Traffic Estimating Procedures for the Local Functional System

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SUMMARY

The provision of guidance to the States concerning effective methods of collecting traffic data and the reporting of this data to public and private groups have been significant components of the FHWA's highway data mission for over 25 years. At present the FHWA's primary source of traffic data is the Highway Performance Monitoring System (HPMS). The HPMS is annually updated with information supplied by each of the states on the traffic activity on each of 12 functionally classified highway systems. On all except the Rural Minor Collector, Rural Local and Urban Local highway systems, the reporting of traffic data to the HPMS is supported by detailed instructions related to the selection of highway locations to be sampled, the times during the year in which sampling should occur, the duration of the monitoring session at the selected locations, and methods of adjusting the collected data to typify average conditions for the year.

In contrast to the procedures for the other nine functional systems, the development of procedures for collecting data on travel on Rural Minor Collector, Rural Local and Urban Local systems is left to each State.

Current issues related to allocating Federal highway funding on the basis of total highway travel as well as the interest in determining travel in urbanized areas as part of the implementation of the Clean Air Act Amendments of 1990 have created the need to develop procedures that can be applied by all State agencies and local governments in their reporting of Local system travel to the HPMS.

The purpose of the present study is to identify and to develop cost-effective procedures for improving the statistical accuracy of VMT estimates developed by State, county and metropolitan traffic data collection agencies for the local functional systems. These procedures should be appropriate for developing statewide estimates of VMT on local rural roads and local urban streets.

Methodology

Under the first part of the study, the Volpe National Transportation Systems Center's (VNTSC) Center for Transportation Information (CTI) considered a variety of monitoring approaches applicable to the estimation of local DVMT. These approaches spanned both conventional traffic counting procedures such as vehicle counts on local roads and unconventional approaches such as a sample of drivers' logs, driver interviews, the use of time series aerial or satellite photos of traffic density, other photographic techniques, and development of a functional relationship of local travel with the intensity of land use development, and with total VMT, and the development of travel-density ratios.

An annotated bibliography was prepared based on a literature search to determine previous methods used in the U.S. or other countries to estimate travel on local roads. This search included methods used to estimate travel on all roads from which travel for other functional systems could be subtracted to estimate local travel. The focus of the search was broad enough to include travel estimates for both State level and metropolitan areas.

"Experts" in the estimation of local travel were identified, and interviewed in order to document their views on the estimation of local travel. This included documenting methods they have used or are aware of that allow estimation of local travel. The interviews also included the experts' critique of the procedures, identifying the procedure's limitations and those elements of the procedure that would most benefit from additional rigor.

Each of the procedures were evaluated to determine the statistical validity of the approach, the problems associated with its national implementation, and the cost of implementation at the national and State

levels. **As a result of this process, no procedure was identified which would be superior to a count-based procedure.**

Assuming the use of a count-based procedure, the key parameters associated with such a program were examined including: sampling procedure; the use of a fixed vs. variable sample frame over time; stratification; precision level; count frequency; count duration; and the need for axle correction factors, and seasonal and day of week adjustment factors. Choices were made from the alternatives available under each parameter which served to define the count based program.

Analyses were performed for urbanized areas with population greater than 200,000, for statewide rural local roads, and for statewide urban local roads.

The example estimates assumed that all local roads could be divided into segments of uniform length and that traffic counts would be taken on a random sample of these segments. In practice, variable section lengths could be used without significantly altering the results of the recommended procedure. The sample was assumed to be distributed randomly over space and over time of year. A fixed sample frame was also assumed. All counts were assumed to be of 24 hour duration. An annual count frequency was assumed, and all counts were assumed to provide vehicle counts, as opposed to axle counts.

Rural local road segment sizes were assumed as: 0.3 mile - minimum; 1 mile - middle; and 10 miles maximum. Urban local road segment sizes were assumed as: 0.1 mile - minimum; 0.5 mile - middle; and 3 miles - maximum. Estimates were prepared assuming both stratified and unstratified samples, as the available data permitted. Stratification was on the basis of the AADT volume groups used in Highway Statistics for urban local roads, and for rural local roads.

For the first part of the analysis, sample size requirements (number of traffic counts) were estimated for precision levels of 90-15, 90-10, 90-05, 95-02, and 80-10.

For the second part of the analysis the precision possible for 95%, 90%, and 80% confidence levels were estimated assuming sampling rates of 10%, 5%, 2%, and 1% from the population of assumed road segments.

Data on local functional system mileage (rural, small urban, and urbanized areas with population greater than 50,000) by volume group, by state and for urbanized areas with population greater than 200,000 was taken directly from Highway Statistics 1990.

For urbanized areas with population greater than 200,000, "local" milage indicated in Highway Statistics was distributed by volume group utilizing the volume group distribution for urbanized areas with population greater than 50,000 for the state containing the urbanized area (or most of the urbanized area).

Existing local roads AADT data files from Georgia, Kansas, and Virginia were used to determine the coefficient of variation of AADT for local rural and urban roads by volume group.

Estimates of the level of monitoring needed to reach the following precision levels were made:

90-15 Rural Statewide and 90-15 Urban Statewide
90-10 Rural Statewide and 90-10 Urban Statewide
90-05 Rural Statewide and 90-05 Urban Statewide
95-02 Rural Statewide and 95-02 Urban Statewide
80-10 Rural Statewide and 80-10 Urban Statewide
90-15 for each Urbanized Area with population > 200,000
90-10 for each Urbanized Area with population > 200,000
95-05 for each Urbanized Area with population > 200,000
95-02 for each Urbanized Area with population > 200,000
80-10 for each Urbanized Area with population > 200,000

The results for the first part of this analysis clearly illustrated the value of stratification by volume group. If the variance of the quantity to be estimated (e.g., traffic volume) is appreciably lower within the individual strata than across strata, then stratification will permit an appreciable reduction in the total size of the sample required to estimate the overall value of the quantity with a given level of precision.[1]

For example, for a 90-10 precision estimate sample size requirements drop from about 2640 (unstratified) to about 130 (stratified). Moreover, they indicate that while the number of counts required to achieve a 95-02 precision level at the state level may be considered excessive (about 4,730 per year), the number of counts required to achieve estimates with a 90% confidence appear reasonable (about 530 per year at the 90-05 precision level).

The cost associated with the data gathering effort in an example State was estimated. This cost estimate was on an annual basis using 1991 dollars, including one time as well as recurring expenses. This cost was determined as the product of the number of counts and an average cost per count. (The development of this average cost per count is described in section 3.1.) The result was the annual cost of each of the portable count program.

The average cost per count is difficult to estimate due to different procedures and equipment that are used. States use a variety of equipment and procedures to generate traffic counts on their highway systems. Some of the most common types of equipment and procedures that are currently being used are described in APPENDIX C.

Recommended Procedure

On this basis, a procedure for estimating DVMT for rural local roads, and for urban local roads is recommended as follows (Each State must sample urbanized areas with a population equal to or greater than 200,000, and urbanized areas that are a part of an NAAQS nonattainment area, regardless of population size, as individual areas. Both rural and small urban area data will be sampled on a statewide basis.):

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[1] Stratifying local road sections on the basis of their traffic volume clearly will produce strata which have relatively low variances in traffic volume. However, this form of stratification poses a potential problem, that of obtaining the traffic-volume estimates required to perform the stratification.

1) - Divide the local road mileage in each state's volume group strata into segments of appropriate size and number, and assign each segment a sequential number;

2) - Estimate sample size requirements by volume group strata to achieve a 90-05 precision level at the volume group level using the equation of section 2.

3) - Select segments to be monitored using a table of random numbers or computer based random number generator to select a random sample of monitoring locations over space (as an alternative, every nth segment could be selected where n is the total number of segments divided by the required sample size);

4) - Select a monitoring schedule by assigning a number to each day of the year from 1 to 365 (or less, if counts can not be taken in certain seasons due to weather conditions), and select specific days using a table of random numbers or computer based random number generator to select a random sample over time, and assign sample locations to sample days for each strata (if counts can not be distributed randomly over time in practice, due to staff assignments and working schedules, then the use of available seasonal adjustment factors would be required);

5) - Perform counts for a 24 hour period on an annual basis (See section 2.1.4 for the justification of use of a 24 hour counting period);

6) - Determine "AADT" for each strata as the average of that year's 24 hour counts for that strata (This assumes that all segments in a strata are of equal length as in the example. In practice if variable length segments are used "AADT" for each strata would be determined as the weighted (on the basis of segment lengths) average of that year's 24 hour counts for that strata.);

7) - Calculate DVMT of each strata as AADT of strata x total miles per strata;

8) - Sum the appropriate strata DVMT to determine rural local or urban local DVMT for the state.

Test Results of Recommended Approach

An attempt was made to test the proposed approach utilizing actual data, and matching the resulting VMT estimates against a known figure. However this process was hindered by a scarcity of actual local roads data, and the lack of "true" VMT figures. While the results of the test are encouraging, they must be considered inconclusive, since we do not know whether or not our bench mark VMT figure is correct.

The only data available for a test of the procedure was a file of urban local roads for the state of Kansas. The VMT estimates produced from this data were compared against the information reported for Kansas in Highway Statistics which is based on state HPMS data submittals.

An attempt was made to determine "actual" DVMT from the Kansas urban local roads data file. The sample mileage of the data file accounts for about 9.5% of the total mileage.

Calculated AVMT was 1,565,000,000 vs. the published figure of 1,721,000,000. The actual data results in a VMT estimate which is about 9% less than the published figure. This may be reasonable in that the published figure is presumably based on 1990 data, while the sample data file includes data for 1988, 1989, 1990, and 1991.

AVMT was calculated, based on the recommended procedure, and using a sample from the same data base, as 1,468,000,000. This was within 6% of the "actual" AVMT as calculated previously, and 15% less than the published figure.[2]

CONCLUSIONS AND RECOMMENDATIONS

The conclusions of this study of traffic estimating procedures for use on the local functional system are:

- There is no better approach to estimating traffic on local roads currently in use, or in theory than that of traffic counting.
- There are very limited amounts of actual traffic data for the local road system.
- Based on the limited data available, it appears that it is possible to get reasonably good estimates of traffic on the local road system, without the need for excessively large sample sizes.
- The sampling based approach to estimating DVMT proposed provides reasonably good estimates, when compared to available bench mark data. However, the bench mark data itself is of unknown origin and quality, and should not be taken as the "real" number.

The recommendations of this study are:

- **FHWA should adopt a count-based approach to estimating traffic on the local road system for use by the states and Metropolitan Planning Organizations.** This will make such estimates consistent with the rest of the functional highway classes now covered by HPMS, and with EPA's VMT tacking and forecasting guidance. Moreover, it would introduce a degree of consistency in the estimates produced by individual states which is not now present.
- **FHWA should initiate a pilot program in a number of selected states in order to refine the proposed approach, and collect data required to verify the assumptions upon which the proposed approach was based.** Such a program would serve to provide additional insight into the values of the coefficient of variation of AADT on local roads; and provide good estimates of bench-mark DVMT's in order to permit a valid check on the results of the sample-based approach.

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[2] It should be noted the example calculations, and the overall discussion of recommended approaches or procedures has assumed an ideal world of traffic counting. In fact, traffic counting is a difficult undertaking. Counts go bad, equipment fails, hoses are cut by cars, vandals steal or damage the equipment, construction crews mistake the locations, pick-up trucks break down, people get sick, weather disturbs the schedules, rain floods the roads and equipment, staff get reassigned to other priorities, etc. The processing of data is also subject to many difficulties including transcription, error correction, editing, validation, historical verification, factorization, etc. Any conclusions regarding the validity of the recommended approach should be tempered by these real world considerations. Actual costs are also greatly affected by these issues.

1.0 INTRODUCTION

1.1 Background

The Federal Highway Administration's Office of Highway Information Management (OHIM) has a broad organizational interest in tracking and measuring trends on the national highway system, including traffic volume, mix, speed and similar characteristics.

The provision of guidance to the States concerning effective methods of collecting traffic data and the reporting of this data to public and private groups have been significant components of the FHWA's highway data mission for over 25 years. At present the FHWA's primary source of traffic data is the Highway Performance Monitoring System (HPMS). The HPMS is annually updated with information supplied by each of the states on the traffic activity on each of 12 functionally classified highway systems. On all except the Rural Minor Collector, Rural Local and Urban Local highway systems, the reporting of traffic data to the HPMS is supported by detailed instructions related to the selection of highway locations to be sampled, the times during the year in which sampling should occur, the duration of the monitoring session at the selected locations, and methods of adjusting the collected data to typify average conditions for the year.

In contrast to the procedures for the other nine functional systems, the development of procedures for collecting data on travel on Rural Minor Collector, Rural Local and Urban Local systems is left to each State.

Throughout the following discussion the references to "local" systems shall be taken to mean facilities that include rural local and minor collector, and urban local functionally classified roads and streets. The traffic data item of particular interest is local Daily Vehicle Miles of Travel (DVMT) which is equivalent to the summation of all vehicle travel on such roads and streets.

The local functional systems contain about 75 percent of all road mileage, but they account for only about 16 percent of total travel. The size of these systems makes it expensive to use the same traffic-counting procedures on these systems as are used on the higher functional systems; and the relatively small amount of traffic that the local systems carry reduces the importance of accuracy in the VMT estimates produced.

Current issues related to allocating Federal highway funding on the basis of total highway travel as well as the interest in determining travel in urbanized areas as part of the implementation of the Clean Air Act Amendments of 1990 have created the need to develop procedures that can be applied by all State agencies and local governments in their reporting of local system travel to the HPMS.

This work is directed to improvement of the statistical accuracy of traffic data collected on rural minor collector and local roads in rural areas, and local roads in small urban and urbanized areas.

1.2 Study Objectives

The purpose of the present study is to identify and to develop cost-effective procedures for improving the statistical accuracy of VMT estimates developed by State, county and metropolitan traffic data collection agencies for the local functional systems. These procedures should be appropriate for developing statewide estimates of VMT on local rural roads and local urban streets.

Recent developments have increased the importance of producing accurate estimates of VMT on the local systems. There is now some interest in using total VMT (including VMT on the local systems) as one factor in the allocation of Federal highway funds to the States. And, more immediately, as a result of Section 187(a) of the Clean Air Act Amendments, starting in 1993, the Environmental Protection Agency (EPA) will require estimates of total VMT in all moderate and serious carbon-monoxide (CO) nonattainment areas,[3] and in ozone nonattainment areas. The actual EPA requirement is for VMT estimates for a "VMT Tracking Area" which approximates the nonattainment area; however, these estimates are to be derived from estimates for the corresponding urbanized area, thus allowing the use of VMT estimates being produced for FHWA. The intended use of these estimates is in estimating the effect of changes in VMT on changes in emissions of CO, hydrocarbons and nitrogen oxides. For EPA's purposes, the quantity of interest is not total VMT, but the change in VMT.

The EPA guidance explicitly requires "the use of systematic traffic ground counts"[4] (as opposed to "driver surveys, odometer data, registration counts, fuel sales, annually validated network models, etc."). However, in view of the potential cost of obtaining ground counts on the local functional systems, this requirement was not intended to extend to these systems. Relevant excerpts from the EPA guidance are included as Appendix B.

1.3 Methodology

VNTSC's Center for Transportation Information (CTI) considered a variety of monitoring approaches applicable to the estimation of local DVMT. These approaches spanned both conventional traffic counting procedures such as vehicle counts on local roads and unconventional approaches such as a sample of drivers' logs, the use of time series aerial photos of traffic density, and development of a functional relationship of local travel with the intensity of land use development.

An annotated bibliography was prepared based on a literature search to determine previous methods used in the U.S. or other countries to estimate travel on local roads. This search included methods used to estimate travel on all roads from which travel for other functional systems could be subtracted to estimate local travel. The focus of the search was broad enough to include travel estimates for both State level and metropolitan areas.

"Experts" in the estimation of local travel were identified, and interviewed in order to document their views on the estimation of local travel. This included documenting methods they have used or are aware of that allow estimation of local travel. The interviews also included the experts' critique of the procedures, identifying the procedure's limitations and those elements of the procedure that would most benefit from additional rigor.

Each of the procedures were evaluated to determine the statistical validity of the approach, the problems associated with its national implementation, and the cost of implementation at the national and State levels. As a result of this process, no procedure was identified which would be superior to a count-based procedure.

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[3] Section 187 VMT Forecasting and Tracking Guidance, Environmental Protection Agency, Washington, D.C., January 1992.

[4] Environmental Protection Agency, op.cit., p.6.

Assuming the use of a count-based procedure, estimates of the level of monitoring needed to reach the following precision levels were made:

- 90-15 Rural Statewide and 90-15 Urban Statewide
- 90-10 Rural Statewide and 90-10 Urban Statewide
- 90-05 Rural Statewide and 90-05 Urban Statewide
- 95-02 Rural Statewide and 95-02 Urban Statewide
- 80-10 Rural Statewide and 80-10 Urban Statewide
- 90-15 for each Urbanized Area with population > 200,000
- 90-10 for each Urbanized Area with population > 200,000
- 95-05 for each Urbanized Area with population > 200,000
- 95-02 for each Urbanized Area with population > 200,000
- 80-10 for each Urbanized Area with population > 200,000

As part of this effort, the frequency with which the data should be collected was determined. The potential problems associated with the implementation of each technique were identified.

The cost associated with the data gathering effort in an example State was estimated. This cost estimate was on an annual basis using 1991 dollars, including one time as well as recurring expenses. On this basis, a set of procedures to be fully developed was recommended. This procedure was then tested using available local roads data.

2.0 ESTIMATED SIZE OF A LOCAL ROADS TRAFFIC COUNTING PROGRAM

A number of key questions must be addressed in order to define a program for collecting traffic data for the local roads system. These parameters are discussed in general below. Some assumptions were made regarding the possible choices for these parameters, thus defining possible data collection programs. Sample size requirements under these alternative assumptions were estimated in an attempt to define a viable approach to a local roads data collection program. The results of this analysis are presented in the following subsection.

2.1 Some Key Parameters

2.1.1 Fixed vs. Variable Sample Frame Over Time

In order to obtain cost-effective, valid comparisons of system performance over time, and to reduce technical effort, a fixed sample is used. The same sections that are inventoried are updated in future years on a cyclical basis. This means of obtaining data is efficient because : (1) the need for the periodic drawing of a complete new sample is eliminated, (2) the need to update or reinventory all data elements for every cycle is eliminated, and (3) only those data elements that change over time need to be updated on a cyclical basis. However, the use of fixed panel sections is not without disadvantages. These include: the possible loss of the sample's representativeness as the highway networks and traffic patterns change, and the inability to assess the correctness of the estimates by comparing them with those of a different sample.[5]

Since we are assuming the use of a fixed sample panel over time, the precision level should be the same from year to year, and should also apply to the difference obtained by subtracting the estimated VMT of one year from the estimated VMT in the following year. EPA wants to measure change in VMT, and to distinguish real change from that due to sampling.

Before a sample can be drawn, the universe from which it will be selected must be defined. This is of the utmost importance because expansion factors relate directly to the universe definition. The first step is to delimit the boundaries between rural, small urban, and urbanized areas. Next, the functional system of all arterial and collector routes within each of these areas must be properly identified. Then, all road sections in each functional system must be assigned to predetermined AADT groups. The difficult part is assigning the sections to the proper volume groups, and maintaining the proper volume group entry over time, since AADT changes will take place each year, some of which will cause volume group changes.

The sections should be relatively homogeneous as to geometrics, traffic volume, cross section and condition, and should be long enough to constitute a logical section for various analyses such as needs appraisal.

The total number of road sections and total length in each volume group are also needed to determine the proper sample size necessary for each functional system. These data define the universe and will be needed for any future readjustments to the sample after adjustment to new AADT conditions.

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[5] Highway Performance Monitoring System Field Manual, Workshop Draft, Federal Highway Administration, February, 1993, p. E-1.

The development of any sample panel requires a well defined universe of roads that has been properly sectionalized to meet the needs of the sampling plan. The boundaries of any urbanized areas or small urban areas must have been established. The functional system definition of roads must be up to date. The universe of road sections and the AADT volume group definition of these sections must be accurate. Gaps in any of these areas will affect the sample. [6]

2.1.2 Stratification

It is possible to divide any universe of observations into several strata, each of which contains only observations that share some similar characteristics. If the variance of the quantity to be estimated (e.g., traffic volume) is appreciably lower within the individual strata than across strata, then stratification will permit an appreciable reduction in the total size of the sample required to estimate the overall value of the quantity with a given level of precision.

Some possible bases for stratifying sections of local road are traffic volume, or surface type.

Stratifying local road sections on the basis of their traffic volume clearly will produce strata which have relatively low variances in traffic volume. However, this form of stratification poses a potential problem, that of obtaining the traffic-volume estimates required to perform the stratification.

A more practical alternative might be for highway planners to assign all sections judgmentally to a few relatively rough volume groupings on the basis of a relatively cursory review of readily identifiable characteristics (e.g., location, type of surrounding developing, etc.). Such an approach likely would produce strata with volumes whose ranges overlap each other but whose variances are smaller than the variance for the entire universe. This lower variance results in more precise estimates for a given sample size or expenditure of effort collecting data. The benefits of stratification by volume group are illustrated in section 2.2 below, and a sample based on stratification is recommended for use in the proposed procedure.

2.1.3 Count Frequency

FHWA requires that traffic on HPMS sample sections be taken once every three years, with counts for one-third of the sample taken in each year. Counts may taken less frequently on road sections that are not part of the HPMS sample. Accordingly, some States that obtain traffic counts on local roads obtain these counts as infrequently as once every eight or nine years.

For a given expenditure of funds, reducing the frequency of counts would allow an increase in sample size and so an increase in the precision of VMT estimates. However, reducing the frequency will also reduce the precision with which year-to-year changes in VMT can be estimated. Also, traffic counts cannot be used to estimate changes in local VMT until the second cycle of traffic counts has begun (i.e., until traffic on at least some sections has been counted for a second time). Because of the importance to EPA of reasonably precise estimates of year-to-year changes in VMT, a significant reduction (below once every three years) in the frequency with which traffic counts are taken on local roads would appear to be undesirable. As indicated in section 2.2, an annual count program is recommended.

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[6] Ibid., p. S-2.

2.1.4 Count Duration

FHWA requires that all short-duration traffic counts on HPMS sample sections be taken over a period of (at least) 48 hours, and recommends that the counts be taken at random. The large majority of States take them only during weekdays. The 48-hour count duration produces a pair of 24-hour counts for each sample section. Advantages of the 48-hour counts are:

- If there is an identifiable equipment malfunction during one 24-hour period, the count for the other period can be used;
- A comparison of the two 24-hour counts can be used to confirm that the counts appear to be reliable and do not reflect the effects of any unusual conditions that might make them inappropriate to use as the basis for estimating AADT; and
- The precision of the resulting AADT estimate for the sample section is improved.

Information available to the FHWA have indicated that the most common monitoring period for volume counting in use today is the 48-hour period followed by the 24-hour period.[7] The 48-hour period can provide more accurate information, but ties-up equipment twice as long and may reduce a total number of locations that can be sampled. The current recommendation of a 48-hour monitoring period is a compromise given various alternatives and is designed to maximize data validity subject to cost and equipment constraints.

The most compelling reason to use a 24-hour time period is that the number of locations that could be sampled using a given amount of resources would be reduced by approximately 33% to 50% by changing the counting period from 24 to 48 hours.

Altogether, the analysis on the stability differences between the 24 and 48-hour counts is largely inconclusive.

In the case of local roads, AADT estimates for individual roads or road sections are not required, but only an overall estimate of total AADT for all local roads in the area. Accordingly, for local roads, the advantages of 48-hour counts relative to 24-hour counts are less important. VMT estimation is less influenced by the length of monitoring periods.[8] Since equipment costs for 48-hour counts are 50 to 100 percent greater than for 24-hour counts (depending upon scheduling practices), there is a clear cost advantage in allowing 24-hour counts on local roads.

2.1.5 Axle Correction Factors

The application of axle correction factors is dependent on the type of equipment in use. Obviously, vehicle detectors do not require axle adjustment. However, the preponderance of equipment dependent on pneumatic tube detectors in counting operations makes the development of these factors a virtual

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[7] Albright, D., 1990 Survey of Traffic Monitoring Practices Among State Transportation Agencies of the United States, Report No. FHWA-HPR-NM-90-05, New Mexico State Highway and Transportation Department, Santa Fe, NM, December, 1990.

[8] Highway Performance Monitoring System Field Manual, FHWA Order M 5600.1A, Federal Highway Administration, December, 1987, p. 3-3-1.

necessity. To represent vehicles, counts taken by axle counting equipment require adjustment by axle correction factors.

The application of the factors is a straightforward procedure. Sample sections where classification counts are taken or where vehicle detecting equipment is used require no adjustment since the number of vehicles are known. Sample sections where axle counts are taken are assigned the factors on the basis of functional class and these are applied in the computation of AADT.[9]

The development of appropriate axle factors is not as straightforward, and introduces the need for classification data. Local roads in general have no truck travel with the exception of mileage leading to gravel pits, farms, logging areas, mines, concrete producers, etc., making the estimation of these factors difficult.

Since the goal is to estimate the traffic volume on all local roads in an entire jurisdiction, rather than on individual roads, it is reasonable to ignore differences in the type of area served by individual roads and to use one factor for all local urban streets and a presumably different factor for all local rural roads. These axle correction factors may be developed specifically for the two local functional systems or, with no more than a very minor effect on results, existing factors for urban collectors and for rural minor collectors may be used for the corresponding local systems.

However, in order to avoid this problem altogether, it is recommended that vehicle counts rather than axle counts be taken, even if this requires the use of more advanced equipment and putting down two hoses or switches instead of one.

2.2 Sensitivity of Results to Key Parameters

In an attempt to define a feasible program for local traffic estimation, two approaches were taken to estimating program size. First sample size requirements, i.e., number of portable counts, needed to achieve certain specified precision levels were calculated. Then, the precision level possible, under the assumption of a fixed rate of sampling of local road segments from the universe of local road segments was determined. These results were then compared to the size of current state portable count programs in order to define a program which would provide credible traffic estimates, yet which would not place an undue burden on the states and metropolitan areas in terms of requiring excessive increases in their current levels of effort.

2.2.1 Methodology

These analyses were performed for urbanized areas with population greater than 200,000, for statewide rural local roads, and for statewide urban local roads.

All estimates assumed that all local roads could be divided into segments of uniform length and that traffic counts would be taken on a random sample of these segments. In practice, variable section lengths could be used without significantly altering the results of the recommended procedure. The sample was assumed to be distributed randomly over space and over time of year. If in fact, counts are not distributed randomly throughout the year then seasonal adjustment factors would have to be applied to the short term counts.

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[9] Ibid., p. 3-3-16

A fixed sample frame was also assumed, i.e., once a road segment was selected for the sample, that same segment would be monitored year after year. All counts were assumed to be of 24 hour duration, and were assumed to provide vehicle counts, as opposed to axle counts.[10]

An annual count frequency was assumed. Rural local road segment sizes were assumed as: 0.3 mile - minimum; 1 mile - middle; and 10 miles maximum. Urban local road segment sizes were assumed as: 0.1 mile - minimum; 0.5 mile - middle; and 3 miles - maximum. Estimates were prepared assuming both stratified and unstratified samples, as the available data permitted. Stratification was on the basis of the AADT volume groups used in Highway Statistics. These are <200, 200-499, 500-1,999, and ≥2,000 for urban local roads, and <50, 50-199, 200-499, and ≥500 for rural local roads.

For the first part of the analysis, sample size requirements (number of traffic counts) were estimated for precision levels of 90-15, 90-10, 90-05, 95-02, and 80-10.

The sample size estimates were derived from the following formula:

$$n = \frac{Z^2 C^2}{d^2}$$

where n = required sample size,
Z = value of the standard normal statistic for an alpha confidence level (two-sided),
C = AADT coefficient of variation, and
d = desired precision rate.

For the second part of the analysis the precision possible for 95%, 90%, and 80% confidence levels were estimated assuming sampling rates of 10%, 5%, 2%, and 1% from the population of assumed road segments.

The precision level was estimated as

$$D = T_{1-d/2,n-1} \frac{C}{\sqrt{n}}$$

where D = precision level as a proportion or percentage of the mean,
C = coefficient of variation of the factors,
T = value of Student's T distribution with 1-d/2 level of confidence and n-1 degrees of freedom,
n = number of locations.

Data on local functional system mileage (rural, small urban, and urbanized areas with population greater than 50,000) by volume group, by state and for urbanized areas with population greater than 200,000 was taken directly from Highway Statistics 1990 (Table HM-67, pp. 185-187, and Table HM-71, pp. 188, 189).

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[10] In practice, appropriate axle correction factors could be applied to axle counts to yield vehicle counts.

For urbanized areas with population greater than 200,000, "local" milage indicated in Highway Statistics 1990 was distributed by volume group utilizing the volume group distribution for urbanized areas with population greater than 50,000 for the state containing the urbanized area (or most of the urbanized area).

Existing local roads AADT data files from Georgia, Kansas, and Virginia were used to determine the coefficient of variation of AADT for local rural and urban roads.[11] The most important variables in local roads data from the States were functional class, rural or urban designation, section length, route surface type and traffic volume. The functional classes of interest were HPMS codes 9 and 19 – Rural Local and Urban Local respectively. The most important variable in the local roads data sets was the actual traffic volume estimates. Additional information of the local roads data collection programs considered is presented in Appendix E.

The coefficient's of variation derived from these data were as follows:[12]

local rural - unstratified -		205%;
by volume group	<50 -	30%;
	50-199 -	10%;
	200-499 -	10%;
	≥500 -	30%;
local urban - unstratified -		236%;
by volume group	<200 -	15%;
	200-499 -	10%;
	500-1,999 -	10%;
	≥2,000 -	50%.

The same coefficient of variation had to be applied throughout the analysis, as appropriate, since the data necessary to compute individual state and urbanized area coefficient's of variation was not available.

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[11] The Georgia DOT provided local traffic data for 1991 for 3841 sites. Their surface type designation was limited to "paved" and "unpaved" and the data did not contain a segment length variable.

The local roads data from Kansas for 1988-91 contained 4959 records. Functional class and AADT were contained on all of the records.

The Virginia local roads data contained over 86,000 records of data for rural and urban local roads. There was no surface type information available for the local roads data, but section length variable was contained on every record.

[12] Coefficients of variation for stratified samples were derived from the mean and variance of stratified samples using the methods described in Cochran, William G., Sampling Techniques, John Wiley & Sons, New York, 1977, p. 90, and Hoel, Paul G., Introduction to Mathematical Statistics, John Wiley & Sons, New York, 1971, p.296.

The coefficient of variation for a stratified sample of urban local roads was 20% for Georgia and Kansas and 30% for Virginia. The coefficient of variation for a stratified sample of rural local roads was 10% for Georgia 12%, for Kansas, and 15% for Virginia.

2.2.2 Results

Sample Size Requirements for Various Target Precision Levels

The results for the first part of this analysis for an example state are summarized in Table 2.1. They clearly illustrate the value of stratification by volume group. For example, for a 90-10 precision estimate sample size requirements drop from about 2,640 (unstratified) to about 130 (stratified). Moreover, they indicate that while the number of counts required to achieve a 95-02 precision level may be considered excessive (about 4730 per year), the number of counts required to achieve estimates with a 90% confidence appear reasonable (about 530 per year at the 90-05 precision level). The Table 2.2 presents results for an example urbanized area with population greater than 200,000. It shows that in order to achieve a 90-05 precision level, approximately 320 counts per year would be required in the example urbanized area.

It should be noted that sample size requirements are not a function of segment size assumptions, when the simplified formulation (which does not include the finite population correction)is used.

These estimates must be placed within the context of current portable count programs in the states. An informal survey of a few states, described in Appendix C, determined that typical programs today generally perform 5,000 to 10,000 counts per year. Thus any local roads count program, which would add to these requirements, probably would not be feasible if it would require a 50 to 100% increase in current efforts, that is any proposed program requiring on the order of 2,500 to 5,000 additional counts per year. It was felt that a program requiring about 500 additional counts per year, a 5 to 10% increase in current efforts, would be more reasonable under existing program constraints.

TABLE 2.1
SAMPLE SIZE REQUIRED FOR ESTIMATING
LOCAL ROADS VMT FOR AN EXAMPLE STATE
AT VARIOUS ASSUMED PRECISION LEVELS AND ROAD SEGMENT LENGTHS

Precision Level	Assumed Road Segment Size	Required Number of Counts	
		Unstratified Sample	Stratified Sample
90-15	Minimum	1,172	59
	Middle	1,172	59
	Maximum	1,172	59
90-10	Minimum	2,637	133
	Middle	2,637	133
	Maximum	2,637	133
90-05	Minimum	10,549	533
	Middle	10,549	533
	Maximum	10,549	533
95-02	Minimum	93,609	4,730
	Middle	93,609	4,730
	Maximum	93,609	4,730
80-10	Minimum	1,602	81
	Middle	1,602	81
	Maximum	1,602	81

Assumed segment lengths are:

Minimum - rural - 0.3 mile
urban - 0.1 mile

Middle - rural - 1 mile
urban - 0.5 mile

Maximum - rural - 10 miles
urban - 3 miles

TABLE 2.2
SAMPLE SIZE REQUIRED FOR ESTIMATING
LOCAL ROADS VMT FOR AN EXAMPLE URBAN AREA
WITH POPULATION > 200,000
AT VARIOUS ASSUMED PRECISION LEVELS AND ROAD SEGMENT LENGTHS

Precision Level	Assumed Road Segment Size	Required Number of Counts	
		Unstratified Sample	Stratified Sample
90-15	Minimum	669	35
	Middle	669	35
	Maximum	669	35
90-10	Minimum	1,505	79
	Middle	1,505	79
	Maximum	1,505	79
90-05	Minimum	6,018	317
	Middle	6,018	317
	Maximum	6,018	317
95-02	Minimum	53,400	2,809
	Middle	53,400	2,809
	Maximum	53,400	2,809
80-10	Minimum	914	48
	Middle	914	48
	Maximum	914	48

Assumed segment lengths are:

Minimum - 0.1 mile

Middle - 0.5 mile

Maximum - 3 miles

Precision Levels Possible with Various Sampling Rates

The results for the second part of this analysis for an example state are summarized in Tables 2.3 and 2.4. As in the first part, they clearly illustrate the value of stratification by volume group. They also serve to illustrate the obvious, in that large sample sizes result in good precision estimates, and small sample sizes result in poor precision estimates at any of the assumed confidence levels. The Table 2.5 presents the results for an example urbanized area with population greater than 200,000.

An additional scenario was tested in which assumed road segment size was varied by volume group as follows: 10 miles for rural roads with less than 50 vehicles per day; 1 mile for all other rural volume groups; 0.5 mile for urban roads with less than 200 vehicles per day, and 200 - 499 vehicles per day; and 0.1 mile for urban roads with 500 - 1,999 vehicles per day, and 2,000 and over vehicles per day.

Sample rates would also vary as follows: 1% for rural roads with less than 50 vehicles per day; 2% for all other rural volume groups; 1% for urban roads with less than 200 vehicles per day, and 200 - 499 vehicles per day; and 2% for urban roads with 500 - 1,999 vehicles per day, and 2,000 and over vehicles per day.

Under the assumptions of this scenario, the example state would require 2,684 urban counts and 1,141 rural counts (3,825 total).

For the example state, the precision possible, with a stratified sample, with 95 % confidence would be: rural 0.6%; urban 0.8%.

For the example state, the precision possible, with a stratified sample, with 90 % confidence would be: rural 0.5%; urban 0.6%.

For the example state, the precision possible, with a stratified sample, with 80 % confidence would be: rural 0.4%; urban 0.5%.

TABLE 2.3 - PRECISION LEVEL POSSIBLE FOR AN EXAMPLE STATE UNDER VARIOUS ASSUMED SAMPLE RATES FROM A POPULATION OF UNIFORM ROAD SEGMENTS (UNSTRATIFIED SAMPLE)

Road Segment Size	Sample Percent	Sample size		Conf. Level(%)	d_{rural}	d_{urban}
		n_{rural}	n_{urban}			
min.	10	19040	15820	95	2.9	4.4
mid.	10	5712	3164	95	5.3	9.9
max.	10	571	527	95	16.9	24.2
min.	10	19040	15820	90	2.5	3.7
mid.	10	5712	3164	90	4.5	8.3
max.	10	571	527	90	14.2	20.3
min.	10	19040	15820	80	1.9	2.9
mid.	10	5712	3164	80	3.5	6.5
max.	10	571	571	80	11.0	15.8
min.	5	9520	7910	95	4.1	6.2
mid.	5	2856	1582	95	7.6	13.9
max.	5	286	264	95	23.9	34.2
min.	5	9520	7910	90	3.5	5.2
mid.	5	2856	1582	90	6.3	11.7
max.	5	286	264	90	20.1	28.7
min.	5	9520	7910	80	2.7	4.1
mid.	5	2856	1582	80	4.9	9.1
max.	5	286	264	80	15.6	22.3

TABLE 2.3 - PRECISION LEVEL POSSIBLE FOR AN EXAMPLE STATE
UNDER VARIOUS ASSUMED SAMPLE RATES
FROM A POPULATION OF UNIFORM ROAD SEGMENTS
(UNSTRATIFIED SAMPLE)

Road Segment Size	Sample Percent	Sample Size		Conf. Level(%)	d_{rural}	d_{urban}
		n_{rural}	n_{urban}			
min.	2	3808	3164	95	6.5	9.9
mid.	2	1142	633	95	11.9	22.1
max.	2	114	105	95	37.8	54.1
min.	2	3808	3164	90	5.5	8.3
mid.	2	1142	633	90	10.0	18.5
max.	2	114	105	90	32.1	46.0
min.	2	3808	3164	80	4.3	6.4
mid.	2	1142	633	80	7.8	14.4
max.	2	114	105	80	24.8	35.5
min.	1	1904	1582	95	9.3	13.9
mid.	1	571	316	95	16.9	31.2
max.	1	57	53	95	54.6	78.1
min.	1	1904	1582	90	7.8	11.7
mid.	1	571	316	90	14.2	26.2
max.	1	57	53	90	45.6	65.2
min.	1	1904	1582	80	6.1	9.1
mid.	1	571	316	80	11.0	20.4
max.	1	57	53	80	35.4	50.5

TABLE 2.4 - PRECISION LEVEL POSSIBLE FOR AN EXAMPLE STATE UNDER VARIOUS ASSUMED SAMPLE RATES FROM A POPULATION OF UNIFORM ROAD SEGMENTS (SAMPLE STRATIFIED BY VOLUME GROUP)

Road Segment Size	Sample %	Sample size		Conf Level %	d_{rural}	d_{urban}
		n_{rural}	n_{urban}			
min.	10	19040	15820	95	0.1	0.1
mid.	10	5712	3164	95	0.3	0.7
max.	10	571	527	95	0.8	1.7
min.	10	19040	15820	90	0.1	0.3
mid.	10	5712	3164	90	0.2	0.6
max.	10	571	527	90	0.7	1.4
min.	10	19040	15820	80	0.1	0.2
mid.	10	5712	3164	80	0.2	0.4
max.	10	571	527	80	0.6	1.1
min.	5	9520	7910	95	0.2	0.4
mid.	5	2856	1582	95	0.4	1.0
max.	5	286	264	95	1.2	2.4
min.	5	9520	7910	90	0.2	0.4
mid.	5	2856	1582	90	0.3	0.8
max.	5	286	264	90	1.0	2.0
min.	5	9520	7910	80	0.1	0.3
mid.	5	2856	1582	80	0.2	0.6
max.	5	286	264	80	0.8	1.5

Assumed segment lengths are:

Minimum - rural - 0.3 mile
urban - 0.1 mile

Middle - rural - 1 mile
urban - 0.5 mile

Maximum - rural - 10 miles
urban - 3 miles

TABLE 2.4 - PRECISION LEVEL POSSIBLE FOR AN EXAMPLE STATE
UNDER VARIOUS ASSUMED SAMPLE RATES
FROM A POPULATION OF UNIFORM ROAD SEGMENTS
(SAMPLE STRATIFIED BY VOLUME GROUP)

Road Segment Size	Sample %	Sample Size		Conf. Level(%)	d_{rural}	d_{urban}
		n_{rural}	n_{urban}			
min.	2	3808	3164	95	0.3	0.7
mid.	2	1142	633	95	0.6	1.5
max.	2	114	105	95	1.9	3.7
min.	2	3808	3164	90	0.3	0.6
mid.	2	1142	633	90	0.5	1.3
max.	2	114	105	90	1.6	3.2
min.	2	3808	3164	80	0.2	0.4
mid.	2	1142	633	80	0.4	1.0
max.	2	114	105	80	1.2	2.5
min.	1	1904	1582	95	0.5	1.0
mid.	1	571	316	95	0.8	2.2
max.	1	57	53	95	2.7	5.4
min.	1	1904	1582	90	0.4	0.8
mid.	1	571	316	90	0.7	1.8
max.	1	57	53	90	2.3	4.5
min.	1	1904	1582	80	0.3	0.6
mid.	1	571	316	80	0.6	1.4
max.	1	57	53	80	1.8	3.5

Assumed segment lengths are:

Minimum - rural - 0.3 mile
urban - 0.1 mile

Middle - rural - 1 mile
urban - 0.5 mile

Maximum - rural - 10 miles
urban - 3 miles

TABLE 2.5 - PRECISION LEVEL POSSIBLE FOR A TYPICAL URBAN AREA
UNDER VARIOUS ASSUMED SAMPLE RATES
FROM A POPULATION OF UNIFORM ROAD SEGMENTS
LENGTH EQUAL TO .1 MILE

Sample Percent	Sample Size n	Conf. Level(%)	d stratified sample	d unstratified sample
10	7524	95	0.4	6.4
10	7524	90	0.4	5.4
10	7524	80	0.3	4.2
5	3762	95	0.6	9.0
5	3762	90	0.5	7.6
5	3762	80	0.4	5.9
2	1505	95	1.0	14.3
2	1505	90	0.8	12.0
2	1505	80	0.6	9.4
1	752	95	1.4	20.2
1	752	90	1.2	17.0
1	752	80	0.9	13.2

3.0 RESOURCE REQUIREMENTS

3.1 Methodology

The cost of each of the portable count programs sized in section 2 was estimated. This cost was determined as the product of the number of counts and an average cost per count. The result was the annual cost of each of the portable count program.

The average cost per count is difficult to estimate due to different procedures and equipment that are used. States use a variety of equipment and procedures to generate traffic counts on their highway systems. Some of the most common types of equipment and procedures that are currently being used are described in APPENDIX C.

The cost of a count varies according to whether the road is urban or rural, if it is an axle or a classification count, and if it is of a single or multiple lanes. In New York, the costs range from a high of $300 for multi-lane classification count in New York City, to $35 for a volume count on a rural road in upstate New York. Texas compensates the local organizations that take the counts at a rate of $65 for every count. Pennsylvania pays contractors $60 dollars for classification counts and $150 for automatic vehicle classification counts. The costs for a simple volume count on a local road seems to be between $38 and $43. This estimate was based on interviews of State traffic data collection officials and estimates of the costs of counters, expendables, travel, labor, and benefits. Table 3.1 shows the estimated cost per count for both 24 and 48 hour counts. Equipment costs were derived from several sources. Discussions with state administrators show that the counting equipment necessary for local roads traffic counting can be purchased for about $1,600 per unit. A survey of price information from several companies seemed to bear this out. Traffic data collection officials indicated that such equipment could be expected to last for ten years or more. Since one traffic counter can make one 48 hour count per week, and traffic counting occurs about 45 weeks in a year, the equipment cost per count can be derived by dividing the cost of a counter by 10(assuming a ten year life span) and then dividing the resulting number by 45(the number of counts in a year). This results in equipment costs of $3.56 per count.

Expendable costs were calculated by factoring in the costs of hoses and hose joints. Assuming 60 feet of hose per counter per year at 37 cents a foot, hose costs were estimated to be about .49 cents per count. The costs of other expendable equipment, including hose joint which can be re-used several times came to $1.25 per count. This gave total expendable costs per count of $1.74.

Travel expenses were assumed to include the cost of travel to and from counter sites. The $10 per count travel costs were based on an estimate of 40 miles of travel per count, at 25 cents per mile. This was thought to be a reasonable estimate since in many cases traffic recorders operated out of a centralized location and were required to visit all different parts of their respective states.

Labor costs were derived by examining the kinds of employees involved in traffic counting and their salaries. The median salary of field crew members and technicians/statisticians from a sample of states was used. Benefits were estimated to be 30% of salary. The proportion of labor used was assumed to include the cost of one administrator for each 10,000 counts, the costs of one technician/statistician for every five field crew members and the cost of field crew members. It was assumed that a field crew member could place 30 counters per week or about 1350 per year.[13] Labor costs brought the total cost

[13] American Association of State Highway and Transportation Officials. AASHTO Guidelines for Traffic Data Programs. (p. 15)

of a 48 hour count to $43.00. The cost of a 24 hour count was estimated to be $38.69.[14]

[14] Traffic Estimating Procedures for the Local Functional System - Statistical Precision and Resource Requirements, prepared for Volpe National Transportation Systems Center, Jack Faucett Associates, Bethesda, MD, November, 1992.

TABLE 3.1 - ESTIMATED COST OF A SINGLE 48 OR 24 HOUR LOCAL ROAD TRAFFIC COUNT

Equipment	48 hour count	24 hour count	Assumptions
Counting Device	$3.56	$1.78	$1600 per unit; 10 year life; 1 - 48 hr ct per week; 40-50 per yr
Expendables	$1.74	$1.74*	$1.74 per ct
Vehicle and Travel	$10.00	$10.00*	40 miles per ct; $.25 per mile
Labor			24 hr cts give 10% efficiency improvement
Administrative	$1.60	$1.45	1 per state; 1/4 effort avg salary $42k
Technical	$4.15	$3.77	1 per every 5 crew members; avg salary $28k
Field Crew	$15.56	$14.14	30 cts per wk or 1200-15-- cts per year; avg salary $21k
Benefits	$6.39	$5.81	30% times labor cost
TOTAL COST/COUNT	$43.00	$38.69	

*The total cost of a single count where there is excess equipment and labor capacity may be as low as $11.74.

3.2 Results

The cost estimates corresponding to the count requirements for the first part of this analysis for an example state are summarized in Table 3.2. Since annual costs were determined as a multiple of the number of counts required, the cost estimates follow the same pattern as the count requirements when comparing alternative count programs. They indicate that while the costs required to achieve a 95-02 precision level may be considered excessive (about $183,000 per year), the costs required to achieve estimates with a 90% confidence level appear reasonable ($20,600 per year at the 90-05 precision level). Table 3.3 presents results for an example urbanized area with population greater than 200,000.

The cost estimates for the second part of this analysis for the example state are summarized in Tables 3.4 and 3.5. Table 3.6 presents results for a typical urbanized area with population greater than 200,000.

For the scenario in which assumed road segment size was varied by volume group, and sample rates were also varied by volume group the cost in the example state was estimated at $148,000 per year.

TABLE 3.2
COST OF ESTIMATING
LOCAL ROADS VMT FOR A EXAMPLE STATE
AT VARIOUS ASSUMED PRECISION LEVELS AND ROAD SEGMENT LENGTHS

Precision Level	Assumed Road Segment Size	Annual Cost of Counts	
		Unstratified Sample	Stratified Sample
90-15	Minimum	$45,340	$2,280
	Middle	$45,340	$2,280
	Maximum	$45,340	$2,280
90-10	Minimum	$102,020	$5,150
	Middle	$102,020	$5,150
	Maximum	$102,020	$5,150
90-05	Minimum	$408,140	$20,620
	Middle	$408,140	$20,620
	Maximum	$408,140	$20,620
95-02	Minimum	$3,621,730	$183,000
	Middle	$3,621,730	$183,000
	Maximum	$3,621,730	$183,000
80-10	Minimum	$61,980	$3,130
	Middle	$61,980	$3,130
	Maximum	$61,980	$3,130

Assumed segment lengths are:

Minimum - rural - 0.3 mile
urban - 0.1 mile

Middle - rural - 1 mile
urban - 0.5 mile

Maximum - rural - 10 miles
urban - 3 miles

TABLE 3.3
COST OF ESTIMATING
LOCAL ROADS VMT FOR A EXAMPLE URBAN AREA
WITH POPULATION > 200,000
AT VARIOUS ASSUMED PRECISION LEVELS AND ROAD SEGMENT LENGTHS

Precision Level	Assumed Road Segment Size	Annual Cost of Counts	
		Unstratified Sample	Stratified Sample
90-15	Minimum	$25,880	$1,350
	Middle	$25,880	$1,350
	Maximum	$25,880	$1,350
90-10	Minimum	$58,230	$3,060
	Middle	$58,230	$3,060
	Maximum	$58,230	$3,060
90-05	Minimum	$232,840	$12,260
	Middle	$232,840	$12,260
	Maximum	$232,840	$12,260
95-02	Minimum	$2,066,050	$108,680
	Middle	$2,066,050	$108,680
	Maximum	$2,066,050	$108,680
80-10	Minimum	$35,360	$1,860
	Middle	$35,360	$1,860
	Maximum	$35,360	$1,860

Assumed segment lengths are:

Minimum - 0.1 mile

Middle - 0.5 mile

Maximum - 3 miles

TABLE 3.4 - COST TO ACHIEVE THE INDICATED PRECISION LEVEL
UNDER VARIOUS ASSUMED SAMPLE RATES
FROM THE EXAMPLE STATE'S POPULATION OF UNIFORM ROAD SEGMENTS
(UNSTRATIFIED SAMPLE)

Road Segment Size	Sample Percent	Annual Cost of Counts	Conf. Level(%)	d_{rural}	d_{urban}
min.	10	$1,348,730	95	2.9	4.4
mid.	10	$343,410	95	5.3	9.9
max.	10	$42,480	95	16.9	24.2
min.	10	$1,348,730	90	2.5	3.7
mid.	10	$343,410	90	4.5	8.3
max.	10	$42,480	90	14.2	20.3
min.	10	$1,348,730	80	1.9	2.9
mid.	10	$343,410	80	3.5	6.5
max.	10	$44,180	80	11.0	15.8
min.	5	$674,370	95	4.1	6.2
mid.	5	$171,710	95	7.6	13.9
max.	5	$21,280	95	23.9	34.2
min.	5	$674,370	90	3.5	5.2
mid.	5	$171,710	90	6.3	11.7
max.	5	$21,280	90	20.1	28.7
min.	5	$674,370	80	2.7	4.1
mid.	5	$171,710	80	4.9	9.1
max.	5	$21,280	80	15.6	22.3

TABLE 3.4 - COST TO ACHIEVE THE INDICATED PRECISION LEVEL
UNDER VARIOUS ASSUMED SAMPLE RATES
FROM THE EXAMPLE STATE'S POPULATION OF UNIFORM ROAD SEGMENTS
(UNSTRATIFIED SAMPLE)

Road Segment Size	Sample Percent	Annual Cost of Counts	Conf. Level(%)	d_{rural}	d_{urban}
min.	2	$269,750	95	6.5	9.9
mid.	2	$68,670	95	11.9	22.1
max.	2	$8,470	95	37.8	54.1
min.	2	$269,750	90	5.5	8.3
mid.	2	$68,670	90	10.0	18.5
max.	2	$8,470	90	32.1	46.0
min.	2	$269,750	80	4.3	6.4
mid.	2	$68,670	80	7.8	14.4
max.	2	$8,470	80	24.8	35.5
min.	1	$134,870	95	9.3	13.9
mid.	1	$34,320	95	16.9	31.2
max.	1	$4,260	95	54.6	78.1
min.	1	$134,870	90	7.8	11.7
mid.	1	$34,320	90	14.2	26.2
max.	1	$4,260	90	45.6	65.2
min.	1	$134,870	80	6.1	9.1
mid.	1	$34,320	80	11.0	20.4
max.	1	$4,260	80	35.4	50.5

TABLE 3.5 - COST TO ACHIEVE THE INDICATED PRECISION LEVEL FOR AN EXAMPLE STATE UNDER VARIOUS ASSUMED SAMPLE RATES FROM A POPULATION OF UNIFORM ROAD SEGMENTS (SAMPLE STRATIFIED BY VOLUME GROUP)

Road Segment Size	Sample %	Annual Cost of Counts	Conf Level %	d_{rural}	d_{urban}
min.	10	$1,348,730	95	0.1	0.1
mid.	10	$343,410	95	0.3	0.7
max.	10	$42,480	95	0.8	1.7
min.	10	$1,348,730	90	0.1	0.3
mid.	10	$343,410	90	0.2	0.6
max.	10	$42,480	90	0.7	1.4
min.	10	$1,348,730	80	0.1	0.2
mid.	10	$343,410	80	0.2	0.4
max.	10	$42,480	80	0.6	1.1
min.	5	$674,370	95	0.2	0.4
mid.	5	$171,710	95	0.4	1.0
max.	5	$21,280	95	1.2	2.4
min.	5	$674,370	90	0.2	0.4
mid.	5	$171,710	90	0.3	0.8
max.	5	$21,280	90	1.0	2.0
min.	5	$674,370	80	0.1	0.3
mid.	5	$171,710	80	0.2	0.6
max.	5	$21,280	80	0.8	1.5

Assumed segment lengths are:

Minimum - rural - 0.3 mile
urban - 0.1 mile

Middle - rural - 1 mile
urban - 0.5 mile

Maximum - rural - 10 miles
urban - 3 miles

TABLE 3.5 - COST TO ACHIEVE THE INDICATED PRECISION LEVEL FOR AN EXAMPLE STATE UNDER VARIOUS ASSUMED SAMPLE RATES FROM A POPULATION OF UNIFORM ROAD SEGMENTS (SAMPLE STRATIFIED BY VOLUME GROUP)

Road Segment Size	Sample %	Annual Cost of Counts	Conf. Level(%)	d_{rural}	d_{urban}
min.	2	$269,750	95	0.3	0.7
mid.	2	$68,670	95	0.6	1.5
max.	2	$8,470	95	1.9	3.7
min.	2	$269,750	90	0.3	0.6
mid.	2	$68,670	90	0.5	1.3
max.	2	$8,470	90	1.6	3.2
min.	2	$269,750	80	0.2	0.4
mid.	2	$68,670	80	0.4	1.0
max.	2	$8,470	80	1.2	2.5
min.	1	$134,870	95	0.5	1.0
mid.	1	$34,320	95	0.8	2.2
max.	1	$4,260	95	2.7	5.4
min.	1	$134,870	90	0.4	0.8
mid.	1	$34,320	90	0.7	1.8
max.	1	$4,260	90	2.3	4.5
min.	1	$134,870	80	0.3	0.6
mid.	1	$34,320	80	0.6	1.4
max.	1	$4,260	80	1.8	3.5

Assumed segment lengths are:

Minimum - rural - 0.3 mile
urban - 0.1 mile

Middle - rural - 1 mile
urban - 0.5 mile

Maximum - rural - 10 miles
urban - 3 miles

TABLE 3.6 - COST TO ACHIEVE THE INDICATED PRECISION LEVEL FOR A TYPICAL URBAN AREA
UNDER VARIOUS ASSUMED SAMPLE RATES
FROM A POPULATION OF UNIFORM ROAD SEGMENTS
LENGTH EQUAL TO .1 MILE

Sample Percent	Annual Cost of Counts	Conf. Level(%)	d stratified sample	d unstratified sample
10	$291,100	95	0.4	6.4
10	$291,100	90	0.4	5.4
10	$291,100	80	0.3	4.2
5	$145,550	95	0.6	9.0
5	$145,550	90	0.5	7.6
5	$145,550	80	0.4	5.9
2	$58,230	95	1.0	14.3
2	$58,230	90	0.8	12.0
2	$58,230	80	0.6	9.4
1	$29,090	95	1.4	20.2
1	$29,090	90	1.2	17.0
1	$29,090	80	0.9	13.2

4.0 RECOMMENDED APPROACH

The procedure for estimating DVMT at the state level for rural local roads, and for urban local roads is as follows (The indicated procedure is for the example case. Real world considerations would require modifications in specific cases as noted below. However, these modifications would not detract from the validity of the overall approach.):

1) - Divide the local road mileage in each state's volume group strata into segments of appropriate size and number, and assign each segment a sequential number;[15]

2) - Estimate sample size requirements by volume group strata to achieve a 90-05 precision level at the volume group level using the equation of section 2.

3) - Select segments to be monitored using a table of random numbers or computer based random number generator to select a random sample of monitoring locations over space (as an alternative, every nth segment could be selected where n is the total number of segments divided by the required sample size);

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[15] Obtaining traffic counts for ever section of local road, if they do not already exist, would require a massive effort that is clearly impractical.

Many states maintain complete inventories of their road system, frequently to provide information for distributing funds to local highway departments. States usually have inventories where the highways are divided into sections based on several criteria. The inventory may be in machine-readable form or it may be a simple printed listing. Detailed road maps may contain all the required information and may constitute a usable inventory in areas where the road system is not too complex. Using available inventories, in actual applications offers great advantages.

A more practical alternative might be for highway planners to assign all sections judgmentally to a few relatively rough volume groupings on the basis of a relatively cursory review of readily identifiable characteristics (e.g., location, type of surrounding developing, etc.).

An alternate stratification for urban areas in commercial, industrial, and residential, with residential areas possibly being distinguished further (e.g., into high rise, low rise, dense single family, and low-density single family).

Information for stratification by adjoining development generally can be provided to traffic data collection agencies in map form by land-use planners, and these planners can also regularly provide the collection agencies with information on changes in adjoining development.

For some areas of interest, incomplete inventories of local roads have already been developed. For example, such inventories have been developed for all urbanized areas in Kansas. Apparently, the Kansas inventories were originally developed by selecting for enumeration a sample of residential, commercial and industrial neighborhoods. (The Kansas procedure is essentially a form of cluster sampling.)
The importance of including all mileage and clearly defining the boundaries of non-attainment areas are some of the major difficulties likely to be encountered in developing adequate sampling frames.

4) - Select a monitoring schedule by assigning a number to each day of the year from 1 to 365 (or less, if counts can not be taken in certain seasons due to weather conditions), and select specific days using a table of random numbers or computer based random number generator to select a random sample over time, and assign sample locations to sample days for each strata (if counts can not be distributed randomly over time in practice, due to staff assignments and working schedules, then the use of available seasonal adjustment factors would be required). Time for recounts should be built into the schedule;

5) - Perform counts for a 24 hour period on an annual basis;

6) - Determine "AADT" for each strata as the average of that year's 24 hour counts for that strata;[16]

7) - Calculate DVMT of each strata as AADT of strata x total miles per strata;[17]

8) - Sum the appropriate strata DVMT to determine rural local or urban local DVMT for the state.

The procedure for estimating DVMT at the urbanized area level for urban local roads would be similar.

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[16] This assumes that all segments in a strata are of equal length as in the example. In practice if variable length segments are used "AADT" for each strata would be determined as the weighted (on the basis of segment lengths) average of that year's 24 hour counts for that strata.

[17] This is equivalent to calculating DVMT as AADT x sample size x segment size x expansion factor, where the expansion factor is total miles/sampled miles, in cases where all segments are not an equal length.

5.0 TEST RESULTS OF RECOMMENDED APPROACH

An attempt was made to test the proposed approach utilizing actual data, and matching the resulting VMT estimates against a known figure. However this process was hindered by a scarcity of actual local roads data, and the lack of "true" VMT figures. The available data and process are described below. While the results of the test are encouraging, they must be considered inconclusive, since we do not know whether or not our bench mark VMT figure is correct.

5.1 Current Estimates

The only data available for a test of the procedure was a file of urban local roads for the state of Kansas. The VMT estimates produced from this data were compared against the information reported for Kansas in Highway Statistics[18] which is based on state HPMS data submittals.

Note that the HPMS Manual does not describe a procedure for "local" data collection/reporting. The Manual also indicates that classification on the basis of pavement type/AADT volume group may be based on data, maps or analyst judgement.

Highway Statistics provides the following information on urban local roads for Kansas:

1) local urban AVMT = 1,721,000,000; and

2) the distribution of local urban mileage by AADT volume group

	<200	200-499	500-199	>2000	total
local small urban 5 -49.9k pop.	1062	807	795	127	2791
local urban 50k or more	1692	995	733	259	3679
total urban	2754	1802	1528	386	6470

5.2 Available Input Data

The only local roads data available was from Kansas. The data is for urban roads only. The data is based on a sample of local roads, and includes counts from 1988, 1989, 1990 and 1991. There was no documentation on how the data was collected or what it includes. We do not know how the sample was derived, or how it relates to the universe of local roads.

The file contained 2166 usable observations, each indicating city, section length, the date of the count, AADT, and additional items such as section numbers and an HPMS code if applicable. Population and DVMT (computed as segment length x AADT) were added to each record to create our working file. A random sample taken from this file is shown in Appendix D.

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[18] U.S. Department of Transportation, Federal Highway Administration, Highway Statistics 1990, Publication No. FHWA-PL-91-03.

5.3 Results

An attempt was made to determine "actual" DVMT from the Kansas urban local roads data file. The file was sorted by population and AADT volume group. DVMT was calculated for each location as section length times AADT. DVMT for each volume group was calculated as the sum of the individual DVMT's times an expansion factor. The expansion factor was calculated as the total mileage in the volume group over the sample mileage of the volume group. Urban local DVMT was calculated as the sum of the volume group DVMT's. Finally AVMT was calculated as DVMT times 365. Tables 5.1 to 5.3 indicate the results of these calculations at the volume group level for small urban areas, large urban areas, and for urban areas in total. It should be noted that the sample mileage of the data file accounts for about 9.5% of the total mileage.

Calculated AVMT was 1,565,000,000 vs. the published figure of 1,721,000,000. The actual data results in a VMT estimate which is about 9% less than the published figure. This may be reasonable in that the published figure is presumably based on 1990 data, while the sample data file includes data for 1988, 1989, 1990, and 1991.

AVMT was calculated, using this same data, based on the procedure recommended in Section 4. First a random sample of observations were extracted from the data, based on the sample size requirements needed to obtain a 90-05 precision level by volume group, estimated using the equation of Section 2. (The number of observations are indicted in Table 5.4 along with the results of the other DVMT calculations.) AADT for each volume group was taken as the average of the sampled AADT's. DVMT for each volume group was calculated as the product of average AADT and total mileage for that volume group. Total local urban DVMT was determined as the sum of the DVMT's of the volume groups, and AVMT was again the product of this total DVMT and 365. AVMT, based on the recommended procedure was calculated as 1,468,000,000. This was within 6% of the "actual" AVMT as calculated previously, and 15% less than the published figure.

TABLE 5.1 - CHARACTERISTICS OF THE KANSAS LOCAL ROADS DATA FOR SMALL URBAN AREAS

	Volume Group				Total Small Urban
	<200	200-499	500-1999	>2000	
Mean AADT	90	333	1041	3616	1329
Mean Seg. Size	0.25	0.29	0.29	0.25	0.27
Number of Obs.	310	300	619	282	1511
DVMT	7459	28738	185692	260583	482472
Sample Miles	76	87	180	71	414
Total Miles	1062	807	795	127	2791
Expan. Factor	13.93152	9.313329	4.410296	1.800652	6.746924
Expanded DVMT	103910	267648	818957	469220	1659734

TABLE 5.2 - CHARACTERISTICS OF THE KANSAS LOCAL ROADS DATA FOR LARGE URBAN AREAS

	Volume Group				Total Large Urban
	<200	200-499	500-1999	>2000	
Mean AADT	104	303	1085	5603	1823
Mean Seg. Size	0.23	0.34	0.34	0.33	0.31
Number of Obs.	173	159	151	172	655
DVMT	4441	16188	56824	294759	372212
Sample Miles	39	54	52	57	202
Total Miles	1692	995	733	259	3679
Expan. Factor	43.40688	18.29717	14.07991	4.54386	18.17508
Expanded DVMT	192772	296186	800082	1339345	2628385

TABLE 5.3 - CHARACTERISTICS OF THE KANSAS LOCAL ROADS DATA FOR ALL URBAN AREAS

	Volume Group				Total Urban
	<200	200-499	500-1999	>2000	
Mean AADT	95	322	1049	4369	1378
Mean Seg. Size	0.24	0.31	0.30	0.28	0.28
Number of Obs.	483	459	770	454	2166
DVMT	11900	44926	242516	555343	854684
Sample Miles	115	141	232	128	616
Total Miles	2754	1802	1528	386	6470
Expan. Factor	23.90417	12.77742	6.577135	3.026739	10.50171
Expanded DVMT	284451	574035	1595063	1680877	4288119

TABLE 5.4 - CHARACTERISTICS OF THE SAMPLE TAKEN FROM KANSAS LOCAL ROADS DATA

	Volume Group				Total Urban
	<200	200-499	500-1999	>2000	
Mean AADT	99	305	970	4444	3772
Sample Size	23	11	11	228	273
Seg. Size	0.5	0.5	0.1	0.1	
DVMT	1143	1678	1067	101334	105222
Sample Miles	11.5	5.5	1.1	22.8	41
Total Miles	2754	1802	1528	386	6470
Expan. DVMT	273603	549610	1482577	1715572	4021363

APPENDIX A - POTENTIAL APPROACHES TO LOCAL ROADS TRAFFIC DATA COLLECTION[19]

The first phase of this project centered around an attempt to identify cost-effective, and theoretically sound alternatives to traffic counting as a basis for estimating VMT on local streets and roads. This effort involved an extensive literature review and interviews with experts in the field. The alternatives identified are discussed below. The major conclusion of this effort was that there were no viable alternatives to a count-based program for estimating VMT on local roads.

A.1 Analytical Procedures

Several possible procedures for estimating local VMT exist that do no require the expense of actually counting traffic on local roads. These analytic procedures estimate local VMT either:

- by using functional relationships; or
- by estimating total VMT from non-count-based data (such as motor-fuel sales) and subtracting count-based estimates of nonlocal VMT.

Of the several procedures discussed, only one, the use of travel-density ratios, has the potential for yielding adequate VMT estimates. However, some of the procedures for estimating total VMT (discussed in the latter half of the section) could be used for other applications.

A.1.1 Functional Relationships

A.1.1.1 Relationships Based on Density of Development

Consider any area that is bounded by nonlocal roads but which contains no nonlocal roads. All travel within this area is local VMT. If the roads within this area have been properly classified as "local," there should be little or no use of these roads by vehicles that are merely passing through the area. Hence, in concept, the VMT in the area can be estimated as the product of two factors:

- the number of trips originating and/or terminating in the area; and
- the average distance traveled on these local roads by vehicles traveling to or from locations in this area.

Estimates of both of these factors can be derived analytically using information obtainable from maps and Census sources. However, the quality of these estimates will depend, in part, on how much effort is used in developing the estimates. For example, in the case of purely residential areas, the average number of trips generated (per unit of time) could be taken to be directly proportional to the number of housing units on the local roads in the specified area. However, better estimates could be derived using additional variables such as: total population, number of vehicles and/or licensed drivers, total income, working-age population, etc. Additional complications arise if the local roads in question serve any nonresidential trip generators.

It appears that these procedures would require a very substantial amount of effort for development,

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[19] Traffic Estimating Procedures for the Local Functional System - Potential Approaches, prepared for Volpe National Transportation Systems Center, Jack Faucett Associates, Bethesda, MD, April, 1992.

calibration and validation, and applying them is also likely to require a fair amount of effort. Even with such an effort, the quality of the VMT estimates for individual groups of local roads is likely not to be very good, though the quality of local VMT estimates at statewide and urbanized-area levels is likely to be better. Such procedures, however, would have one important limitation: they would not be capable of measuring the effects of public policies for reducing VMT. As such, they could not be used to estimate the effectiveness of any such policies adopted by CO nonattainment areas.

A.1.1.2 Travel-Density Ratios

Functional relationships can also be defined using the average ratio of travel density (VMT per mile of road) on local roads to travel density on roads in a slightly higher functional system. These ratios can be developed from national data on VMT and miles of road for a sample of roads. Separate sets of ratios can be developed for urban local streets to urban collectors and for rural local roads to rural minor collectors. If desired, a third set of ratios can be developed for rural minor collectors to rural major collectors. Ideally, separate ratios would be developed for each rural "type of development" ("rural" or "dense") and for each type of location in urbanized areas and small urban areas (using the five urban-location types distinguished by HPMS: central business district (CBD), CBD fringe, outlying business district, residential, or rural).

To estimate VMT on local roads in dense rural areas in a given jurisdiction, for example, the resulting ratio, R_{lrd} could then be used in the equation:

$$VMT_{lrd} = R_{lrd} \times \frac{VMT_{crd}}{M_{crd}} \times M_{lrd}$$

where VMT_{crd} and M_{crd} are the VMT and mileages for minor collectors in dense rural areas in the jurisdiction, and VMT_{lrd} and M_{lrd} are the corresponding quantities for local roads in dense rural area in the jurisdiction. Local VMT for "rural" rural areas and for the ten types of locations in urbanized areas and in small urban areas could be estimated from analogs to this equation.

This equation and its analogs would provide a very simple means of estimating local VMT, and estimation and validation of the travel-density ratios required by these equations would be somewhat simpler than development of relationships based on density of development. Estimates produced by these equations are likely to be quite unreliable for small areas, but they could be reasonably accurate at the statewide and urbanized-area levels. Also, the estimates do use actual vehicle counts (for urban collectors and rural major or minor collectors), and so they satisfy the EPA requirements for the use of a count-based methodology.

The most important disadvantages of the procedures are:

- the VMT estimates it produces would be based, at least in part, on national travel-density ratios; and
- these VMT estimates would be sensitive: to the way roads are assigned to functional systems; and to the functional classification of roads that place them near the boundary of the local and collector systems.

Also, any errors in the VMT estimates for the lowest functional systems for which traffic counts are collected (i.e., urban collectors and either rural minor collectors or rural major collectors) would result in corresponding errors in the VMT estimates obtained for the local (and rural minor collector) systems.

The above characteristics of the VMT estimates could have two significant effects:

- They almost certainly would result in consistent biases in the estimates of local VMT produced for individual areas, and smaller biases in the resulting estimates of total VMT and year-to-year changes in total VMT; and
- They would provide planning agencies with the ability to reduce year-to-year growth in estimated VMT by reclassifying relatively low-volume local roads as collectors (or by reclassifying relatively high-volume collectors as local roads).

The second effect can be controlled by providing guidelines for the reclassification of sections and by also requiring all collection agencies to justify all reclassification and to provide traffic counts for reclassified sections. However, as discussed below, only some aspects of the first effect can be controlled. The use of national travel-density ratios that vary only by urbanized, small urban, or rural location and, perhaps, by type of surrounding development implicitly presumes that these ratios are reasonably constant across all States and all urbanized areas. To the extent that the ratios actually vary, the resulting estimates of local VMT for specific areas would be biased. It seems likely that variations in these ratios could be caused by existing variations in rural population density across States and (perhaps to a lesser extent) by existing variations in population density across urbanized areas. Such unavoidable variations in travel-density could be aggravated substantially be variations in the extent to which individual roads have their functional system misclassified. Significant misclassification is suggested by traffic counts on individual local roads that are as high as 15,000 vehicles per day[20]. Unfortunately, it may be difficult to detect such misclassification without actually counting traffic on all local roads.

A.1.2 The Relationship with Total VMT

At the present time several States use a non-count-based methodology for estimating total VMT in any area and derive corresponding estimates of local VMT by subtracting count-based estimates of VMT on the higher functional systems. The estimates of total VMT may be derived from data on:

- vehicle registrations and estimates of average miles traveled per vehicle;
- driver licenses and estimates of average miles driven per driver; or
- fuel consumption and estimates of average miles per gallon (mpg).

A fourth potential source for estimates of total VMT would be annual odometer readings. Such readings could be obtained either in conjunction with emissions inspections or by equipping all vehicles with transponders that automatically provide odometer readings to roadside electronic interrogation devices.

Regardless of the quality of the estimates of total VMT, the resulting estimates of local VMT share a significant deficiency: any estimate of a small quantity that is obtained by taking the difference between independent estimates of two much larger quantities is subject to substantially greater errors than those associated with the two original estimates. Thus, even if relatively reliable estimates are available for both total VMT and nonlocal VMT, the resulting estimates of local VMT would be appreciably less reliable. For example, since local roads carry only 14 percent of total traffic, a one percent error in an estimate of total VMT would introduce a seven percent error in the resulting estimate of local VMT. Accordingly, this approach is not a particularly good one for estimating local VMT.

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[20] David Spillman, Georgia Department of Transportation, personal communication, April 6, 1992.

On the other hand, if we are not interested in local VMT for its own sake, but only as a component of total VMT, the above approach warrants some further consideration.

VMT estimates derived from numbers of vehicle registrations or driver licenses are not capable of directly reflecting the effects of changes in vehicle usage due to policies designed to discourage such usage. However, VMT estimates derived from fuel sales or odometer readings would reflect such effects.

The quality of VMT estimates that are derived from fuel sales depends significantly on the quality of the estimated relationships between VMT and the consumption of gasoline and diesel fuel. Unfortunately, good estimates of these relationships require a substantial amount of analysis. At the national level, they require estimates of the relationship between VMT and fuel consumption as a function of, at least, vehicle type, vintage, fuel type, and road type (by type and vintage), climate, altitude, terrain, level of congestion, and differences between typical flow restrictions on area roads and those assumed for national roads. In practice, fuel-consumption relationships are derived using a less detailed analysis, reducing the accuracy of the resulting VMT estimates. In the important case of estimates of the change in VMT from year to year, simplifications that reduce or eliminate the ability of the estimates to reflect changes in fuel efficiency over time are a particular concern.

Such analytic problems do not exist for VMT estimates derived form odometer readings. However, VMT estimates derived from both sources have boundary-effect problems: fuel consumption in a given area is different from fuel sales in the area; and odometer readings include out-of-area mileage of "in-area" vehicles while excluding in-area mileage of "out-of-area" vehicles. These effects would tend to bias the VMT estimates produced by either of these procedures - most likely in a downward direction for most urbanized areas. More importantly, some of the potential VMT-reduction policies could be expected to increase this bias, thus resulting in overestimates of the effects of the policies: increasing fuel taxes in nonattainment areas would tend to shift some fuel purchases from in-area service stations to out-of-area service stations; while an emissions tax applied to vehicles registered or garaged in nonattainment areas would tend to promote evasion by causing some vehicle owners to take steps to cause their vehicles to be treated as "out-of-area" vehicles.

A.2 Other Alternatives to Conventional Traffic Counters

Traffic counts on local roads and streets are usually obtained with some type of automatic traffic counting and recording device. The low traffic volumes on these roadways do not pose any technological challenges to these devices; however, they do make their use relatively expensive when measured on a per vehicle counted basis.

Potential alternatives to conventional automatic traffic counters are discussed here. None of these alternatives appear to warrant any further consideration, though aerial or satellite photography techniques may be of some value for estimating traffic volumes on remote rural roads.

A.2.1 Aerial or Satellite Photography

One potential procedure for counting traffic and estimating VMT would be to take a pair of consecutive aerial or satellite photographs and to examine all apparent vehicular movement on all (or a subset of) the local roads and streets appearing in the photograph. The advantage of such a procedure would be that a single pair of photographs would provide information on VMT for a relatively large number of local roads and streets.

One significant problem with this procedure is extracting the VMT information from the photographs. This step could be performed by clerks. However, the cost of such a manual procedure per vehicle counted would be high, and the combination of tedium and exacting requirements is likely to lead to a high error rate. A more attractive alternative would be to develop a computer program to scan the photographs and to identify all vehicular movement automatically. However, no such computer program currently exists, the development of such a program would be relatively expensive, and, until such a program has been developed and evaluated, the accuracy of such a program cannot be assessed.

Perhaps a more basic problem with the aerial or satellite photography approach is statistical in nature. Automatic traffic counters provide data for a relatively small number of roadway sections for a 24 or 48-hour period, while a pair of photographs provides data for a much larger number of sections for very short periods of time-probably no more than few seconds.[21] Extrapolation of data from such short periods of time to 24-hour traffic volumes (and then to annual volumes) presents a significant statistical problem, especially in the case of localized areas where traffic volumes exhibit very strong peaking patterns (e.g., areas in the vicinity of a manufacturing plant) and where there may be little relationship between peak and nonpeak traffic volumes. The obvious solution to this problem, increasing the number of pairs of photographs used for a given area and distributing them over the day, has the undesirable effect of multiplying the cost of the procedure.

The statistical benefits of collecting data for a greatly increased number of sections also are not as great as they may seem. The increase would result primarily (or exclusively) from replacing individual sections with geographical clusters of sections. This increase would capture the effect of variations in traffic volume across local roads and streets within a cluster, but, unless the number of clusters photographed is at least as great as the number of locations at which ground counters are used, photographic procedures will suffer from a reduced ability to capture the effect of traffic-volume variations across parts of a region.

Other problems with aerial or satellite photography include: tree cover, shadows, and other factors that may obscure or camouflage vehicles; for satellite photography, the availability of photographs with adequate resolution; and, for aerial photography, the number of flights that would be required to obtain a set of photographs with adequate geographic and temporal coverage.

Satellite photographs with a resolution of five meters are now becoming available, and resolutions of two to three meters are expected to be available in the future. Since most automobiles are slightly less than five meters in length, and appreciably narrower, it is by no means clear that these photographs will be usable for counting vehicles with any degree of accuracy. Furthermore, even if the technological issues can be solved satisfactory, the statistical issues, discussed above, will remain.

There is, however, one very specialized situation in which aerial or satellite photography techniques may be warranted: when a randomly selected sample of local rural roads includes one or more roads whose remoteness would make travel to and from the site to set up and retrieve a conventional traffic counter particularly expensive. If satellite photographs of the road in question can be obtained with sufficient resolution, they might provide an inexpensive means of estimating traffic on the road. Otherwise, one or more aerial photographs could be used, an alternative that may be less expensive than collecting ground-based 24 or 48-hour counts but is likely to produce poorer estimates of total travel.

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[21] The time lapse between photographs must be short enough so that the position of a vehicle in the two photographs can be paired unambiguously. Since a speed of 30 mph equals 44 feet per second, the ideal time lapse is probably not much more than a couple of seconds.

A.2.2 Other Photographic Techniques

The Autoscope is an image-processing system developed by Prof. Panos Michalopaulos of the University of Minnesota that is designed for collecting data on traffic volume, lane occupancy, average speed, and the speed of individual vehicles.[22]

The original model used an IBM-compatible computer to process images from a camera mounted near a roadway being monitored. When the camera is mounted overhead , the system is capable of monitoring traffic in all lanes of the road, but its visibility may bias the speed data collected. When the camera is located at the roadside, it can be hidden from view, but, for heavily traveled roads, visual blockage may result in some loss of information about activity in the far lanes. A new model was scheduled for release in April 1992. This model is environmentally hardened and uses an 80486 microprocessor to process images from up to four cameras located in the vicinity of the microprocessor. It is suitable for collecting traffic-flow data relating to the use of a single intersection or interchange but not for collecting data on four separate randomly selected roads.

The Autoscope appears to have some interesting potential for collecting and processing data on congestion and speed. However, for the limited purpose of collecting traffic counts, especially on lightly traveled roads, it does not appear to offer any advantages over conventional technology.

A.2.3 Interviews and Driver Logs

Travel estimates for any set of roads can be derived from usage data collected for a sample of these roads by conventional traffic counters or from photographs. An alternative approach is to collect the necessary data from a sample of the users of these roads. Such data can be collected by asking a sample of such users to maintain detailed logs of all trips made and routes used over a specified period of time (e.g., given day or week) or by collecting this information via in-person or telephone interviews. The collecting agency could then transcribe all route information onto a map and derive VMT estimates for the roads of interest (e.g., all local roads and streets).

These procedures entail two types of cost: those of data collection, and those of processing the information. Both of these types of cost will vary with sample size and are likely to prove to be appreciable if data are to be obtained from a significant sample of road users. Of the three types of data collection, telephone interviews will have the lowest overall data-collection costs, but they are also very likely to produce incomplete responses, thus biasing the resulting travel estimates downwards. Driver logs will result in very low data-collection costs to the collection agency, but a very high reporting burden - a burden that may result in biasing the sample of road users agreeing to participate in the study.

The information processing costs are likely to be dominated by the costs of transcribing all routes used onto maps and identifying the portions of each trip made on the roads of interest. The cost of the latter step could potentially be reduced if computerized maps are used.

Other problems with these procedures are:

- choosing the appropriate sampling frame (i.e., the population from which the sample is to be drawn);

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[22] Dick Magnuson, Image Processing Systems, Minneapolis, Minn., personal communication, March 16, 1992.

- selecting an unbiased sample (a particular problem if driver logs are used); and
- obtaining accurate and complete information about all trips made.

Incomplete trip information (and inaccurate route information) is a concern regardless of the procedure used for collecting the information. However, it is likely to be a particular problem if relatively short, non-probing, telephone interviews are used. Also, any interview procedures may be inadequate for obtaining accurate information from high-mileage drivers who do not travel repetitive routes. (Such drivers would include traveling salesmen and drivers of certain types of delivery vehicles.)

The issue of the appropriate sampling frame is an interesting one. A sample of all licensed drivers living in or near the area of interest might be appropriate. If this is the sample used, it would be necessary to collect data only for travel made when the sampled individual is actually driving the vehicle. There is also the question of in-area driving by commuters and visitors living outside the designated area and out-of-area driving by persons living inside the designated area - a question that might be resolved by making the assumption that the two effects would tend to cancel each other out.

Interviews and driver logs appear to be relatively expensive sources of information for estimating travel, and that designing procedures to use these sources to produce reasonably accurate unbiased estimates of travel would be relatively difficult.

APPENDIX B - EPA REQUIREMENTS

Sections 187(a)(2)(B) and 187(b)(2) require Serious CO non-attainment areas and Denver, Colorado to adopt and implement enforceable transportation control measures (TCMs) to offset any growth in emissions from growth in vehicle miles traveled and numbers of vehicle trips, and to achieve reductions in mobile source emissions as are necessary in conjunction with other control measures to comply with the periodic emission reduction requirements of the CAAA.....

Section 187(d) requires Serious CO non-attainment areas to submit to EPA by March 31, 1996 a demonstration that the emission reductions anticipated to occur by December 31, 1995 as specified in the 1992 State Implementation Plan revision have, indeed, occurred. Serious CO non-attainment areas that miss this milestone must submit to EPA a SIP revision to implement an economic incentive and transportation control program sufficient to achieve the annual emission reductions specified in the SIP by the attainment date.[23]

Air quality forecasting and attainment planning require an estimate of emissions in a certain geographic area in a past period with known air quality, and forecasts of future emissions under various alternative strategies designed to reduce emissions. Motor vehicles are the dominant source of CO in most non-attainment areas. CO from highway motor vehicles are a product of gram per mile emission factors (reflecting periods of both travel and parking) and the number of miles driven. The emission factors in turn are a function of trip length and traffic flow, with average traffic speed being the most common indicator of flow.

While trip length and traffic flow characteristics also influence emissions and are to some extent sensitive to influence by clean air programs, the more VMT growth there is in an area, the more effort is required to reduce both per vehicle and stationary source emissions to attain the ambient CO standard by the required deadlines. Consequently, the CO attainment plan is built largely around forecasted VMT in the attainment year.....

A feature of the Clean Air Act Amendments of 1990 is annual VMT tracking in CO areas in the period prior to the target attainment date. This is intended to spot situations in which the actual VMT growth occurring in the non-attainment area is higher than the forecasted VMT growth used in the attainment demonstration. Such a situation may arise from higher than expected population or economic growth, or lower than expected success at promoting alternative modes of travel. Under these circumstances, attainment is in jeopardy, and action beyond that originally contemplated in the demonstration might be necessary. Such actions include further reducing VMT growth and per mile vehicle emissions, as well as further controlling stationary emissions sources.

Because of the safety-net role played under the CAAA by a good tracking system and contingency measures, uncertainty in the initial VMT forecast is of somewhat less concern than it otherwise might be, since deviations from the forecast can be detected and mid-course corrections can be made to preserve the attainment date. This guidance, therefore, places as much emphasis on a well-defined and quality-assured tracking method as it does on valid forecasting methods. **In particular, the guidance specifies the use of systematic traffic ground counts as the underlying data for estimates in the future of actual VMT, at least in the urbanized area. This method is considered by EPA to be superior in terms of both practicality and effectiveness to other methods such as driver surveys, odometer data, registration counts, fuel sales, annually validated network models, etc......**

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[23] Section 187 VMT Forecasting and Tracking Guidance, Environmental Protection Agency, Washington, D.C., January 1992.

For all areas, estimates of actual 1993 and later vehicle miles traveled should be derived from traffic ground counts consistent with the existing Highway Performance Monitoring System. Since participation in this system is already a requirement of the FHWA, this approach will involve minor costs above those imposed in the same time period by the FHWA requirement.[24]

EPA has determined, in consultation with the Department of Transportation, that there is a statistical variability in the estimates of actual annual VMT generated through HPMS. Since forecasts of future VMT are based upon past VMT levels also generated from HPMS, using the "Historical Area-Wide VMT Method", this statistical variability similarly applies to VMT forecasts. Given the statistical variability in these numbers, EPA believes that it is appropriate to conclude that an estimate of actual annual VMT or a subsequent forecast of future VMT has exceeded the most recent prior forecast of VMT in any year only if the difference between the two numbers exceeds the variability in the accuracy of the numbers themselves. Although EPA is confident that this statistical variability exists and always will, EPA is not certain of the exact magnitude of the variability. Presently, EPA's best estimate of the variability of HPMS estimates and forecasts based on recent traffic counts is five percent. However, since EPA expects states to improve their HPMS programs over the next few years in response to FHWA guidance and this EPA guidance, EPA anticipates that the variability will be reduced to three percent....

In light of EPA's uncertainty as to the exact magnitude of the statistical variability in VMT calculations, and EPA's concern about the implications for SIP planning presented by the potentially uncontrolled VMT growth that can result from the application of a statistical error band every year, EPA believes that a cap must be imposed to prevent VMT estimates and forecasts from exceeding a defined margin above the VMT forecast relied upon as the basis of the approved attainment demonstration for a non-attainment area. Thus, while EPA believes that it is appropriate to allow areas the benefit of the 5.0, 4.0, or 3,0 percent variability, EPA believes that it is appropriate only as long as, cumulatively, estimates of actual VMT or VMT forecasts never exceed by more than 5.0 percent the VMT forecast relied upon in the area's attainment demonstration.

In practice, then, there are two ways in which an estimate of actual VMT or an updated forecast can be found to exceed a prior forecast. Individual yearly comparisons can result in an exceedance of the prior forecast by more than the prescribed percentage for that year, and exceedances can accumulate so that, cumulatively, they exceed the 5.0 percent "exceedance budget", which is based on the attainment demonstration forecast. So, even though actual VMT or an updated forecast remains within the error band around the most recent prior forecast for a particular year, the individual exceedance for that year plus the exceedances accumulated over previous years could amount to more than 5.0 percent above the forecast used in the attainment demonstration, thus triggering the automatic contingency measures.[25]

While HPMS includes state-provided estimates of VMT on the local functional system, these estimates are not generally based on current ground counts at statistically representative sites. Instead the estimates are based on a method chosen by the state in light of its own circumstances. States may continue to use the same methodology to estimate actual 1990, 1993, 1994 and 1995 VMT on the local functional system within the VMT Tracking Area.[26]

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[24] Environmental Protection Agency, op.cit., pp. 5-8.

[25] Environmental Protection Agency, op.cit., pp.11-13.

[26] Environmental Protection Agency, op.cit., p. 16.

The provision that contingency measures be triggered whenever a new forecast exceeds an old forecast, even if the actual VMT has not yet exceeded any forecast, appears to be intended to address as early as possible any situation in which a trend towards higher than expected VMT has been detected, since such a trend may affect the forecasted attainment date.

The need to preserve the integrity of the attainment demonstration and to react to unexpected VMT growth must be balanced against the desirability of preventing a false trigger of the contingency measures caused by the uncertainty in the VMT estimation and re-forecasting processes. This uncertainty can result in a merely transitory appearance in one year that actual or newly re-forecasted VMT exceeds the original VMT forecast, with the situation reversing in the next year or the year thereafter.

The sampling and non-sampling error inherent in HPMS points to a practical and theoretical need for a margin of error around VMT estimates and forecasts so that contingencies are not triggered for small and possibly random deviations from forecasted VMT. At the same time, actual annual VMT cannot be allowed to creep above the original attainment-producing forecast without limit. Though successively higher forecasts may remain within the established margin of error compared to the previous forecasts, they could, in fact, be drifting further and further from the original forecast.

In order for a margin of error to serve the purpose of preventing a false trigger of contingency measures without allowing unchecked VMT growth, actual annual VMT and later forecasts should never be allowed to be more than the defined margin above the forecast that is the basis for an approved attainment demonstration. The use of an attainment-producing forecast as the base for measuring deviations ensures that growth in VMT remains consistent with the attainment demonstration, except for a de minimis deviation, or, if it does not, that contingency measures are triggered.

Consequently, as previously explained in Section 2.3, contingency measures will be triggered in any case where an estimate of actual annual VMT or an updated VMT forecast exceeds the most recent prior VMT forecast by more than 5.0 percent in 1994, 4.0 percent in 1995, and 3.0 percent thereafter. Contingency measures will also be triggered even though the margin of error is less than the specified percentage for that year if, cumulatively, estimates of actual VMT or VMT forecasts exceed the VMT forecast relied upon in the attainment demonstration for area by more than 5.0 percent.[27]

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[27] Environmental Protection Agency, op.cit., pp. 24-25.

APPENDIX C - DATA COLLECTION EQUIPMENT AND PROCEDURES [28]

States use a variety of equipment and procedures to generate traffic counts on their highway systems. This appendix describes some of the most common types of equipment and procedures that are currently being used. The two most common types of equipment used for generating traffic counts are pneumatic tubes and induction loops. Pneumatic tubes operate in a way similar to the tubes often used at gasoline stations to announce customers, and are much more commonly used than induction loops. The counter registers the disturbance in the air flow through the tube at the passage of a vehicle. A drawback of this type of equipment is that it counts the number of axles and not the number of vehicles that pass over it. This problem is dealt with in one of two ways, axle adjustment factors, which is more common, or classification counts. The total axle count generated by the counter is divided by the axle adjustment factor, which is usually slightly larger than two, to approximate the number of vehicles which passed over the counter. The axle adjustment factor is derived from classification counts.

A classification count differs from an axle count in that it counts the number of vehicles that pass the counter. Pneumatic tubes can be used to generate classification counts by placing two tubes approximately 16 feet apart and observing the time that passes between when a vehicle hits the first tube and when it hits the second. From this time reading the counter can classify the vehicle as a motorcycle, car, truck, or bus, etc.. The other way to generate classification counts is by using an induction loop. The loop consists of an electrical wire that is placed two to three inches beneath the pavement, with the end of the wire exposed at the side of the road. The loop can easily be laid after the road has been paved by simply cutting a small trench in the pavement, laying loop in the trench, and resealing the trench. At the side of the road the counter is then attached to the exposed ends of the wire loop and a current is run through the loop. The counter registers disturbances in the electrical field created by the loop as a passing vehicle. The counter classifies the vehicle according to the size of the disturbance. In addition to generating classification counts, induction loops are used on freeways and other highways where vehicles in different lanes are going at different speeds. Multi-lane highways usually have a different induction loop for each lane. Approximately ten percent of all traffic counts are classification counts. In some states, such as Florida, there is a movement to place permanent induction loops into the pavement, and hook up the portable counter whenever a count is needed at that location.

The counters themselves are more electronic than mechanical. Many of the newer counters can receive data from both induction loop and pneumatic tubes and determine the classification of the passing vehicle from that data. Some of the more advanced can receive data from eight different sources at once. These machines can be used to gather data on traffic flow in both directions on multi-lane highways or from more than one exit or entrance ramp on highways. The cost of these counters vary with their capabilities but the average is approximately $1,600 for the newer models. The usable life span of these counters is extremely long. More counters are lost due to theft, damage from vehicles or vandals, or obsolescence than due to normal wear and tear. Some state organizations did estimate ten years as the reasonable expected life span of the counters.

Most of the newer counters have internal timers that allow the user to program when it will start the count and when it will stop and at what intervals the counter records the data. Most states generate counts over 48 periods and record the data on one hour intervals, although Florida records data on fifteen minute intervals. The counter will usually store the data electronically on a removable data module or, more commonly, on a RAM chip. The data that is stored on removable cartridges must be accessed by

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[28] Traffic Estimating Procedures for the Local Functional System - Statistical Precision and Resource Requirements, prepared for Volpe National Transportation Systems Center, Jack Faucett Associates, Bethesda, MD, November, 1992.

a reader located in an office. The data on RAM chip can be downloaded onto a cartridge which is inserted into the counter (which can store multiple files), a data reader (usually a small microprocessor), or a lap-top PC. However the data is retrieved initially, its ends up on a PC. Table C-1 shows equipment and labor costs for different state traffic counting programs.

The structure for the organizations that are responsible for collecting the data varies from state to state. Some states, such as Texas or Florida, have very decentralized programs, while other states, such as Indiana or New York, favor more centralized programs. In general the personnel involved in a program can be divided into three categories; field crews, statisticians/technicians, and administrators. In many programs there is some amount of overlap between these groups. That is, some field crews and administrators assist the technician/statisticians in analyzing the data. In some states, such as Florida, the agency responsible for developing the traffic counts hires contractors to generate the counts. In others states, such as Pennsylvania and Texas, the responsibility for generating the counts are partially passed on to local governments.

The field crews consist of anywhere from one to three members for each highway region. On the average, states maintain between four and seven field crews. Most members of a field crew have a high school diploma and some technical back ground. Their job classification is often Engineer/Technician and their annual salary is in the $21,000 range. In almost all cases they are full time, and in most states year-round.[29] The major responsibility of these personnel tends to be the placing of counters and the retrieval of data. One exception to this is when the responsibility is passed on to local institutions as is the case when the Pennsylvania Bureau of Transportation System Performance asks the local Metropolitan Planning Administrations (MPAs) to perform counts. In these cases the counts are often additional responsibilities for the organization's employees. However most centralized state programs maintain their own full-time field crews. The field crews are often partially responsible for the initial development of the data. In many cases they screen the data for discrepancies due to equipment failings or disruption of the traffic pattern due to accidents or special events. To minimize these disturbances, the counts are not taken on weekends and holidays when the traffic patterns are not normal flows.

Once the data is developed, it is sent to a central office were a staff of two or three technician/statisticians prepare the data. These employees have a higher grade than the field crews, usually Engineers, and earn about $28,000 a year. They apply the axle adjustment factors to the axles counts and also apply the seasonal adjustment factors. Some states also have day of week, week of year, or even hour of day adjustment factors. The axle adjustment factors are derived from classification counts. Other adjustment factors are derived from permanent traffic counters that are in operations continually through out the year. Many states have developed software packages to apply these adjustment factors and analyze the finished data. Almost all states mark their data so that the location where the count was made can be easily determined. Supervising this entire process is an Administrator who earns approximately $48,000 a year. It is estimated that approximately one-third of his/her time is spent overseeing the traffic collection effort.

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[29] Pennsylvania and New York do not take traffic counts during the winter due to weather conditions (ice and snow). On the average, states are unable to perform counts seven weeks out of the year.

TABLE C.1 - EQUIPMENT, LABOR AND OTHER TRAFFIC COUNTS BY STATE

	NY	FL	PA	CA	IN	NC	WA	AZ	MN
No. of Counters	340	280	40	1000	110	940	558	235	1292
Cost of Counters	$1200-1600	$900-1500	$1300	$1500	$1300	$150-1500	$600-2200	$1600-2200	$200-2000
No. of Counts	5000	10000	4600	12500	5000	10000	5000	6400	13000
Classification	500	2000	3450	625	4500			180	
Axle	4500	8000	1150	11875	500			6220	
Expendable Costs per Count	$1.74	$1.74	$1.74	$1.74	$1.74	$1.74	$1.74	$1.74	$1.74
No. of Personnel	11	24	13	27	15	29	8	10	15
Administrators	1	1	1	1	1	1	1	1	1
Field Crews	8	21	9	24	10	24	5	7	9
Statisticians	2	2	3	2	4	4	2	2	5
Salaries of									
Administrators	$50000	$45000	$45000	$45000	$40000	$35000	$35000	$40000	$40000
Field Crews	$24000	$22000	$17000	$21000	$14000	$15000	$25000	$20000	$21000
Statisticians	$40000	$28000	$26000	$27000	$20000	$20000	$30000	$28000	$30000

APPENDIX D - AVAILABLE LOCAL ROADS DATA

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Pittsburg	19	0.19	89-01-10	13	2.47
Iola	7	0.17	88-11-09	20	3.4
Atchinson	11	0.07	89-03-08	29	2.03
Iola	7	0.14	88-12-27	40	5.6
Manhattan	33	0.07	89-02-28	45	3.15
Manhattan	33	0.36	89-02-28	50	18
Atchinson	11	0.15	89-03-07	56	8.4
Emporia	25	0.14	89-02-21	64	8.96
Wichita	279	0.08	91-07-15	69	5.52
Chante	11	0.2	01-30-89	78	15.6
Topeka	115	0.24	89-06-22	84	20.16
Topeka	115	0.22	89-07-17	94	20.68
Atchinson	11	0.2	89-03-06	103	20.6
Topeka	115	0.12	89-07-20	113	13.56
Winfield	10	0.3	91-05-20	125	37.5
Kansas City	161	0.05	89-09-07	132	6.6
Topeka	115	0.03	89-07-18	139	4.17
Manhattan	33	0.17	89-03-15	145	24.65
Hutchinson	40	1	91-07-01	157	157
Pittsburg	19	0.5	89-01-10	166	83
Parsons	13	0.25	89-01-10	176	44
Kansas City	161	0.17	89-08-07	188	31.96
Lawrence	53	0.33	89-02-01	199	65.67
Ottawa	11	0.5	88-10-10	200	100
Kansas City	161	1	89-08-16	219	219
Olathe	37	0.12	89-09-12	240	28.8
Kansas City	161	1.04	89-09-06	260	270.4
Kansas City	161	0.29	89-08-14	282	81.78
Fort Scott	9	0.6	89-01-17	300	180
Concordia	7	0.52	90-03-21	321	166.92

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Fort Scott	9	0.07	89-01-17	343	24.01
Topeka	115	0.16	89-09-25	368	58.88
Winfield	10	0.32	91-05-21	395	126.4
McPherson	12	0.13	90-07-12	427	55.51
Topeka	115	0.15	89-07-17	500	75
Wellington	8	0.47	91-07-17	570	267.9
Ottawa	11	0.29	88-08-08	639	185.31
Topeka	115	0.11	89-06-22	718	78.98
Salina	42	0.57	90-04-02	806	459.42
Winfield	10	0.21	91-05-21	901	189.21
Emporia	25	0.37	89-02-21	1000	370
Wichita	279	0.25	88-06-09	1132	283
Augusta	7	0.25	91-07-15	1274	318.5
Garden City	18	0.39	91-01-16	1466	571.74
Parsons	13	0.37	89-01-09	1667	616.79
Leavenworth	33	0.72	89-03-07	2008	1445.76
Abiline	6	0.46	89-12-07	2013	925.98
Russell	5	0.13	90-09-18	2022	262.86
Salina	42	0.16	90-03-26	2044	327.04
Garden City	18	0.51	91-02-06	2055	1048.05
Topeka	115	0.5	89-07-20	2070	1035
Wichita	279	0.51	91-07-22	2077	1059.27
Iola	7	0.1	88-11-16	2080	208
Salina	42	0.25	90-03-29	2086	521.5
Independence	11	0.22	89-01-10	2105	463.1
Emporia	25	0.25	89-02-22	2113	528.25
Atchinson	11	0.07	89-03-27	2117	148.19
Ottawa	11	0.08	88-11-07	2123	169.84
Parsons	13	0.26	89-01-09	2141	556.66
Junction City	19	0.07	90-01-24	2157	150.99

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Olathe	37	0.25	89-08-30	2160	540
Topeka	115	0.16	89-07-17	2174	347.84
Manhattan	33	0.09	89-03-07	2178	196.02
Manhattan	33	0.36	89-03-06	2185	786.6
Parsons	13	0.07	89-01-03	2193	153.51
McPherson	12	0.75	90-07-12	2197	1647.75
Junction City	19	0.66	90-01-23	2200	1452
Kansas City	161	0.27	89-08-15	2218	598.86
Hutchinson	40	0.44	91-06-19	2230	981.2
Fort Scott	9	0.2	89-01-17	2237	447.4
Winfield	10	0.38	91-07-09	2256	857.28
Pittsburg	19	0.22	89-01-25	2258	496.76
Pittsburg	19	0.07	89-01-09	2267	158.69
Augusta	7	0.39	91-07-15	2271	885.69
Hays	17	0.16	90-10-31	2288	366.08
Pittsburg	19	0.2	89-01-10	2294	458.8
Wichita	279	0.75	91-07-31	2296	1722
Leavenworth	33	0.13	89-03-22	2303	299.39
Abiline	6	0.14	89-12-07	2309	323.26
Topeka	115	0.6	89-07-17	2311	1386.6
Independence	11	0.5	88-11-22	2317	1158.5
Emporia	25	0.14	89-03-01	2329	326.06
Pittsburg	19	0.39	89-01-11	2336	911.04
Manhattan	33	0.35	89-02-21	2344	820.4
Garden City	18	0.4	91-01-16	2351	940.4
Independence	11	0.23	89-01-30	2361	543.03
Kansas City	161	0.64	89-08-15	2364	1512.96
Topeka	115	0.45	89-07-17	2381	1071.45
Emporia	25	0.17	89-03-01	2390	406.3
Wichita	279	0.45	88-06-13	2393	1076.85

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Derby	10	0.07	91-07-25	2398	167.86
El Dorado	10	0.23	91-07-02	2427	558.21
Lawrence	53	0.07	89-02-23	2430	170.1
Atchinson	11	0.15	89-03-08	2438	365.7
Leavenworth	33	0.33	89-03-21	2443	806.19
Lawrence	53	0.53	89-02-13	2465	1306.45
Great Bend	17	0.38	91-04-29	2472	939.36
Lawrence	53	0.3	89-02-21	2476	742.8
Parsons	13	0.1	89-01-09	2484	248.4
Emporia	25	0.09	89-03-01	2495	224.55
Leavenworth	33	0.5	89-03-07	2535	1267.5
Independence	11	0.08	89-01-25	2539	203.12
El Dorado	10	0.42	91-07-01	2566	1077.72
Leavenworth	33	0.26	89-03-09	2569	667.94
Great Bend	17	0.15	91-04-29	2571	385.65
Leavenworth	33	0.09	89-03-21	2588	232.92
Parsons	13	0.15	89-01-04	2603	390.45
Manhattan	33	0.09	89-02-13	2619	235.71
Kansas City	161	0.68	89-08-30	2627	1786.36
Junction City	19	0.15	90-01-23	2636	395.4
Topeka	115	0.16	89-06-22	2636	421.76
Colby	6	0.14	91-03-05	2647	370.58
Fort Scott	9	0.45	89-01-11	2657	1195.65
Pittsburg	19	0.26	89-01-04	2662	692.12
Lawrence	53	0.11	89-02-28	2690	295.9
Kansas City	161	0.5	89-08-23	2691	1345.5
Iola	7	0.06	88-11-17	2706	162.36
Atchinson	11	0.67	89-03-06	2710	1815.7
Olathe	37	0.55	89-08-30	2737	1505.35
Topeka	115	0.57	89-07-20	2759	1572.63

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Manhattan	33	0.26	89-03-07	2775	721.5
Olathe	37	0.1	89-08-01	2787	278.7
Chante	11	0.07	11-29-88	2788	195.16
Newton	16	0.54	91-06-20	2814	1519.56
Garden City	18	0.1	91-01-16	2826	282.6
Atchinson	11	0.5	89-03-06	2852	1426
Atchinson	11	0.16	89-03-28	2893	462.88
Newton	16	0.5	91-05-28	2906	1453
Kansas City	161	0.25	89-08-28	2912	728
Topeka	115	0.64	89-07-20	2925	1872
Salina	42	0.27	90-03-26	2967	801.09
Hays	17	0.13	90-10-31	3002	390.26
Leavenworth	33	0.29	89-03-07	3011	873.19
Liberal	15	0.78	90-12-03	3013	2350.14
Derby	10	0.78	91-07-24	3018	2354.04
Great Bend	17	0.11	91-05-01	3037	334.07
Fort Scott	9	0.27	89-01-11	3057	825.39
Emporia	25	0.33	89-02-22	3072	1013.76
Independence	11	0.26	88-11-22	3089	803.14
Newton	16	0.07	91-06-20	3098	216.86
Emporia	25	0.1	89-02-28	3151	315.1
McPherson	12	0.07	90-06-25	3153	220.71
Great Bend	17	0.35	91-04-30	3190	1116.5
Fort Scott	9	0.23	89-01-17	3211	738.53
Goodland	6	0.07	90-08-15	3235	226.45
Wichita	279	0.43	88-06-07	3238	1392.34
Bonnon Spring	6	0.23	89-06-19	3251	747.73
Salina	42	0.67	90-03-26	3259	2183.53
Olathe	37	0.76	89-08-02	3263	2479.88
Manhattan	33	0.27	89-03-08	3299	890.73

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Manhattan	33	0.25	89-02-21	3321	830.25
Wichita	279	0.15	91-07-09	3325	498.75
Dodge City	18	0.17	91-02-11	3347	568.99
Winfield	10	0.28	91-05-21	3382	946.96
Lawrence	53	0.09	89-02-21	3394	305.46
Manhattan	33	0.17	89-02-28	3428	582.76
Dodge City	18	0.12	91-02-11	3429	411.48
Emporia	25	0.09	89-02-13	3439	309.51
Emporia	25	0.07	89-02-13	3459	242.13
Kansas City	161	0.44	89-09-14	3469	1526.36
Kansas City	161	1.01	89-08-30	3482	3516.82
Parsons	13	0.14	89-01-04	3505	490.7
Topeka	115	0.12	89-07-20	3519	422.28
Kansas City	161	0.52	89-08-23	3524	1832.48
Leavenworth	33	0.12	89-03-22	3552	426.24
Leavenworth	33	0.36	89-03-21	3561	1281.96
Kansas City	161	0.39	89-08-07	3590	1400.1
McPherson	12	0.25	90-08-14	3601	900.25
Topeka	115	0.08	89-07-19	3644	291.52
Lawrence	53	0.25	89-02-21	3656	914
Olathe	37	0.2	89-08-01	3714	742.8
Iola	7	0.12	88-12-27	3737	448.44
Hays	17	0.51	90-10-31	3749	1911.99
El Dorado	10	0.19	91-07-02	3799	721.81
Topeka	115	0.1	89-07-18	3842	384.2
Olathe	37	0.11	89-08-01	3860	424.6
Olathe	37	0.2	89-08-02	3901	780.2
Kansas City	161	0.21	89-08-15	3911	821.31
Great Bend	17	0.36	91-04-30	3919	1410.84
Parsons	13	0.14	89-01-04	3979	557.06

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Topeka	115	0.14	89-07-19	4065	569.1
Topeka	115	0.63	89-07-20	4077	2568.51
Dodge City	18	0.07	91-02-11	4081	285.67
Atchinson	11	0.15	89-03-28	4105	615.75
Salina	42	0.08	90-07-26	4109	328.72
Wichita	279	0.28	91-07-23	4112	1151.36
Lawrence	53	0.21	89-02-13	4126	866.46
McPherson	12	0.07	90-07-12	4163	291.41
Arkansas City	13	0.17	91-07-09	4214	716.38
Independence	11	0.25	88-11-22	4223	1055.75
Kansas City	161	0.32	89-08-07	4286	1371.52
Kansas City	161	0.25	89-08-01	4301	1075.25
Kansas City	161	1.02	89-09-07	4335	4421.7
Wichita	279	0.5	91-07-29	4347	2173.5
Kansas City	161	0.5	89-09-06	4357	2178.5
Independence	11	0.15	89-01-30	4365	654.75
Emporia	25	0.17	89-02-28	4389	746.13
Pittsburg	19	0.07	89-01-04	4442	310.94
Kansas City	161	0.62	89-09-07	4535	2811.7
Salina	42	0.14	90-07-26	4550	637
Iola	7	0.12	89-01-30	4577	549.24
Hays	17	0.19	90-10-17	4612	876.28
Manhattan	33	0.15	89-03-06	4689	703.35
Salina	42	0.1	90-03-29	4766	476.6
Junction City	19	0.11	90-06-04	4806	528.66
Kansas City	161	0.51	89-09-12	4836	2466.36
Hutchinson	40	0.04	91-06-25	4880	195.2
Colby	6	0.44	91-03-05	4910	2160.4
Kansas City	161	0.96	89-09-18	5024	4823.04
Lawrence	53	0.3	89-02-01	5050	1515

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Lawrence	53	1.03	89-02-23	5085	5237.55
Wichita	279	0.16	91-07-24	5136	821.76
Topeka	115	0.17	89-06-22	5183	881.11
Colby	6	0.13	90-10-29	5193	675.09
Hutchinson	40	0.07	91-06-25	5257	367.99
Salina	42	0.19	90-07-26	5311	1009.09
Kansas City	161	0.5	89-09-11	5334	2667
Topeka	115	0.08	89-07-17	5361	428.88
Salina	42	0.09	90-03-29	5392	485.28
Salina	42	0.03	90-03-29	5429	162.87
Wichita	279	0.06	88-06-07	5481	328.86
Manhattan	33	0.3	89-03-07	5559	1667.7
Wichita	279	0.04	91-07-31	5584	223.36
Topeka	115	0.5	89-07-20	5657	2828.5
Hays	17	0.47	90-11-01	5742	2698.74
Garden City	18	0.37	91-01-16	5788	2141.56
Kansas City	161	0.69	89-08-15	5797	3999.93
Lawrence	53	0.26	89-02-13	5853	1521.78
Emporia	25	0.03	89-02-22	5899	176.97
Independence	11	0.08	89-01-30	5924	473.92
Topeka	115	0.37	89-07-19	6031	2231.47
Independence	11	0.15	88-11-22	6127	919.05
Topeka	115	0.08	89-07-18	6190	495.2
Manhattan	33	0.08	89-03-06	6306	504.48
Manhattan	33	0.1	89-03-01	6402	640.2
Kansas City	161	0.19	89-10-17	6455	1226.45
Olathe	37	0.38	89-08-30	6550	2489
Lawrence	53	0.06	89-02-23	6608	396.48
Topeka	115	0.37	89-07-19	6646	2459.02
Kansas City	161	0.09	89-09-18	6662	599.58

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Kansas City	161	0.38	89-09-11	6820	2591.6
Kansas City	161	0.06	89-09-18	6878	412.68
Atchinson	11	0.21	89-03-08	6884	1445.64
Augusta	7	0.6	91-08-12	6951	4170.6
Kansas City	161	0.84	89-08-07	6992	5873.28
Derby	10	0.18	91-07-24	7113	1280.34
Topeka	115	0.07	89-07-20	7160	501.2
Wichita	279	0.13	91-07-24	7195	935.35
Garden City	18	0.23	91-01-16	7360	1692.8
Wichita	279	0.98	91-07-24	7389	7241.22
Kansas City	161	0.5	89-08-28	7614	3807
Kansas City	161	0.42	89-08-08	7663	3218.46
Independence	11	0.08	89-01-30	7714	617.12
Topeka	115	0.16	89-07-18	7843	1254.88
Olathe	37	0.45	89-08-30	7904	3556.8
Topeka	115	0.1	89-07-20	7907	790.7
Lawrence	53	0.08	89-02-28	7952	636.16
Lawrence	53	0.13	89-02-28	8001	1040.13
Topeka	115	0.08	89-07-17	8038	643.04
Kansas City	161	0.71	89-08-15	8100	5751
Wichita	279	0.13	91-07-23	8629	1121.77
Manhattan	33	0.08	89-03-06	8849	707.92
Wichita	279	0.31	91-07-10	9000	2790
Lawrence	53	0.23	89-02-28	9186	2112.78
Topeka	115	0.1	89-07-18	9533	953.3
Wichita	279	0.35	91-07-22	9676	3386.6
Kansas City	161	0.5	89-09-06	10392	5196
Topeka	115	0.32	89-07-18	11253	3600.96
Manhattan	33	0.49	89-03-08	12004	5881.96
Topeka	115	0.14	89-07-17	12799	1791.86

TABLE D.1 - SAMPLE OF KANSAS URBAN ROADS DATA

City	Population (thousands)	Segment Size (miles)	Date of Count	AADT	DVMT
Kansas City	161	0.67	89-08-28	13313	8919.71
Kansas City	161	0.25	89-08-28	16885	4221.25
Kansas City	161	0.15	89-09-11	49064	7359.6

APPENDIX E - LOCAL ROADS DATA COLLECTION PROGRAMS

Georgia

Georgia classifies all counties into four population groups and stratifies local roads on the basis of urban or rural location and paved or unpaved surface. In 1990, a sample of 2500 local road sections was distributed across counties on the basis of the miles of local road in each county. For each county, a sample of local sections was obtained randomly, apparently without consideration as to surface type or urban/rural location.

For each of the 16 population/road-type strata, an average traffic count is obtained as a weighted average of the counts for all sample sections in the stratum. The weights are taken to be equal to the section length.

Total travel on local roads in each county is obtained by multiplying the mileage of local roads in each of the county's four strata by the corresponding estimate of average traffic. All counts were obtained during a two-month period and there apparently was no correction made for seasonal factors.

Except for the urban unpaved strata (which contain very few sample sections), the estimates of average traffic for all strata were found to have a precision of +-25% or better.

In 1991, an additional 1100 sections were added to the sample of local roads, but no information is provided on the distribution of these sections or the selection procedure used.[30]

Iowa

In Iowa traffic counts are taken on a sample of local roads in each county every eight years, with all counts that are taken in a given year being for a sample of counties in one quadrant of the State. Counts are taken on a small statewide sample of urban streets (apparently every year). The sampling procedure used is not described.[31]

Kansas

The Kansas Department of Transportation (DOT) uses a set of county-level road maps to provide a computer inventory of the rural local roads, using the rectangular grid pattern of these roads as the basis for an ordered listing. For some areas of interest, incomplete inventories of local roads have already been developed. For example, such inventories have been developed for all urbanized areas in Kansas. Apparently, the Kansas inventories were originally developed by selecting for enumeration a sample of residential, commercial and industrial neighborhoods. The Kansas procedure is essentially a form of cluster sampling.

Kansas evidently classifies urban local sections as "rural/city," "urban/city," or "urban/non-city." Counts currently are taken only on a sample of urban sections. If a Highway District is currently using a sample

[30] "Development of Local Road DVMT Estimates in Georgia," no date.

[31] Traffic Monitoring System, Iowa Department of Transportation, June 2, 1989.

size of more than 30 for any one of three classes of urban local sections, the sample may be reduced, otherwise the entire sample should be used.

A nine-year counting cycle is recommended for local sections (compared to six years for minor collectors not in the HPMS sample and three years for all other sections). Twenty-four-hour counts are specified for non-HPMS sections and 48-hour counts for HPMS sections.[32]

Kentucky

Kentucky uses a variant of the HPMS Field Manual cluster sampling procedure. Kentucky's version of this procedure differs in the following respects:

1. Traffic estimates for local rural roads are developed separately for three types of counties; coal producing, coal impact, and other. Thus the procedure distinguishes among three types of rural counties that may well have different intensities of local road use. (However, small urban areas are not distinguished in this way but, only on the basis of whether or not their population exceeds 25,000.)

2. In the formula for determining sample size, the multiplier used for the rural systems is 30 percent (instead of 10 percent), and the multiplier used for small urban areas with populations over 25,000 is 20 percent (instead of 10 percent). The other multipliers are not changed.

3. Of the resulting sample of 3340 local sections, traffic counts are obtained for only 1200 sections. Counting is performed on a three-year cycle, with approximately 400 counts performed every year.

The last two modifications result in reducing the number of sample local urban sections for which traffic counts are obtained by a factor of nearly three for urbanized areas and for small urban areas with a population exceeding 25,000, and a factor of nearly 1.5 for other small urban areas. There is virtually no net effect on the number of local rural sections for which counts are obtained.[33]

Virginia

Virginia maintains a complete inventory of road sections in all but two counties, with each section being one block long (i.e., connecting a pair of adjacent intersections). The Virginia local roads data contains over 86,000 records of data for rural and urban local roads. Surface type information is not available for the local roads data. Section length is available for every record.

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[32] Kansas Traffic Sampling Plan for Non-State Routes, April 1986.

[33] "Highway Performance Monitoring System (HPMS): Local Roads Sample File," written material sent by Donald L. Ecton, Kentucky Transportation Cabinet, to Paul Svercl, Federal Highway Administration, November 26, 1990.

Under Virginia's new procedure, traffic on every section of local road is counted once every four years with three exceptions:

Counts are repeated at two-year intervals on unpaved roads whose most recent count shows average daily traffic (ADT) of at least 40. (If the count reaches 50, these sections can be paved.)

A series of consecutive sections with very similar traffic counts are combined into one section and only one count is taken to represent the series. (In effect, these sections are treated as a separate stratum that is sampled only once.)

It is assumed that, once all housing units in a residential subdivision are sold, VMT in the subdivision remains constant; traffic counts obtained once this condition occurs are assumed to be usable indefinitely afterwards. This procedure should produce very good estimates of local VMT, though it could require more traffic counts than would a sampling procedure that is statistically designed to produce estimates of equal precision. Unfortunately, the assumption that VMT in "closed out" subdivisions never changes limits the procedure's ability to capture the effects of policies (or economic changes) that affect trip-making, thus compromising somewhat the value of the resulting VMT estimates to EPA.

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