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Stratification of Locally Owned Roads for Traffic Data Collection

Final Report

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16. Abstract

In Pennsylvania, there are over 72,000 miles roadways owned by 2,565 municipalities that are not on the Federal-aid system, and are classified as local roads. Currently, the Pennsylvania Department of Transportation (PennDOT) does not have a systematic approach to monitoring the traffic volumes on this portion of the highway system to produce estimates of vehicle-miles traveled (VMT). Federal guidelines such as the Highway Performance Monitoring System (HPMS) Field Manual and Traffic Monitoring Guide (TMG) are of some benefit but provide the most complete and detailed guidance for higher class facilities.

This research project aimed to determine a sampling method to collect the data required to produce VMT estimates on local roads owned by municipalities. The proposed research methodology built upon (1) the guidance contained in the TMG and HPMS Field Manual; (2) the experiences of others as discovered through a survey of state DOTs; (3) and an extensive literature search, to develop a plan specific to the circumstances facing PennDOT. It was designed to be feasible within the resources PennDOT has available to devote to local road monitoring, and to provide a foundation of data upon which VMT estimates could be made at the county level for each urban / rural code. The end result was a plan that contained 7,171 count stations spread proportionally over 152 strata.

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EXECUTIVE SUMMARY

In Pennsylvania, there are over 72,000 miles roadways owned by 2,565 municipalities which are not on the Federal-aid system, and are classified as local roads. Currently, the Pennsylvania Department of Transportation (PennDOT) does not have a systematic approach to monitoring the traffic volumes on this portion of the highway system to produce estimates of vehicle-miles traveled (VMT). Federal guidelines such as the Highway Performance Monitoring System (HPMS) Field Manual and Traffic Monitoring Guide (TMG) are of some benefit, but their guidance is more oriented towards higher class facilities.

This research project aimed to determine a sampling method to collect the data required to produce VMT estimates on local roads owned by municipalities. The plan was tailored to the specific needs of PennDOT, and was built upon (1) the guidance contained in the TMG and HPMS Field Manual; (2) the experiences of others as discovered through a survey of state DOTs; (3) and an extensive literature search.

Establishing the sample panel selection methodology essentially involved deciding on the variables by which the local roads would be stratified and the sample sizes within each stratum. The roadway network, which was provided from the Municipal Services database, was already segmented, eliminating the need for this step. Once the sample panel selection methodology was in place, it then became a matter of randomly drawing the required sample from each strata.

Since the research team did not have confidence in the potential surrogate measures for AADT, it was decided to stratify the roadway segments according to the manner in which the VMT estimates would be made. It was indicated by the Department that VMT estimates would be made at the county level for each of the four urban / rural codes. Therefore, this scheme was selected as the basis for stratifying the roadway segments.

This approach was designed to be feasible within the resources PennDOT has available to devote to local road monitoring, and to provide a foundation of data upon which VMT estimates could be made at the county level for each urban / rural code. The end result was a plan that contained 7,171 count stations spread proportionally over 152 strata.

PennDOT can begin collecting AADT counts at the locations identified in the sample panel immediately. It should be noted that in 88 of the municipalities, specific locations will need to be selected by the Department, as a segmented database was not available for these municipalities. Also, none of the count locations within the selected segments have been identified. This should be done by the data collection technicians in the field at the time of data collection, as it is a function of the type of equipment used in the data collection.

It is anticipated that the 7,171 counts will be spread out over a time frame of up to 10 years. However, PennDOT will likely do as many as feasible at the kick-off of this endeavor. The Department should re-evaluate the overall number of counts, and the sample size in each stratum at various times over the data collection process. Of particular importance will be precision analysis when 45 counts are accumulated in a given strata, and the coefficient of variation for the AADT data within each strata. The plan presented in this research is a starting point that was not based on any statistical analysis of local road AADT data. It can be revised as appropriate once data become available.

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CHAPTER 1 – INTRODUCTION

1.0 Background and Problem Statement

The Pennsylvania Department of Transportation executes an extensive statewide traffic volume monitoring program in compliance with Federal Highway Administration (FHWA) guidelines. The foundations of this program are the continuous count program at the statewide automatic traffic recorder (ATR) locations, the Highway Performance Monitoring System (HPMS) counts, and additional coverage counts.

The Traffic Monitoring Guide (TMG), issued by FHWA and last released in 2001, provides guidance on the design and execution of a statewide traffic volume monitoring program for estimating vehicle-miles traveled (VMT). For higher classified roads, recommendations for sampling include counts that are a minimum duration of 48-hours and occur on a maximum three-year cycle. The basis for this sampling strategy is a framework in which AADT is projected from short-term counts using a series of factors to adjust for temporal variations.

Chapter VII of the HPMS Field Manual (FHWA, 2000) also provides guidance on the design of the HPMS data collection program. Specifically, it lays out detailed procedures for the stratification of the roadway network and selection of a sample panel. This includes an equation for the computation of required sample size. The general methodology to be followed in developing the sample panel is straightforward and readily understood. However, three factors complicate this effort when the network to be monitored is locally-owned and locally-classified. First, both the HPMS Field Manual and the TMG lack sufficient guidance for local roads. In both instances, the guidance provided for the higher class facilities is more complete, detailed, and is presented with more confidence. Second, segmenting and stratifying the system, at least for higher class facilities, requires existing AADT data, which is not available for the local road system. Third, in Pennsylvania, there are over 72,000 miles roadways owned by 2,565 municipalities that are not on the Federal-aid system, and are classified as local roads. The sheer magnitude of this problem can present issues because it involves working with a very large database.

These three issues suggest that serious consideration is warranted before designing a sampling strategy for collecting traffic data for the purpose of estimating VMT on local roads. **The purpose of this research is to determine a sampling method to collect the data required to produce VMT estimates on local roads owned by municipalities.** The proposed research methodology is to build on the guidance contained in the TMG and HPMS Field Manual, and to develop a program specifically for Pennsylvania by (1) leveraging the experiences of others, as discovered through a targeted survey of peer state DOTs and an extensive literature search and (2) by customizing the program to the specific circumstances facing PennDOT.

1.1 Research Objectives

The overall goal of this research is to determine a sampling method to collect the data required to estimate VMT on locally-owned, locally-functionally classified roads. To that end, a research methodology is executed that is focused on determining and capitalizing on the experiences and progress made by others in this regard. The following objectives are proposed:

- To thoroughly review the Traffic Monitoring Guide (TMG) and HPMS Field Manual to determine the guiding principles of statewide traffic volume monitoring that are applicable to low volume, locally-owned, or locally-classified roads. Additionally, to review the HPMS Field Manual to identify the procedures for developing a sample panel for HPMS data collection.

- To conduct a literature review of research related to statewide traffic volume monitoring as it relates to low volume, locally-owned roads, or locally-classified roads.

- To conduct a targeted survey of other state DOTs to determine how other states monitor these roads in compliance with HPMS requirements.

- To synthesize the findings of the literature review (including the TMG and HPMS Field Manual) and survey in the development of a methodology for establishing a sample panel for the local road system in Pennsylvania. The target result will be a sampling strategy that is scientifically-based and one that can be accomplished within the resources available to PennDOT.

- To use the Municipal Services database maintained by the Department to randomly select a sample panel and panel of alternates according to the established methodology. The Municipal Services Database contains most of the municipal-owned roadway links and includes the following attributes: County; Municipality; Road Name; Beginning and Ending Termini of the Road; Length; and Urban/Rural location. Special considerations will be needed for those municipalities that do not yet have their roadways in the Municipal Services Database.

- To provide a final report, *Ideas Have Consequences* form, and a technology transfer session.

1.2 Organization of the Report

Chapter 1 provides an overview of the project, including the problem statement and the research objectives. Chapter 2 documents the literature review and background information on sampling strategies for local road traffic monitoring. Chapter 3 describes the work performed in developing a sampling strategy, along with the final strata, sample sizes, and sampling process. Chapter 4 concludes this report with final remarks and recommendations for the implementation of the local road traffic volume monitoring program.

CHAPTER 2– BACKGROUND INFORMATION AND REVIEW OF STATES' PRACTICES

2.0 Introduction

This chapter presents the findings of a literature review and survey of other states' practices related to statewide traffic volume monitoring of low volume, locally-owned, or locally-classified roads. The literature review focuses on the guidance provided by the Federal Highway Administration (FHWA) in the Highway Performance Monitoring System (HPMS) Field Manual and Traffic Monitoring Guide (TMG). A summary of interviews and supporting documentation of other states' monitoring of local roads in compliance with HPMS requirements is also provided. This includes some review of literature in instances where the state practices have been appropriately documented.

2.1 Federal Guidance

Three guides are available from the Federal Highway Administration (FHWA) that provide some insight on the sampling of traffic volume and have some bearing on this project: the Traffic Monitoring Guide (FHWA, 2001), the HPMS Field Manual (FHWA, 2000), and Traffic Estimating Procedures for the Local Functional System (FHWA, 1994). Each is discussed below.

The information for Traffic Estimating Procedures for the Local Functional System was taken from a study performed by Kittelson & Associates, Inc (2004) since the actual FHWA document was not available to the research team. According to Kittelson (2004), this FHWA document indicates that local road sampling should:

> Individually conduct daily traffic counts in all urbanized areas with a population equal to or greater than 200,000 and in all urbanized areas that are part of a National Ambient Air Quality Standards (NAAQS) non-attainment area, regardless of population size. Conduct counts in the remaining urban areas and the rural areas on a statewide basis.
>
> The counting program can be designed to provide annual estimates of local VMT for each of the individual urban areas, the small urban areas, and the rural system, and, by aggregation, provide statewide totals.

According to Kittelson (2004), this FHWA document also recommends a 24-hour count duration.

The Traffic Monitoring Guide (TMG), issued by FHWA and last released in 2001, provides guidance on the design and execution of a statewide traffic volume monitoring program. For higher classified roads, recommendations for sampling include counts that are a minimum duration of 24-hours, but preferably 48-hours, and that occur on a three-year to six-year cycle. They also recommend that highway segments be sampled individually when there is more than a 10% difference in Annual Average Daily Traffic (AADT). The basis for this sampling strategy is a framework in which AADT is projected from short-term counts using a series of factors to adjust for temporal variations.

Chapter VII of the HPMS Field Manual (FHWA, 2000) also provides guidance on the design of the HPMS data collection program. Specifically, it lays out detailed procedures for the stratification of the roadway network and selection of a sample panel. This includes an equation for the computation of required sample size, which is shown below:

$$n = \frac{Z^2 C^2 / d^2}{1 + (1/N)\left((Z^2 C^2 / d^2) - 1\right)}$$

Where:

n = Required sample size

Z = Value of the standard normal statistic for an alpha confidence level (two-sided), of which values are given for 70%, 80%, and 90%, with 90% reserved for all arterial functional classes, including minor arterials, 80% reserved for collectors, and 70% reserved for minor arterials and collectors in individual urbanized areas with three or more such areas statewide

C = AADT coefficient of variation from a State's AADT data, of which an example value of 0.4 is provided

d = Desired precision rate, of which 5% is provided for freeways and other principal arterials, and 10% is provided for minor arterials and collectors. However, rates of up to 15% were also included, and are to be used for lower class facilities in individual urbanized areas with three or more such areas statewide.

N = Universe or population stratum size (number universe sections available for sampling in a volume group). The population is supposed to be stratified by AADT, which in this particular case is not possible, and typically is not for local roads.

It should be mentioned that the sample size for an individual stratum is most sensitive to the precision rate (d), confidence level (Z), and AADT coefficient of variation (C). The equation is relatively insensitive to the number of segments the stratum (N), which alleviates concerns related to segmenting the system, at least as it relates to sample size computation. In fact, Traffic Estimating Procedures for the Local Functional System (FHWA, 1994) contains a simplified equation for sample size that omits N and is only a function of d, Z, and C.

One concern with applying the HPMS procedures to local roads is the selection of a stratification variable. Generally speaking, stratified sampling is more efficient than simple sampling when the stratification variable is strongly related to what is being sampled, so that the variances within the strata are less than the variance in the overall population. With the higher class facilities, the stratification for AADT sampling is volume itself. For local roads, in the absence of traffic volume information that can be used to stratify the roads, the relationship between AADT and the stratification variable will likely be weaker. This may result in a higher coefficient of variation (C), which will result in the need for a larger sample for each stratum. One advantage of stratified sampling that can be realized in this particular instance is that a sample is collected for each stratum. Therefore, if the strata are based on the geographic areas for which VMT estimates are needed (e.g., counties), at the very least, the stratification will achieve a sample that provides statistically sound VMT estimates at that geographic level.

Once d, Z, and C are set, the number of stratum into which the system is grouped has the largest bearing on overall sample size and data collection effort, since a sample will be needed for each stratum. Ultimately, the number of counts required in Pennsylvania has less to do with the overall size of the system (73,000 miles) and more to do with how finely it is stratified. In that regard, Chapter VII of the HPMS Field Manual encourages the use of individual samples for urbanized areas, particularly those with a population greater than 200,000 that are in National Ambient Air Quality Standard (NAAQS) Non-Attainment areas. The use of samples for collective urbanized areas will be phased out in the future if it has not been already.

Finally, they note that sections should be selected from the universe of each stratum using a random number table or random number generation computer software, until the required number of samples is reached. In Pennsylvania, for municipalities in which the segmented database has been provided, this is a straightforward process. For the 88 municipalities for which only total mileage has been provided, this will require some virtual segmenting of the system, with additional challenges to achieve random site selection. To be random, all segments in the stratum must have an equal chance of selection.

The general methodology to be followed in developing the sample panel is straightforward and readily understood. However, two factors complicate this effort. First, both the HPMS Field Manual and the TMG lack sufficient guidance for local roads. In both instances, the guidance provided for the higher class facilities is more complete, and detailed. Second, segmenting the system, at least for higher class facilities, requires existing AADT data, which is not available for the local road system in Pennsylvania. Other attributes of the local roads and the area in which they are located will likely be used to stratify the local roads. The latter was one the primary focuses of the survey of other states and the research.

2.2 Survey of State Practices

In April 2002, the FHWA conducted a nationwide survey regarding local road traffic volume monitoring on a statewide level (FHWA, 2003). This was a comprehensive survey that included all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico. In this survey, five states were identified as the most noteworthy: Georgia, Kansas, Texas, Kentucky and New York. In addition, the Department had specific interest in the states of Vermont and Florida due to previous knowledge of their respective monitoring programs. Representatives from these seven states were contacted and interviewed about their current practices. Additional documentation was provided to the researcher from Kansas, Texas, Kentucky, Florida and Vermont. An overview of the current practices is provided below.

2.2.1 Georgia

Information for Georgia was taken from the both the FHWA survey (FHWA, 2003) and a survey that GDOT completed and electronically mailed back to the researchers. Prior to 1991, GDOT used 16 strata, which were a combination of four population groups and four pavement types. Over these 16 strata, 2,500 counts were collected. This yielded a precision of 9% at 90% confidence for the statewide estimate of local area travel (which included rural minor collectors). In contrast, they currently list their strata as follows:

- Non-Atlanta Urbanized
- Atlanta Urbanized
- Small Urban
- Rural Paved
- Rural Unpaved
- Cul-de-sacs/ Dead-End Roads

In the FHWA survey (FHWA, 2003), rural local roads were listed as a single stratum, and cul-de-sacs / dead-end roads were not broken out as a separate stratum. In the recent survey, they indicated a statewide sample size of approximately 3,000 stations, which are counted over a three-year period. In the FHWA survey (FHWA, 2003), a sample size of over 4,000 was indicated.

Their counting program uses the same sample panel each year, with a counting duration of 48-hours. Sample sizes were computed using HPMS procedures assuming 80% confidence.

The GDOT program appears to monitor the local roads in accordance with HPMS procedures for higher functional class facilities. In the FHWA survey, it was indicated that more than one-third of their local road sample was located in the Atlanta Area, and that more counts were taken in this particular area than all of the local rural roads combined. It is hypothesized that the “Atlanta Area” is either the NAAQS Atlanta Non-Attainment area, which is believed to cover 13 counties, or the metropolitan statistical area, which is believed to cover 20 counties. Texas also reported taking a disproportionately high number of samples in NAAQS Non-Attainment areas. It is believed that Georgia has other NAAQS Non-Attainment areas, however, it is not known if these were in place in 2002 at the time of the survey.

2.2.2 Kansas

Kansas Department of Transportation (KSDOT) has devised a “non-state road” traffic counting schedule for major collectors, minor collectors and local roadways. KSDOT has six districts which are disaggregated into the following subareas:

- Counties
- Cities with population less than 5,000
- Cities with population greater than 5,000

In general, in the cities, KSDOT counts all functional classes above local roads on a three-year cycle. In the rural areas, they count major collectors and above on a three-year cycle and minor collectors on a six-year cycle. Local roads are counted on a nine-year cycle regardless of location.

They maintain a nine-year schedule that shows the year in which local roads will be counted in a county or city. Counties and cities are covered as units to achieve a 10% sample within the limits of a one-year period. For example, if 2008 is the year to count Abilene (city), then all of the local road counts that will be taken in Abilene in the nine-year cycle are taken in 2008. Approximately one-ninth of the counties, and less than five cities are covered each year. At the end of the nine-year cycle, a 10% sample of all the local roads (urban and rural) within the state is complete.

Kansas has 42 urban areas with populations greater than 5,000, in which they collect approximately 400 counts each year, totaling approximately 3,600 over the nine-year cycle, and averaging approximately 90 per urban area. Approximately 500 counts are collected per year in the rural areas (including the 119 “cities” with populations less than 5,000), for a total of 4,500 counts over the nine-year period. In total, the nine-year period yields approximately 8,100 counts over a 105-county area, which is an average of 77 counts per county. The average of 90 counts per urban area is an indicator that the urban areas are sampled more intensely than the statewide average.

Within a city / county unit, the count locations are not necessarily random, nor are they necessarily at the same location from cycle to cycle. The sample is picked manually with consideration given to what was collected in the previous effort.

The counts are 24 hours in duration and are taken year round. No seasonal factors are applied to compute AADT.

Since VMTs are built up from the county / city level, no collective grouping of urbanized areas is required, however, it is uncertain if this is related to any air quality issues, because it is not believed that Kansas has any NAAQS non-attainment areas.

2.2.3 Texas

Due to the need to improve local road VMT projections in their four air quality non-attainment areas, the Texas Transportation Institute (TTI) in cooperation with the Texas Department of Transportation (TxDOT) and the Technical Working Group (TWG) on Air Quality recently developed an improved methodology for the collection of local traffic data and the estimation of local VMT (Frawley, 2004). Previously, Texas used count locations that were not randomly selected. These manually-selected sites tended to be at intersections with arterial and collector streets which resulted in average AADT projections that were biased upwards (Frawley, 2004). TxDOT's new approach uses randomly selected locations that include a wider spectrum of local roads and streets, including cul-de-sacs, and are believed to better represent the overall local road and street system (Frawley, 2004).

Texas has used considerable research effort in developing an electronic GIS-based method for randomly selecting sites for sampling using an electronic grid overlaid on their street system (Frawley, 2004). According to Frawley (2004), each grid cell, containing a small number of streets, is given a unique number. A random number generator is used and the selected cell is highlighted. The functional classification of the road within the selected cell is verified to contain at least one local road. If the cell contains more than one local road, the road nearest to the center of the cell is selected. The process is repeated for each selected cell until the appropriate number of local roads has been selected.

For sampling the local road system, it was indicated in the April 2002 FHWA survey (FHWA, 2003) that Texas subdivides each of its 25 Districts into urban and rural areas based on population, with the average number of count locations per population group as shown in Table 2-1.

Table 2-1 Average Number of Count Locations per TxDOT District

Group	Population	Count Locations
Large Urban	> 200,000	175
Large Urban	50,000 to 200,000	65
Small Urban	5000 to 50,000	40
Rural	< 5000	40

Source: State Practices Used to Report Local Area Travel (FHWA, 2003).

These count thresholds were apparently based on a statistical analysis that determined the "point of diminishing returns" for additional counts (Frawley, 2004). Table 2-1 indicates an average of 320 counts per District. With 25 Districts, this is approximately 8,000 counts statewide. In the spirit of employing random sampling, a new sample panel is selected each time the counts are performed. Frawley (2004) advised selecting additional count locations, above the recommended thresholds, to allow for an adequate number of data samples should a problem with field collection arise such as a private road, difficulty with equipment setup, or equipment malfunction. All counts are 24 hours in duration and are typically collected while school is in session.

2.2.4 Kentucky

From approximately 1980 to 2002, the Kentucky Transportation Cabinet (KyTC) used a method for determining local VMT that was based on taking samples in select counties. The sample panel was derived in 1980 at a time when HPMS requirements were to include a local road component. This system was thought to have many drawbacks, including the fact that 50 counties contained no local road counts. There were additional concerns because of the way in which county-level HPMS data and VMT estimates, including those at functional class level, were being used by the EPA. Due to these concerns, a new method was needed to derive the local VMT by county. This new method was outlined in the article Estimating Travel on Local Roads, which was presented at the HPMS Issues Workshop in 2002 (Rogers, 2002) and in the research report “Analysis of Traffic Growth Rates” (Abu-Lebdeh, et al, 2001).

Since KyTC has full count coverage on all collectors and arterials, this new method sought to leverage this information to model local road travel by developing a relationship between local road travel and collector travel. If this relationship could be developed then a reasonable estimate of local road volume could be obtained from data that would be collected for other purposes.

The KyTC, in cooperation with the University of Kentucky, conducted research to determine a relationship between urban collector AADT (FC 17) and urban local AADT (FC 19), and rural minor collector AADT (FC 08) and rural local AADT (FC 09) (Abu-Lebdeh, et al, 2001). First cut ratios were as follows:

- Urbanized County: FC 19 / FC 17 = 0.28
- Non-Urbanized County: FC 19 / FC 17 = 0.12
- All Counties: FC 09 / FC 18 = 0.33

There were several concerns with these ratios, including evidence that showed that they changed over time, so the research attempted to develop different relationships. To develop this relationship, a one-time random sample of 4,000 count locations within 28 counties was taken. From the counts, mathematical relationships, including both ratios and functions, were developed to predict local road AADT as a function of collector AADT. Four model forms were tested:

- Ratios – Different models developed for urban and rural facilities
- Linear Regression – Different models developed for urban and rural facilities
- Power Regression – Single model for urban and rural facilities
- Logarithmic – Single model for urban and rural facilities

A power equation with an exponent less than one was found to be the best fit. It is shown below (Abu-Lebdeh, et al, 2001):

$$\text{Local ADT} = 3.3439 \times (\text{Collector ADT})^{0.6248}$$

The report notes that the relationship had an R^2 (coefficient of regression) value of 0.73 and had the ability to predict reasonable local AADT even at very low levels of collector AADT (Abu-Lebdeh, et al, 2001).

With the input of DVMT by county and functional class into a customized spreadsheet, the Local Average AADT is computed as a function of the Average Collector AADT. AADT for Urban Local Roads (FC 19) are calculated from AADT of Urban Collector Streets (FC 17) while AADT for Rural Local Roads (FC 9) are calculated from AADT of Rural Minor Collectors (FC 8). The local VMT is calculated as the average AADT times the mileage of the local roads. In this manner, the KyTC has determined local VMT for the last two HPMS submittals. Because they estimate local road AADT in this manner, they have no need for an ongoing local road sampling program, although they indicated that they may perform another round of counts to update the function relating local road AADT to collector AADT in the future.

<u>Estimating Travel on Local Roads</u> (Rogers, 2002) also outlined methods which Kentucky was using in 2002 to improve their traffic count system.

- Traffic counts are graphically reviewed and compared to previously recorded AADT to identify any discrepancies and determine immediately if a recount is required.
- Urban ITS sites are used for traffic data collection.
- Non-intrusive traffic data collection methods are being evaluated.
- Improved access to volume data using GIS-generated traffic count maps and a database and viewer for historic AADT at each count station.

2.2.5 New York

At the time of the FHWA survey in 2002, New York was weighing two options for their local road stratification, one of which did not require AADT for volume group stratification, and one that did (FHWA, 2003). Sample size calculations based on the procedures in the HPMS Field Manual were conducted for each scheme. The difference in sample sizes was dramatic, as over 1,700 counts would be required for the scheme that did not include volume groups, compared to less than 450 for the scheme with volume groups. A yearly sample size of 1,700 was considered too great for their available resources, while the difficulty in pre-determining the volume groups for yet uncounted roads complicated the second option. At the time, they had indicated a proposed compromise that collected 2,700 counts over a three-year period, leveraging counts already taken for other purposes, including their local bridge program, railroad count crossing program, and county counter initiative. The first year of this new program was to be 2003, which means the first cycle would have been complete by 2005.

It is not believed that New York followed through on this original plan. During the survey conducted by the researchers, they indicated that they stratify local roads into Urban Local and Rural Local by New York State Department of Transportation

(NYSDOT) Region. New York has 11 “Regions”, which are various groups of its 62 counties, and are similar to PennDOT’s Engineering Districts.

A statistical analysis by NYSDOT determined that 2,000 counts would yield a significant sample size for the state. It is uncertain whether this statistical analysis, including the sample size calculation, was performed using the procedures in the HPMS Field Manual since the analysis was not shared.

A five-year schedule is used to gather the 2,000 counts. Each year a new sample is selected by the NYSDOT Regional Staff. The sample is not random and does not contain cul-de-sacs or dead-end roads. The minimum duration of the counts is 48 hours. No seasonal factors are applied, however, the counts are not performed during a snow event. The average ADT of the local roads within a DOT region are prorated by the total mileage of the DOT region. A five-year cycle has not yet been completed. At the completion of the five-year cycle, they will begin discarding information more than five years old and replacing it with the new information.

Finally, it should be noted that New York was identified as a noteworthy state in the FHWA April 2002 survey based on the plan in place at the time (FHWA, 2003). It is believed that this plan was never executed, and that they are currently operating under a different plan.

2.2.6 Florida

In 2004, the Florida Department of Transportation (FDOT) funded a study titled <u>HPMS Rural and Local Roads Reporting</u> (Kittelson and Associates, Inc., 2004) to develop a methodology to estimate VMT on local roads in Florida. In this document, FDOT’s practices for estimating local road AADT were reviewed. Through the survey performed by the researchers, this methodology was found to still be in place, as no changes were made as a result of their study in 2004.

In summary, FDOT is provided AADT on Rural Minor Collectors by the cities and counties. The data or the methods used to collect / estimate it are not verified. Local Roads are not counted but rather estimated using a residual methodology. Local Road VMT is calculated as a percentage of the VMT of the entire network based on the percentages contained in the 1989 Highway Functional Classification Manual Concepts, Criteria and Procedures (Kittelson and Associates, Inc., 2004). In short, local road VMT is 10 to 30% of total VMT in urban areas, and 5 to 20% in rural areas.

<u>HPMS Rural and Local Roads Reporting</u> (Kittelson and Associates, Inc., 2004) identified and analyzed four potential approaches to estimate VMT on local roads. The approaches considered and the recommendations made are described below.

Census Data and Trip Generation. This residual approach quantifies VMT by using Census household data and Single-Family Housing and Apartment trip generation rates from the ITE *Trip Generation* Handbook. From the Census, the number of owner-occupied and renter-occupied households is determined by county (or other boundary). Trip generation rates for Single-Family Housing are applied to owner-occupied households while trip generation rates for Apartments are applied to renter-occupied households. The difficulty with this approach begins with trying to determine the mileage of the trip. Distance can be calculated from travel time and average speed. Average speed by county is likely not known and can be highly variable. The travel distance is multiplied by the number of trips to get the VMT estimate for all functional classifications within the county. Local Road VMT is calculated by subtracting all other functional classification VMTs from the results. See Table 2-2 for an overview of this approach.

Table 2-2 Overview of the Census Data and Trip Generation Approach

Approach Type	Residual
Description	Uses Census household data and Single-Family Housing and Apartment trip generation rates from the ITE *Trip Generation* Handbook
Advantages	• Low volume of work to implement and update • ITE Trip Generation Handbook and the Census are considered reliable data sources. • Results can be calculated directly for counties or other boundaries
Disadvantages	• Results are not based on actual counts • Does not capture tourist travel unless additional land codes are used. • Average speeds are not known and are likely variable • Assumes all daily trips are home based • VMT of higher functional classifications are subtracted from result to yield VMT of local roads • Does not estimate local VMT for local roadway functional classifications.

Source: HPMS Rural and Local Roads Reporting (Kittelson and Associates, Inc., 2004)

Gasoline Sales and Average Vehicle Mileage. In this residual approach, Total VMT is estimated by using vehicle gasoline consumption rates and total gasoline sales. Data sources include: population and employment density, total gasoline sales, vehicle registration and licensed driver statistics. Kittelson and Associates, Inc. (2004) did not detail the equations necessary to perform this analysis. Local Road VMT is calculated by subtracting VMT of higher classification roadways from the result. See Table 2-3 for an overview of this approach.

Table 2-3 Overview of the Gasoline Sales and Average Vehicle Mileage Approach

Type	Residual
Description	Uses vehicle gasoline consumption rates and total gasoline sales to estimate VMT
Advantages	• Low volume of work to implement and update • Gasoline sales are an available and reliable data source. • Results can be calculated directly for counties or other boundaries depending on the availability of gasoline sales data • Captures tourist travel
Disadvantages	• Results are not based on actual counts • The percentage of commercial vehicle gasoline consumption rates is known. • VMT of higher functional classifications are subtracted from result to yield VMT of local roads • Does not estimate VMT for local roadway functional classifications.

Source: HPMS Rural and Local Roads Reporting (Kittelson and Associates, Inc., 2004)

Census Data and Sampling. In this count-based approach, VMT is estimated from a sample of counts on local roads within geographic boundaries. The boundaries can be counties, zip codes, census tracts, cities, DOT districts, etc. Within each boundary the total road mileage must be known, as well as the average AADT, which is derived from the sample counts. The selected boundary is then stratified by socioeconomic or other data such as urban or rural, population, roadway surface, population density, employment density or some combination. Once the stratification method is chosen, thresholds are developed to create areas with "uniform local road traffic patterns". For each stratum, the number of counts must be determined. Procedures contained in the HPMS Field Manual (FHWA, 2000) or some other statistical analysis can be used. Census Data and Sampling was the recommended method for Florida in the Kittelson (2004) study. See Table 2-4 for an overview of this approach.

Table 2-4 Overview of the Census Data and Sampling Approach

Type	Count-Based
Description	Uses Census socioeconomic data for local road stratification and ground counts for AADT estimation.
Advantages	• Estimates of VMT are based on real ground count data, and not subtraction of two other VMT estimates. • The accuracy of the AADT and VMT estimates can be statistically evaluated. • The Census data required for stratification relies on information that is readily available and presumed reliable.
Disadvantages	• The approach can require a large amount of resources to conduct enough counts to achieve statistical validity.

Source: HPMS Rural and Local Roads Reporting (Kittelson and Associates, Inc., 2004)

Applications of Distance-based Travel Pricing Research. In this approach, it is proposed that data collected as part of "pay as you drive" insurance premiums, mileage-based vehicle lease pricing, and VMT fees designed to replace fuel taxes might be leveraged to verify relationships between overall VMT and local road VMT, or collector AADT and local road AADT. As it is understood, this does not appear to be a standalone approach unless these data could be used to query local road travel specifically. Furthermore, the feasibility of what is proposed under this approach is highly speculative due to a host of reasons, including data availability. This may change in the long-term, so it is at least worth mentioning.

The recommended alternative in the study was Census Data and Sampling Approach. The criteria used in this selection were as follows (Kittelson and Associates, Inc., 2004):

- Minimal increase to annual program costs
- Affordable start-up costs
- Improved accuracy & reliability in estimations
- Straight-forward, reasoned methodology
- Potential for increased accuracy over time
- Opportunity to apply methodology and/or results for more purposes
- Opportunity to share data & strengthen partnering agency relationships

It is interesting that two of the criteria dealt with the cost of the program, however, the program is yet to be implemented because it is deemed cost-prohibitive by FDOT.

In the recommended approach, the roadways were stratified according to (1) roadway density, which was computed as centerline miles per square mile of area and (2) density sum, which was computed as population plus employment per square mile of area. Both were computed for each of the zip codes in the state. Zip codes were then combined into eight classes for both of the stratification variables. Sample sizes were computed for both using the simplified HPMS equation and using 70-15, 80-10, and 95-10 for confidence level-precision. At 80-10, required sample sizes were 323 for density sum, and 536 for roadway density.

2.2.7 Vermont

The Vermont local road monitoring program was documented in the paper Enhancements to the Process for Estimating Vehicle-Miles of Travel on Local Roads in Vermont (Byrne, et al, 2005), which was presented at the 2005 Annual Meeting of the Transportation Research Board (TRB) as a poster presentation, potentially submitted to TRB for publication and presentation consideration at the 2006 annual meeting, and provided to the research team by the corresponding author. The information contained in this review was taken largely from this paper.

Vermont Agency of Transportation (VTRANS) uses a "cross-classification" approach to categorizing local roads with the functional classifications of rural minor collector (FC 08), rural local (FC 09) and urban local (FC 19). Traffic data to develop this approach was obtained from VTRANS' Traffic Monitoring System (TMS) and counts from a 2004 special local road count program. Pavement type (paved vs. unpaved) was identified as having a significant impact on local road AADT. Therefore, local roads were first stratified into categories of pavement type. Population Density was also thought to have significant impact on local road AADT. The project team used statistical analysis to develop unique population density categories for each pavement type within each functional class. See Table 2-5 for the stratification categories, sample size requirements, miles of road, and latest AADT for each functional class.

Table 2-5 Key Statistics from the Vermont Local Road Monitoring Program

<table>
<tr><th>Functional Class</th><th>Pavement Class</th><th>Density (Per./sq. mi..)</th><th>Miles of Road</th><th>Sample Size for 95-10</th><th>AADT (2004)</th></tr>
<tr><td rowspan="5">8 – Rural Minor Collectors</td><td rowspan="3">Paved</td><td>0-60</td><td>358.898</td><td>166</td><td>590.42</td></tr>
<tr><td>60 - 140</td><td>196.285</td><td>113</td><td>1191.12</td></tr>
<tr><td>>140</td><td>35.691</td><td>109</td><td>1875.20</td></tr>
<tr><td rowspan="2">Unpaved</td><td>0-40</td><td>186.309</td><td>116</td><td>284.70</td></tr>
<tr><td>>40</td><td>109.507</td><td>85</td><td>410.74</td></tr>
<tr><td rowspan="6">9 – Rural Locals</td><td rowspan="3">Paved</td><td>0-40</td><td>457.65</td><td>146</td><td>519.81</td></tr>
<tr><td>40 - 140</td><td>1037.377</td><td>308</td><td>955.78</td></tr>
<tr><td>>140</td><td>300.47</td><td>463</td><td>1312.967</td></tr>
<tr><td rowspan="3">Unpaved</td><td>0-20</td><td>1375.96</td><td>158</td><td>69.13</td></tr>
<tr><td>20 - 140</td><td>6499.355</td><td>300</td><td>280.20</td></tr>
<tr><td>>140</td><td>239.216</td><td>263</td><td>535.95</td></tr>
<tr><td rowspan="3">19 – Urban Locals</td><td rowspan="2">Paved</td><td>0-2500</td><td>605.362</td><td>211</td><td>1532.36</td></tr>
<tr><td>>2500</td><td>91.829</td><td>212</td><td>2579.91</td></tr>
<tr><td>Unpaved</td><td>All</td><td>186.343</td><td>202</td><td>916.43</td></tr>
</table>

Source: Enhancements to the Process for Estimating Vehicle-Miles of Travel on Local Roads in Vermont, (Byrne, Croft, Spicer, and Pologruto, 2005)

VTRANS uses a short-term program and a long-term program to collect counts. Short term counts are 48-hour tube counts performed in the summer months on a 10-year cycle. Counts are distributed by county throughout the state according to the following assumptions as detailed in the VTRANS document titled Conduct of the Local Road (FC08, 09, & 19) AADT Short-Term Count Program:

1) The total number of FC09 counts needed is 2,000.
2) The number of FC08 & FC19 counts should be in the same proportion as total state FC08 & FC19 road mileage is to total state FC09 road mileage.
3) All classes of counts by county should be in proportion to the mileage of road in that county in that class to total mileage of that class of road in the entire state.
4) Counts will be conducted over the entire State of Vermont each year and will be distributed proportionally to each year.

Locations are selected on both paved and unpaved surfaces in locations of various population densities throughout the state. The number of counts is based on the length of the summer season. An estimated 200 to 250 counts for one season for each of 10 years yields approximately 2,300 counts from which to calculate AADT.

Annual Average Daily Traffic (AADT) from short-term counts is estimated using day-of-the-month and monthly factors from a different classification of roads with similar seasonal characteristics.

The second type of count program gathers long-term counts. Since rural primary and secondary factor groups are used to calculate AADT from short term local road counts, VTRANS "adopted a long-term count program to come up with factors for local roads". Continuous Traffic Counters will be set at various locations across the state. Counts are to occur on unpaved as well as paved surfaces. A pilot program is being under taken to develop a methodology to overcome difficulties collecting data on unpaved roadways. This program is still being implemented.

In computing VMT, the most recent ten years of data are used. Growth factors are applied to the previous nine years of data. The daily VMT estimate is computed simply as the total length of road in each category in each town multiplied by its mean AADT. The aforementioned paper (Byrne et al, 2005) presented local road VMT estimates for each county in Vermont. It also contained statistical analysis of the local road VMT estimates. Tables 2-6 and 2-7 present the precision rates for rural local roads and urban local roads respectively. As can be seen, the program yields statistically sound results.

Table 2-6 Precision Rates for VMT for Rural Local Roads in Vermont

Level of Significance	Precision Rate		
	Paved	Unpaved	Total
95%	1.33%	0.81%	1.54%
90%	1.11%	0.68%	1.29%
80%	0.87%	0.53%	1.01%
70%	0.70%	0.43%	0.82%

Source: <u>Enhancements to the Process for Estimating Vehicle-Miles of Travel on Local Roads in Vermont,</u> (Byrne, Croft, Spicer, and Pologruto, 2005)

Table 2-7 Precision Rates for VMT for Urban Local Roads in Vermont

Level of Significance	Precision Rate		
	Paved	Unpaved	Total
95%	1.08%	0.00%	1.65%
90%	0.91%	0.00%	1.39%
80%	0.71%	0.00%	1.08%
70%	0.58%	0.00%	0.88%

Source: <u>Enhancements to the Process for Estimating Vehicle-Miles of Travel on Local Roads in Vermont,</u> (Byrne, Croft, Spicer, and Pologruto, 2005)

2.3 Concluding Remarks

Looking at the commonalities, differences, and innovations among the seven states reviewed, a number of interesting observations can be made that should be considered in the development of local road traffic volume monitoring program for Pennsylvania:

- There are a number of approaches which can be adopted having a wide variety of traffic data collection requirements. Residual approaches and the Kentucky approach in which local road VMT is a function of traffic volumes on the collector system have no annual traffic data collection requirements above what would be collected for other purposes. Count-based approaches that follow HPMS sampling procedures can have significant annual traffic data collection requirements.

- The least cost approach to estimating local road VMT that would be based on some annual ground counts would be to adopt the Kentucky approach, including the mathematical relationship that they already developed between local road and collector traffic volumes. It could be questioned as to whether this mathematical relationship is transferable from Kentucky to Pennsylvania.

- The highest cost approach to estimating local road VMT is likely to be one in which the local road system is treated like the higher functional classes, and VMT is projected from a sample of counts using HPMS procedures.

- All of the states reported building up statewide local road VMT estimates from the county level. The selected approach should allow for local road VMT to be developed at the county level.

- If a count-based approach is used, the sampling plan must differentiate between urban and rural areas, and should treat NAAQS non-attainment urban areas separately.

- Some states report using randomly-selected count sites, while some choose their sites strategically. HPMS procedures indicate that sites should be randomly-selected. New York reported deliberate omission of cul-de-sacs and dead-end roads, however, Texas considered that to be a major drawback of their previous approach because it biased the local road VMT estimate upwards.

- Some states reported collecting their required sample over a number of years to alleviate the data collection burden. Vermont spread their sample out over the most years by using 10 years to collect the required data. Similarly, it takes Kansas nine years to collect data at all of their required sites.

CHAPTER 3 – SAMPLE PANEL METHODOLOGY DEVELOPMENT AND SELECTION

3.0 Introduction

After review of the various alternatives for projecting local road VMT, the Department desired a program that was based on a traffic counting program. As such, the key deliverable of this research was the sample panel. The general process for establishing a sample panel to monitor traffic volumes is as follows:

(1) The roadway network in question is segmented
(2) The segments are organized into strata according to some key variable
(3) Sample sizes are determined for each stratum
(4) The required sample size is randomly drawn from each stratum

In general, establishing the sample panel selection methodology essentially involved deciding on the variables by which the local roads would be stratified and sample sizes within each stratum. The roadway network, which was provided from the Municipal Services database, was already segmented, eliminating the need for this step. Once the sample panel selection methodology was in place, it then became a matter of randomly drawing the required sample from each stratum.

This chapter documents the process by which ideas from the literature review, federal guidance, and survey of other states, were used in the formulation of a sample panel for monitoring traffic volumes on locally-owned, locally-classified roadways in Pennsylvania. It begins in Section 3.1 with a description of the Municipal Services database, which is at the foundation of this process. Next, Section 3.2 explores the various alternatives for stratifying the road segments in the database. Section 3.3 follows with a description of the alternatives considered for computing sample size for each stratum. It culminates with a presentation of the strata and corresponding samples sizes that were selected for use. Section 3.4 briefly describes how the sample panel was drawn from the Municipal Services database. Sections 3.5 and 3.6 present the proposed sample panel and panel of alternates.

3.1 Municipal Services Database

The Muncipal Services database, which contains 72,873.30 roadway miles, is maintained by PennDOT in cooperation with the local municipalities. It was developed to aid in the distribution of liquid fuels money from the Department to local municipalities for the maintenance of these roads. It was not yet complete at the time of the study, as there were 88 municipalities for which only the total mileage was known, and another 5 municipalities which had no mileage in the database. This comprised a total of 3,689.45 miles, or approximately 5% of the database. For the City of Pittsburgh, the 700.07 mile roadway network was segmented; however, it was only available in hardcopy form. For the remaining municipalities, the database contained road segments in electronic form that contained the following attached attributes:

- County
- Municipality
- Road Name
- Beginning and Ending Termini of the Segment
- Length
- Urban/Rural Designation

The Urban/Rural designation was a numerical code between 1 and 4 as follows:

1 = Rural
2 = Small Urban (population between 5,000 and 49,999)
3 = Urbanized (population between 50,000 and 199,999)
4 = Urbanized (population 200,000 and greater)

Some minimal cleaning of the data was required to fill in blank entries, however, in general, the database was used in the condition in which it was provided. Some key statistics from the electronic portion of the database (68,215.58 miles or 94%):

> Number of Segments: 336,693
> Average Segment Length in Rural Areas: 0.41 miles
> Average Segment Length in Small Urban Areas: 0.10 miles
> Average Segment Length in Urbanized (50k to 200k population): 0.10 miles
> Average Segment Length in Urbanized (>200k population): 0.12 miles
> Maximum Segment Length in Rural Areas: 9.61 miles
> Maximum Segment Length in All Urban Areas: 5.29 miles

In the entire database, there were 42828.44 rural miles and 30044.86 urbanized miles.

As noted earlier, for some municipalities, only total mileage was available. In these cases, there were no segmented roadway links, and proportion of mileage in each of the urban / rural areas was estimated using other databases available to the Department, including a local road GIS database published in 2005. These municipalities are as follows:

- Bonneauville borough, Adams County
- East Berlin borough, Adams County
- Fairfield borough, Adams County
- McSherrystown borough, Adams County
- Clairton city, Allegheny County
- Duquesne city, Allegheny County
- Forward township, Allegheny County
- Frazer township, Allegheny County
- McKeesport city, Allegheny County
- Munhall borough, Allegheny County

- North Braddock borough, Allegheny County
- North Versailles township, Allegheny County
- Wilkinsburg borough, Allegheny County
- German township, Fayette County
- Archbald borough, Lackawanna County
- Blakely borough, Lackawanna County
- Carbondale city, Lackawanna County
- Clarks Summit borough, Lackawanna County
- Covington township, Lackawanna County
- Dunmore borough, Lackawanna County
- Jessup borough, Lackawanna County
- Olyphant borough, Lackawanna County
- Ransom township, Lackawanna County
- Roaring Brook township, Lackawanna County
- Scranton city, Lackawanna County
- South Abington township, Lackawanna County
- Taylor borough, Lackawanna County
- Vandling borough, Lackawanna County
- East Donegal township, Lancaster County
- East Hempfield township, Lancaster County
- Mount Joy township, Lancaster County
- Catasauqua borough, Lehigh County
- Emmaus borough, Lehigh County
- Hanover township, Lehigh County
- Lower Macungie township, Lehigh County
- North Whitehall township, Lehigh County
- Salisbury township, Lehigh County
- South Whitehall township, Lehigh County
- Upper Macungie township, Lehigh County
- Upper Milford township, Lehigh County
- Upper Saucon township, Lehigh County
- Washington township, Lehigh County
- Whitehall township, Lehigh County
- Dallas township, Luzerne County
- Hazleton city, Luzerne County
- Kingston borough, Luzerne County
- Kingston township, Luzerne County
- Nanticoke city, Luzerne County
- Newport township, Luzerne County
- Pittston township, Luzerne County
- Plains township, Luzerne County
- Rice township, Luzerne County
- Swoyersville borough, Luzerne County
- West Pittston borough, Luzerne County

- Wilkes-Barre township, Luzerne County
- Chestnuthill township, Monroe County
- Bethlehem city, Northampton County
- Easton city, Northampton County
- Dingman township, Pike County
- Lackawaxen township, Pike County
- Blythe township, Schuylkill County
- East Brunswick township, Schuylkill County
- Upper Mahantongo township, Schuylkill County
- Apolacon township, Susquehanna County
- Auburn township, Susquehanna County
- Choconut township, Susquehanna County
- Franklin township, Susquehanna County
- Harford township, Susquehanna County
- Herrick township, Susquehanna County
- Jackson township, Susquehanna County
- Jessup township, Susquehanna County
- Lathrop township, Susquehanna County
- Lenox township, Susquehanna County
- Liberty township, Susquehanna County
- Middletown township, Susquehanna County
- New Milford township, Susquehanna County
- Oakland township, Susquehanna County
- Cherry Ridge township, Wayne County
- Manchester township, Wayne County
- Oregon township, Wayne County
- Unity township, Westmoreland County
- Braintrim township, Wyoming County
- Clinton township, Wyoming County
- Meshoppen borough, Wyoming County
- Monroe township, Wyoming County
- Goldsboro borough, York County

Additionally, the following five municipalities had zero mileage in the database:

- New Morgan borough, Berks County
- Colebrook township, Clinton County
- Valley-Hi borough, Fulton County
- Cold Spring township, Lebanon County
- Green Hills borough, Washington County

3.2 Stratification Alternatives

The sampling strategies contained in HPMS promote stratified sampling of AADT when the strata are setup according to AADT. This is somewhat of a “best case scenario” when the population is grouped according to the variable to be measured. In this case, AADT was not available in the Municipal Services database, therefore AADT could not be used as the stratification variable. The objective in identifying a stratification variable was to either (1) find a good surrogate for AADT, which ideally would yield a stratified population that would be similar to one that could be directly stratified by AADT; or to (2) stratify the database according to the structure in which the results need to be reported, thus ensuring that each reported number would be based on an adequate sample.

A number of different variables were considered for stratifying the local roads database. Since the Municipal Services database contained a “Municipality” field, any data that could be queried at the municipal level could be used as a stratification variable.

Using the census data, the following data were queried at the municipal level for possible attachment to the road segments in the Municipal Services database:

- Population
- Housing Units
- Employment
- Total Area
- Roadway Miles (from Municipal Services database)

From these basic measures, a number of combinations were computed, including:

- Population Density
- Household Density
- Employment Density
- Housing Units + Employment / Roadway Miles

For each of these measures, basic statistics such as average and range were computed across all municipalities. The municipalities were also sorted by each measure to determine if the order appealed to common sense, and if those at the top and bottom appeared reasonable. In the end, none instilled sufficient confidence in the research team to be used as a surrogate for AADT in the stratification process.

Since the research team did not have confidence in the potential surrogate measures for AADT, it was decided to stratify the roadway segments according to the manner in which the VMT estimates would be made. It was indicated by the Department that VMT estimates would be made at the county level for each of the four urban / rural codes. Therefore, this scheme was selected as the basis for stratifying the roadway segments. Table 3-1 contains the mileage in each of the strata.

Table 3-1 Local Road Mileage According to the Selected Stratification Scheme

County	Code 1 Mi	Code 2 Mi	Code 3 Mi	Code 4 Mi
Adams County	696.09	107.17	0.00	0.00
Allegheny County	94.19	0.00	0.00	3777.97
Armstrong County	999.95	121.35	0.00	18.53
Beaver County	376.12	0.00	0.00	595.88
Bedford County	903.13	0.00	0.00	0.00
Berks County	1283.99	59.99	81.24	755.84
Blair County	350.65	32.70	309.91	0.00
Bradford County	1533.78	49.94	0.00	0.00
Bucks County	436.28	0.00	0.00	1886.59
Butler County	1054.09	249.11	0.00	216.04
Cambria County	522.12	157.10	293.59	0.00
Cameron County	122.31	0.00	0.00	0.00
Carbon County	311.50	16.67	6.07	55.88
Centre County	575.09	60.30	180.58	0.00
Chester County	649.17	82.68	65.06	1475.43
Clarion County	919.00	22.14	0.00	0.00
Clearfield County	966.32	154.25	0.00	0.00
Clinton County	317.09	75.95	0.00	0.00
Columbia County	729.23	147.71	0.00	0.00
Crawford County	1354.28	131.51	0.00	0.00
Cumberland County	561.51	176.95	0.00	417.33
Dauphin County	460.19	4.44	0.00	691.30
Delaware County	0.00	0.00	0.00	1245.45
Elk County	319.93	49.43	0.00	0.00
Erie County	946.79	80.97	599.07	0.00
Fayette County	890.37	64.83	284.09	14.99
Forest County	157.66	0.00	0.00	0.00
Franklin County	698.61	275.12	8.17	0.00
Fulton County	315.92	0.00	0.00	0.00
Greene County	893.75	33.88	0.00	0.00
Huntingdon County	594.99	27.46	0.00	0.00
Indiana County	1099.46	119.82	0.00	0.00
Jefferson County	799.66	36.64	0.00	0.00
Juniata County	372.57	0.00	0.00	0.00
Lackawanna County	279.61	0.00	0.00	647.69
Lancaster County	1336.22	131.58	0.00	1171.42
Lawrence County	512.79	200.91	0.00	42.05
Lebanon County	405.27	0.00	279.35	68.94
Lehigh County	433.77	0.00	0.00	977.81
Luzerne County	666.12	21.91	222.31	659.84
Lycoming County	880.51	47.66	263.61	0.00
McKean County	424.09	45.00	0.00	0.00
Mercer County	916.84	69.54	0.00	199.01

County	Code 1 Mi	Code 2 Mi	Code 3 Mi	Code 4 Mi
Mifflin County	288.91	77.76	0.00	0.00
Monroe County	621.10	370.78	0.00	0.00
Montgomery County	155.03	0.00	190.81	2027.91
Montour County	197.78	27.44	0.00	0.00
Northampton County	451.71	0.00	0.00	927.40
Northumberland County	643.60	198.94	0.00	0.00
Perry County	574.35	0.00	0.00	25.11
Pike County	247.87	0.00	0.00	0.00
Potter County	633.21	0.00	0.00	0.00
Schuylkill County	903.42	308.48	20.46	0.00
Snyder County	440.79	48.04	0.00	0.00
Somerset County	1196.85	48.66	26.50	0.00
Sullivan County	296.97	0.00	0.00	0.00
Susquehanna County	1053.10	0.00	13.93	7.51
Tioga County	1134.89	0.00	0.00	0.00
Union County	240.26	57.23	0.00	0.00
Venango County	688.36	115.81	0.00	0.00
Warren County	542.03	60.84	0.00	0.00
Washington County	1051.05	35.34	198.88	400.36
Wayne County	670.66	21.31	0.00	2.88
Westmoreland County	913.42	61.69	139.09	1088.06
Wyoming County	390.05	0.00	0.00	4.87
York County	1332.02	194.64	792.01	160.42
Philadelphia County	0.00	0.00	0.00	2025.95

3.3 Sample Size Alternatives

The starting point for the computation of sample size of each stratum was the HPMS equation provided in Section 2.1. Using the Z values corresponding to 80% confidence and precision rates of 10% yielded sample sizes of approximately 25 for each stratum. Increasing the confidence to 90% yielded sample sizes of approximately 45 for each stratum. At 90% confidence – 10% precision, a total sample size of approximately 7,000 was computed, which PennDOT considered to be in line with the amount of resources available to devote to this endeavor.

It was interesting to note that the sample size was almost completely insensitive to the mileage in each stratum. Therefore, strata with vastly different amounts of mileage had the same number of count locations predicted by the sample size equation. These proved problematic as some of low mileage strata had more than one count location per mile of roadway, while some of the high mileage strata would have been sampled only once per 50 to 100 miles of roadway. This was counter-intuitive and not considered to be acceptable.

Instead of a bottom-up approach in which the sample size computation is performed individually for each stratum, it was decided that a top-down approach would be used with proportional sampling. Since a total sample size 7,000 was consistent with the original 90-10 computations and the resources available to PennDOT, it was accepted as the total sample size. The number counts in each stratum were then assigned in proportion to the mileage in each stratum in the following manner:

1. The target sampling rate in rural areas was one count every 15 miles.

2. The target sampling rate in urban areas was one count every 7 miles.

3. The minimum sample size for a stratum was 10 in rural areas and 5 in urban areas.

4. Any strata with less than 10 miles would not be sampled since this would result in a high density of counts per mileage of roadway. These were all urban areas where a sliver of an urbanized area extended into an adjacent county. There were five such instances with a total mileage of only 26 miles. The VMT estimates for these five areas can be made from the data collected in the remainder of the respective urbanized area. The omitted areas, listed by Urban/Rural Destination Code and county, are as follows:

- Code 3 mileage in Carbon County (Allentown / Bethlehem / Easton Urbanized Area)
- Code 2 mileage in Dauphin County (Elizabethtown Urbanized Area – See Lancaster County)
- Code 4 mileage in Susquehanna County (Scranton / Wilkes-Barre Urbanized Area)
- Code 4 mileage in Wayne County (Scranton / Wilkes-Barre Urbanized Area)
- Code 4 mileage in Wyoming County (Scranton / Wilkes-Barre Urbanized Area)

Table 3-2 presents the sample sizes by stratum for the sample panel. There are a total of 7,171 counts over 152 strata. There is on average one count for every 10.2 miles of roadway.

Table 3-2 Sample Sizes by Stratum

County	Code 1	Code 2	Code 3	Code 4
Adams County	46	15		
Allegheny County	10			540
Armstrong County	67	17		5
Beaver County	25			85
Bedford County	60			
Berks County	86	9	12	108
Blair County	23	5	44	
Bradford County	102	7		
Bucks County	29			270
Butler County	70	36		31
Cambria County	35	22	42	
Cameron County	10			
Carbon County	21	5		8
Centre County	38	9	26	
Chester County	43	12	9	211
Clarion County	61	5		
Clearfield County	64	22		
Clinton County	21	11		
Columbia County	49	21		
Crawford County	90	19		
Cumberland County	37	25		60
Dauphin County	31			99
Delaware County				178
Elk County	21	7		
Erie County	63	12	86	
Fayette County	59	9	41	5
Forest County	11			
Franklin County	47	39		
Fulton County	21			
Greene County	60	5		
Huntingdon County	40	5		
Indiana County	73	17		
Jefferson County	53	5		
Juniata County	25			
Lackawanna County	19			93
Lancaster County	89	19		167
Lawrence County	34	29		6
Lebanon County	27		40	10
Lehigh County	29			140
Luzerne County	44	5	32	94
Lycoming County	59	7	38	
McKean County	28	6		
Mercer County	61	10		28

County	Code 1	Code 2	Code 3	Code 4
Mifflin County	19	11		
Monroe County	41	53		
Montgomery County	10		27	290
Montour County	13	5		
Northampton County	30			132
Northumberland County	43	28		
Perry County	38			5
Pike County	17			
Potter County	42			
Schuylkill County	60	44	5	
Snyder County	29	7		
Somerset County	80	7	5	
Sullivan County	20			
Susquehanna County	70		5	
Tioga County	76			
Union County	16	8		
Venango County	46	17		
Warren County	36	9		
Washington County	70	5	28	57
Wayne County	45	5		
Westmoreland County	61	9	20	155
Wyoming County	26			
York County	89	28	113	23
Philadelphia County				289

It should be noted that the counts will be collected over a number of years, perhaps as long as 10 years. It is recommended that the Department evaluate the proposed plan at interim points over that time period. As part of any evaluations, it is recommended to bear in mind the sample size of 45, which generally corresponds to 90% confidence and 10% precision using the HPMS equation. For strata with large sample sizes, such as the Code 4 mileage in Philadelphia County, a sample size of 45 may prove to be adequate, thus allowing resources to be devoted elsewhere if desired. As a general rule, the Department may not want to collect more than 45 counts in any stratum without performing precision analysis and verifying that additional counts are needed or desired.

Likewise, as the counts are performed and the variability in the counts is revealed, the statistical analysis could and likely should be revisited. A key variable in the HPMS sample size equation is the coefficient of variation of the AADT data, which can be computed with the mean and standard deviation of the collected traffic counts. A value of 0.4 was used in the calculations performed in this research, as both the total sample size of 7,000 and the stratum sample size of 45 are both based on this number. If the counts on local roads are less variable, then fewer counts might be justified, or vice versa. The plan reflected in Table 3-2 should be viewed as a starting point that was based on limited information, and that will evolve as more information becomes available.

3.4 Random Selection Process

The roadway segments to be sampled were drawn from the Municipal Services database using *Microsoft Excel* in the following way:

1. A separate *Excel* worksheet was created for each of the 152 stratum.
2. If the strata contained municipalities for which the electronic segmented database was not available, an average segment length was applied to the mileage in the stratum, and an appropriate number of "dummy" segments were inserted in the database.
3. Each segment was given an identification number, which started at one and skipped no numbers.
4. The Random Number Generation Analysis Tool was used to select an appropriate number of segments from the identification number field.
5. These segments were flagged, consolidated, and copied into a new workbook entitled "Sample Panel".
6. For segments in the City of Pittsburgh, Allegheny County, the selected segment numbers were related to the paper database that was provided, and the locations randomly pulled as appropriate. These were then typed into the "Sample Panel" workbook manually. A reference relating the selected segment and its position (page number and line on the page) in the paper database was also provide in case the Department requires clarification on any of the sites in the City of Pittsburgh.

3.5 Proposed Sample Panel

The proposed sample panel generated in accordance with the methodology set forth in this chapter is provided on the accompanying CD.

3.6 Proposed Panel of Alternates

A panel of alternates was also generated using the exact same procedures as described in this chapter, with the exception that it is designed to be only 10% of the proposed sample panel in size—subject to the same minimum sample sizes of 10 and 5 in rural and urban areas respectively. The panel of alternates is also provided on the accompanying CD.

CHAPTER 4 – CONCLUSIONS AND RECOMMENDATIONS

4.0 Summary of Research

This research project aimed to determine a sampling method to collect the data required to produce VMT estimates on local roads owned by municipalities. The proposed research methodology built upon the guidance contained in the TMG and HPMS Field Manual, the experiences of others as discovered through a nationwide survey of state DOTs, and an extensive literature search to develop a plan specific to circumstances facing PennDOT. It was designed to be feasible within the resources available to PennDOT to devote to local road monitoring, and to provide a foundation of data upon which VMT estimates could be made at the county level for each urban / rural code. The end result was a plan that contained 7,171 count stations spread proportionally over 152 strata.

4.1 Recommendations for Implementation

PennDOT can begin collecting AADT counts at the locations identified in the sample panel immediately. It should be noted that in 88 of the municipalities, specific locations will need to be selected by the Department, as a segmented database was not available for these municipalities. Also, none of the count locations within the selected segments have been identified. This should be done by the data collection technicians in the field at the time of data collection, as it is a function of the type of equipment used in the data collection.

It is anticipated that the 7,171 counts will be spread out over a time frame of up to 10 years. However, PennDOT will likely do as many as feasible at the kick-off to this endeavor. As was noted in Section 3.3, the Department should re-evaluate the overall number of counts, and the sample size in each stratum at various times over the data collection process. Of particular importance will be a precision analysis when 45 counts are accumulated in a given strata, and the coefficient of variation for the AADT data within each strata. As noted, the plan presented in this research is a starting point that was not based on any statistical analysis of local road AADT data. It can be revised as appropriate when data become available.

4.2 Recommendations for Future Work

In the literature review and survey of state practices, there were almost as many ways of monitoring local road traffic as there are states. This is clearly an area where further guidance is needed on a national level. PennDOT may want to consider publishing any results of statistical analysis performed in conjunction with the local road monitoring program. Of interest to others nationwide will also be the evolution of the PennDOT program, any unique arrangements made with municipalities to achieve the required data collection, and any use of advanced technologies to collect, process, or analyze the local road traffic volume database.

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