dispersion in VMT rates by functional classification (such as the rate for a local road compared with an Interstate rate), this statistic was considered to be insignificant.

The coefficient of variation was then computed for each stratum and for each functional classification by

$$C = S/R \qquad (8)$$

where

C = coefficient of variation,
S = $\sqrt{S^2}$ = standard deviation of the mean VMT rate per mile, and
R = mean VMT rate per mile.

STUDY RESULTS AND COMPARISONS

Estimations of VMT were computed for each of the eight geographic subareas previously defined and for four highway functional classifications in each subarea. Since three of these subareas did not contain any freeway links, a total of 29 subtotals were obtained. A sample of the VMT computations, which follows the procedure previously outlined, is given below (ADT based on a 5 percent sample):

Strata	Number of Samples	Total Sample Mileage	Total Sample VMT	VMT Rate per Mile		Total Mileage		Expanded VMT
23	15	6.96	42 841.04	6155.32	x	13.11	=	80 696.25

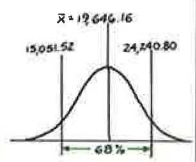
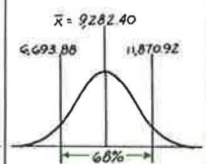
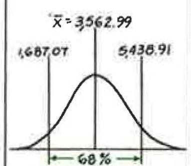
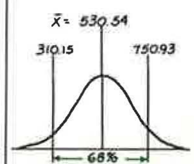
This method, which uses Equations 3, 4, and 5, was followed for expanding VMT for each stratification throughout the study area.

The geographic stratification was made in order to provide local planners with the ability to assess relative travel and make VMT comparisons within their area of responsibility. For the purpose of this research evaluation, VMT estimations were compiled by functional classification, as given below:

Functional Classification	Total Mileage	Total VMT
Freeways	48.12	846 170.28
Arterials	175.16	1 739 944.93
Collectors	113.68	392 031.93
Locals	645.12	376 284.53
Total	982.08	3 354 431.67

A comparison of the total VMT estimation with the VMT estimation produced annually through Georgia's coverage counting program was made (for city street

Figure 2. Variability of estimates of vehicle miles of travel.

	Freeways	Arterials	Collectors	Locals
Mean VMT: $\overline{VMT}_{(fc)} = \frac{\overline{VMT}_{h(fc)}}{n_{(fc)}}$	19,646.16	9,282.40	3,562.99	530.54
Variance: $s^2_{(fc)} = \frac{\overline{VMT}_{h(fc)} - \overline{VMT}^2_{(fc)}}{n_{(fc)}}$	21,110,718.00	6,700,447.60	3,519,079.88	48,573.17
Standard Deviation: $s_{(fc)} = s^2_{(fc)}$	4,594.64	2,588.52	1,875.92	220.39
Coefficient of Variation: $c_{(fc)} = \frac{s_{(fc)}}{\overline{VMT}_{(fc)}}$	0.234	0.279	0.527	0.415
Distribution Curve:				

and county road estimates, ADT was based on a 5 percent sample):

Route Designation	Miles	VMT Rate (mean ADT)	Total VMT
State routes			
Savannah urban area	66.66	15 243	1 016 098
Chatham County	91.77	10 151	931 557
Estimated	16.38	12 293	201 366
City streets			
Savannah urban area	100.13	7 976	798 603
Chatham County	1.76	510	899
Estimated	309.47	317	98 102
County roads			
Chatham County	33.17	2 099	69 619
Estimated	395.89	317	125 497
Total	982.08		3 241 740

As noted, the research methodology produced a daily total VMT of 3 354 431 compared with 3 241 740 produced by Georgia's current methodology—a difference of only 3.48 percent.

A comparison was also made between these two methodologies in the cost of field data collection:

Item	Amount ($)
Research methodology	
Salary (54.9 days at $45.39/day)	2491.67
Benefits (at 37.05 percent)	923.17
Subsistence	0
Vehicle use (4888 miles at $0.094/mile)	459.47
Total	3874.31
Coverage count methodology	
Salary (22 days at $45.39/day)	998.58
Benefits (at 37.05 percent)	369.97
Subsistence (15 days at $22.00/day)	330.00
Vehicle use (1392 miles at $0.094/mile)	130.85
Total	1829.40

In summary, the research methodology cost 111.78 percent more than Georgia's conventional method and yielded only a 3.48 percent difference in the VMT estimation.

VARIABILITY OF ESTIMATIONS OF VMT

Once the computations were made for each stratum, the variance from the mean VMT per mile for the corresponding stratum was obtained by using Equation 6. To maintain consistency with the VMT tabulations, variance was computed by functional classification. This was accomplished by using Equation 7 to compute the variance of the mean VMT rate per mile by functional classification. A standard deviation for the estimate by road class was then obtained by simply taking square root of the variance.

The variability of VMT estimations could then be computed by finding the coefficient of variation by using Equation 8. These computations and numeric distributions for each functional classification are shown in Figure 2.

CONCLUSIONS

The once obscure statistic, vehicle miles of travel, required annually by the Statistical Division of FHWA, has in recent years become very important information. With the U.S. Department of Energy and the Environmental Protection Agency now requiring VMT estimates in their planning and policy evaluation process, VMT estimates have assumed new significance. In the past, many methods and combinations of methods have been used to calculate this statistic. Recent survey documentations indicate a wide range in methodologies for calculating VMT and in the variance of the data provided.

This approach of sampling links in various strata selected randomly to account for spatial and temporal variations provides a uniform systematic method for computing VMT. The idea of a uniform method is a positive approach to resolving a problem that will increase in magnitude as programs become more dependent on the VMT statistic.

As shown by the comparisons presented in this paper, the temporal variation can be addressed in a less costly manner than that outlined in the FHWA Guide with only a minor variation in results. Factors of temporal variation are readily available from continuous-count and seasonal-control programs that are currently maintained in most states. This study does, however, point out the desirability of using counting locations that are randomly selected by functional classification to allow for spatial variation in computing VMT.

In summary, the use of current counting programs combined with this research methodology could yield a better procedure for estimating VMT to provide consistent reporting in the future.

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Travel Data from the U.S. Census: A New Foundation for Transportation Planning

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The 1980 U.S. Census of Population and Housing will include the largest source of urban transportation data ever available for a single point in time. To properly use these data requires that planners understand the difference between census definitions and those commonly used in transportation. This paper describes those differences as well as the data that will not be included in the census. It recommends methods of local data collection that can supplement the census data to complete the measurement of total travel. Finally, it proposes a method of keeping the census commuting data up to date without extensive inventory data for 1980. The method is suitable for small urban areas as well as large metropolitan regions.

Plans for the 20th decennial census of the United States are virtually complete. Since the 1970 census, there have been drastic changes in the nature of transportation planning. At the same time, almost no new data on areawide travel patterns have been collected through regional transportation studies. This makes it essential for those interested in obtaining current travel information to learn about possible applications of census data as well as supplemental data needed to fill in the picture of total travel. Now is the time to plan for the supplemental data that must be collected by state, county, and municipal transportation agencies to get the maximum value from the 1980 census.

This paper identifies additional data needed to measure commuting in terms that are useful to transportation planners as well as appropriate measures of nonwork travel. Perhaps even more importantly, it proposes a means of keeping the commuting data up to date so that the 1990 census could be used to verify such information rather than being used as the sole source.

SUPPLEMENTAL DATA ON COMMUTING

As described elsewhere (1), the journey-to-work data included in the 1980 U.S. Census of Housing and Population will include work destination, "usual" means of travel, and average travel time. Although this information, if properly collected and coded, will provide an excellent means of estimating overall commuting patterns within an urbanized area, it leaves some significant gaps in comparison with data that are commonly available through travel surveys. Trip frequency and work schedules are believed to be essential items for all urban areas if census commuting data are to be used properly. The other items described should probably be considered only for large urban areas.

1. Trip frequency—The 1980 census plans to ask about the usual means of travel used in the preceding week. Transportation planners generally use an average-day definition. Although work-trip generation rates have been relatively stable in the past, it would be very valuable to verify these rates for 1980, especially with increasing opportunities for four-day weeks and part-time employment.
2. Work schedules—An understanding of work schedules is critical to factoring average daily work trips to estimates of peak-hour utilization. Although the per-