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Evaluation of Methodology for Determining Truck Vehicle Miles Traveled in Illinois

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16. Abstract

Nationwide surveys of DOTs, MPOs, and classification vendors/producers were conducted to determine the state of practice on equipment and methodologies used to determine truck VMT. The current IDOT methodology was evaluated and it was found that it overestimated truck VMT for multi-unit trucks on all eight functional classes except on the minor urban arterials. The average overestimation was 11.5% and it varied from –10% to +44%. The current method overestimated truck VMT for single-unit trucks in five and underestimated in three functional classes. The under/over estimation ranged from –6% to +35%, but the average value was close to zero. To calculate truck VMT more accurately, this study proposed two different methods based on average truck percentage (ATP) and average section length (ASL). In the ATP method, truck VMT is calculated by multiplying the average truck percentage for a group of roadway sections by the total VMT of that group. The ATP method should be used when the average truck percentages and the total VMT by volume groups are available. In the ASL method, the total truck volume for the sampled sections is multiplied by the average section length. The ASL method should be used when the information required for ATP is not available or not reliable. Sample size influences the accuracy of truck VMT estimation and the decision on sample size must consider the error level that is acceptable. This study looked at the likely error for different sample sizes and recommended using 8% to 16% of the number of roadway sections. The sections should be distributed among the volume groups. Recently, IDOT collects vehicle classification data for three categories at about 10,000 sections, biennially. It is recommended to evaluate the truck VMT calculation using recent data.

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EXECTUTIVE SUMMARY

The Illinois Department of Transportation (IDOT) was interested in evaluating its methodology for determining truck VMT and the technologies available for truck classification. This study conducted national surveys of all state DOTs, 54 largest Metropolitan Planning Organizations (MPOs), and 29 vehicle classification vendors/producers to determine the state of practice on equipment and methodologies used to determine truck VMT. The current IDOT methodology is evaluated and new procedures to estimate truck VMT more accurately are developed.

Over two-thirds of state DOTs, over half of the MPOs, and about one-fifth of the vendors/producers returned the survey. To compute truck VMT, most state DOTs responding to the survey collect traffic data by their staff. Several state DOTs use traffic counts and other sources in computing truck VMT. The majority of state DOTs collect data for the FHWA's 13 categories (F-13 scheme), but three state DOTs use fewer categories. Truck data are collected using machine classifiers unless certain conditions would demand collecting the data manually. The majority of DOTs use the number of axles and axle spacing to classify vehicles. A few DOTs use other variables such as vehicle length and weight.

The majority of state DOTs collect short-term vehicle classification data. The number of 24-hour or less classification stations ranged from 0 to 42 stations per 1,000 miles of total highway system. For short-term classifications, most state DOTs use portable devices with pneumatic road tubes. Some state DOTs use the combination of the tubes with other sensors, such as loop detectors, piezoelectric sensors, or fiber optic sensors. Peek 1000/2000 and Peek 241 with a variety of sensor technologies dominate the market of portable classification devices. Illinois DOT uses Peek 241 and Hi-Star NC-97 devices in its vehicle classification program. IDOT prefers the Hi-Star NC-97 because of ease of installation and desirable performance.

The current IDOT method overestimated truck VMT for multi-unit trucks on all eight functional classes except on the minor urban arterials. The overestimation was 11.5 % and it varied from -10 % to +44 %. For single-unit trucks, the current method overestimated in five and underestimated in three functional classes. The range of under/overestimation was from -6 % to +35 %, but overall it was close to zero because the overestimates cancelled out the underestimates.

To calculate truck VMT more accurately, this study proposed two different indirect methods to estimate truck VMT: average truck percentage (ATP) and average section length (ASL). In the ATP method, truck VMT is calculated by multiplying the average truck percentage for a group of roadway sections by the total VMT of that group. The ATP method should be used when the average truck percentages and the total VMT by volume groups are available. When the ATP method is used, a simple arithmetic average of truck percentages should be used. The second method, ASL, uses the average section length. First, the total truck volume for the sampled sections is calculated; then, it is multiplied by the average section length. The ASL method should be used when the information required for ATP is not available or it is considered not reliable. This method only requires truck volume information by volume group. It is suggested to use the average section length at roadway functional class level.

Highways should be grouped into roadway functional class by the area type (urban and rural) and traffic volume level. For the marked routes eight functional classes are suggested: interstate urban, interstate rural, freeway and expressway, other principal urban arterial, other principal rural arterial, minor rural arterial, major rural collector, and minor urban arterial. The traffic volume levels should be selected such that the total length of roadway sections is approximately equally distributed among the volume groups. It is suggested that interstate highway systems be grouped into 14 volume groups, freeway and expressway systems into seven volume groups, other principal arterials into 16 volume groups, minor rural arterials into 20 volume groups, major rural collectors into 15 volume groups, and minor urban arterials into 10 volume groups.

Sample size influences the accuracy of truck VMT estimation and the decision on sample size must consider the error level that is acceptable. The study looked at the likely error, expressed as MAF, for each possible sample size. It is recommended to use the minimum sample size that yields more stable MAF. It is recommended to use 8% to 16% of the number of roadway sections. These roadway sections should be distributed among the volume groups. This study proposes two different ways to distribute the sample size. The first approach allows the sample distribution to be proportional to the total VMT distribution among volume groups. Thus, a greater number of sampled sections are taken from volume groups with a larger contribution to the total VMT. Instead of using the total VMT distribution, the second approach uses the truck VMT distribution as the basis for distributing sampled sections. When historical data on truck VMT are available, the study verified that the second approach would provide better results. Furthermore, within a volume group, the sampled sections can be randomly selected from the sections that are in that volume group. The random selection can be replaced with more systematic selection if desired.

Once the truck VMT for the sampled sections is calculated, it should be expanded to obtain truck VMT on that highway functional class. It is suggested to use the ratio of the number of total roadway sections in the functional class to the number of sampled sections from that functional class as the expansion factor. The estimated truck VMT should further be adjusted by applying the methodology adjustment factors (MAF). The MAF is used because the ATP and ASL are indirect methods. A set of MAFs was developed for different roadway functional classes and truck types (single-unit and multi-unit trucks).

Truck VMT data are used for various purposes and an accurate estimation of truck VMT is essential. Recently, IDOT collects vehicle classification data for three categories (passenger cars, multi-unit, and single-unit trucks) at about 10,000 sections biennially. Vehicles are classified according to their length. This data collection program provides IDOT with a very rich database for truck classification and VMT calculation. It is recommended to evaluate the accuracy and efficiency of truck VMT calculation using the recent data, to investigate the merits of such length-based classifications, to compare the proposed methodology with the recent IDOT data. It is recommended to verify the results of the proposed methodology and to develop a user's manual for it. It is recommended to develop adjustment factors for multi-unit and single-unit trucks.

1 INTRODUCTION

Trucking is vitally important to the Illinois economy and a significant portion of the US truck traffic passes through Illinois. More than 12 billion tons of freight were transported by the U.S. transportation system, and trucks (including for-hire and private) accounted for more than half (53%) of the total tonnage (2). Over two-thirds (72%) of the total shipments by value, and nearly one-quarter (24%) of the total ton-miles shipped were by trucks (2). Approximately 5,700 miles out of 160,800 miles of the national highway system are in Illinois (20) and Illinois ranks third in terms of national highway system road mileage. The total truck VMT in the US (in 1994) was approximately 170 billion and in Illinois it was 6.2 (18). Illinois ranks number seven in terms of the highest annual truck VMT. On the one hand truck traffic helps the Illinois economy, on the other hand it deteriorates the infrastructure.

Vehicle miles traveled (VMT) is a key element in studying fuel consumption, environmental quality, highway safety, transportation planning, highway design and operations. An accurate determination of the contribution of truck miles traveled to total VMT is important. The VMT itself is not directly measured, but is estimated from other measurements. The VMT estimation methods can be classified into two broad categories: traffic count based and non-traffic count based. Non-traffic count based VMT estimation methods use data such as fuel sales, population, numbers of licensed drivers and registered vehicles. Most of these data are expensive to collect on a regular basis, so rough updates of previously collected data are often used for estimated VMT, producing questionable results (7). In addition, VMT estimates based on non-traffic count data are associated with problems relating to distribution of trips. For example, VMT estimates based on fuel sales raise questions as to how much of the fuel was used for travel in Illinois only. Indirect measure of truck VMT at the national level has been performed using various national databases. The Census Bureau collects transportation data covering travel, transportation of commodities, and trucks (16). The Truck Inventory and Use Survey (TIUS) provides data on the physical and operational characteristics of the nation's truck population. It is claimed that TIUS estimates of the truck VMT appear to be the best estimates currently available (12). Kuzmyak (8) suggested using the Highway Statistics, the Nationwide Personal Transportation Survey, the Highway Inventory and Performance Study and the Regional Transportation Energy Conservation Data Book to forecast national total VMT.

On the other hand, the VMT estimate based on traffic counts is the most direct method and it uses actual traffic volume. This approach assumes that the vehicle miles traveled in a state during a year can be estimated by counting the traffic on representative sections of roadway during short periods of time and expanding these results to statewide totals. The highway sections have homogenous traffic volumes and on local streets they are from 0.25 to 0.5 miles, on arterials from 0.5 to 1.0 miles, and on freeways from 1.0 to 2.0 miles (10). Sampling procedures are designed to estimate VMT using counts from selected sections. To compute VMT, the traffic volume on a sample section is multiplied by length of the section. Then, appropriate adjustment factors are applied. The accuracy of traffic count-based VMT estimates is determined by the accuracy of the traffic data used for the estimation. Therefore, the sample size and sampling locations are very important factors in determining truck VMT. Other procedures are suggested for estimating VMT or increasing its accuracy (1, 3, 5, 6, 9, 11, and 13).

The Illinois Department of Transportation (IDOT) is interested in evaluating its methodology for determining truck VMT and the technologies available for truck classification. IDOT is also interested in evaluating the current distribution and number of counting locations in light of the changes in travel patterns, increase in truck traffic, and recent advances in technology for measuring and counting traffic. IDOT estimates truck VMT through the use of counts at 300 locations statewide. Data are collected from these locations according to the procedure given in the Illinois Traffic Monitoring Program report (15). The Illinois program is based on the procedures outlined in the FHWA Traffic Monitoring Guide (TMG) (17) and the AASHTO Guidelines for Traffic Data Programs (14).

This study conducted national surveys of state DOTs, a number of the largest Metropolitan Planning Organizations (MPOs), and vehicle classification vendors/ producers to determine the state of practice on equipment and methodologies used to determine truck VMT. Current methodology used by IDOT is evaluated and procedures to estimate truck VMT based on sampling techniques are developed.

2 SUMMARY OF LITERATURE REVIEW

2.1 Truck Classification Technologies

Recent developments in sensor technologies permit the use of a variety of concepts for classifying trucks on highways. The choice of technology depends on many factors such as cost, reliability, precision, life span, installation, maintenance, and type of data it provides. In general, vehicle classification methodologies can be grouped into three major categories: axle based, vehicle length based, and machine vision (visual) based. These three categories are briefly discussed below.

2.1.1 Axle Based Classifiers

These classifiers measure the number of axles and axle spacings. The axle spacings are determined from the speeds of vehicles and the times the axles passed over the sensors. A vehicle speed is obtained by measuring the time the front axle traveled from the first to the second sensors. The number of axles and axle spacings are used to determine the class of vehicles.

The axle-based methodology is used to group vehicles into the 13 categories recommended by the Federal Highway Administration (FHWA). Errors in the form of unclassified vehicles are normally found during data collection due to either the incorrect measurement of the number of axles or a considerable change of vehicle speed over the sensors. Unclassified vehicles are generally the type of vehicles that do not fit into any of the prescribed classes of vehicles.

The accuracy of these classifiers depends on several factors including the type of sensors used (loops, tubes, piezoelectric, etc), roadway geometry conditions at the site of the sensors, installation and maintenance of the sensors. According to the 2000 TMG (21), to maintain a desired level of accuracy for axle based classifiers, one has to control the accuracy of measuring the distance between the two sensors and the accuracy of the sensors themselves. The sensors must be installed such that a vehicle stays in a single lane until it completely passes over both sensors. Traffic conditions also influence the accuracy of the classification. This includes the traffic speed to which the axle sensors can respond and the presence of different types of vehicles with a similar axle spacing. Moreover, a constant vehicle speed over the two sensors is assumed in calculating spacing between axles. Finally, the accuracy depends on the classification algorithms, which are proprietary that has to cover all possible axle configurations and vehicle types. The axle based methodologies normally work very well in uncongested traffic conditions. When traffic gaps between vehicles are relatively small, the accuracy of this approach deteriorates.

Table A.1 of Appendix A describes several types of axle-based classification equipment. These include TC/C 500 and TC/C 540 from International Road Dynamics Inc. (IRD), IVS 2000 from International Development Corporation, MSC 3000 and 4000 from Mitron System Corporation, and Unicorn/Phoenix from Diamond Traffic Product.

2.1.2 Vehicle Length Based Classifiers

These classifiers use vehicle length to group vehicles into different classes. A single or combinations of different types of length sensors are normally used. The sensor might be loops, piezoelectric, or electrical contact closures. Inductive loops are normally selected to allow for a reliable and long-lasting installation. Vehicle length is computed by dividing the total time required for the vehicle to traverse the loop by the speed of the vehicle. The speed is estimated based on the time difference the vehicle was detected by the first and the second loops. The dual loop system may classify vehicles into fewer categories than the FHWA 13 vehicle classes. This is because the system cannot accurately measure a small difference in vehicle length. Using this loop system, a single long vehicle unit may not be easily differentiated from two smaller units hitched together, since the gap between the hitched units may be too small to detect. Despite the limitations, this system remains popular in some states partly because fewer categories (four) are sufficient for a variety of traffic monitoring purposes, and partly because a loop detector system is low cost technology and reliable.

Similar to the axle-based classifiers, the length-based classifiers that use loops experience the same operational problems, especially on the roadways where vehicle speeds are not constant over the loop detectors. This causes inaccurate classification as the length of vehicles is incorrectly computed. The loop system also is less accurate in classifying closely spaced cars. In general, the loop system tends to work best at locations with low traffic volume. To overcome the weaknesses of the loop system, a combination of the axle and loop sensors is used. This concept utilizes two loop detectors and an axle detector, which are placed in sequence in a short segment of highway. This system of detectors measures the length, axle spacing, speed, and distance gap for each vehicle. Then it compares the axle numbers and spacing data of the vehicle with a database that contains a pre-determined axle number and spacing ranges.

Table A.2 of Appendix A describes some of the length-based classifiers. These include the Peek ADR family (ADR 2000, 3000, and 4000) from Peek Traffic, DAW 100 and 190 from PAT Traffic Control Corporation, and NC-97 Hi-Star from Nu-Metric.

2.1.3 Machine Vision Based Classifiers

Machine vision, also known as image processing or artificial vision, is a technology that combines video imaging with computerized pattern recognition. Classifiers based on this technology are developed to provide a system that does not require installation of sensors on roadways. This technology can provide more detailed information about vehicles such as width, height, and character profile of individual vehicles. Normally a video camera is used to record video images (frames) that are taken at contiguous time instants spaced at regular time intervals. A digitizer converts the frames into digital signals that are sent to a computer for extraction of vehicle features.

These visual-based classifiers are subject to the drawbacks of measuring speed accurately and the issues in differentiating among closely spaced vehicles. Image sensing technologies are also subject to inaccuracy caused by occlusion (the blocking of the line of sight by a second vehicle). Moreover, this technology cannot directly obtain the number of axles, a piece of information needed for vehicle classification.

Table A.2 of Appendix A describes various types of machine vision based classifiers. These include Autoscope ECP and ISS 2004 systems from Econolite Control Products, Inc., TAS2 from Computer Recognition Systems, Inc., and IDET 100 from Sumitomo Electric Industries, Ltd., ect.

2.1.4 Other Sensor Technologies

Research and development of new sensor technologies such as infrared, light emission, microwave, and radar are in progress. Guha (4) demonstrated the use of photoelectric technology for vehicle classification. This classifier consists of photoelectric sensors and reflectors mounted on steel posts on either side of the road. The sensors use infrared light beams to detect the presence of vehicles. The beam is focused on a reflector located across the roadway.

Different types of equipment are used to classify vehicles. The accuracy of classification results depends on lane sensor devices that record the physical characteristics of vehicles. This section briefly discusses several sensor technologies used to determine vehicle classification. Table 2.1 shows several lane sensor devices and their manufacturers.

Inductive loops are wires placed in channels cut into the pavement and are used to detect vehicle presence by sensing the metallic mass of the vehicle. Classifiers with inductive loops have been used in many states mostly for continuous classification counts. Pressure-sensitive Treadles are sensor devices that are placed in frames and installed in the pavement to determine the number of axles, number of wheels, and direction of a vehicle crossing the treadles. A parallel series of sensor devices detects the direction of axle movement by the sequence of sensor activation.

Table 2.1 Lane sensor devices for classifying vehicles and their manufacturers

No.	Vehicle Classifiaction Devices	Manufacturers
1	Inductive Loops	3M Diamond Traffic Golden River Mayfield Peek Traffic Systems
2	Electromechanical Treadles	Cubic The Revenue Markets Inc (TRMI)
3	Resistive Rubber Treadles	International Road Dynamics (IRD) Technotel
4	Optical Treadles	Trindel
5	Piezoelectric Treadles	Peek Traffic Systems The Revenue Markets Inc (TRMI) Traffic 2000 Ltd
6	WIM with Bending Plates	PAT Peek Traffic Systems
7	WIM with Capacitive Strips	Golden River
8	WIM with Piezoelectrics	Diamond Traffic PAT Peek Traffic Systems Philips
9	Light Beams	Syntonic
10	Light Curtains	Banner CGA-Alta Scientific Technologies Inc (STI)
11	Ultrasonic Scanners	Cubic
12	Infrared Scanners	Computer Recognition Systems, Inc. Elsydel MBB SensTech Schwartz Electro-Optics
13	Laser Scanners	Schwartz Electro-Optics
14	Video Image Processors	Golden River

* Table is constructed from http://wwww.ettm.com/avc.html

Four types of treadles are available depending on the physical principle used to convert the pressure of a vehicle's wheel into electrical signals recognized by the logic units of the treadles. The first is electromechanical treadles. These devices are in widespread use for low-speed applications, but they are inaccurate at speeds over 55 mph. The second is resistive rubber treadles, which are similar to electromechanical treadles, but use resistive rubber rather than metal for contact closure. They are specified to operate accurately at speeds from 2 - 80 mph. Resistive rubber treadles have a lower maintenance cost than electromechanical treadles. The third is optical treadles. These devices utilize infrared beams inside a tube. When beam is broken due to the pressure of a vehicle's wheel, an electrical signal is generated. These devices are specified to be accurate at higher speeds and have a long life and low cost of maintenance. They can be installed in standard treadle frames. The fourth is piezoelectric treadles. These devices use special material inside a tube that generates an electric current when subjected to pressure caused by crossing vehicles. The devices are accurate classifying vehicles at speeds over 5 mph, and recent developments have made them accurate even in the 0-5 mph range.

Weigh-in-Motion (WIM) devices have been used in many states for several purposes. Like treadle devices, WIM devices are pressure-sensitive. These devices generally are placed in frames installed in the pavement and are commonly used to determine the axle weight of vehicles. Several types of sensors are used for WIM devices, such as bending plates, capacitive strips, and piezoelectric sensors. Bending plates generate an electric current when subjected to pressure caused by an axle crossing the plates. The degree of pressure on capacitive strips as an axle crosses a strip allows calculation of axle weight. WIM devices with piezoelectric sensors utilize special material inside a tube that generates a varying electric current proportional to the weight of the axle crossing the sensor.

Several non-intrusive sensor technologies have been introduced to classify vehicles. At least two types of light emission based technologies are currently available: light beam and light curtain devices. Light beam devices consist of a single infrared light beam that is broken as a vehicle passes through the beam. They are used to detect vehicle presence and vehicle height. The functionality of light beam devices is limited in that they cannot accurately separate vehicles with trailer hitches or provide a profile of the vehicle. Another disadvantage of light beams is that the single beam of light is transmitted through vehicle windows without impediment, thereby causing the appearance of a separation of the vehicle where none exists. Light curtain devices emit multiple horizontal light beams to measure vehicle presence and profile. A transmitting tower sends light beams across the lane to a receiving tower. As a vehicle breaks the light beams, a two-dimensional profile of the vehicle can be produced. Trailer hitches can be detected down to approximately one-half inch.

Another non-intrusive way to classify vehicles is to scan them using ultrasonic waves, infrareds, or laser beams. Scanning devices generate radiation at various frequencies to detect vehicle presence and profile. Ultrasonic scanners emit ultrasonic waves, which are reflected back to the transmitting device to detect vehicle presence and two-dimensional profile. Ultrasonic scanner, however, are subject to distortion from air turbulence and changes in temperature and humidity. Infrared scanners are used to separate and profile vehicles using a vertical or horizontal infrared scanning camera system. The output is two-dimensional images, which are compared to vehicle classification templates to determine vehicle type. Laser scanners are capable of detecting and classifying vehicles operating in high speed, high volume conditions. Output from the device is processed to produce 3-dimensional images that are compared to stored templates of various vehicle profiles to determine vehicle type.

Table A.2 of Appendix A describes several classifiers using new technologies that are on the market. These include SAS-1 Acoustic Sensor from SmarTek System and SmartSonic from International Road Dynamics Inc.

2.2 Truck VMT Estimations

The FHWA requires state DOTs to report the percentage of trucks operating on interstate highways and the vehicle miles traveled (VMT) by them. The data are essential for determining accident exposure, accident rates for trucks, and deriving the Federal Highway fund apportionment formulae. Truck VMT refers to the total miles traveled by all truck categories on roadways. Since obtaining information about individual truck travel is not possible, sampling methods have been used to obtain truck VMT estimates. The Highway Performance Monitoring System (HPMS) of the FHWA collects information on the physical and usage characteristics, including traffic count and pavement condition on a sample of various highway systems. This HPMS method is currently the most accepted method for estimating truck VMT because it is based on the actual truck traffic data. The HPMS procedure is based on traffic counts on a sample of roadway sections. Other procedures are also used to estimate truck travel. The Truck Inventory and Use Survey (TIUS) and the Nationwide Truck Activity and Commodity Survey (NTACS), for example, provide data on the physical and operational characteristics of trucks. Truck data for both surveys are obtained from sample surveys of truck owners or drivers. The following sections describe the HPMS method.

2.3 HPMS Method

The HPMS data is a nationwide inventory of all public roads. The HPMS procedure for estimating VMT is based on traffic count data. VMT estimation involves the use of adjusted 24-hr traffic counts or Annual Average Daily Traffic (AADT), obtained on sample sections identified through a systematic stratified random sampling process (7). The procedure starts with calculating Daily Vehicle Miles Traveled (DVMT) stratified by functional system for each sample section. This is merely the product of the section AADT and road segment mileage. The expansion factor (EF) is then used to extrapolate the sample section data to area wide VMT. The EF is defined as a ratio of the total mileage in a functional class to the total mileage in the sampled sections. The result is statewide (total) VMT for all vehicles in that functional class. Truck VMT is calculated by multiplying the total VMT by the average truck percentages for that functional class. The truck percentages are generated from classification counts conducted on at least 300 sites over a 3-year time period.

The HPMS procedure eliminates problems associated with non-traffic count based methods because it uses actual count data. If coverage counts were available for all roadway systems, the VMT obtained would be the best possible estimate. However, in reality only a sample of coverage data is available. HPMS standard sampling as defined in the 1999 HPMS manual (19) provides guidelines for developing an efficient sampling procedure.

2.4 Sources of Errors in Estimating VMT Using HPMS

Kumapley (7) reported that estimating VMT using the HMPS method is impractical due to the lack of input data. The HMPS procedure requires traffic count data and centerline mileage for all roads in the state. The centerline mileage for all roadway systems is known, but traffic count data is unavailable for some functional classes, such as local roads. Estimating VMT, therefore, is expected to be more accurate if a more comprehensive inventory database is used. Indiana Department of Transportation, for example, holds about 620,000 samples of traffic data as opposed to only 4,000 samples covered by HPMS database.

Minggo and Wolff (9) discussed that the raw vehicle classification data reported under HPMS area-wide reporting system contain many apparent anomalies and inconsistencies. This has caused substantial discrepancies between truck estimates based on the FHWA VM-1 table and other notable national truck VMT estimates. A comparison between 1987 TIUS (Truck Inventory and Use Survey) estimates and 1987 Highway Statistics VM-1 truck VMT estimates showed that FHWA overestimated other single unit truck VMT by 36 percent, and combination VMT by 51 percent (9). They argued that part of the problem of overestimation stems directly from inconsistent definition for combination vehicles and exclusive use of weekday classification counts. The HPMS manual defines 13 vehicle classes for which states report area-wide classification data. Three of these classes include light passenger vehicles, one includes buses, three include single-unit trucks, and the remaining six include combination trucks. In contrast to the HPMS classification, state DOTs policy tends to limit the class of vehicles known as 'combination' to only those vehicles with a heavy or cargo-carrying trailer.

Minggo and Wolff suggested improvements in the way the FHWA derives truck VMT estimates, and these include: a) systematic consideration of temporal count variations; b) a new definition of combination vehicles; c) new guidance to states; and d) FHWA corrections to state-reported data. They also recommended producing separate estimates of travel by truck-trailer combinations and tractor-trailer combinations, and excluding light trailers and light trucks from both categories of combinations.

Weinbalt (12) indicated that a source of error in truck VMT estimation was due to temporal count variations. By comparing different sources of truck VMT data, he showed that the current procedures using weekday classification counts substantially overestimate truck VMT. He suggested using seasonal and day-of-week adjustment factors to reduce the errors in truck AADT estimates and to eliminate the upward bias in truck VMT estimates that result from the use of weekday classification counts. To develop the factors, he recommended that the highway system be divided into at least three factor groups (urban, rural interstate, and rural other), and that permanent stations be established on a representative sample of five to eight sections in each factor group. Furthermore, he recommended that seasonal and day-of-week factors should be developed for several groups of vehicle classes for each of several highway groups, i.e. urban, rural interstates, and rural other. Five groups of vehicle classes are recommended: 1) four-tire vehicles (class 2 and 3); 2) buses (class 4); 3) other six-tire, two-axle vehicles (class 5); 4) other single unit vehicles with three or more axles (class 6 and 7); and 5) combination trucks (class 8-13).

2.5 Current IDOT procedures

The IDOT current procedure for truck VMT calculation follows the HPMS procedure and is based on comprehensive volume counts and a limited number of classification counts (approximately 100 locations per year on HPMS sections). Information obtained from the volume counts is stored in the Illinois Roadway Information System (IRIS) database which contains roadway inventory and information about all publicly owned roads, including local roads, in the state of Illinois. IRIS uses 9 functional classifications and two area types (urban and rural). The roadways are composed of segments. The information is stored so that a single record contains a roadway segment and all the pertinent information on the segment including length, ADT, etc.

Approximately 15,000 to 20,000 volume counts per year provide the traffic volume data for IRIS. These coverage counts are made both on the HPMS and non-HPMS sample sections. The HPMS sample sections located on the state system or marked routes are volume counted for 24-hours every 2 years. Those not located on the system are counted for 48-hours every three years. The Office of Planning and Program of IDOT supervises the statewide count program, while district offices carry out the counting. All district offices have access to and the ability to update the IRIS database. The update is based on a comprehensive traffic counting program including continuous counts, short classification counts on HPMS sample sections, short coverage (volume and classification) on marked routes, and county counts on local roads. The ADT stored in the IRIS database is derived from the following sources: first, a current year coverage count at a location that is considered representative of the segment; second, a prior year coverage count factored to represent the current year traffic; and third, a default traffic count when no prior year coverage count is available.

Truck VMT is calculated from the VMT of all vehicles. The total VMT is calculated by multiplying each segment's length and the corresponding ADT. The VMT for all roadway segments are added to obtain the total VMT. The average of truck percentages by truck type and functional class derived from the limited counts of the FHWA 13-vehicle categories is applied to the total VMT to obtain truck VMT. For publication, truck VMT is then summarized by eight roadway functional classes, area types (Urban and Rural), and eight vehicle types. The eight roadway functional classes are: 1) Interstate (Urban and Rural), 2) Freeway and Expressway (Urban), 3) Other Principal Arterial (Urban and Rural), 4) Minor Arterial (Urban and Rural), 5) Major Collector Rural, 6) Minor Collector Rural, 7) Collector Urban, and 8) Local (Urban and Rural). The eight vehicle categories are: 1) Passenger Cars (4-tires), 2) 6-tire Single Units, 3) 3-axle Single Units, 4) Buses, 5) 3-axle Multi Units, 6) 4-axle Multi Units, 7) 5-axle Multi Units, and 8) 6-axle or more Multi Units.

Currently, IDOT collects 3-vehicle category classification data at approximately 10,000 locations biennially on marked routes using Hi-Star NC-97 classifiers. The Hi-Star stores data for 3 classes of vehicles. This categorization is based on vehicle length. Any vehicle less than 22 feet long is categorized as Passenger Vehicle (PV), between 22 and 40 feet as Single Unit (SU), and larger than 40 feet as Multi Unit (MU) vehicles. The IRIS database does not have traffic volume data for the FHWA 13-vehicle categories. Instead, these three vehicle categories are used: PV, SU, and MU. IDOT is proposing to FHWA to use this classification data for calculating truck VMT.

Other states are using different procedures for calculating truck VMT. To find out what is the state of practice in truck VMT calculation, a nationwide survey was conducted. The results of the survey are discussed in the next section.

3 SURVEY AND INTERVIEW RESULTS

This section and the following four sections provide the results of three surveys and an interview series conducted as a part of this study. One survey is for state DOTs, one survey for Metropolitan Planning Organizations (MPOs), and the third survey is for the manufacturers of vehicle classification equipment. The interview is for IDOT employees. A survey of 50 state DOTs and Puerto Rico DOT on equipment and methodologies used for determining truck VMT was conducted. A similar survey of the 54 largest MPOs was also conducted. The MPOs were selected according to population, i.e. larger than 500,000. The list of MPOs can be found at http://www.bts.gov/tmip/MPOlist/mpoindex.htm. The surveys solicited information on how the DOTs and MPOs collected truck data and used it to calculate truck VMT. Seven groups of questions were included in the survey:

1) General questions
2) Sample size and location of truck classification counts
3) Data collection on HPMS sections
4) Field data collection for truck VMT
5) Data collection equipment for truck VMT
6) Processing of field data
7) Calculating and reporting truck VMT.

In addition, a third survey of 29 vehicle-classification equipment vendors/producers was carried out. The survey attempted to obtain up-to-date information on costs and sensor technologies for vehicle classification equipment. The vendors were selected based on the search on the Internet, including the Vehicle Detector Clearing House of the University of New Mexico, http://www.nmsu.edu /~traffic/. Copies of the surveys are included in Appendix B. Table 3.1 shows the number of surveys returned. A great majority of DOTs (71 %), over half of MPOs (54 %), and about one-fifth of the vendors returned the survey. The names of DOTs, MPOs, and equipment vendors that returned the surveys are provided in Appendix C.

Table 3.1 Organizations and surveys returned

Organizations	Survey Sent	Survey Returned	Rate of Response
DOT	51 *	36	71%
MPO	54	29	54%
Industry (Equipment)	29	6	21%

* 50 state DOTs and Puerto Rico DOT

3.1 Survey Results: State DOTs

3.1.1 Source of Truck VMT and Field Data Collection

3.1.1.1 Truck Data Collection

State DOTs were asked to indicate whether their truck classification data was collected in-house or by contractor staff, or both. The results in Table 3.2 are for those DOTs that responded the survey. For 17% of the DOTs responding to the survey (shown as other in the table) all of the truck data and in one-half (50%) of the DOTs almost all of the truck data is collected by their staff. In 16% of the DOTs that responded, most of the data is collected by staff and some by contractor. However, for 11% of the DOTs, almost all of the data is collected by contractors. The remaining 6% did not respond to this question. Thus, 83 % of state DOTs collect at least most of the data in house.

Table 3.2 Truck data collection

Truck Data Collection	No. of State	(%) *
Almost all of truck classifiaction data is collected by DOT staff	18	50
Mostly by DOT, but some by contractor staff	6	16
Almost all of truck classifiaction data is collected by contractor staff	0	0
Mostly by contractor, but some with DOT staff	4	11
Other	6	17
No Response	2	6

* Based on those responding

State DOTs were also asked whether they have a written procedure to collect truck classification data. Nine state DOTs have written procedures for the data collection, while 25 state DOTs do not. Two state DOTs did not respond to this question.

3.1.1.2 Other Truck Data Sources

State DOTs were asked whether they obtain truck classification data to compute truck VMT, from any other agency within their state. The majority of the state DOTs (81%) do not obtain data from other agencies. About 11% (four state DOTs) obtain some truck traffic data from other agencies. Pennsylvania

DOT obtains the data from PA Turnpike; Idaho DOT from Tax Commission and OHPI (Office of Highway Policy Information); New Jersey DOT from Delaware Valley Regional Planning Commission; and Kansas DOT from Kansas Turnpike Association (KTA). About 8% (three state DOTs) did not respond to this question.

State DOTs were also asked to identify whether they used sources other than traffic volume count data to calculate truck VMT. About 70% of state DOTs do not use other sources, see Table 3.3. About 19% of the state DOTs (7 DOTs) use additional non-traffic data along with truck volume count data. Idaho, Virginia and Wisconsin use the State Fuel Tax Report. In addition, Idaho also uses data from the OHPI (Office of Highway Policy Information) on the annual vehicle distance traveled and other data by highway categories and vehicle types. Virginia also uses the state fuel consumption data but its use is only for unofficial truck VMT estimation. Three state DOTs (Kentucky, Nevada and Washington) use weigh station data and one state DOT (Oregon) uses the weight-mile tax and flat fee tax data. About 11% of the DOTs did not respond to this question.

Table 3.3 Sources of information other than truck data.

Sources	**No. of State DOTs**	**(%)**
State Fuel Tax Report	3	8
Truck Inventory and Use Survey (TIUS)	0	0
Nationwide Truck Activity and Commodity Survey (NTACS)	0	0
National Truck Tripc Information Survey (NTTIS)	0	0
International Registration Plan (IRP)	0	0
Weigh station data	3	8
Other	1	3
None	25	70
No response	4	11

3.1.1.3 Short Term (24 Hr Or Less) Classifications

State DOTs were asked the number of locations at which they collected short-term (24 hours or less) truck classification data. In addition, state DOTs were asked the number of classification counts they conduct both on HPMS (48-hour and permanent classifications) and non-HPMS sections. The numbers of short-term classification count stations are presented in Table 3.4. These numbers represent the total number of stations for all roadway sections including the HPMS sections. Twenty-three state DOTs and Puerto Rico DOT collect classification data for 24 hours or less, and eight state DOTs (Arkansas, California, Connecticut, Louisiana, Massachusetts, North Carolina, Nevada, and Wyoming) do not collect such data. Four state DOTs (Hawaii, Indiana, Michigan, and West Virginia) did not provide the classification information.

Table 3.4 Numbers of short-term (24-hr or less) classification count stations

No.	State	Interstate	Arterial	Collector	Local	Total
1	AK	25	20	20	-	65
2	AR	0	0	0	0	0
3	AZ	12	25	9	0	46
4	CA	0	0	0	0	0
5	CO	0	150	75	0	225
6	CT	0	0	0	0	0
7	HI	-	-	-	-	-
8	IA	0	2	250	150	402
9	ID	30	95	14	0	139
10	IL	400	2,600	300	0	3,300
11	IN	-	-	-	-	-
12	KS	21	151	61	31	264 *
13	KY	60	170	70	10	310
14	LA	0	0	0	0	0
15	MA	0	0	0	0	0
16	MI	-	-	-	-	-
17	MN	15	30	-	-	45
18	MT	20	150	30	0	200
19	NC	0	0	0	0	0
20	NE	40	301	153	84	578
21	NH	10	10	10	0	30
22	NJ	40	162	50	82	334
23	NV	0	0	0	0	0
24	OK	40	80	50	0	170
25	OR	-	50	50	-	100
26	PA	35	100	100	25	260
27	PR	13	40	24	2	79
28	SC	58	161	63	0	282
29	SD	17	40	12	4	73
30	UT	40	300	150	70	560
31	VA	-	-	-	0	2,100
32	VT	12	600	-	-	612
33	WA	9	10	0	0	19
34	WI	5	120	30	5	160
35	WV	-	-	-	-	-
36	WY	0	0	0	0	0

- there is no information (no response)
* Data is collected for both 24 (or less) and 48 hours.

As shown in Table 3.4, two state DOTs (Illinois and Virginia) have large numbers of 24-hour or less classification count stations. Illinois DOT collects 24-hour classification data at 3,300 locations and Virginia DOT collects the data at 2,100 locations. These sites are located on interstate, arterial, and collector roadways. None are on local roads.

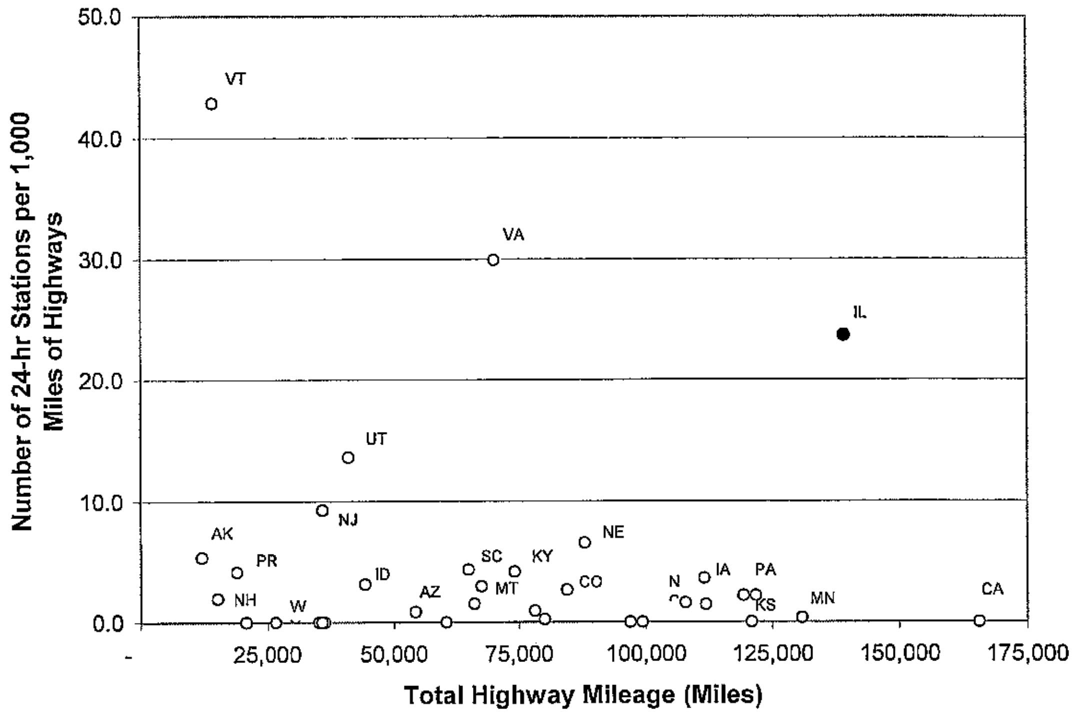
The eight state DOTs that do not have short-term (24-hour or less) classification count stations (indicated by zero in the last column of Table 3.4), have extensive 48-hour classification count stations. Arkansas and California DOTs, for example, have very extensive classification count stations on the HPMS sections for a longer duration. This will be discussed in the next sections. Louisiana DOT collects 48-hour data at 25 locations on interstate, 56 on arterial, and 27 on collector roadways. Louisiana DOT no longer collects 24-hour data because the scheduling of the work for 24-hour and 48-hour sessions is not intermixed easily. All short-term classifications at North Carolina DOT are collected for 48 hours for machine counts, and 16 hours for manual sessions. North Carolina DOT has 65 classification count stations on interstate, 350 on arterial, 200 on collector, and 30 on local roads. Wyoming collects classification data for 48 hours at 20 sites on interstate, 30 on arterial, 15 on collector, and five on local roads.

Figure 3.1 shows the number of short-term classification count stations per 1,000 miles of total highway systems for different state DOTs. The density of classification stations ranges from zero to 42 stations per 1,000 miles. Vermont DOT collects the short classifications at 612 locations with 14,274 miles of all its highway systems. This makes its density the highest, that is 42 stations per 1,000 miles. Virginia DOT performs 2,100 24-hr classifications on 70,137 miles of its highway system and that corresponds to 30 stations per 1,000 miles of highways. Illinois DOT used 3,300 short-term stations in the year 2000 covering 139,159 miles of highways, or about 24 stations per 1,000 miles. For these state DOTs, the density of short-term classification count stations is greater than 20, but for the remaining state DOTs it is less than 20 stations per 1,000 miles.

3.1.1.4 Permanent/Continuous Classifications

In terms of the number of permanent classification stations, Oklahoma DOT has the highest number of permanent stations, that is 290 stations, followed by California DOT with 250 stations and Virginia DOT with 247 stations. Table 3.5 shows the numbers of permanent classification stations maintained by state DOTs.

Figure 3.1 Density of short-term (24-hour or less) classification count stations by state



The number of permanent classification stations should depend on the highway miles in order to get adequate coverage of the entire highway system. Figure 3.2 shows the number of permanent classification stations per 1,000 miles of total highway systems. Idaho DOT has the highest permanent station density and maintains 3.8 permanent stations per 1,000 miles of highway. Connecticut DOT has 3.6 permanent station per 1,000 highway miles, which is the second highest permanent station density. Virginia ranks the third and maintains 3.5 stations per 1,000 highway miles. Eleven state DOTs operate at least one permanent station for every 1,000 highway miles. These are Idaho, Connecticut, Virginia, Oklahoma, New Jersey, Utah, Washington, California, West Virginia, Wyoming, and Montana. The rest of the state DOTs, including Illinois DOT, use less than one permanent station per 1,000 miles of highway.

Four state DOTs reported not maintaining permanent classification stations. These are Kansas, Louisiana, Massachusetts, and Oregon. Louisiana DOT has several permanent vehicle volume monitoring sites where a piezoelectric cable has been installed in conjunction with inductive loop detectors to give the DOT the capability of collecting continuous data. Louisiana DOT, however, reported not collecting classification data due to staffing issues.

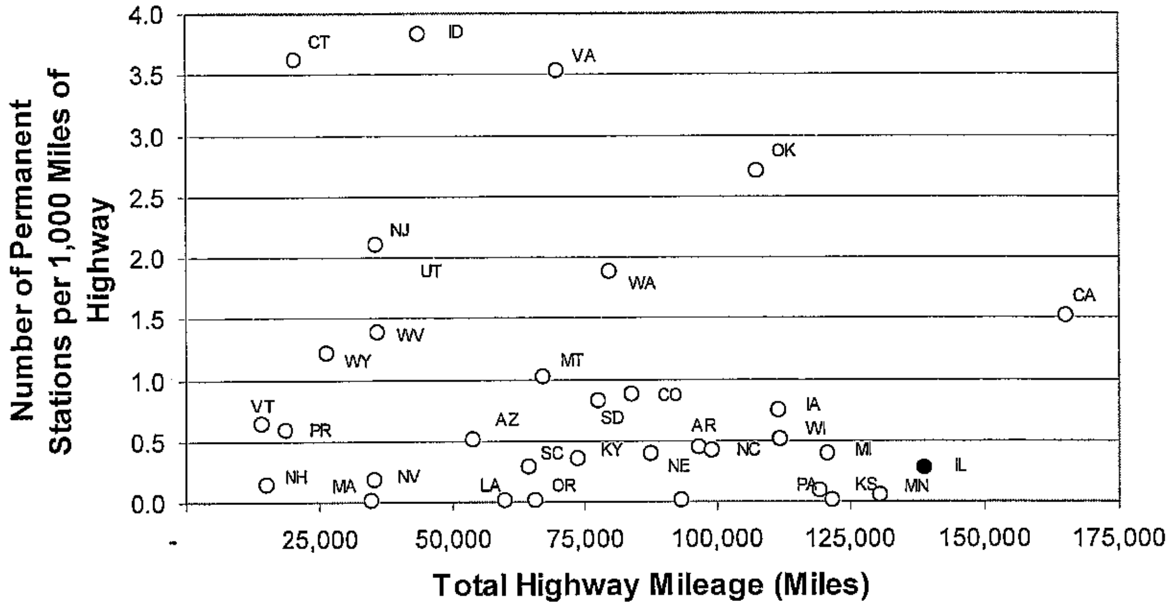
Table 3.5 Numbers of permanent classification count stations

No.	State	Interstate	Arterial	Collector	Local	Total
1	AK	-	-	-	-	-
2	AR	17	20	4	1	42
3	AZ	9	13	5	0	27
4	CA	250 *	-	-	-	250
5	CO	19	36	18	0	73
6	CT	37	38	0	0	75
7	HI	-	-	-	-	-
8	IA	20	51	10	0	81
9	ID	39	115	15	0	169
10	IL	10	26	1	0	37
11	IN	-	-	-	-	-
12	KS	0	0	0	0	0
13	KY	10	13	2	.	25
14	LA	0	0	0	0	0
15	MA	0	0	0	0	0
16	MI	22	24	-	-	46
17	MN	3	2	-	-	5
18	MT	18	40	9	1	68
19	NC	12	17	9	2	40
20	NE	11	19	3	0	33
21	NH	2	0	0	0	2
22	NJ	20	54	1	0	75
23	NV	6	0	0	0	6
24	OK	70	150	70	0	290
25	OR	0	0	0	0	0
26	PA	6	3	0	0	9
27	PR	9	2	-	-	11
28	SC	11	4	3	-	18
29	SD	14	27	11	11	63
30	UT	40	39	3	0	82
31	VA	87	100	60	0	247
32	VT	4	5	-	-	9
33	WA	150	0	0	0	150
34	WI	16	38	2	-	56
35	WV	15	23	12	0	50
36	WY	11	15	5	1	32

- there is no information (no response)

* including those stations on arterials and collectors

Figure 3.2 Density of permanent classification count stations by state



3.1.1.5 Classification on HPMS Sections

State DOTs were asked to provide the number of count stations for permanent and short-term classifications on HPMS sections. Table 3.6 shows the number of classification count stations by state DOTs. Figure 3.3 and 3.4 show the density per 1,000 miles of highway for permanent and 48-hour classification stations, respectively. California and Oklahoma DOTs each maintain 250 permanent classification stations on their HPMS sections. These two states have the highest number of permanent classification stations on HPMS sections. The densities per 1,000 miles of total highway is the highest for Idaho (2.8), followed by Oklahoma (2.3), Washington (1.9), Connecticut (1.8), California (1.5), and West Virginia (1.4). The remaining state DOTs maintain less than one station per 1,000 miles of highway systems. Five state DOTs (Kansas, Louisiana, Massachusetts, Montana, and Oregon) reported not operating any permanent station on HPMS sections.

The number of 48-hour classification count stations on HPMS sections also varies across state DOTs, as shown in Table 3.6 and Figure 3.4. Arkansas DOT operates 1,240 48-hour classification stations on HPMS sections or about 12 stations per 1,000 miles of highway. Vermont and Washington DOTs each operate 600 stations. The density for Vermont is about 42 stations per 1,000 miles of highway, which is the highest density for 48-hour classification stations. Three state DOTs (New Jersey, Utah, and Washington) reported maintaining between five to ten stations on every 1,000 miles of highway. The rest of the responding state DOTs had less then five stations per 1,000 miles of highway.

Table 3.6 Numbers of classification count stations on HPMS sections by state

No.	State	Permanent	48-hour
1	AK	10	60
2	AR	30	1,240
3	AZ	27	46
4	CA	250	50
5	CO	25	50
6	CT	37	15
7	HI	-	-
8	IA	57	15
9	ID	123	90
10	IL	3	100
11	IN	-	-
12	KS	0	100
13	KY	46	100
14	LA	0	109
15	MA	0	0
16	MI	8	40
17	MN	0	-
18	MT	60	180
19	NC	20	280
20	NE	35	35
21	NH	2	-
22	NJ	25	331
23	NV	6	63
24	OK	250	150
25	OR	0	250
26	PA	9	0
27	PR	11	35
28	SC	18	300
29	SD	63	-
30	UT	20	300
31	VA	-	-
32	VT	9	600
33	WA	150	600
34	WI	54	40
35	WV	50	100
36	WY	13	12

- there is no information (no response)

Figure 3.3 Density of permanent classification count stations on HPMS sections by state

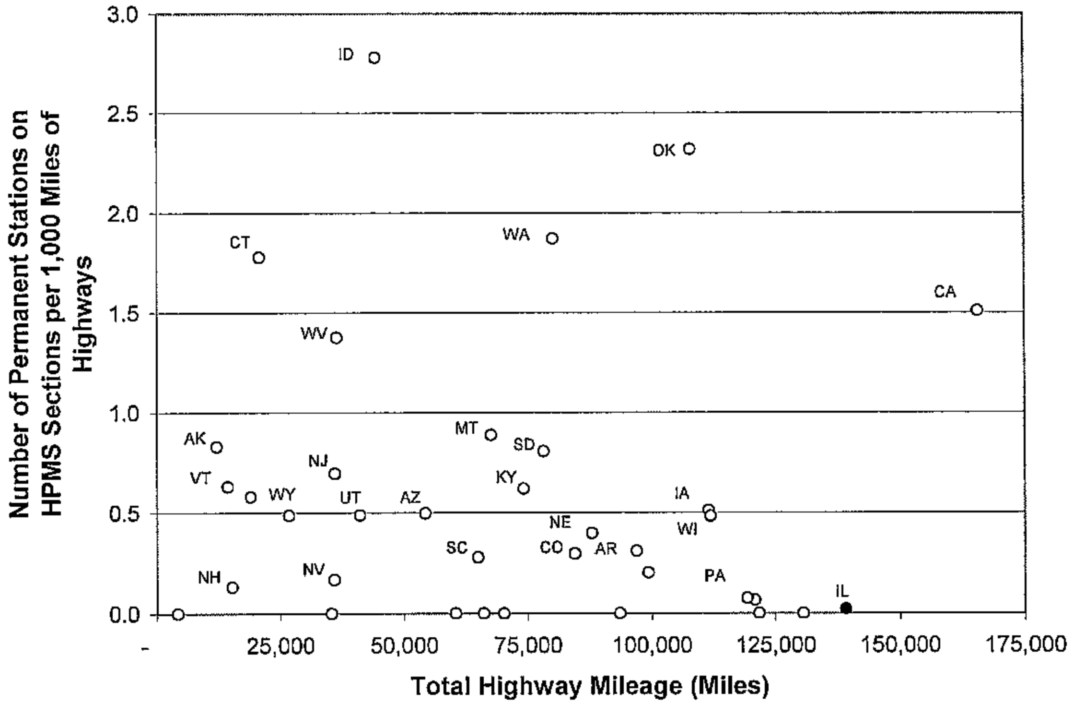
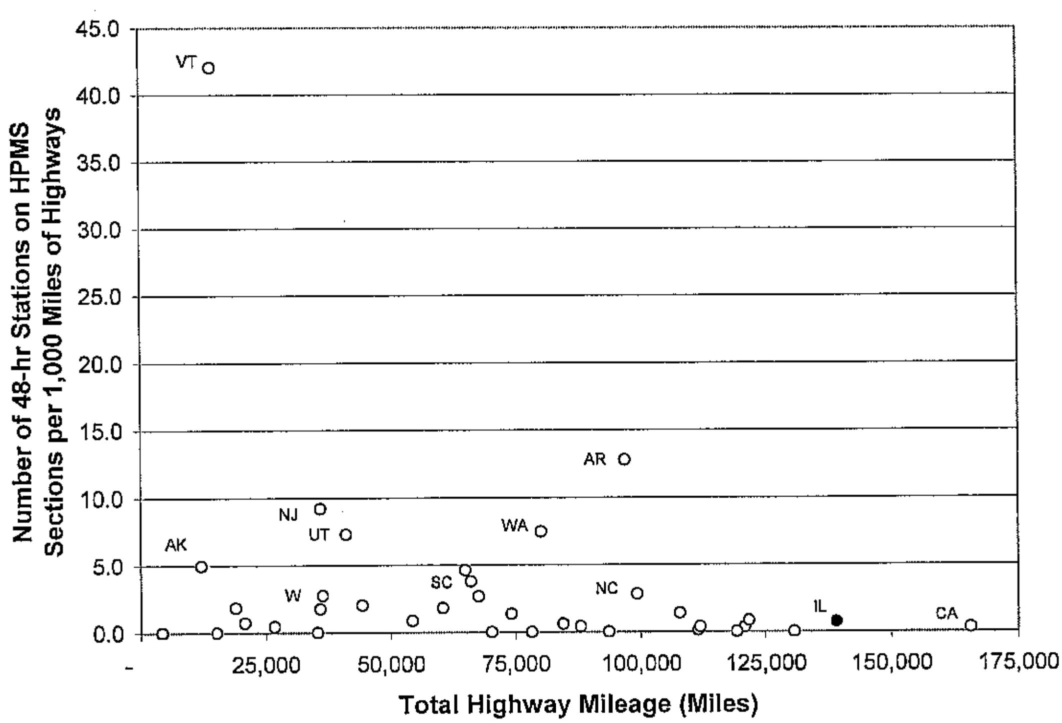


Figure 3.4 Density of 48-hour classification count stations on HPMS sections by state



3.1.1.6 Classification on Non HPMS Sections

The duration of classification counts on non-HPMS sections varies across the states as shown in Table 3.7.

Table 3.7 Numbers of classification count stations on non-HPMS sections by state

No.	State	12-hour	24-hour	48-hour	other
1	AK	-	-	-	0
2	AR	-	-	240	-
3	AZ	-	-	0	0
4	CA	-	-	-	0
5	CO	-	-	175	-
6	CT	0	0	30	-
7	HI	-	-	-	-
8	IA	0	10	0	0
9	ID	-	-	40	28 (4)+
10	IL	100	3,200	-	-
11	IN	-	-	-	-
12	KS	-	-	200	-
13	KY	-	-	100	-
14	LA	0	0	0	-
15	MA	-	-	-	-
16	MI	-	-	250	-
17	MN	-	-	150	50 (16)
18	MT	-	-	20	-
19	NC	-	-	250	100 (16)
20	NE	-	-	-	115 (32)
21	NH	30	0	0	0
22	NJ	-	-	94	-
23	NV	0	0	5	5 (7 days)
24	OK	-	10	10	-
25	OR	-	-	-	-
26	PA	0	0	0	25 (8)
27	PR	20	-	15	-
28	SC	-	-	10	-
29	SD	-	60	-	-
30	UT	-	-	-	-
31	VA	-	-	-	-
32	VT	-	-	-	-
33	WA	-	-	-	-
34	WI	0	0	-	0
35	WV	-	-	-	-
36	WY	-	-	-	-

- there is no information (no response)

+ Numbers in parantheses indicate the duration of classification counts in hours

The shortest classification count period was 3-4 hours at 28 locations in Idaho and the longest count period lasted seven days at five locations of Nevada. Two state DOTs collect classification data for 12 hours. They are Illinois with 100 stations and New Hampshire with 30 stations. Puerto Rico collects classification data for 12 hours at 20 stations. Four state DOTs (Iowa, Illinois, Oklahoma, and South Dakota) collect data for 24 hours. Illinois DOT operates 3,200 stations for this classification, and it is the only state DOT that has a considerable coverage of classification count stations on non-HPMS sections. South Dakota DOT maintains 60 stations, while Iowa and Oklahoma each has only 10 stations. Fifteen state DOTs collect classification data for 48 hours on non-HPMS sections. Seven out of 15 state DOTs collect this data at more than 100 locations. Michigan and North Carolina each collect at 250 locations, Arizona at 240 locations, Kansas at 200 sites, Colorado at 175 locations, Minnesota at 150 locations and Kentucky at 100 sites.

The classification count cycle for non-HPMS sections varies by state DOT. Two state DOTs (Arkansas and North Carolina) use a 12-month cycle, two state DOTs (Nebraska and Oklahoma) use a 24-month cycle, and ten state DOTs apply a 36-month cycle. The ten DOTs are Arizona, Louisiana, Montana, New Jersey, Nevada, Pennsylvania, South Dakota, Utah, Washington, and Wisconsin. Illinois DOT uses a 48-month cycle and Kentucky DOT utilizes a 72-month cycle. The cycle in Colorado DOT varies between 12 and 36 months, in Connecticut DOT between three and 36 months, in Kansas DOT between 36 and 72 months, in Michigan and Virginia DOTs between three to six years. Seven state DOTs did not specify the cycle as it is generally based on a special request, and seven state DOTs did not respond.

3.1.1.7 Sample Size and Location

Table 3.8 summarizes the sources used to determine the sample size and location of classification count stations. To determine the number of stations (sample size) for truck classification, 27 state DOTs use the FHWA Traffic Monitoring Guide (TMG). Thirteen out of the 27 DOTs use only TMG. Four of them (Connecticut, Kansas, West Virginia, and Wyoming) use the TMG in conjunction with other criteria that depend on the objective of the data collection, such as pavement management, truck traffic projection, special projects, etc. Ten state DOTs use AASHTO's Guidelines in addition to the TMG. Idaho DOT uses the TMG, AASHTO's Guidelines and the HPMS manual as sources to determine sample size.

Six state DOTs (Colorado, Michigan, Minnesota, Pennsylvania, Virginia, and Vermont) reported using sources other than the TMG and the Guidelines. Colorado DOT determines the sample size such that it is enough to cover its state highway system. Michigan DOT determines the sample size on "the state needs" basis. Minnesota DOTs determines the sample size based on "resources" available. Pennsylvania DOT determines the sample size according to the HMPS sample requirement, while Virginia DOT relies on the study of traffic data conducted by a third party (by contract). Vermont DOT has converted the entire coverage count program to classification, and the sample size is defined accordingly.

To determine the locations of truck classification stations, 27 state DOTs use the FHWA Traffic Monitoring Guide (TMG). Fifteen out of the 27 DOTs use only TMG. Four of them (Connecticut, Kansas, West Virginia, and Wyoming) use the TMG together with sources that depend on the objective of the data collection, such as "the state needs", specific projects, etc. Eight state DOTs use AASHTO's Guidelines in addition to the TMG. Idaho and Washington DOTs use the TMG, AASHTO's Guidelines and other sources such as "the state needs" (Washington) and the HPMS manual (Idaho).

Table 3.8 Sources to determine the sample size and location of classification stations

Sources	No. of State DOTs	State DOTs
1) To determine the sample size		
TMG *	13	AK CA KY LA MA MT NH NJ NV PR SC SD UT
TMG and Other	4	CT KS WV WY
TMG and AASHTO's Guidelines	9	AR AZ IL NC NE OK OR WA WI
TMG, AASHTO's Guidelines and Other	1	ID
Other	6	CO MI MN PA VA VT
No Response	3	HI IA IN
2) To determine the location where truck classifiactions are conducted		
TMG	15	AK AR CA KY LA MA MT NH NJ NV PR SC SD UT WI
TMG and Other	4	CT KS WV WY
TMG and AASHTO's Guidelines	6	IL NC NE OK OR VT
TMG, AASHTO's Guidelines and Other	2	WA ID
Other	7	AZ CO IA MI MN PA VA
No Response	2	HI IN

* TMG = Traffic Monitoring Guide published by FHWA

Seven state DOTs reported not using the TMG nor the AASHTO's Guidelines. Arizona DOT determines the data collection stations at intersecting routes since the boundary of roadway sections are generally established at intersections. This is to minimize the travel of the field crew, and allow more than one station to be counted concurrently by one field crew. Colorado DOT uses its own judgment to define the stations. Iowa DOT uses its own TMG. Michigan DOT selects the sites as needed by the state and the ability to set up counting machines at those sites. Minnesota DOT determines the sites according to the geographic coverage focusing on the truck highway system. Pennsylvania DOT decides the sites based on the HPMS sample distribution. Similar to the way the sample size is determined, Virginia DOT relies on the study on traffic data performed by the third party (contracted).

3.1.1.8 Truck Categories for Field Data Collection

In response to the question regarding how many truck categories are used to collect classification data, 31 state DOTs use the FHWA scheme F-13, see Table 3.9. Twenty six of the 31 state DOTs use only the FHWA scheme F-13 categories. Five state DOTs (Colorado, Illinois, Montana, North Carolina, and Oklahoma) also use additional truck categories along with the F-13 scheme. Colorado DOT regroups the F-13 categories into three categories. Vehicle types 1,2, and 3 of the F-13 categories are grouped as passenger vehicles, 4,5,6, and 7 as single unit trucks, and vehicle types 8 to 13 as combination trucks. Similarly, Illinois DOT uses three different categories where vehicles are grouped according to the length of vehicle. Passenger vehicles (PV) are those with 0-21 feet length, single units (SU) are between 22 and 40 feet, and vehicles longer than 40 feet are categorized as multi units (MU). Montana DOT groups trucks into small and large trucks. Oklahoma DOT adds vehicle type 15 for unclassified vehicles along with the F-13 scheme.

Table 3.9 Truck categories for data collection

Vehicle Classifications	No. of State DOT	State DOTs
FHWA Scheme (F-13 Categories)	26	AK AR AZ CA CR IA KS KY LA MA MI MN NE NH NJ PA PR SC SD UT VA VT WA WI WV WY
FHWA Scheme (F-13 Categories) and Others	5	CO IL MT NC OK
Others	3	ID NV OR
No Response	2	HI IN

In manual classification, North Carolina DOT uses four different categories. The first group is passenger vehicles and consists of vehicle types 1,2, and 3 of the F-13 categories. This is similar to the classification used by Colorado DOT. The second group is "duals" (vehicle types 4,5,6,7 of the F-13 categories). The third group is single trailer trucks composed of vehicle types 8,9, and 10, and the last group is equivalent to vehicle types of 11,12, and 13 of the F-13 scheme ("twins").

Three state DOTS (Nevada, Idaho, and Oregon) did not use the F-13 categories. Nevada DOT uses four categories: buses (2 and 3 axles), single units (light 2 axle, 2 axle, 3 axle, 4 axle), single trailers (3 axle, 4 axle, 5 axle, 6 axle and greater), and multi units (5 axle, 6 axle, 8 axle and greater). Idaho DOT's software could collect an "infinite" number of combinations of number of axles and axle spacings. In general as many as 20 vehicle types are defined according to the number of axles and axle spacings. Oregon DOT collects 19 vehicle categories based on the vehicle's axle configuration.

3.1.1.9 Data Collection On Congested Roadway Sections

In response to whether they used any specific equipment and/or procedures to collect truck classification data on congested roads, ten state DOTs and Puerto Rico DOT (see Table 3.10) said that they conduct manual classifications. The duration of classifications and the procedures to collect truck data on these sections varied among the DOTs. Kansas DOT, for example, collects data for 24 hours. Puerto Rico DOT collects truck data for 14 hours. Arizona DOT assigns a larger number of staff to classify truck traffic by direction. Minnesota DOT collects truck data manually if automatic classifiers with tubes cannot be installed on those sections. Idaho DOT conducts manual classification with the help of a specific procedure developed for a laptop computer and called "Genlog." This procedure allows users to log 20 types of vehicles during data collection and records the time of data collection for an individual vehicle including the color of the vehicle. North Carolina DOT uses manual classification and puts vehicles in 4 categories (passenger vehicles, "duals", single trailer trucks, and "twins"). These manual count categories are then disaggregated into the F-13 scheme using the ratios generated from automatic classifiers. Pennsylvania DOT uses weigh in motion procedures to collect data on congested sections along with manual counts.

Six state DOTs utilize automatic classifiers with more sensitive input sensors and several different sensor configurations to collect data on congested sections. California DOT uses piezoelectric sensors, and South Carolina DOT uses them along with loop detectors. New Jersey DOT collects truck data per lane with two tubes and loops between the tubes. Nevada DOT also uses an axle sensor – loop detector – axle sensor configuration. Oklahoma DOT utilizes electronic switches in each lane, and Virginia DOT uses a portable system of loops and tubes.

Table 3.10 Specific procedures/equipment to collect truck data on congested roadway sections

Procedures	No. of State DOT	State DOTs
Manual Classifiactions	11	AZ CO ID IL KS KY MN NC PA PR WA
Automatic classification with additional sensors	6	CA NJ NV OK SC VA
Vary by site	1	OR
No data collection	1	WY
No specific procedures	14	AK AR CT IA LA MA MI MT NE NH SD UT WI WV
No response	3	HI IN VT

One state DOT (Oregon) reported implementing specific procedures to collect truck data on congested sections, which vary depending on the speed of traffic stream and data collection site. However, the state claimed that they have no written procedures on how truck data is collected. One state DOT (Wyoming) reported not collecting truck data on congested sections.

3.1.1.10 Manual Classification Data

The DOTs were asked whether they performed manual truck classification counts to compute truck VMT. Seventeen state DOTs perform manual classification counts. The duration of the manual classification counts ranges from two to 48 hours, see Table 2.11. South Dakota DOT collects manual truck classification data for two-three hours. West Virginia DOT collects the data in different duration and times, such as three hours (7 to 10 a.m.), two hours (11 a.m. to 1 p.m.), and four hours (2 to 6 p.m.). Idaho DOT collects the data for four hours using the "Genlog" procedure. Arizona DOT collects the manual data for six hours if AADT of roadway sections is less than 6,000. New Jersey DOT conducts manual classifications for eight hours (10 a.m. to 6 p.m.) on 12 sites. North Carolina DOT collects the data for 16 hours from 6 a.m. to 2 p.m. (AM shift with 1/2 hour break), and from 2 p.m. to 10 p.m. (PM shift with 1/2 hour break). Typically the same field crew collects truck data on two different days. Four state DOTs collect truck data for 24 hours (Iowa, Kansas, Michigan, and Wyoming). Michigan DOT collects the data for 12-16 hours. Wyoming DOT performs the 24 hour classification counts in three shifts of eight hours. There is only one state (Nebraska) that collects the data manually for 32 hours, which is performed in four shifts of eight hours. Two state DOTs (Minnesota and Nevada) collect the manual data for 48 hours. Minnesota DOT also conducts 16-hour classifications along with the 48-hour classifications.

3.1.2 Truck Classification Equipment and Procedures

State DOTs were asked to identify the equipment and sensor technologies used to collect truck data, and to report their degree of satisfaction with the equipment. The DOTs were also asked to describe the main problems they have had with the devices and their solutions. The following sections discuss variables the DOTs use to classify vehicles followed by the equipment and sensor technologies used.

Table 3.11 Duration of data collection in manual classifications

Duration of manual classifiactions	No. of DOTs	State DOTs							
2-3 hours	1	SD							
4 hours	2	ID	MT						
6 hours	1	AZ							
8 hours	2	NJ	PA						
9 hours	1	WV							
12 hours	3	CA	IL	WA					
16 hours	2	KY	NC						
24 hours	4	IA	KS	MI	WY				
32 hours	1	NE							
48 hours	2	MN	NV						
No manual classifications	15	AK OR	AR PR	CO SC	CT UT	LA VA	MA VT	NH WI	OK
No response	2	HI	IN						

3.1.2.1 Variables Used for Classification

Variables used for automatic truck classification differ among the state DOTs. Table 3.12 shows the variables and their utilization by state DOTs responding to the survey. A great majority of the states DOTs, 32 out of 36 states, use the number of axles and axle spacing as the only variables or in conjunction with other variables. Eight DOTs (Arkansas, Arizona, Iowa, Idaho, Illinois, Utah, Vermont, and Washington) use the vehicle length along with axle spacing. Five DOTs (California, Minnesota, New Jersey, West Virginia, and Wyoming) use the vehicle weight in addition to axle spacing. Four state DOTs (Colorado, Kentucky, Montana, and Nevada) use all the three variables (axle spacing, vehicle length, and vehicle weight) in classification. None of the state DOTs use vehicle length alone as the classifying variable. Similarly, none of them use the combination of vehicle length and vehicle weight in classification.

Table 3.12 Classification variables used by state DOTs

Variables	No. of State DOTs	State DOTs							
Axle spacing	15	CT	KS	LA	MA	MI	NC	NE	NH
		OK	OR	PA	PR	SC	VA	WI	
Axle spacing and total length of vehicles	8	AR	AZ	IA	ID	IL	UT	VT	WA
Axle spacing and weight of vehicles	5	CA	MN	NJ	WV	WY			
Axle spacing, length and weight of vehicles	4	CO	KY	MT	NV				
Total length of vehicles	0								
Total length and weight of vehicles	0								
No response	4	AK	HI	IN	SD				

3.1.2.2 Sensor Technologies

Table 3.13 shows the sensor technologies used by state DOTs in portable and permanent classification devices. In portable devices, the pneumatic road tubes are the most popular (32 state DOTs) sensor technology used to collect short-term truck classification data. Some state DOTs reported using the tubes in conjunction with other types of sensors. For example, five state DOTs (Indiana, Minnesota, Nevada, Virginia, and Wisconsin) use both pneumatic road tubes and loop detectors. Montana DOT uses road tubes and piezoelectric sensors, and Wyoming DOT uses road tubes and fiber optic sensors. Moreover, four state DOTs (Colorado, Connecticut, Kentucky, and South Carolina) utilize road tubes, piezoelectric, and loop based sensors.

In permanent devices, as many as 24 state DOTs use loop detectors and piezoelectric sensors. Five of these (California, Nevada, Washington, Wisconsin, and West Virginia) also use bending plate sensors. Washington is the only state DOT that uses radar along with loops, piezoelectric, and bending plate sensors. Three state DOTs (Massachusetts, Montana, and New Jersey) use only piezoelectric sensors. One state DOTs (New Hampshire) uses this technology along with load cell sensors.

3.1.2.3 Classification Devices

Table 3.14 lists portable vehicle classification devices used by state DOTs. The products from two manufacturers, Peek Traffic and Diamond Traffic Products, dominate the market. The products of Peek Traffic (Peek ADR 1000/2000 and Peek 241) with a variety of sensor technologies are used by 16 state DOTs. Peek 241, for example, is used in Illinois, Massachusetts, Louisiana, South Carolina, Virginia, and Wisconsin. Peek ADR 1000 is used in Iowa, Kentucky, Louisiana, North Carolina, and Oklahoma DOTs. Peek ADR 2000 is used in Alaska, Kentucky, and Puerto Rico DOTs. Portable devices from Diamond Traffic Products (Unicorn and Phoenix) are used by 12 state DOTs. Unicorn with tube sensors, for instance, is used in Kansas and Washington DOTs. Phoenix with tube sensors is used in Michigan and Wyoming DOTs, and Phoenix with fiber optic sensors is used by Wyoming DOT.

Table 3.13 Sensor technologies used in portable and permanent classification devices

Sensor Technologies	No of State DOTs	State DOTs
Sensor Types for portable devices		
Road Tubes	18	AK AR AZ CA IA KS MA NC NE NH NJ OK OR PA SD VT WA WV
Road Tubes and Loops	6	ID MN NV VA WI UT
Road Tubes, Loops, and Piezoelectric	4	CO CT KY SC
Road Tube and Fiber Optic	2	MI WY
Road Tube and Piezoelectric	1	MT
Road Tube and Magnetic	1	IL
Loops and Piezoelectric	1	PR
No Response	3	HI IN LA
Sensor types for permanent devices		
Loops and Piezoelectric	19	AK AR CO CT IA ID IL KY MI NC NE OK PA PR SC UT VA VT WY
Loops, Piezoelectric, and Bending Plate	4	CA NV WI WV
Piezoelectric	3	MA MT NJ
Loops and WIM	1	AZ
Loops, Piezoelectric, Bending Plate, and Radar	1	WA
Piezoelectric and Load Cell	1	NH
Bending Plate	1	SD
WIM Scales	1	MN
No response	5	HI IN KS LA OR

Four state DOTs (Arkansas, Colorado, Michigan, and Virginia) use the products of International Traffic Corporation (ITC). Arkansas and Colorado DOT use ITC with tube sensors while Michigan DOT uses fiber optic sensors. Illinois DOT uses Peek 241 and Nu-Metrics Hi-Star NC-97, a magnetic imaging classification device. New Hampshire DOT uses GK 5000 with tube sensors, and Washington DOT uses GK 5000 and 6000.

Table 3.14 Portable classification devices used by state DOTs

No.	State DOTs	Classifiying Devices
1	AK	Peek ADR 2000 (Tubes)
2	AR	ITC Traffic A.C.E (Tubes), TC III (Tubes)
3	AZ	Golden River Archers (Tubes)
4	CA	Peek (Tubes), Diamond (Tubes)
5	CO	ITC (Tubes), Diamond (Tubes), Diamond (Loops, Piezoelectrics)
6	CT	(Loops, Piezoelectric, Tubes) *
7	HI	**
8	IA	Peek ADR 1000 (Tubes), TraffiCam 3 (Tubes)
9	ID	Diamond (Tubes), Diamond (Loops)
10	IL	Nu Metric Hi-Star NC-97 (Magnetic Imaging), Peek 241 (Tubes)
11	IN	**
12	KS	Diamond Unicorn (Tubes)
13	KY	Peek ADR (Tubes), ADR 1000 (Piezoelectrics), ADR 2000 (Loops)
14	LA	ADR 1000, Peek 241 *
15	MA	Peek 241 (Tubes)
16	MI	Peek (Tubes), Diamond/Phoenix (Tubes); ITC (Fiber Optic)
17	MN	TimeovK (Tubes), Timeovk (Loops)
18	MT	Diamond (Tubes), ECM (BL Piezoelectrics)
19	NC	Peek ADR 1000 (Tubes)
20	NE	Diamond (Tubes)
21	NH	GK 5000 (Tubes)
22	NJ	(Tubes) *
23	NV	Diamond (Tubes), PAT Equipment (Capacitance Mat/Loops)
24	OK	Peek ADR 1000 (Tubes), Mitron (Tubes, PET), Peek-Swtich (PET)
25	OR	Peek (Tubes), Diamond (Tubes)
26	PA	(Tube)*
27	PR	ADR 2000 (Loops), ADR 2000 (Piezoelectrics)
28	SC	Peek 241 (Loops, Piezoelectrics), Peek 241 (Tubes)
29	SD	Diamond (Tubes)
30	UT	ADR (Tubes); ADR (Loops)
31	VA	Peek 241 (Tubes), Peek ADR (Loops), ITC *
32	VT	Jamar Trax II (Tubes)
33	WA	GK 5000, 6000 (Tubes), Diamond/Unicorn (Tubes)
34	WI	Peek 241/ADR (Tubes), Peek 241/ADR (Tubes/Loops)
35	WV	(Tubes) *
36	WY	WIM (Capacitive mat), Diamond 2001 (Tubes), Diamond Phoneix (Tubes), Diamond 2001/ Phoeni

* No Information available on either classification devices or sensor types

** No response

Permanent classification devices manufactured by Peek Traffic and Diamond Traffic Products are used by a considerable number of state DOTs, see Table 3.15. Fourteen state DOTs use the Peek ADR family, and 9 state DOTs use Diamond Traffic Products. Peek ADR 1000 with loop detectors is used in Kentucky. Peek ADR 2000 with a variety of loops and piezoelectric sensors is used in many states such as Alaska, Iowa, Kentucky, and South Carolina. Peek ADR 3000 with loops and piezoelectric sensors is used in North Carolina and Puerto Rico. In addition to using Peek 241 with loop and piezoelectric sensors, Wisconsin DOT uses Peek ADR 4000 and this is the only state which reported using the most advanced device of the Peek ADR family. Other Peek products are used by state DOTs, such as Peek TC III with loop-piezoelectric-loop combination (Arkansas), and Peek 241 (Illinois and Oklahoma).

Table 3.15 Permanent classification devices used by state DOTs

No	State DOTs	Classifying Devices
1	AK	Peek ADR 2000 (Loop-Piezoelectric-Loop)
2	AR	Peek ADR (Piezoelectric-Loop-Piezoelectric), Peek TC III (Loop-Piezoelectric-Loop), ITC RakTel (Piezoelectric-Loop-Piezoelectric)
3	AZ	IRD ICC 530 (Loops), IRD WIM *
4	CA	Peek (Piezoelectrics-Loops), Diamond (Piezoelectrics-Loops), PAT (Bending Plate-Loops), IRD (Bending Plate-Loops)
5	CO	Diamond (2 Loops), Diamnod (2 Loops and Piezoelectric), ECM WIM (1 Loop and 2 Piezoelectrics), IRD WIM (1 Loop and 2 Piezoelctrics)
6	CT	Vibracoax Encapsulated Sensors (Piezoelectric), Vibracoax Uneancapsulated Sensors (Piezoelectric)
7	HI	**
8	IA	Peek ADR 2000 (Loops and/or Piezoelectric), TraffiCam 3 (Loops and/or Piezoelectric)
9	ID	Diamond (2 Loops), Hestia WIM (2 Piezoelectric and Loop)
10	IL	Peek ADR (Loop-Piezoelectrics), Peek 241 (Loop-Piezoelectric), RakTel (Loop-Piezoelectric)
11	IN	**
12	KS	**
13	KY	Peek ADR 1000 (Loops), Peek ADR 2000 (Piezoelectrics)
14	LA	**
15	MA	IRD WIM (Piezoelectric), ECM WIM
16	MI	Diamond (Piezoelectrics), PAT (Piezeoelectrics and Bending Plates)
17	MN	IRD WIM (Wim Scales)
18	MT	Diamond (Piezoelectric), ECM (Piezoelectric)
19	NC	Peek ADR 3000 WIM (Loops and Piezoelectrics)
20	NE	Diamond Unicorn (Loops and Piezoelectrics), Diamond Phoenix (Loops and Piezoelectrics)
21	NH	WIM (Piezoelectrics) , WIM (Load Cells) *
22	NJ	IRD TCK 540 (Piezoelectric), IRD TCK 500 (Dynox), IRD WIM (Piezoelectric)
23	NV	Diamond (Piezoelectrics-Loops), PAT (Bending Pate-Loop-Piezoelectrics), PAT (Piezoelectrics-Loops), ECM (Piezoelectric-Loops)
24	OK	Peek ADR (Piezoelectrics or Loops), Peek 241 (Piezoelectrics or Loops), IRD 1060 (Piezoelectrics or Loop)
25	OR	**
26	PA	(Loop/Piezoelectrics) *
27	PR	ADR 3000 (Loops or Piezoelectrics)
28	SC	Peek 2000 (Loops and Piezoelectric)
29	SD	PAT (Bending Plate)
30	UT	Peek ADR (Loops), Peek ADR (Piezoelectrics)
31	VA	Peek ADR (Piezoelectrics), IRD WIM (Piezeoelctrics or Loops)
32	VT	IRD (Piezoelectrics or Loops)
33	WA	IRD WIM (Bending Plates-Piezoelectrics), Diamond Phoenix (Piezoelectrics), Golden River (Loops), EIS/RTMS (Radar)
34	WI	Peek ADR/241 (Loop-Piezoelectrics), Peek ADR 4000 (Loop IDRIS), PAT DAW 200 (Loops-Bending Plate)
35	WV	PAT WIM (Bending Plate-Loop), PAT (Piezoelectrics-Loops), Peek (Piezoelectrics-Loops), ECM (Piezoelectrics-Loops)
36	WY	WIM (Piezo Electric) *, Diamond Phoenix (Loop-Piezoelectric-Loop)

* No information available on either the classifycing devices or the sensor types

** No response

Diamond Traffic Products are used by state DOTs with a variety of sensors. Two state DOTs (Colorado and Idaho) use the Diamond with 2-loop sensors. Three state DOTS (Michigan, Montana, and Washington) use it with piezoelectric sensors, and four state DOTs (California, Nebraska, Nevada, and Wyoming) use it with a combination of piezoelectric and loop sensors.

Ten state DOTs use the International Road Dynamic (IRD) products with various sensor types and configurations. Arizona DOT uses the IRD TCC 530. New Jersey DOT uses the IRD TCC 540 fitted with piezoelectric sensors and the IRD TCC 500 fitted with Dynax sensors. Oklahoma DOT uses IRD 1060 fitted with various configurations of piezoelectric and loop sensors. California DOT uses the IRD product with bending plates and loop sensors. The IRD product with Weigh-in-Motion (WIM) classification systems is used in 8 state DOTs (Arizona, Massachusetts, New Jersey, Minnesota, Washington, Colorado, Virginia, and Vermont). Massachusetts and New Jersey DOTs use it with piezoelectric sensors. Washington DOT uses it with bending plates and piezoelectric sensors. Colorado, Virginia and Vermont DOTs use it with loops and piezoelectric sensors.

Six state DOTs use the PAT systems of the PAT Traffic Control Corporation. California, Wisconsin and West Virginia DOTs use the systems with bending plates and loop sensors. Michigan DOT uses the PAT systems with bending plates and piezoelectric sensors, and Nevada DOT with loops and piezoelectric sensors and a combination of loop, piezoelectric, and bending plates.

Only two states (Illinois and Arkansas) use the ITC (International Traffic Corporation) RakTel with piezoelectric and loop sensors. Other products are also used by state DOTs, such as Hestia WIM of Electronic Control Measure (Idaho, Colorado, Massachusetts, Montana, Nevada, and West Virginia) and TraffiCam 3 of Rockwell International (Iowa).

3.1.2.4 Degree of Satisfaction with Sensors

State DOTs were asked to report the degree of satisfaction on several sensor technologies commonly used in vehicle classification. Table 3.16 shows the degree of satisfaction reported by state DOTs. The choices for the degree of satisfaction were "Very Unsatisfied", "Somewhat Unsatisfied", "Somewhat Satisfied", and "Very Satisfied". The last column of the table shows the average score weighted by the number of state DOTs responding to the survey. The pneumatic road tubes were rated "Somewhat Unsatisfied" by seven DOTs, "Somewhat Satisfied" by 14 DOTs, and "Very Satisfied" by 11 DOTs. As a result, the average degree of satisfaction of this technology is (7x2+14x3+11x4) / (6+14+11)=3.13. Similarly, the average degree of satisfaction for each sensor technology was calculated.

Table 3.16 Satisfaction level of state DOTs on various input sensors and equipment technology

No	Sensor/Equipment Technology	No. of DOTs	Very Unsatisfied (score=1)	Somewhat Unsatisfied (score=2)	Somewhat Satisfied (score=3)	Very Satisfied (score=4)	Average Score
1	Road Tube	32	-	7	14	11	3.13
2	Magnetic Imaging	1	-	-	-	1	4.00
3	Electrical Contact Closure	4	-	2	-	2	3.00
4	Loop Detector Only	11	1	-	7	3	3.09
5	Loop Detector plus Axle Sensors	22	-	1	11	10	3.41
6	Video Image	1	-	-	1	-	3.00
7	Photoelectric Sensor	0	-	-	-	-	-
8	Fiber Optic	2	1	1	-	-	1.50
9	Laser/Lider	0	-	-	-	-	-
10	Acoustic	1	-	-	-	1	4.00
11	Microwave	2	-	1	1	-	2.50
12	Infrared	0	-	-	-	-	-
13	Ultrasonic	0	-	-	-	-	-
14	Radio Wave	0	-	-	-	-	-
15	WIM Device	29	1	3	11	14	3.31

The degree of satisfaction for magnetic imaging and acoustic sensor technologies is the highest (4.0). But there is only one state using the magnetic imaging technology and one state using acoustic technology. The degree of satisfaction for the loop detector plus axle sensors is the second highest (3.41), followed by the WIM device (3.31), the pneumatic road tube (3.13), loop detector only (3.09), video image and electrical contact closure (3.0), microwave (2.50), and fiber optic (1.50) sensors.

3.1.2.5 Problems with Sensors and Suggested Solutions

The following sections discuss the main problems that state DOTs have had with the equipment/technology, and solutions they have suggested to overcome the problems.

Pneumatic tubes

Problems were reported when a portable classification device with pneumatic tubes was used to collect data under heavy traffic conditions. The problems are related to installation, level of accuracy, and the durability of the tubes. The tube system is not reliable on Freeways or Interstates due to the time consuming and potentially unsafe condition during installation of the system. State DOTs reported that the tubes are very vulnerable to human errors at the time of installation. This may cause a high rate of unclassified vehicles. Moreover, the tubes cannot stay down on the pavement for a long time and they tend to stretch, thus affecting the accuracy of classification.

Many state DOTs reported that the pneumatic tube system has a precision problem, specifically on congested roads. This accuracy problem is due to several reasons, such as the occasional double counting due to traffic backups, closely following passenger cars that are misclassified as class 8 (4 or less axle single trailer) trucks. One state DOTs claims that the tubes are appropriate for counting trucks but not accurate for classifying them. Two state DOTs reported that the tubes work satisfactorily on rural two-lane highways with low traffic volume (Arizona DOT reported for AADT less than 5,000). Similarly, one state DOT reported that the tubes on two-lane highways with one lane being counted provide good accuracy. The tubes work well except when they are stretched across more than one lane with high volume traffic. The tubes cannot work well at permanent count sites because they cannot stay long enough to derive meaningful traffic data. To overcome the problems, many states indicated that they conduct manual classification counts to obtain classification data on congested highways.

Loop detectors

Using loop detectors alone in congested traffic conditions frequently overestimates the number of trucks because passenger cars with light trailers are counted as single unit trucks. They can appropriately classify large truck but misclassify small trucks. The installation of this sensor is considered to be labor intensive. One state DOT reported that this technology has a telemetry problem along with high failure rates for installation. When this sensor was combined with an axle sensor, one state DOT reported that the combination system had a short life span and labor intensive installation.

Piezoelectric

This sensor technology is relatively new and requires extensive oversight during installation since many electrical contractors are still not familiar with piezoelectric sensor. Moreover it requires extensive maintenance once it is installed. During operation, it is very sensitive to temperature, so any significant change in temperature results in calibration changes. Similar to loop detector, this sensor technology also has telemetry problem along with high failure rates for installation.

Fiber optic

This sensor technology is also relatively new, and currently its implementation is in experimental stage and of limited use. Four state DOTs including Oregon, Michigan, Wisconsin, and Wyoming have implemented fiber optic sensors and they experienced installation problems. Oregon DOT reported that the sensor system came apart after three weeks due to inferior installation. For Wisconsin DOT, the optic sensor is in a test stage with the first installation location and the installation method questionable. At this time, Wisconsin DOT reviews options for the installation.

WIM classification systems

One state DOT reported that this technology misses a certain vehicle class, and the algorithm irregularities embedded in the system results in many unclassified vehicles or auto/motorcycle miss-classification. One state DOT claimed that sensors to be used with portable WIM systems were expensive and its installation was labor intensive. Moreover, for the permanent WIM devices with piezoelectric sensors, high temperature causes serious accuracy problems.

Video image

Video image technology has been used in New Jersey and Nevada DOTs where it was only capable of classifying vehicles based on their lengths. Occlusions by intervening vehicles and problems with shadows were reported.

3.1.2.6 Remedies for Sensor Problems

These are some suggested solutions by state DOTs. For a congested section, use visual based classification at location where conventional sensors, such as road tubes and loop detectors, are impractical. Alternatively, perform a manual classification count to provide at least some measure of truck volume on such sections. One state DOT also suggested that for a heavy traffic condition, where tubes cannot provide good classification, more loops should be installed.

For misclassification using tubes, one should try to change the tube type, length and spacing for various conditions. Alternatively, one can put additional counters, block the roads/lanes on which tubes are located, and in some cases, use portable loops. WIM (portable loops and piezoelectric strips) can also be used for 24 hours at the location where pneumatic tubes fail to operate (high unclassified rate).

3.1.3 Adjustment Factors for Traffic Volume

A variety of procedures to adjust truck data collected from short-term classification counts are reported. Some state DOTs do not collect truck data for less than 24 hours, so they do not need to expand the data into daily truck data. Table 3.17 shows the types of traffic volume adjustment factors and their utilization by state DOTs.

Table 3.17 Adjustment factors and their utilization by state DOTs

Type of Adjustment Factor	Cars versus Trucks	No. of DOTs	State DOTs
Short Term Expansion Factors	The same factor for trucks and cars	1	WV
	Different factor for trucks and cars	7	CA IA IL MN NE OR PA
Day-of-week Adjustment Factors		11	AZ CA MN NE PA PR UT VA VT WV WY
Seasonal Adjustment Factors	The same factor for trucks and cars	11	AR AZ CA ID MT NJ PR VA VT WA WV
	Different factor for trucks and cars	8	IA IL MI MN NE PA UT WY

To convert truck data collected from less than 24-hour counts, West Virginia DOT uses the expansion (time-of-day) factors that are derived from 24-hour volume counts. In other words, truck data is expanded using factors that are similar to the factors for expanding total traffic data. To obtain annual average daily truck traffic (AADTT), roadway sections are first grouped according to their functional class and area type. Six roadway groups are defined; three groups are for rural, two groups are for urban roadways, and one group is for recreational roadway. The three rural roadway groups consist of rural principal arterial and rural interstate with AADT larger than 20,000, urban principal arterial and rural interstate with AADT less than 20,000, and other rural roadways. The two urban roadway groups comprises urban principal arterial and interstate, and other urban roadways such as urban principal arterial, expressways or freeways, minor arterial, and collector. The day-of-week and seasonal variation factors are derived for each group. Thus, there are (6 group x 7 days) = 42 day-of-week factors and (6 groups x 12 months) = 72 seasonal adjustment factors.

Seven DOTs (excluding West Virginia) use different time-of-day expansion factors for trucks and cars. These state DOTs are California, Iowa, Illinois, Minnesota, Nebraska, Oregon, and Pennsylvania. Ten state DOTs and Puerto Rico DOT use the day-of-week factors to convert daily traffic volumes to monthly data. These state DOTs are Arizona, California, Minnesota, Nebraska, Pennsylvania, Utah, Virginia, Vermont, West Virginia, and Wyoming. Seasonal adjustment factors to adjust the monthly data to yearly data are used by 19 state DOTs. Eleven of these state DOTs apply the same adjustment factor for cars and trucks, and eight of them implement different seasonal factors for cars and trucks (Illinois, Iowa, Michigan, Minnesota, Nebraska, Pennsylvania, Utah, and Wyoming). Arkansas DOT uses combined adjustment factors (monthly and day-of-week) based on total volume.

There are only five of the responding state DOTs that use all three adjustment factors (expansion, day-of-week, and seasonal factors). These DOTs are California, Minnesota, Nebraska, Pennsylvania, and West Virginia. Moreover, only three of them (Minnesota, Nebraska and Pennsylvania) have implemented different adjustment factors for cars and trucks. They developed these adjustment factors from truck data collected at continuous classification stations.

Some of the state DOTs provided detailed information about their procedures. These are summarized below. Virginia DOT does not collect less than 24-hour vehicle classification data. Therefore, the expansion factors are not applied. For 24-hour and 48-hour classification counts, Virginia DOT uses the day-of-week and seasonal variation factors to obtain AADTT. These factors are road specific and developed based on continuous classification counts on all major roads in the state. A short classification count taken on a specific road is adjusted using factors taken from the nearest continuous classification counts on that road. A factor computed for a specific road is not applicable to any other road. On its national highway system, one continuous classification count is associated with adjacent short-term counts, while on other systems a group of continuous counts is used to develop factors. In addition, Virginia DOT uses combined monthly and weekly factors. In total, this DOT uses a total of 84 factors (12 month x 7 days). The procedure requires a large number of continuous classification counts but provides considerable insight into the pattern of truck movement within the state.

Unlike Virginia DOT that uses specific road factors, Iowa and Pennsylvania DOTs use group adjustment factors. Iowa DOT uses two types of truck adjustment factors: the expansion factors ("vehicle classification type percentage") and the seasonal variation factors ("monthly truck factor"). These adjustment factors are developed for different groups of roadway sections that are clustered according to their functional classification, area type, and other criteria (park, municipality, etc). Eight groups are defined: rural interstate, municipal interstate, rural primary, municipal primary, secondary, state parks, municipal streets, and other routes. In addition, the factors are developed for two different types of trucks: single-unit and multi-unit trucks. For a specific type of truck and for a specific month when truck data are collected, there are seven different truck factors, each for a different day.

Pennsylvania DOT uses a group of continuous classification counts to develop adjustment factors and clusters its roadway sections into ten different traffic pattern groups (TPG). Individual classification counts are categorized into one of ten TPG. This grouping is based on highway functional classification, geographic area, and urban/rural characteristics. Thus, for example, TPG 1 is urban interstate, TPG 2 is rural interstate, TPG 3 is urban other principal arterials, etc. Using the hourly percentage factors (expansion factors) developed for each TPG, traffic data that are collected for less than 24 hours (automatic or manual) are first expanded to a 24-hour volume. Different expansion factors are used for trucks and total vehicles. The 24-hour data is then processed to annual daily truck traffic through the application of a "day of week by month" factor, combining day-of-week and seasonal variation factors. Similar to the expansion factor, this factor is developed for each TPG and is different for trucks and total vehicles. The expansion factors are developed using traffic data that are collected statewide from 1,400 automatic classification counts. The "day of week by month" factor is developed based on continuous truck data obtained from the Pennsylvania Turnpike Commission toll collection facilities. Delaware River toll bridges and SHRP locations that collects continuous classification data are being evaluated and may be used for developing future truck adjustment factors.

Minnesota DOT converts the counts that are less than 24 hours into daily volumes using different expansion factors for trucks and cars. The expansion factors are developed from traffic data that are collected at WIM sites. Day-of-week and seasonal adjustment factors are then applied to obtain AADTT. Similar to the expansion factors, the seasonal adjustment factors are also different for trucks and cars.

All of the adjustment factors (expansion, day-of-week, and seasonal variation) used by Nebraska DOT are developed from traffic data that are collected from continuous classification counts. These factors are applied to convert short-term classification data to AADTT.

Wyoming DOT calculates day-of-week and seasonal variation factors that are derived from traffic data collected from continuous volume and classification counts.

California DOT develop truck factors from truck counts that are made throughout the state on a program of continuous truck count sampling. The sampling includes a partial day, 24-hour, 7-day and continuous classification counts. The partial day and 24-hour counts are usually made on high volume, urban highways. The 7-day counts are on low volume, rural highways. The counts are usually taken only once on the year. About one-sixth of the locations are counted annually. Fifty locations were monitored continuously using Weigh-in-Motion equipment. The resulting counts are adjusted to estimate annual AADTT by compensating for seasonal influence and weekly variation.

3.1.4 Truck VMT Calculation

Two different methods for truck VMT calculation have been used by state DOTs. The first method calculates truck VMT on a highway segment by multiplying truck ADT by the length of roadway section. This method requires truck data on the highway segment. Truck traffic on a roadway segment is usually represented as a percentage of the total ADT. As shown in Table 3.18, 10 state DOTs (California, Iowa, Kansas, Kentucky, Michigan, Montana, Nebraska, Pennsylvania, Virginia, and Wyoming) use this method. California DOT calculates truck VMT based on 3,800 truck counting locations on its state highway system. Truck traffic on a highway segment between two consecutive mile post locations is calculated by averaging the estimated truck traffic at the two mile post locations, and then multiplying the average by the distance between the two points. Nebraska DOT calculates truck VMT on a biennial basis, during the years when traffic counts are conducted on its state highway system. Truck VMT on the highway system is calculated from the state's "traffic log files", and truck VMT off the highway system is estimated from sample manual counting data.

Table 3.18 Truck VMT calculation by states DOTs

Truck VMT Calculation Methods	No. of DOTs	State DOTs
Method (1): Truck ADT Times Roadway Section Length	10	CA IA KS KY MI MT NE PA VA WY
Method (2): Average Truck Percentage Times Total Vehicle Mile Traveled (HPMS)	9	CT IL MN NJ NV OK SD VT WV
Both Methods (1) and (2)	2	AZ CO
Method (1) and Non-Traffic Data Procedures	1	ID
Method (2) and Non-Traffic Data Procedures	1	WI
Both Methods (1), (2), and Non-Traffic Data Procedures	1	OR
Do not Calculate Truck VMT	8	AK LA MA NC NH PR SC WA
No Response	4	AR HI IN UT

The second method calculates truck VMT by multiplying total VMT (by functional class) by the average truck percentages (by truck types). This is the HPMS method developed by the FHWA for estimating truck VMT. This method requires state DOTs to calculate the total VMT and the statewide average truck percentage for a specific roadway group (by functional class and vehicle types). The total VMT is obtained from the HPMS database that records AADT for HPMS highway segments. This HPMS database is updated annually through the state DOTs' traffic monitoring program. The average truck percentages by roadway functional class and vehicle types are obtained from truck data collected at permanent classification sites. Eight state DOTs (Connecticut, Minnesota, New Jersey, Nevada, Oklahoma, South Dakota, Vermont, and West Virginia) use this method.

Two state DOTs (Arizona and Colorado) use the two methods simultaneously. These state DOTs implement the first method (by highway segment) for their State Highway System. The second method (HPMS) is implemented for all public roads or areawide HPMS sections, not just the State Highway System. To calculate truck VMT, Arizona DOT uses two truck types: single and multi-unit trucks, while Colorado DOT uses single units and combinations.

In addition to using traffic data, other sources are used for calculating truck VMT. Traffic count based methods are used when there are enough resources to collect traffic data. For state highway systems, state DOTs generally rely on this method since the resources are available and the standards for conducting traffic counts are also available. However, some states are lacking the necessary resources to adequately sample ADTs on the local road systems.

Idaho DOT calculates a statewide truck VMT based on fuel consumption data and calculates truck VMT for the State Highway System based on the first method (truck ADT times roadway section length). Two state DOTs (Oregon and Wisconsin) estimate the statewide VMT based on the fuel consumption data. Using the second method (HPMS), these DOTs use the statewide VMT to calculate truck VMT. Oregon DOT also calculates truck VMT for the state highway system according to the first method.

Seven state DOTs (Alaska, Louisiana, Massachusetts, North Carolina, New Hampshire, South Carolina, and Washington) and Puerto Rico DOT reported that they did not calculate truck VMT.

3.2 Survey Results: MPOs

The results of the survey of MPOs are summarized in Table 3.19. Eleven out of the 29 MPOs who returned the survey neither collect truck classification data nor calculate it. Seven MPOs use the truck VMT data computed by other agencies. Four MPOs calculate truck VMT although they do not collect the data. Only seven MPOs collect truck classification data and three of the seven also calculate truck VMT.

The MPOs that collect truck data use either contractor or MPO staff to do the data collection. The staff in three MPOs do almost of all of the data collection. These MPOs are Delaware Valley Regional Planning Commission (Delaware), SRPEDD (Massachusetts), and Metropolitan Washington Council of Governments (Washington D.C.). Almost all of the data collection in two MPOs is contracted out. These MPOs are DRCOG (Denver Regional Council of Governments (Colorado) and Maricopa Association of Governments (Arizona). One MPO (Southeast Michigan Council of Governments) uses contractors, consultants, and staff of local government to collect the truck data. One other MPO (Metroplan of

Arkansas) uses consultant staff to collect truck classification data, and this is only when the MPO conducts an areawide travel study.

Table 3.19 Truck data collection and used by MPOs

No.	Categories	No. of MPOs	Names of MPOs
1)	Only use truck VMT data calculated by other agencies	7	Association of Central Oklahoma Governments, OK North Central Texas Council of Governments, TX Hillsborough County Metropolitan Planning Organization, FL South Central Regional Council of Governments, CT Wilmapco, DE Regional Transportation Commission of Southern Nevada, NV Greenville County Planning Commission, SC
2)	Collect truck data but do not calculate truck VMT	4	Delaware Valley Regional Planning Commission, PA Metroplan, AR Maricopa Association of Governments, AZ SRPEDD, MA
3)	Collect truck data and calculate truck VMT, but do not use truck VMT data from other agencies	3	Southeast Michigan Council of Governments, MI DRCOG (Denver Regional Council of Governments), CO Metropolitan Washington Council of Governments, DC
4)	Do not collect truck data but calculate truck VMTand use/obtain truck VMT from other agencies	2	Chicago Area Transportation Study, IL Baltimore Metropolitan Council, MD
5)	Do not collect truck data but calculate truck VMT, and do not use truck VMT from other agencies	2	Metro, Transportation Department, OR Ohio-Kentucky-Indiana (OKI) Regional Council of Governments, OH
6)	Do not collect truck data nor calculate/use truck VMT	11	Berkeley-Charleston-Dorchester Council of Governments, SC PSRC, WA Miami - Dade MPO, FL MAPA, NE South Jersey Transportation Planning Organization, NJ KIPDA (Kentuckiana Regional Planning and Development Agency), KY INCOG, OK Hampton Road Planning District Commission, VA Oahu Metropolitan Planning Organization, HI Metropolitan Development Division of Planning, IN South California Association of Governments, CA

3.2.1 MPOs That Collect Truck Data and Calculate Truck VMT

3.2.1.1 Denver Regional Council of Governments (Colorado)

This MPO collects truck classification data using contractor staff that performs almost all of the data collection. The 13 FHWA categories are used. The data collection is performed for 24 hours or less at seven stations on interstate, 38 on arterial, 12 on collector. Forty-eight of the stations are located in metropolitan area randomly selected and only nine stations are outside the metropolitan area. Classification data at five out of nine stations on external sites are manually collected. All of the stations are part of the 8-county travel behavior inventory. No permanent classification stations are maintained. Truck VMT is calculated by first adjusting the truck data using the truck seasonal factors provided by the Colorado DOT. These adjustment factors are the same for trucks and passenger cars.

To calculate truck VMT, this MPO uses two different methods: traffic count data and the commercial vehicle travel survey data. Using traffic count data, truck VMT is calculated as the product of the 24-hour traffic volume and the segment length. The calculations are made separately for each vehicle type and for the total vehicles at each location of data collections. The results are sample truck VMT, and are expanded using the ratio of the lane-miles of the roadway segment universe to the lane-miles of the sample.

3.2.1.2 Metropolitan Washington Council of Governments (D.C.).

This MPO collects truck data not on a regular basis. The data collection is made when a travel demand study is conducted. During the study, MPO staff carries out almost all of the data collection. The number of axles is used for vehicle classifications. Three truck categories are defined: single unit trucks (2 A GT, 3 axles, 4-plus axle), tractor with or without trailers (3 axles, 4 axles, 5 axles, and 6-plus axles), and double trailers. Truck VMT is calculated as a part of the regional 4-step travel demand forecasting procedures.

3.2.1.3 Southeast Michigan Council of Governments (Michigan)

Contractor, consultant, and local governments collect truck classification data for this MPO. For classification, this MPO uses the number of axles and axle spacing. Both the FHWA's TMG and AASHTO's guidelines are used to determine the sample sizes. To collect truck classification, this MPO uses classifiers with three different types of sensors: road tubes, loops, and loops-axle sensors. This MPO calculates truck VMT and does not use truck VMT data from any other agencies. To calculate truck VMT, this MPO also uses additional sources such as Truck Inventory and Use Survey (TIUS) and National Truck Activity and Commodity Survey (NTACS).

3.2.2 MPOs That Collect Truck Data But Do Not Calculate Truck VMT

3.2.2.1 Metroplan (Arkansas)

This MPO collected truck classification data during the Areawide Travel Study in 1993. A consultant collected the truck data. Four classification stations were located on interstate and 14 on arterials. These were all short term (24 hour or less) data collection sessions. All stations were external ones in the travel demand model network. Vehicles were classified based on the weight of vehicles and the number of axles. Vehicles were placed in 10 categories (one for motorcycles, one for passenger cars, and the rest for trucks). The data collection was carried out manually on typical weekdays between the hours of 7:00 a.m. to 7:00 p.m. At the same stations, 24-hour automatic classifications were also conducted. This MPO does not calculate nor use truck VMT.

3.2.2.2 Maricopa Association of Governments (Arizona)

This MPO collects truck classification using contractor staff that performs almost all of the data collection. This MPO does not calculate nor use truck VMT.

3.2.2.3 SRPEDD (Massachusetts)

MPO staff collects almost all of the truck classification data for this MPO. For classification, the number of axles and axle spacing are used. There are 15 short-term classifications (24-hour or less) using automatic classifiers (JAMAR fitted with road tube sensors) distributed over arterials (5 stations), collectors (5 stations), and local roads (5 stations). The number and locations of count stations are determined as needed depending on the specific study undertaken by the MPO.

3.2.2.4 Delaware Valley Regional Planning Commission (Pennsylvania)

The MPO staff collects almost all of the truck classification data. All data collection are conducted for 48 hours at 10 stations (interstate), 15 stations (arterials), and 5 stations (local roads). In addition, the MPO also collects classification data for 12 hours at 30 stations. No permanent stations are maintained. The MPO uses the number of axles and axle spacing for vehicle classifications. The MPO uses the F-13 vehicle category of FHWA. For manual counts, the MPO uses 16 categories (Pennsylvania DOT), and 15 categories (New Jersey DOT).

3.2.3 MPOs That Do Not Collect Truck Data But Calculate Truck VMT

3.2.3.1 Chicago Area Transportation Study (Illinois)

This MPO obtains truck data from Illinois DOT and vehicle registration data from Secretary of State. In addition, the MPO carries out commercial vehicle surveys. The MPO calculates truck VMT using a regional travel simulation model, and also obtains truck VMT data from Illinois DOT.

3.2.3.2 Baltimore Metropolitan Council (Maryland)

This MPO obtains truck classification data from the State Highway Administration (SHA). Truck VMT is calculated based on truck count data from SHA for light and heavy trucks. The truck VMT for each truck type is then broken down using gas and diesel powered trucks. To calculate truck ADT, expansion and seasonal adjustment factors derived from SHA are used. Additional information used for truck VMT estimates are the state fuel tax report and weigh station data. In addition, this MPO uses truck VMT data computed by SHA.

3.2.3.3 Ohio-Kentucky-Indiana (OKI) Regional Council of Governments

This MPO obtains truck data from the Ohio DOT and calculates truck VMT per highway segment. Truck VMT of each segment is calculated as the product of ADT, truck percentage, and the length of the segment. Truck count data is the only source for truck VMT estimation used by this MPO.

3.2.3.4 Metro, Transportation Department (Oregon)

The major source of truck count data is Oregon DOT and the port of Portland. Truck VMT is calculated using simulation model. An additional source used for truck VMT estimation is the Truck Inventory and Use Survey (TIUS).

3.2.4 MPOs That Only Use Truck VMT Data From Other Agencies

Seven MPOs do not collect classification data on a regular basis (see Table 3.19). Such data is normally obtained from state DOTs. Greenville County Planning Commission (South Carolina), for example, reported that Planning Commission staff normally collects truck data, but only when a study on travel behavior is conducted. North Central Texas Council of Governments reported using truck VMT estimate available at the county level from HPMS. The association of Central Oklahoma Government uses truck VMT data supplied by Oklahoma DOT. Hillsborough County Metropolitan Planning Organizations uses truck VMT calculated by Florida DOT. South Central Regional Council of Governments uses truck VMT data calculated by Connecticut DOT, Wilmapco by Delaware DOT, Regional Transportation Commission of Southern Nevada by Nevada DOT, and Greenville County Planning Commission by South Carolina DOT.

3.2.5 MPOs That Neither Collect Truck Data Nor Calculate/Use Truck VMT

Some MPOs reported that they do not regularly collect nor use truck VMT data. The Southern California Association of Governments (SCAG), for example, does not collect truck traffic data, but is planning on collecting truck ADT and

VMT data in the future. SCAG reported on planning to hire a consultant to work on the data collection in the future. Miami-Dade MPO (Florida) use truck VMT data from Florida DOT (District 6, Miami) and from the Central Office (Tallahassee), but only on a limited ad-hoc basis.

3.3 Survey Results: Classification Equipment Vendors

A survey on classification equipment was sent to 29 equipment vendors. The surveys asked what classification equipment they manufactured, the cost of one unit installed, the number of state DOTs that have used the products, and the number of units sold in the past 5 years. Six equipment vendors returned the survey, they are International Road Dynamics, Transport Data Systems, Scientific Technologies, Inc., Measurement Specialties, Inc., Computer Recognition Systems, and Smartek Systems. The following are detailed responses from the vendors.

3.3.1 International Road Dynamics

International Road Dynamics (IRD) produces IRD TC/C 540 classifiers. This classifier can collect classification data for portable (short-term) and permanent data collection sessions. Six state DOTs (New Jersey, Hawaii, Arizona, Texas, Indiana, and Michigan) reported using this equipment at permanent classification sites. The cost of a fully functioning permanent system is $30,000 to $35,000, and for a portable system is $20,000 to $25,000. Approximately 30 units of this equipment for permanent operations have been sold in the USA in the past 5 years.

3.3.2 Transport Data Systems

Transport Data Systems manufactures Doppler Radar Based Automatic Vehicle Classifiers. This equipment is only for permanent data collection, and costs about $ 20,000 per installed lane. New Jersey Turnpike and Garden State Parkway uses this equipment. The number of units soled in the past 5 years is 550.

3.3.3 Scientific Technologies, Inc

Scientific Technologies, Inc. does not manufacture vehicle classifiers. Equipment manufactured by this company, however, is used in several electronic toll collection systems as part of the vehicle classifiers. This company manufactures a vehicle scanner that most often is used as a vehicle separator. A few integrators, however, have used the scanner to provide a profile of the vehicle, which the classifier interprets to determine class.

3.3.4 Measurement Specialties, Inc

Measurement Specialties, Inc. manufactures MSI BL sensors. This sensor fitted with the permanent classifiers is claimed to be used by all state DOTs. Florida and Michigan DOTs use this sensor with portable classifiers. The cost for one unit equipment is $ 600 and installation cost for a permanent site is $ 2,100.

3.3.5 Computer Recognition Systems

Computer Recognition Systems (CRS) manufactures Traffic Analysis System (TAS) with magnetometers (permanent system) and magnetometers (portable system). TAS provides real-time vehicle detection and traffic flow monitoring. This unit uses proprietary algorithms and special image processing modules to achieve high performance, and robust video image processing. One unit of installed TAS costs about $ 25,000 for a permanent site, and an installed magnetometer is $ 3,000 for either a permanent or portable site. The number of TAS units with magnetometers sold in the past five years is less than 10, and no portable magnetometers have been sold.

3.3.6 Smartek Systems

Smartek Systems manufactures the SAS-1 Acoustic sensor. This is a roadside traffic sensor that detects the presence of vehicles and measures associated traffic-flow parameters on a lane by lane basis. The cost of one unit of installed SAS-1 is $3,500 for 4 to 5 lanes for either a portable or permanent site. Five state DOTs have used this equipment (Arizona, Ohio, North Carolina, New York, and Virginia).

3.4 Interviews of IDOT Employees

Three categories of IDOT employees were interviewed to obtain information on how truck data is collected, how truck VMT is calculated, and how truck data is used within IDOT. The interviews were conducted on September 12 and 14, 2000 at the IDOT Central Office. IDOT employees from Districts 6 and 8, and several units from the Central Office were interviewed. The questions asked of each group are given in Appendix B.

3.4.1 District 6

3.4.1.1 Data Collection for Truck Classification

District 6 collects truck classification data for 24 hours at 360 sites on marked routes in two years, 180 sites per year. In the past, the Peek 241 was used to collect the truck data. Currently, the District uses Hi-Star NC-97 classifiers to collect traffic data in 3 categories: Passenger Cars, Single Unit, and Multi Unit trucks. The District also collects traffic volume data for 24 hours at about 1,000 sites with a 2-year cycle.

3.4.1.2 HPMS Data Collection

The District collects truck classification data for 48 hours on HPMS sections at 10-15 locations per year. The FHWA F-13 vehicle categories are used. As a part of the data validation process, the District recounts roughly 10% of the locations per year.

3.4.1.3 Classification Equipment

For safety reasons, the District prefers the Hi-Star NC-97 device as opposed to the Peek 241 for truck classification. This is because the Peek 241 requires more time to install than the Hi-Star NC-97, which requires only 3 minutes to install. The District currently operates 200 units of Hi-Stars NC-97. The manpower and equipment required for data collection is 3.5 person, 2 vans and the classification devices.

3.4.1.4 Uses of Truck VMT

The District's Bureaus use truck VMT data for pavement and geometric design. The Bureau of Operation uses truck VMT for speed studies. The District obtains truck VMT data from the OPP and does not use other sources. The District is satisfied with the quality of truck VMT data. The District normally performs recounting at several locations and checks the result of the recounts with historical count data.

To update truck VMT, the District uses Access software for new data entry, and sends the data to the Central Office for further processing no later than March every year.

3.4.2 District 8

3.4.2.1 Data Collection for Truck Classification

The number of sites for truck data collection in District 8 is 360 sites covering all marked routes. Truck data are collected over 2 years – 180 sites per year. The truck classification counts are conducted for 24 hours on almost all sites (99%), and continuously on the remaining sites. Three vehicle types are used: Passenger Car, Single Unit and Multi Unit trucks. In addition to truck volume, at the selected sites the total traffic volume (hr/lane) and speed of vehicles are also collected.

The sites at which truck classification data is collected were chosen based on demographic information, experience with the local area, presence of manufacturing facilities, truck routes, marked routes, and past history. Generally, the sites remain the same for many years unless there is a relocation of a marked route or new development such as a big new manufacturing facility.

District 8 also collects traffic volume data at 1,042 sites on the marked routes (Interstate, US marked routes and Illinois marked routes). These are all 24-hour counts collected using Hi-Stars NC-97 devices. The cycle of data collection is two years. The criteria for selecting the sites are similar to those used for selecting the sites for truck classification counts. Major intersections are normally selected for traffic volume counts. All selected sites for traffic data collection can be located using the Geographical Information System (GIS) at the Central Office. District 8 maintains a map of the coverage for each data collection site.

3.4.2.2 County Coverage

The District also collects traffic volume for 24 hours at 7,379 sites on non-marked routes. These county coverage counts are distributed throughout the 10 counties within the District and are on a five-year cycle. The number of data collection sites for each county is shown in Table 3.20. For the county coverage counts, the District uses Mitron traffic counting devices with a single road tube. District 8 equips 7 sites with Traffic Logging System (TLS). The TLS uses the loop detectors at signalized intersections to count vehicles.

Table 3.20 Number of 24-hour county coverage counts for District 8

No.	Counties	24-hour Count Sites
1	Bond	657
2	Clinton	839
3	Madison	2,013
4	Calhoun	180
5	Greene	398
6	Jersey	475
7	St. Clair	879
8	Monroe	577
9	Randolph	664
10	Washington	697
	Total	7,379

In addition to collecting traffic volume, District 8 also obtains traffic data from other sources, such as traffic volume data on toll bridges, weigh station data, and traffic data on ferries. Local governments (cities and counties) sometimes assist District 8 in collecting traffic data. District 8 supplies the necessary equipment for the data collection.

3.4.2.3 HPMS Data Collection

On HPMS sections, District 8 collects vehicle classification data with F-13 categories for 48 hours at 34 sites on a three-year cycle. The sites are selected to represent all roadway functional classifications in urban and rural area types. During the first two years, the District collects truck data at 13 different sites each year, and at 8 sites on the third year. These truck classifications use the FHWA F-13 vehicle categories, and cover both the marked and non-marked routes. In addition, the District collects traffic volume data for 48 hours at 566 sites on a three-year cycle: 188 sites on the first year, 203 on the second year, and 175 on the third year. These traffic volume counts are conducted on HPMS sections of non-marked routes.

3.4.2.4 Classification Equipment

District 8 prefers to collect 3 categories of truck types rather than the F-13 scheme. The District is satisfied with the equipment used for truck classification (Hi-Stars NC-97) because the device requires only 3 minutes to install and provides desirable vehicle classification results where only 5% of recorded vehicles are left unclassified. This device is for a single lane.

To collect the 13 categories of vehicles on HPMS sections District 8 uses the Peek 241 device with road tubes. The District is somewhat unsatisfied with this device because 7-10% of the counts are left unclassified. To collect traffic volume and truck data for District 8, 3.5 full time staff plus 2 Vans are needed.

3.4.2.5 Uses of Truck VMT

The District's Bureau of Design uses truck VMT information for pavement and geometric design. The District supplies truck VMT data for MPOs. The District does not calculate truck VMT but obtains truck VMT data from the Office of Planning and Programming (OPP) of the Central Office. The District is satisfied with the quality of the data.

3.4.3 The Office of Planning and Programming (OPP)

3.4.3.1 Uses of Truck VMT

The Office of Planning and Programming (OPP) is required to report travel by vehicle type for each roadway functional classification in the state to the FHWA's HPMS. This office also prepares an annual IDOT publication, *Illinois Travel*

Statistics, which includes a tabular summary of travel by vehicle type on all Illinois roadway systems. The current and four previous editions of *Illinois Travel Statistics* are available on the IDOT Internet homepage at www.dot.state.il.us.

The OPP supplies truck VMT to the Illinois Division of Traffic Safety, Bureau of Safety Data and Data Services for their use in calculating truck-related accident rates. This information is also provided to the Illinois Environmental Protection Agency, where it is used in air-quality analysis.

Annual truck VMT is used by the OPP to develop truck travel trends, which play an important role in determining project priorities in IDOT's highway improvement program. The OPP provides truck VMT trend data to the Illinois Division of Highways, Bureau of Materials and Physical Research for use in pavement and structure design formulas.

3.4.3.2 Calculation of Truck VMT

Calculation of truck VMT begins with vehicle classification data obtained from 48-hour portable machine counts on a sample set of 300 HPMS sections throughout the state. As required by the FHWA, field data is collected for 13 vehicle categories. The 300 sample sections are selected from the state's entire population of approximately 3,100 HPMS sections, and are representative of all roadway functional classifications in both area types (rural and urban). Approximately 100 of the 300 sections are scheduled for counting each year, according to guidelines found in the FHWA's *Traffic Monitoring Guide*. The counts are temporarily spaced throughout the year to account for seasonal variation in truck volumes.

The IDOT district offices conduct these counts and forward the field data to OPP, where truck VMT is calculated. The OPP first groups the 100 counts by roadway functional class/area type, then determines for each group the total number of vehicles counted in each of the 13 vehicle categories. A percentage breakdown by vehicle category is then calculated for each roadway functional class/area type. These percentages are applied to the total VMT on each system to calculate the VMT by vehicle category (Total VMT on each roadway functional classification is derived from IDOT's comprehensive volume count program.)

3.4.3.3 The OPP Equipment and Repair Lab

The OPP Equipment and Repair Lab conducts statewide maintenance of traffic counting and classification equipment for both portable and permanent systems. The Lab evaluates new devices and develops procedures to install traffic counting equipment on busy roadway sections. The Lab also provides technical support for all IDOT Districts, distributes equipment, and supervises replacement or reinstallation of equipment.

A current study on the use of Hi-Star NC-97 conducted by the Lab indicates that the device cannot be installed close to high-tension lines because they tend to influence the quality of recording. The device's warm-up time is about 30 minutes before it starts recording. The installation time is about 3 minutes on low volume highway sections and about 8 minutes on busy roads.

3.4.4 The Division of Traffic Safety

The primary use of truck VMT data in the Division of Traffic Safety is to estimate crash rates and identify truck-related high accident locations. Several studies are conducted using truck VMT. The Division uses truck VMT to conduct studies on high accident locations, speed limits, work zones, and large truck issues. For corridor studies, however, truck VMT data that is available needs to be broken down into smaller categories.

The Division obtains truck VMT data from the OPP. In addition, the Division uses other sources such as vehicle registration information. To examine truck VMT that is available for possible data error, the Division looks carefully at the data and contacts the OPP for validation. This request occurs when there is an unreasonable fluctuation of the data especially when the data is stratified according to functional class. The office also examines the historical trend of truck VMT data.

The Division of Traffic Safety does not maintain truck VMT data but only stores crash data. To make the truck VMT data more useful, the Division expressed a need for a model that describes the relation between ADT and the truck percentage for different truck types.

3.4.5 The Division of Highways

The Central Bureau of Operations, Division of Highways, collects truck volume data at 31 weigh stations (20 sites on Interstate Highways and 11 sites on primary routes). These weigh stations are single platforms with static scales. Of the 20 sites on Interstate Highways, 3 sites operate in 24 hours, 5 days a week, 14 sites for 16 hours/day, and 3 sites for 8 hours/day. To obtain more coverage, the office plans to include 4 to 5 weigh stations in the future. In addition, the Bureau operates a WIM system at 14 sites. The office uses categories 5 to 12 of the FHWA F-13 scheme for data collection, but reports the data as truck volume in total. The equipment used includes IRD sorter and Fairbank Static Scales.

The Bureau only needs one person to coordinate the portable scale operation with the State Police, and one person to coordinate the operation of the permanent weigh stations. The District has an operation and maintenance unit to conduct the data collection. Mostly the data collection is contracted out. Cost for the data collection is recorded in an annual report titled "Annual Size and Weigh Certification"

The Bureau uses data collected at weight stations and reports annually to FHWA on truck weight and weight violations. To enforce the vehicle size more effectively in accordance with the vehicle size standard, the Bureau uses truck length data that are obtained from OPP. The Bureau is satisfied with the quality of the data.

The Bureau of Materials and Physical Research of the Division of Highways collects number of axles (not the spacing between axles) and vehicle weight data mostly using portable scales. To select data collection sites the Bureau cooperates with the Bureau of Operations and chooses locations using AADT maps. Data is collected for 4-5 hours per day with a portable scale system and for 2-3 months with a permanent scale system. The cost of data collection and analysis is about $ 40,000 per year. One working person for a year period suffices for the data collection.

In addition using truck VMT for pavement design, the Bureau uses it for cost allocation studies conducted in every 3 years and for other studies, such as the economic impacts of increased traffic loads on pavement life. The Bureau obtains truck VMT data from OPP. To validate the data particularly on higher speed highway sections, the Bureau normally collects traffic data on those sections.

3.5 Summary of Survey Findings and Interviews

A survey of 50 state DOTs, Puerto Rico DOT, and the 54 largest MPOs on equipment and methodologies for determining truck VMT was conducted. In addition, a survey of 29 vehicle-classification vendors/producers was carried out. A great majority of DOTs (71%), over half of MPOs (54 %), and about one-fifth of the vendors returned the survey.

To compute truck VMT, the majority of the DOTs do not obtain truck data from other agencies but collect most, almost all, or all of truck data by their staff. Only a few of the DOTs hired contractors to collect truck data. A majority of the DOTs collect traffic data based on 13 categories suggested by FHWA (F-13 scheme), but a few (three DOTs) used smaller number of categories than the F-13 scheme. Only nine of the DOTs reported having written procedures for data collection. To compute truck VMT, twenty-five of the DOTs use only traffic count data, but seven DOTs use traffic count data and sources other than traffic counts.

Twenty-four of the DOTs (including Puerto Rico) collect classification data for 24 hours or less, but eight DOTs do not. The number of classification stations ranges from zero to 42 stations per 1,000 miles of total highway systems. The density for three state DOTs (Illinois, Vermont, and Virginia) is greater than 20 stations per 1,000 miles of highways. The density for Utah DOT is 13.6. For the remaining state DOTs, the density is less than 10.

In terms of the number of permanent classification stations located on all highway systems, Oklahoma has the highest number of permanent stations (290), followed by California (250) and Virginia (247). In terms of the density per 1,000 miles of total highway systems, Idaho maintains 3.8 (the highest) permanent stations, followed by Connecticut with 3.6, and Virginia DOT with 3.5. Eleven state DOTs operate at least one permanent station for every 1,000 highway miles. The rest of the state DOTs, including Illinois, use less than one permanent station per 1,000 miles of highway. On HPMS sections, California and Oklahoma DOTs maintain the highest number of permanent classification stations, each with 250 stations. The densities per 1,000 miles of total highway is the highest for Idaho (2.8), followed by Oklahoma (2.3), Washington (1.9), Connecticut (1.8), California (1.5), and West Virginia (1.4). The remaining state DOTs maintain less than one station per 1,000 miles of highway systems. Arkansas DOT operates 1,240 48-hour classification stations on HPMS sections (12 stations per 1,000 miles of highway). Vermont and Washington DOTs each operate 600 stations. The density for Vermont is about 42 stations per 1,000 miles of highway, which is the highest density for 48-hour classification counts. Three state DOTs (New Jersey, Utah, and Washington) reported maintaining between five to ten stations on every 1,000 miles of highway. The rest of the responding state DOTs had less then five stations per 1,000 miles of highway

The duration of classification counts on non-HPMS sections varies by state DOTs. The shortest count period was three-four hours in Idaho and the longest one lasted seven days in Nevada. Illinois DOT operates 24-hour classification counts on 3,200 stations on non-HPMS sections. The classification count cycle for non-HPMS sections also varies by state DOTs, ranging from a 12-month to a six-year period.

To compute truck VMT, seventeen of the DOTs perform manual classification counts lasting between two and 48 hours. For instance, South Dakota DOT collects manual truck classification data for two-three hours, Idaho DOT for four hours, Arizona DOT for six hours, and Nebraska DOT for 32 hours.

To determine the sample size and the locations for truck classification counts, 27 of the DOTs use the FHWA Traffic Monitoring Guide (TMG). To determine the sample size, ten of the DOTs use AASHTO's Guidelines in addition to the TMG. To determine the locations, eight state DOTs use AASHTO's Guidelines in addition to the TMG. Six DOTs reported using other criteria than the TMG and the Guidelines, depending on the state's need for truck data and the sources available at the DOT.

To collect truck classification data on congested roads, 11 DOTs (including Puerto Rico) conduct manual classifications, but six DOTs utilize automatic classifiers with more sensitive input sensors and several different sensor configurations. The duration of manual classification counts on these sections varied among the DOTs. Kansas DOT, for example, collects data for 24 hours, and Puerto Rico DOT collects truck data for 14 hours.

To classify vehicles, a great majority of the DOTs (32) uses the number of axles and axle spacing as the only variables or in conjunction with other variables. Eight DOTs use the vehicle length along with axle spacing. Five DOTs use the vehicle weight in addition to axle spacing. Four state DOTs use three variables (axle spacing, vehicle length, and vehicle weight). None of the state DOTs use vehicle length alone to classify trucks. Similarly, none of them use the combination of vehicle length and vehicle weight.

In portable classification devices, the pneumatic road tubes are the most popular (32 state DOTs use them) sensor technology used to collect short-term truck classification data. The tube-based classifying system worked well for classifying on rural two-lane highways with low traffic volume. However, it has a precision problem, specifically when it is used to collect data on congested roadways. Other sensors are used by state DOTS to collect short-term classification data. Portable classifiers with inductive loops are labor- intensive installation, and they reported incorrectly classifying passenger cars with light trailers as single-unit trucks. Hi-Star NC-97, used by IDOT, is a magnetic-imaging-based classifier and provides accurate results for classifying vehicles according to their length. The installation time is relatively short, which makes it very an attractive option for use to collect classification data on large volume roadway sections. IDOT currently use this magnetic-imaging system only for classifying three types. New Jersey and Nevada DOTs use a video image based classifier. This classifier uses video cameras to scan traffic and uses built-in software to determine vehicle profile information such as length, width and height from scanned vehicle images. With this system, however, occlusion by intervening vehicles and problems with shadows were reported. The products from two manufactures, Peek Traffic and Diamond Traffic Products, dominate the market of the portable devices. The products of Peek Traffic (Peek ADR

1000/2000 series and Peek 241) with a variety of sensor technologies are used by 16 state DOTs.

In permanent classification devices, as many as 24 state DOTs use loop detectors and piezoelectric sensors. Of these 24 DOTs, five also use bending plate sensors. Washington is the only state DOT that uses radar along with loops, piezoelectrics, and bending plate sensors. One DOT uses only piezoelectric sensors. Permanent classification devices manufactured by Peek Traffic and Diamond Traffic Products are used by a considerable number of state DOTs. Fourteen state DOTs use the peek ADR family, and nine state DOTs use the devices of Diamond Traffic Products.

A variety of procedures are reported to convert traffic data obtained from short-term classification counts to annual values. Several states use different adjustment factors for cars and trucks. Only five state DOTs use all three adjustment factors (time-of-day expansion, day-of-week, and seasonal factors), and only three out of five have implemented different adjustment factors for cars and trucks.

Two different methods for truck VMT calculation have been used by the DOTs. The first method calculates truck VMT on a highway segment by multiplying truck ADT by the length of roadway section. Ten DOTs use this method. The second method (HPMS) calculates truck VMT by multiplying total VMT (by functional class) by the average truck percentages (by truck types). Eight state DOTs use the second method. Two DOTs (Arizona and Colorado) use the first method for State Highway System, and use the second method for all public roads or areawide HPMS sections. Some state DOTs (Idaho, Oregon, and Washington) use additional sources, such as the fuel consumption data. Eight DOTs (including Puerto Rico) reported not calculating truck VMT.

Eleven out of the 29 MPOs that returned the survey neither collect truck classification data nor calculate it. Seven MPOs use the truck VMT data computed by other agencies. Four MPOs calculate truck VMT although they do not collect the data. Only seven out of 29 MPOs collect truck classification data. Three of the seven MPOs also calculate truck VMT. MPOs who collect truck data use either contractor or MPO staff to do the data collection. Three MPOs collects almost of all of the data collections by their staff. In two MPOs, almost all of the data collections are contracted out. One MPO uses contractors, consultants, and staff of local government to collect the truck data. One other MPO uses consultant staff to collect truck classification data, and this is only when the MPO conducts study of areawide travel study.

A survey on classification equipment was sent to 29 equipment vendors. The surveys asked what classification equipment manufactured, the cost of one unit installed, the number of states that have used the products, and the number of unit sold in the past five years. Only six equipment vendors returned the survey. They are International Road Dynamics, Transport Data Systems, Scientific Technologies, Inc., Measurement Specialties, Inc., Computer Recognition Systems, and Smartek Systems.

To obtain the information on how truck data is collected and how truck VMT is calculated and used in IDOT, IDOT employees from District 6, District 8, and several units at the Central Office were interviewed. These units are the Office of Planning and Programming (OPP), the Division of Traffic Safety, and the Division of Highways. For truck VMT purposes, IDOT uses vehicle length and classifies vehicles into three categories (passenger cars, single-unit, and multi-unit trucks). These categories are also suggested by TMG 2000 for classification.

4 PROPOSED METHODOLOGY FOR TRUCK VMT ESTIMATION IN ILLINOIS

The IDOT procedure for truck VMT calculation is based on a limited number of FHWA's 13-category classification counts (approximately 100 locations annually on HPMS sections) and on a comprehensive set of volume counts. To calculate truck VMT, the average truck percentages for different truck types and functional classes are multiplied by the total VMT generated from the volume counts. This is called the HPMS method. The truck percentages are obtained from classification counts. The truck percentage of a roadway section is simply the ratio of truck volume to the total volume carried by that section. The truck VMT is then grouped into 8 roadway functional classes and 8 vehicle types (see section 2.5). Recently, IDOT collects 3-category classifications at 10,000 locations biennially. This categorization is based on vehicle length. Any vehicle less than 21 feet long is categorized as Passenger Vehicle (PV), between 22 and 40 feet as Single Unit (SU), and larger than 40 feet as Multi Unit (MU) vehicles.

This section discusses the methodologies this study developed for truck VMT calculation that do not require a complete set of data for all roadway sections. The traffic data used is for all sections on marked routes for the year 1996. When a complete set of data is available, the true truck VMT is calculated by multiplying truck volume by the corresponding section length and summing it up for all sections. Since such a complete data set is not normally available, two methods to estimate truck VMT are developed. The first method is called the Average Truck Percentage (ATP) method. Under this method, truck VMT is calculated by multiplying the average truck percentage for a group of roadway sections by the total VMT of that group. The grouping of roadway sections is based on functional class and traffic volume. The truck percentage for a given roadway section is the ratio of truck volume to the total traffic volume on that section. This method requires information on total traffic volume, truck volume, and total length of the sampled roadway sections. This is basically a method similar to the current IDOT procedure (the HPMS method), but calculates truck VMT at volume group level.

The second method is called the Average Section Length (ASL) method. In the second method for truck VMT calculation, the average roadway section length is multiplied by the total corresponding truck volume. Unlike the first method, the ASL method requires information only on truck volume and the average section length, either at population or sample level. For practical reasons, the average length should be taken at population level. Therefore, for a given functional class the average length is fixed regardless of the sample size. The advantages and disadvantages of ATP and ASL will be discussed and their outcomes will be compared. In the next section, the difference between the true truck VMT and the one estimated by the IDOT HPMS method is examined first.

4.1 Deviation of IDOT HPMS Method

The truck VMT estimated using the IDOT method for Multi Unit and Single Unit trucks are shown in Tables 4.1 and 4.2, respectively. Column (1) of the tables shows the category number. Column (2) shows the functional classification. Column (3) shows the number of roadway sections in the data set that belongs to that category. Column (4) shows the total length of all roadway sections in the data set that belongs to this category. Column (5) shows VMT for all vehicles on those sections included in the data set. Column (6) is the true truck VMT calculated by multiplying the length of each individual roadway section in the data set that belongs to this category by the corresponding truck volume. Column (7) shows the average truck percentage for all sections included in the data set for this category. Column (8) shows the estimated truck VMT that is obtained by multiplying the total VMT (Column 5) by the truck percentage (Column 7). The last two columns show the deviations between the estimated and the true truck VMT values. Column (9) shows the absolute difference and Column (10) shows the ratio of estimated to true truck VMT.

According to Table 4.1, the IDOT method generally overestimates VMT for Multi Unit trucks. It overestimates Multi Unit truck VMT by 354.52 millions (23 %) for Interstate Urban and by 102.41 millions for Interstate Rural (about 6 %). Only on Minor Urban Arterials does the IDOT method underestimates truck VMT (by 10 percent). Overall deviation is 513 millions (about 11.5 %) higher than the true value for Multi Unit trucks. For Single Unit trucks, the overall deviation is negligible because underestimations and overestimations cancelled out each other, however the deviations for some functional classes are large.

4.2 Sample Stratification

To reduce the deviations and to provide a more accurate truck VMT estimate, roadway sections should be stratified not only by functional class, but also by traffic volume. For each functional class, the number of volume groups should depend on the range of traffic volume. The grouping should be made such that the total section length for each group is roughly equal. Appendix D shows the suggested volume groups for each functional class. Area type did not change the volume group thresholds. Thus, the volume group thresholds for rural and urban of a similar functional class are the same.

4.3 Sample Size Distribution Among Volume Groups

Once the volume groups are identified, the number of sections to be sampled from each volume group needs to be determined. For a given functional class, the number of roadway sections sampled should depend on the desired accuracy of truck VMT estimation. The accuracy is defined as the deviation of the estimated truck VMT from the true truck VMT. The highway sections that made large contributions to truck VMT should be estimated more accurately than those with smaller contributions. This is because the error in the first group significantly affects the accuracy of the overall truck VMT estimation. Therefore, a larger sample size should be assigned to the volume groups that contribute a larger portion of the total VMT. This following section discusses how the sample size is distributed among volume groups.

Table 4.1 Truck VMT Estimated Using the Current IDOT Method: Multi Unit Trucks

No.	Functional Classification	No. of Sections	Length (miles)	Total VMT (millions)	True Truck VMT (millions)	Average % Truck	Estimated Truck VMT (millions)	Truck VMT Difference	Truck VMT Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(5)(7)	(9)=(8)-(6)	(10)=(8)/(6)
1	Interstate Urban	986	591.09	17,015.19	1,558.36	11.24	1,912.88	354.52	1.23
2	Interstate Rural	451	1,238.70	7,791.20	1,810.86	24.56	1,913.28	102.41	1.06
3	Freeway and Expressway Urban	78	73.15	847.96	41.12	6.98	59.16	18.04	1.44
4	Other Principal Arterial Urban	3,462	2,001.57	13,608.91	392.87	2.94	400.24	7.37	1.02
5	Other Principal Arterial Rural	1,435	2,289.32	4,009.81	283.45	7.42	297.46	14.01	1.05
6	Minor Arterial Rural	2,535	4,302.22	4,592.27	270.51	6.29	288.75	18.24	1.07
7	Major Collector Rural	672	1,135.00	933.96	35.19	4.18	39.06	3.88	1.11
8	Minor Arterial Urban	511	366.75	1,964.53	49.49	2.26	44.35	-5.14	0.90
	Total	10,130	11,997.80	50,763.81	4,441.85		4,955.16	513.32	

Table 4.2 Truck VMT Estimated Using the Current IDOT Method: Single Unit Trucks

No.	Functional Classification	No. of Sections	Length (miles)	Total VMT (millions)	True Truck VMT (millions)	Average % Truck	Estimated Truck VMT (millions)	Truck VMT Difference	Truck VMT Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)=(5)(7)	(9)=(8)-(6)	(10)=(8)/(6)
1	Interstate Urban	986	591.09	17,015.19	480.21	2.88	490.38	10.17	1.02
2	Interstate Rural	451	1,238.70	7,791.20	285.00	3.25	266.97	-18.03	0.94
3	Freeway and Expressway Urban	78	73.15	847.96	23.91	3.08	32.29	8.39	1.35
4	Other Principal Arterial Urban	3,462	2,001.57	13,608.91	426.81	3.00	408.80	-18.02	0.96
5	Other Principal Arterial Rural	1,435	2,289.32	4,009.81	161.53	4.17	167.35	5.82	1.04
6	Minor Arterial Rural	2,535	4,302.22	4,592.27	187.20	4.27	196.14	8.94	1.05
7	Major Collector Rural	672	1,135.00	933.96	36.13	4.25	39.67	3.54	1.10
8	Minor Arterial Urban	511	366.75	1,964.53	60.83	3.06	60.06	-0.76	0.99
	Total	10,130	11,997.80	50,763.81	1,661.61		1,661.67	0.05	

Suppose that the sample size is decided to be 30 % of the number of Interstate Urban sections. The total number of roadway sections for Interstate Urban is 986 and is divided into 14 volume groups. Thus, the number of sample sections is 0.3x986 = 296. To determine the number of sample sections for each volume group one needs to know the total VMT and the contribution of each volume group to the total. Volume Group 8 of this functional class, for example, contributes 9.8 % to the total VMT. Therefore, 9.8 % of 296 sections, or 29 sections, should be selected from the roadway sections in this volume group. This is shown in Column (6) of Table 4.3. These 29 sections should be randomly selected from the 118 sections in this volume group.

Table 4.3 Sample Sizes by Volume Group for Interstate Urban Highways

No.	Volume Group Range (AADT)	No. of Sections	Total VMT (millions)	Share of Total VMT (%)	Sample Size of 30 % Sampled (section)	Sample Size of 51 % Sampled (section)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	0 - 5,000	6	28	0.17	0	1
2	5,000 - 10,000	25	78	0.46	1	2
3	10,000 - 15,000	50	215	1.26	4	6
4	15,000 - 20,000	39	276	1.62	5	8
5	20,000 - 25,000	42	450	2.64	8	13
6	25,000 - 30,000	26	289	1.70	5	9
7	30,000 - 35,000	48	783	4.60	14	23
8	35,000 - 40,000	118	1,662	9.77	29	49
9	40,000 - 60,000	53	1,028	6.04	18	30
10	60,000 - 80,000	36	1,225	7.20	21	36
11	80,000 - 100,000	67	2,074	12.19	36	61
12	100,000 - 120,000	124	2,734	16.07	48	81
13	120,000 - 140,000	352	6,172	36.27	107	182
14	140,000 - Larger					
Total			17,015	100.00	296	501

The proportion of sections sampled (39 %) from Volume Group 12 is higher than the proportion (25 %) from Volume Group 8. This is because Volume Group 12 contributes 16.1 % of the total VMT compared to 9.8 % that comes from Volume Group 8. The largest portion of sample is taken from Volume Group 13 to satisfy the requirement of having more sections from groups that contribute more to the total VMT. When the sample size is increased to 51 %, note that all roadway sections in Volume Group 10 (36 sections) are selected. The effect of this sample saturation will be addressed later.

4.4 Truck Adjustment Factors

To obtain annual average daily truck traffic (AADTT), truck data taken from short-term counts and collected at sampled sites should be expanded and adjusted for temporal variation. This section discusses a procedure to determine truck adjustment factors. The 2000 TMG strongly recommended that the factors be computed only for three to four "generalized" vehicle categories. The categories are passenger cars and light trucks, single-units and conventional buses, combination vehicles, and multi-trailer trucks. Three categories are sufficient for states with few multi-trailer trucks. This recommendation is made because volumes in many of the FHWA 13-categories are generally very low. When volumes within a vehicle category are low, the adjustment factors computed for those vehicles become unstable and, thus, inaccurate. A highly aggregated category provides stability to the factors computed.

The 2000 TMG indicated two different approaches to calculate and apply truck adjustment factors. The first is similar to what Virginia DOT uses, that is, the "specific road" approach, and the second approach is "group truck factor" approach. In the first approach, continuous classification counters should be available on all major routes and data collected from these continuous counts are used to develop "road specific" adjustment factors. Thus, any short-term classification count collected on a specific roadway is adjusted using factors from the nearest continuous classification counter on that roadway.

The second approach to develop truck adjustment factors requires that roadway sections be grouped according to both roadway functional classification and truck travel patterns. The travel patterns are generally governed by the amount of long distance "through" truck versus the amount of local trucks, the existence of large truck generators, and the presence or absence of large populations that require the delivery of freight and goods. In this approach, deciding roadway groups is part of the procedure. Initial grouping should be checked for truck pattern similarity. If a large variation of factors is found for a given roadway grouping, regrouping is necessary until the variation is acceptable. Truck adjustment factors are computed using truck data collected from continuous classification counts located within each roadway group. The average adjustment factors are used to adjust short-term truck data that are collected at locations within that group. A number of state DOTs use the procedure similar to this second approach, such as Iowa and Pennsylvania.

The major advantage of having a specific adjustment factor for a specific roadway is that it reduces errors associated with applying average factors to compute AADTT. It also reduces the number of short-term classifications that are required because the continuous counts also provide classification data. Furthermore, it simplifies the calculation of the adjustment factors and their application. However, this approach is costly since the state DOT has to maintain a large number of continuous counters. When roadways are quite long and their truck patterns vary over their length, an adjustment factor taken on a section in western half, for example, may not be applicable to a section on the same road in the eastern half. This situation is problematic since not only does this require a larger number of continuous counters, but also it creates a difficulty in deciding the location of the short-term classification counts relative to the two continuous counts. The accuracy of adjustment factors is also questionable, as the distance between the short-term counts and the continuous counts becomes longer.

An investigation on truck travel pattern in Illinois should be conducted to obtain a better understanding how different truck types travel, which corridors of roadway systems carry the highest truck volume, what is temporal variation of truck volumes for the same section of roadways, etc. This information guides IDOT to define the best grouping for calculating truck adjustment factors. In the mean time, the roadway grouping based on traffic volume as discussed in section 4.2 can be used. Thus, group truck factors for single-unit and multi-unit trucks can be calculated for each volume group. In addition, as also suggested by TMG, IDOT should consider a procedure that calculates truck factors using the two approaches simultaneously. For example, specific road truck factors are developed for the most important roads in the state, and group truck factors are created for roadway corridors without continuous classification counters.

4.5 Truck VMT Estimation

Depending on the availability of truck traffic data, there are two different methods to calculate truck VMT: direct and indirect methods. The direct method (DM) multiplies truck volume by section length to obtain a section truck VMT. This method can be used when truck volume and roadway section length are known for individual sections. When all or part of the information is not available, the indirect method (IM) is used to estimate truck VMT. The IM relies on variables such as the average truck percentage (either total or by truck class), total truck VMT, the average section length, etc. The direct method will be discussed below followed by the indirect method.

4.5.1 Direct Method

The basic concept of the DM is simple. For each volume group j, truck VMT is calculated by adding up truck VMT of all sections of that group, as formulated in the following equation:

$$truck\ \overline{VMT}_j = \sum_{i=1}^{n_j} (l_{ij})\,(truck\ V_{ij}) \qquad (1)$$

Where l_{ij} is the roadway length for section i in volume group j, and $truck\ V_{ij}$ is the corresponding truck volume on that section. Then, Equation (2) is used to calculate truck VMT when sample size is n. n_j is the total number of roadway sections sampled from the volume group j, thus $n = \Sigma\ n_j$, for $j=1,..,G$, where G is the number of volume groups. For a given sample size n, the true total truck VMT is calculated as the summation of truck VMTs for volume groups.

$$truck\ \overline{VMT}_n = \sum_{j=1}^{G} truck\ \overline{VMT}_j = \sum_{j=1}^{G} \sum_{i=1}^{n_j} (l_{ij})\ truck\ V_{ij} \tag{2}$$

To obtain truck VMT for a functional class, the truck VMT for the sample is expanded using the expansion factor. The expansion factor is the ratio of total section length for the functional class (population) to the total section length of the sample. Thus, the truck VMT for population is computed by Equation (3); where *N* is the number of roadway sections in that functional class.

$$truck\ \overline{VMT} = truck\ \overline{VMT}_n \left(\frac{\sum_{i}^{N} l_i}{\sum_{j}^{G} \sum_{i}^{n_j} l_{ij}} \right) \tag{3}$$

4.5.2 Indirect Method

Two different indirect methods for estimating truck VMT are developed. The first method is called the Average Truck Percentage (ATP) method and uses the average truck volume percentage for each volume group. This average value is then multiplied by the total VMT (all vehicles) of the group to obtain truck VMT. The second method is called the Average Section Length (ASL) method. It uses the average section length. To obtain truck VMT, the truck volume is multiplied by the average section length for that volume group.

4.5.2.1 Average Truck Percentage (ATP) Method

The basic concept for the ATP method is described in this section. For Volume Group j, truck VMT is estimated as the product of the average truck percentage and the total VMT of the group. The equation below is used to calculate truck VMT, where p_j is the average truck percentage for Volume Group j, and V_{ij} is the AADT of roadway section i of Volume Group j. So, if there are n_j sections in Volume Group j, truck VMT for Volume Group j is calculated as:

$$truck\ VMT_j = (p_j)\left[\ total\ VMT_j\right] = (p_j)\left[\sum_{i=1}^{n_j} (l_{ij}) V_{ij}\right] \tag{4}$$

There are 3 approaches to calculate the average truck percentage. The first approach finds the arithmetic average of truck percentages for all roadway sections that belong to a volume group. Equation (5a) is used to calculate the average truck percentage.

$$p_j = \frac{\sum_{i=1}^{n_j} \frac{truck\,V_i}{V_i}}{n_j} \tag{5a}$$

The numerator of this equation represents summation of truck percentages. The truck percentage for a roadway section is simply the ratio of truck volume to total volume of that section. The arithmetic average considers each section equally important regardless of the length of the section. The second approach is to find the average truck percentage weighted by section length, as shown in Equation (5b).

$$p_j = \frac{\sum_{i=1}^{n_j} (l_i)\left(\frac{truck\,V_i}{V_i}\right)}{\sum_i^{n_j} l_i} \tag{5b}$$

This weighted percentage requires knowing the lengths of roadway sections. The second approach considers the section length, but not the traffic volume. The third approach finds the average truck percentage weighted by traffic volume of each section. Equation (5c) expresses this approach. The third approach yields an average truck percentage that is the ratio of total truck volume to total volume of all vehicles for a given volume group.

$$p_j = \frac{\sum_{i=1}^{n_j} (V_i)\left(\frac{truck\,V_i}{V_i}\right)}{\sum_i^{n_j} V_i} \tag{5c}$$

To choose the most appropriate approach to compute the average truck percentage, a comparison of the estimated truck VMT values from the three approaches should be made. The approach that provides the smallest deviation from the true truck VMT should be selected.

For a given sample size, the estimated truck VMT is then calculated using Equation (6).

$$truck\,VMT_n = \sum_{j=1}^{G} (p_j)\,total\,VMT_j = \sum_{j=1}^{G}\sum_{i=1}^{n_j} (p_j)(l_{ij})V_{ij} \tag{6}$$

This truck VMT is for the sampled sections and needs to be expanded to obtain the truck VMT at the functional class level. The expansion factor of *N/n* is used. Where N is the total number of roadway sections in that functional class. The estimated truck VMT at functional class level is formulated in Equation (7).

$$truck\ VMT = \left(\sum_{j=1}^{G}\sum_{i=1}^{n_j}(p_j)(l_{ij})V_{ij}\right)\left(\frac{N}{\sum_{j=1}^{n_j} n_j}\right) \tag{7}$$

$$where \quad n = \sum_{j=1}^{n_j} n_j$$

4.5.2.2 Average Section Length (ASL) Method

Instead of using the method that is based on the average truck percentage, truck VMT can also be calculated using the average length of roadway sections. To find the average roadway section length three approaches were examined: the average section length at functional class, at sample, and at volume group levels. The average section length at functional class level is easy to compute, but at sample and volume group levels it is difficult to obtain.

Average Section Length at Roadway Functional Class Level

The average roadway section length for a roadway functional class is simply the ratio of total roadway length to the total number of roadway sections in that functional class. The average calculated as:

$$\frac{\sum_{i=1}^{N} l_i}{N} \tag{8}$$

Where N is the number of roadway sections in that functional class and l_i is the length of an individual roadway section.

When a sample size consisting of n sections is used, truck VMT is calculated as the product of the average section length and the summation of truck volumes. If G is the number of volume groups, and V_j is the total truck volume for Volume Group j, truck VMT is calculated using Equation (9).

$$truck\ VMT_n = \left(\sum_{j=1}^{G} truck\ V_j\right)\left(\frac{\sum_{i=1}^{N} l_i}{N}\right) \tag{9}$$

$$where \quad truck\ V_j = \sum_{i=1}^{n_j} truck\ V_{ij}$$

This truck VMT is for n sections and should be expanded to obtain the truck VMT at the functional class level using Equation (10). Note that *N/n* is the expansion factor.

$$truck\ VMT = \left(\sum_{j=1}^{G} truck\ V_j\right)\left(\frac{\sum_{i=1}^{N} l_i}{N}\right)\left(\frac{N}{\sum_{j=1}^{G} n_j}\right) \tag{10}$$

Average Section Length at Sample Level

Instead of using the average length of all sections in a functional class, this method uses the average roadway section length that comes from the sampled sections. In other words, the average section length may vary by sample size. Equation (11) gives the average section length for sample size *n*.

$$\frac{\sum_{j=1}^{G}\sum_{i=1}^{n_j} l_{ij}}{\sum_{j=1}^{G} n_j} \tag{11}$$

Thus, truck VMT is calculated using Equation (12).

$$truck\ VMT_n = \left(\sum_{j=1}^{G} truck\ V_j\right)\left(\frac{\sum_{j=1}^{G}\sum_{i=1}^{n_j} l_{ij}}{\sum_{j=1}^{G} n_j}\right) \tag{12}$$

This truck VMT needs to be expanded to obtain the truck VMT at the functional class level using the following equation.

$$truck\ VMT = \left(\sum_{j=1}^{G} truck\ V_j\right)\left(\frac{\sum_{j=1}^{G}\sum_{i=1}^{n_j} l_{ij}}{\sum_{j=1}^{G} n_j}\right)\left(\frac{N}{\sum_{j=1}^{G} n_j}\right) \tag{13}$$

Average Section Length at Volume Group Level

Under this method, truck VMT is first calculated at volume group level. For each volume group, an average roadway section length is calculated. Then, this value is multiplied by the total truck volume to obtain truck VMT for that volume group. Equation (14) gives truck VMT for Volume Group *j*.

$$truck\ VMT_j = \left(\sum_{i=1}^{n_j} truck\ V_i\right)\left(\frac{\sum_{i=1}^{n_j} l_{ij}}{n_j}\right) \quad (14)$$

n_j is the number of sections in the group, and l_{ij} is the length of a roadway section i in volume group j.

The truck VMT at sample level is the summation of the truck VMT of the volume groups (Equation 15), where G is the number of volume groups.

$$truck\ VMT_n = \sum_{j=1}^{G}\left(\left(\sum_{i=1}^{n_j} truck\ V_i\right)\left(\frac{\sum_{i=1}^{n_j} l_{ij}}{n_j}\right)\right) \quad (15)$$

Truck VMT at functional class level is calculated by expanding the sample truck VMT (Equation 16), where N is the number of roadway sections in the functional class.

$$truck\ VMT = \sum_{j=1}^{G}\left(\left(\sum_{i=1}^{n_j} truck\ V_i\right)\left(\frac{\sum_{i=1}^{n_j} l_{ij}}{n_j}\right)\right)\left(\frac{N}{\sum_{j=1}^{G} n_j}\right) \quad (16)$$

4.5.3 Methodology Adjustment Factor (MAF)

Truck VMT methodology adjustment factor (MAF) is a used to adjust truck VMT estimated by the indirect method. The MAF is the ratio of the true truck VMT to the estimated truck VMT. Equation (17) is used to calculate the MAF.

$$\frac{truck\ \overline{VMT}}{truck\ VMT} \quad (17)$$

When it is larger than unity, the indirect method (IM) underestimates, and when the factor is less than one, it overestimates the truck VMT. The absolute difference between the estimated truck VMT and the true truck VMT is the error (ε) and is computed as:

$$\varepsilon = \left| truck\ VMT - truck\ \overline{VMT} \right| \quad (18)$$

4.6 Development of MAF

The IRIS database contains all the information needed (ADT, truck volumes, and section length) to calculate truck VMT for all marked routes that are in the database. The 1996 IRIS database was used to calculate the MAF.

Different sample sizes (number of roadway sections) were used to estimate truck VMT and to calculate true truck VMT for the sections. Then, for each sample size, an MAF was computed. The minimum sample size was 5 % of the number of roadway sections. An increment of one percent was used until an upper bound was reached. The upper bound was chosen as the sample size at which all of roadway sections in at least one of the volume groups are selected. In other words, increasing the sample size beyond the upper bound would not affect the truck VMT calculation for at least one of the volume groups since all sections of this group have been selected. For example, the Interstate Urban Highway has 14 volume groups. When the sample size is 51 %, all of the roadway sections in Volume Group 10 are selected. Therefore, 51% is the upper bound used for developing the MAF for Interstate Urban Highways, and this corresponds to 501 roadway sections. The upper bounds for sample sizes for all functional classes are shown in Table 4.4.

Table 4.4 Upper bounds for Sample Size

No	Functional Classification	Total No. of Sections	Sample Upper Bound	Upper Bound (%)
1	Interstate Urban	986	501	51
2	Interstate Rural	451	202	45
3	Freeway and Expressway	78	23	29
4	Other Principal Arterial Urban	3462	690	20
5	Other Principal Arterial Rural	1435	503	35
6	Minor Arterial Rural	2535	1166	46
7	Major Collector Rural	672	456	68
8	Minor Arterial Urban	511	113	22

For a given functional class, the total number of highway sections is greater than the number of sections that can be selected (sample upper bound) for truck VMT estimation using the indirect method. The selection of the sites to be included in such computation should be random. For a given sample size, there are many combinations of sites to be selected. Limiting the selection to one set of these sites may not provide a good representation of truck VMT for that functional class. To reduce the randomness effects, 100 sets of selections (runs) were used for each functional class. For each run, truck VMT was estimated using the average length that is based on the sections in the largest sample size allowed (upper bound). Note that the average length at the upper bound level is used, not that of the functional class level. The average truck VMT value for each set was calculated, and was then expanded to the functional class level using the expansion factor. The true truck VMT was also calculated at the functional class level, and served as a benchmark to develop the truck VMT MAF. Moreover, the same procedure was carried out using the ATP method. The results are provided in the following sections.

4.6.1 MAF for Interstate Urban Highways: ASL Method

The MAF is developed for each vehicle type, area type, and functional classification. Table 4.5 shows the calculation for Multi Unit trucks on Interstate Urban Highways using the ASL method. Column (1) of the table is the sample size in terms of percentage of the population of that functional class. Column (2) is the corresponding number of roadway sections selected. Column (3) shows the total length of the section selected in Column (2). Column (4) shows the true truck VMT for sections selected in Column (2). Column (5) shows the total truck volume on sections selected in Column (2). The average section length for the largest sample size (51%) is 294.866/501=0.589. Multiplying this factor by the truck volumes of column (5) provides the estimated truck VMT. The results are shown in column (6). To obtain the estimated truck VMT at functional class level, multiply the estimated truck VMT by the expansion factor. The expansion factor is the ratio of the total number of sections at functional class level to the number of section of the sample. The results are shown in column (7). The last column is the MAF and is calculated as the ratio of the true truck VMT at population level to the estimated truck VMT.

As an illustration, for 25 % sample size the estimated Multi Unit truck VMT is (2345.14)(365)(0.589)/1,000 = 503.790 millions. The number of sections in the population is 986 and that in the sample is 246. Multiplied this VMT by expansion factor (986/246) to obtain the estimated truck VMT which is 2,019.26 millions. The true Multi Unit truck VMT at population level for Interstate Urban Highways is 1,558.36 millions. The MAF is then calculated as 1,558.36/2,019.26, which equals 0.772. A similar procedure is applied to Single Unit trucks.

Figure 4.1 shows the plot of the MAF as a function of sample size for both Multi and Single Unit trucks on Interstate Urban Highways, and Figure 4.2 shows that on Interstate Rural Highways. It should be noted that when the sample size is very small, less than about 15 %, MAF fluctuated, but as the sample size increased the MAF became more stable. For Interstate Urban Highways, for example, if sample size is greater than 15 %, the MAF remains almost constant, that is 0.77 for Multi Unit trucks and 0.71 for Single Unit trucks. The MAF for Interstate Rural Highways are higher than that for Interstate Urban Highways. These are 0.94 for Multi Unit trucks and 0.87 for Single Unit trucks. This is shown in Figure 4.2.

Table 4.5 MAF for Multi Unit Trucks on Interstate Urban Highways: ASL Method

Sample Size (1)	No. of Roadway Sections Selected (2)	Total Length (miles) (3)	True Truck VMT (Millions) (4)	Truck Vol (Thousands) (5)	Estimated Truck VMT (Millions) (6)	Expanded Truck VMT (Millions) (7)	MAF (8)
5	50	29.59	88.01	473.23	101.66	2004.74	0.777
6	60	35.65	103.91	564.98	121.37	1994.53	0.781
7	68	39.57	116.03	647.94	139.19	2018.27	0.772
8	80	47.15	139.36	764.73	164.28	2024.76	0.770
9	87	51.40	152.39	833.85	179.13	2030.14	0.768
10	100	59.86	175.96	949.83	204.05	2011.89	0.775
11	108	64.88	191.21	1026.48	220.51	2013.19	0.774
12	118	69.98	206.88	1124.06	241.47	2017.74	0.772
13	129	76.51	226.69	1225.30	263.22	2011.91	0.775
14	137	81.46	242.30	1309.71	281.36	2024.94	0.770
15	149	88.65	262.08	1421.53	305.38	2020.82	0.771
16	157	92.97	274.15	1495.61	321.29	2017.79	0.772
17	167	98.23	290.83	1596.09	342.88	2024.41	0.770
18	178	105.01	311.37	1700.91	365.39	2024.03	0.770
19	186	109.48	324.72	1779.26	382.23	2026.20	0.769
20	196	114.66	341.81	1881.45	404.18	2033.26	0.766
21	207	121.73	360.44	1973.81	424.02	2019.73	0.772
22	218	128.60	379.83	2080.02	446.84	2021.01	0.771
23	226	132.85	393.12	2157.09	463.39	2021.70	0.771
24	236	138.32	409.75	2253.16	484.03	2022.26	0.771
25	246	144.81	428.45	2345.14	503.79	2019.26	0.772
26	254	149.22	441.73	2424.80	520.90	2022.09	0.771
27	265	155.47	460.13	2530.72	543.66	2022.81	0.770
28	275	161.99	478.89	2621.86	563.23	2019.45	0.772
29	287	168.84	497.72	2730.63	586.60	2015.29	0.773
30	296	174.04	512.55	2818.09	605.39	2016.60	0.773
31	305	180.02	528.82	2904.19	623.89	2016.89	0.773
32	315	186.32	548.23	2999.24	644.30	2016.77	0.773
33	326	192.72	565.50	3100.61	666.08	2014.59	0.774
34	336	197.95	580.91	3199.43	687.31	2016.93	0.773
35	346	204.39	598.81	3287.63	706.26	2012.63	0.774
36	355	209.14	614.88	3382.95	726.73	2018.48	0.772
37	366	216.31	634.08	3478.75	747.31	2013.25	0.774
38	376	221.78	652.09	3576.92	768.40	2015.02	0.773
39	386	227.83	668.91	3670.22	788.45	2014.01	0.774
40	394	231.98	682.24	3750.02	805.59	2016.02	0.773
41	405	239.04	702.24	3852.74	827.66	2014.98	0.773
42	414	244.43	718.67	3941.35	846.69	2016.52	0.773
43	425	251.34	739.92	4046.75	869.33	2016.85	0.773
44	432	254.41	751.00	4121.76	885.45	2020.95	0.771
45	444	261.93	770.90	4228.01	908.27	2017.02	0.773
46	454	267.73	788.33	4328.04	929.76	2019.26	0.772
47	462	272.01	800.61	4403.73	946.02	2019.00	0.772
48	475	280.56	825.07	4523.65	971.78	2017.22	0.773
49	483	284.76	839.11	4606.50	989.58	2020.14	0.771
50	492	290.14	854.88	4692.50	1008.06	2020.21	0.771
51	501	294.87	868.40	4778.68	1026.57	2020.35	0.771

Figure 4.1 MAF (ASL Method) versus Sample Size: Interstate Urban Highways

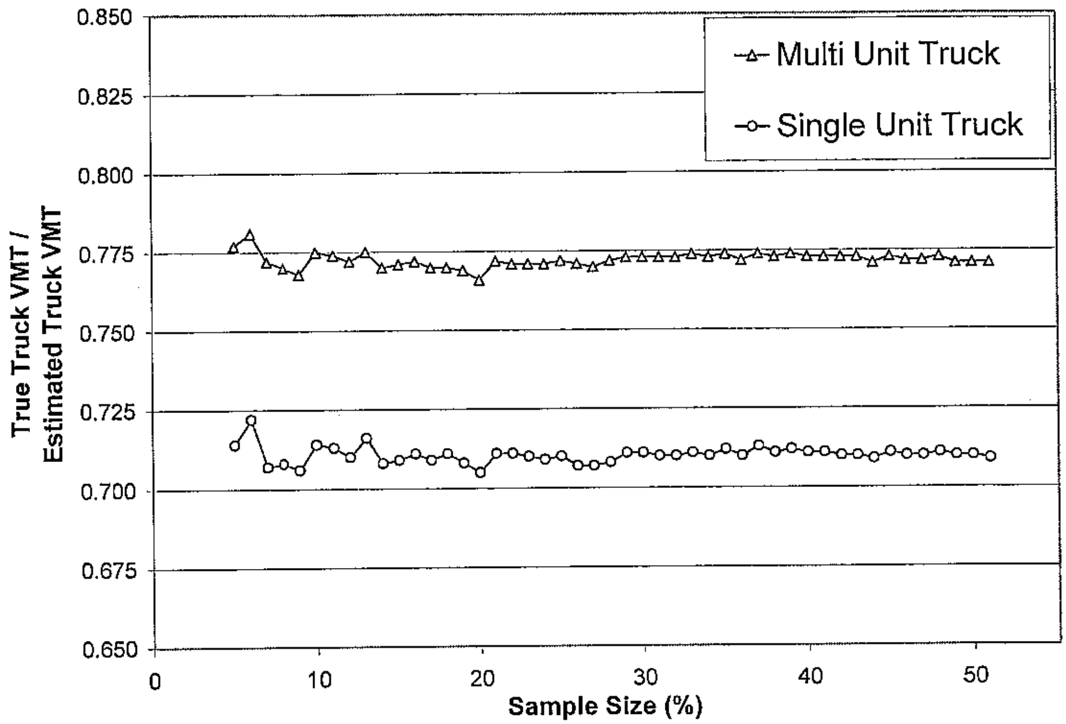
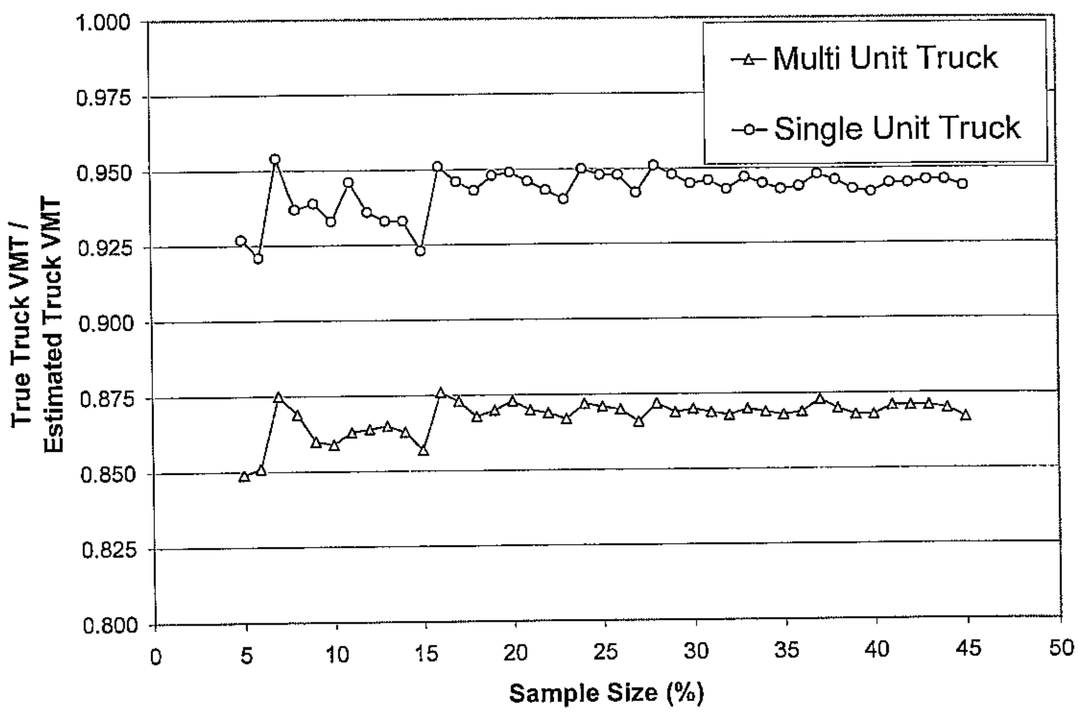


Figure 4.2 MAF (ASL Method) versus Sample Size: Interstate Rural Highways



4.6.2 MAF for Other Roadway Functional Classes: ASL Method

A similar procedure was used to develop MAF for other functional classes. For some functional classes, MAF for Multi and Single Unit are different and for some other classes they are similar. Table 4.6 shows the MAF if the sample size is set to 15 %. MAF remains at this level, as shown in Appendix E1 and E2, as the sample size is increased. Appendix E.1 shows the tables for truck VMT and MAF calculations and Appendix E.2 shows the plots of MAF versus sample size for all functional classes.

Table 4.6 MAF calculated using the ASL Method

No	Roadway Functional Classification	MAF	
		Multi Unit	Single Unit
1	Interstate Urban	0.77	0.71
2	Interstate Rural	0.87	0.94
3	Freeway and Expressway	0.68	0.57
4	Other Principal Arterial Urban	0.65	0.65
5	Other Principal Arterial Rural	0.94	0.91
6	Minor Arterial Rural	0.91	0.87
7	Major Collector Rural	0.88	0.87
8	Minor Arterial Urban	0.61	0.63

4.6.3 MAF for Interstate Urban Highways: ATP Method

The MAF was also developed using the average truck percentage (ATP) method. The ATP can be computed as a simple arithmetic average, a weighted average by section length, or a weighted average by ADT (see Equations (5a), (5b), and (5c)). For a given functional class, the ATP values for each volume group are calculated using the three approaches. For instance, for Interstate Urban Highways that has 14 volume groups, 42 ATP values were calculated (14 for each approach).

For all functional classes, it is found that the MAF calculated using the simple arithmetic average approach is not very different than the one calculated using the weighted average by ADT. This is expected because the volume groups have a narrow range of ADT. Thus, it is sufficient to use the arithmetic average approach when ADT is divided into volume groups. Figure 4.3 shows the MAF for Multi Unit trucks on Interstate Urban Highways. Note that for Multi Unit trucks the three approaches provide fairly similar MAF. For Single Unit trucks as shown in Figure 4.4, however, the MAF calculated using the weighted average by section length is much less than those calculated by the other two. In other words, for Single Unit trucks using the ATP from the weighted average section length approach yields less accuracy in truck VMT estimation.

Figure 4.3 Comparison of MAF (ATP Method) for Multi Unit Trucks: Interstate Urban Highways

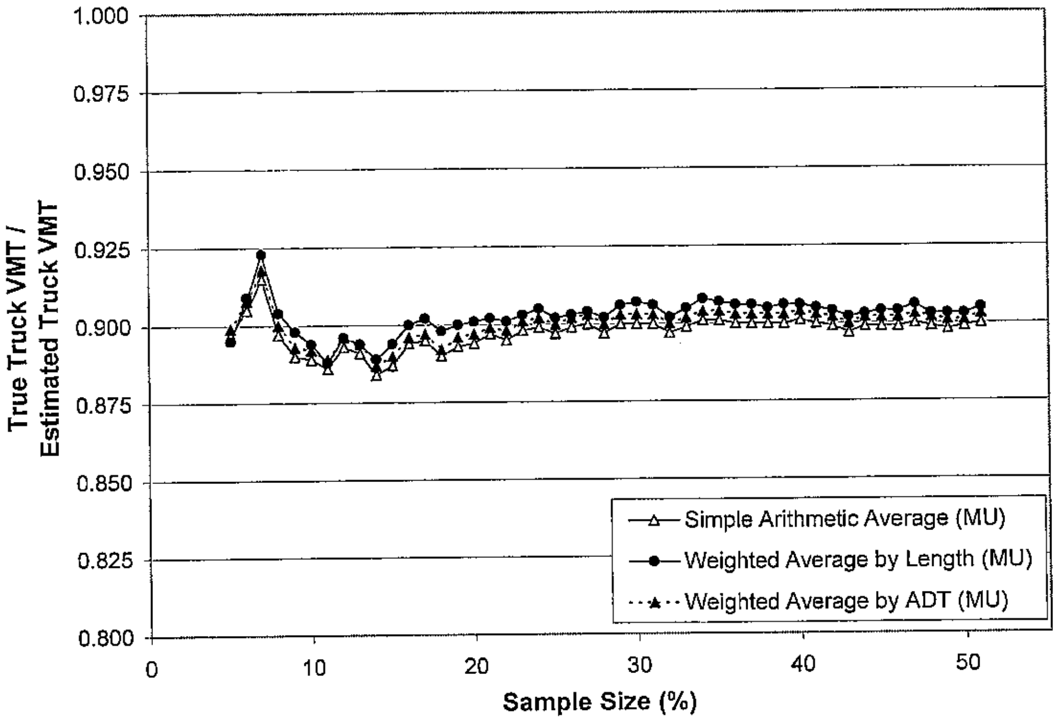
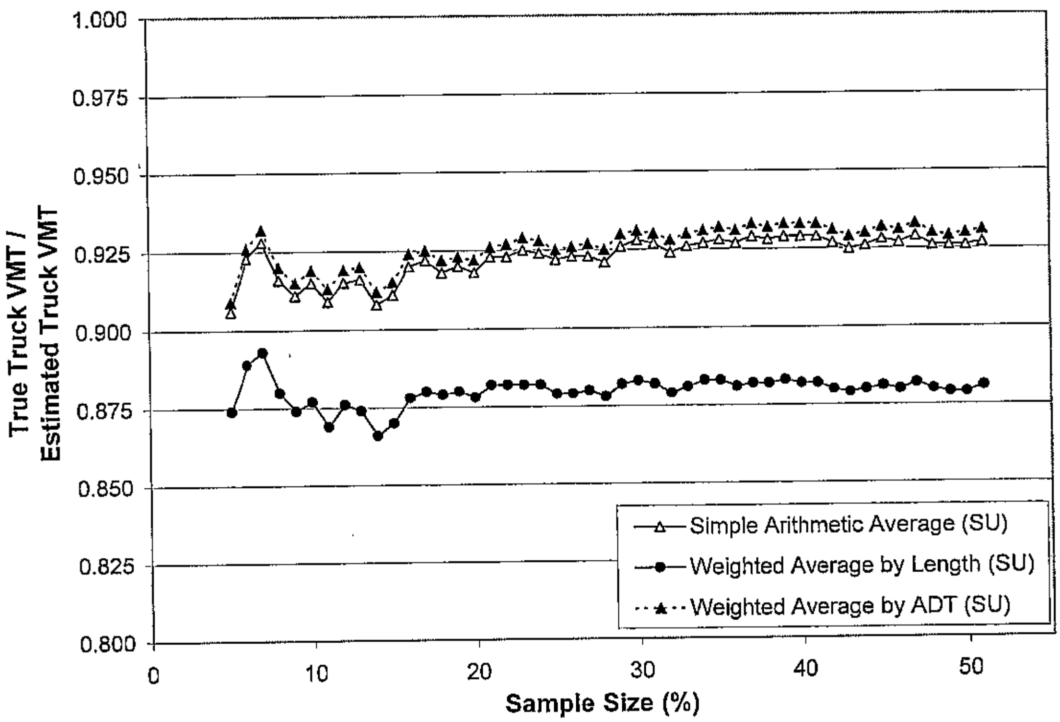


Figure 4.4 Comparison of MAF (ATP Method) for Single Unit Trucks: Interstate Urban Highways



Appendix F.1 shows a comparison of MAF using three different truck percentage calculation approaches for other functional classes. The simple arithmetic average and the weighted average by ADT approaches, consistently provide similar results convincing that the simple arithmetic average is sufficient. In addition, the weighted average by section length approach generally does not improve the accuracy of truck VMT estimation. Therefore, the simple arithmetic average approach to find ATP is considered sufficiently accurate in estimating truck VMT.

Figure 4.5 gives the MAF using a simple arithmetic average approach for the two truck types on Interstate Urban Highways, and Figure 4.6 shows that for Interstate Rural Highways. It can be seen that when sample size was small, less than about 15 %, the MAF fluctuated, but as the sample size increased the MAF became more stable.

4.6.4 MAF for Other Functional Classes: ATP Method

The MAF were developed using the ATP method for all functional classes. The results are shown in Appendix F.2 and Appendix F.3. The summary of MAF is provided in Table 4.7 when the sample size is assumed to be 15 %.

Table 4.7 MAF calculated using the ATP method

No	Roadway Functional Classification	MAF	
		Multi Unit	Single Unit
1	Interstate Urban	0.90	0.93
2	Interstate Rural	0.88	0.94
3	Freeway and Expressway	0.70	0.62
4	Other Principal Arterial Urban	0.58	0.58
5	Other Principal Arterial Rural	1.00	0.99
6	Minor Arterial Rural	1.03	1.01
7	Major Collector Rural	0.98	0.98
8	Minor Arterial Urban	0.55	0.57

4.6.5 The Use of Truck VMT MAF

The MAF provides a quantitative measure of the deviation of the estimated truck VMT from the true values. To reduce (eliminate) the deviation, the MAF is used to adjust the estimated truck VMT values. For a given functional class and truck VMT method (ASL or ATP), when the MAF is larger than one, then the calculated truck VMT underestimates the true truck VMT value. Similarly, if the MAF is less than one, the calculated truck VMT overestimates the true value. The calculated truck VMT needs to be adjusted by multiplying the calculated truck VMT by the MAF factor.

Figure 4.5 MAF (ATP Method) versus Sample Size: Interstate Urban Highways

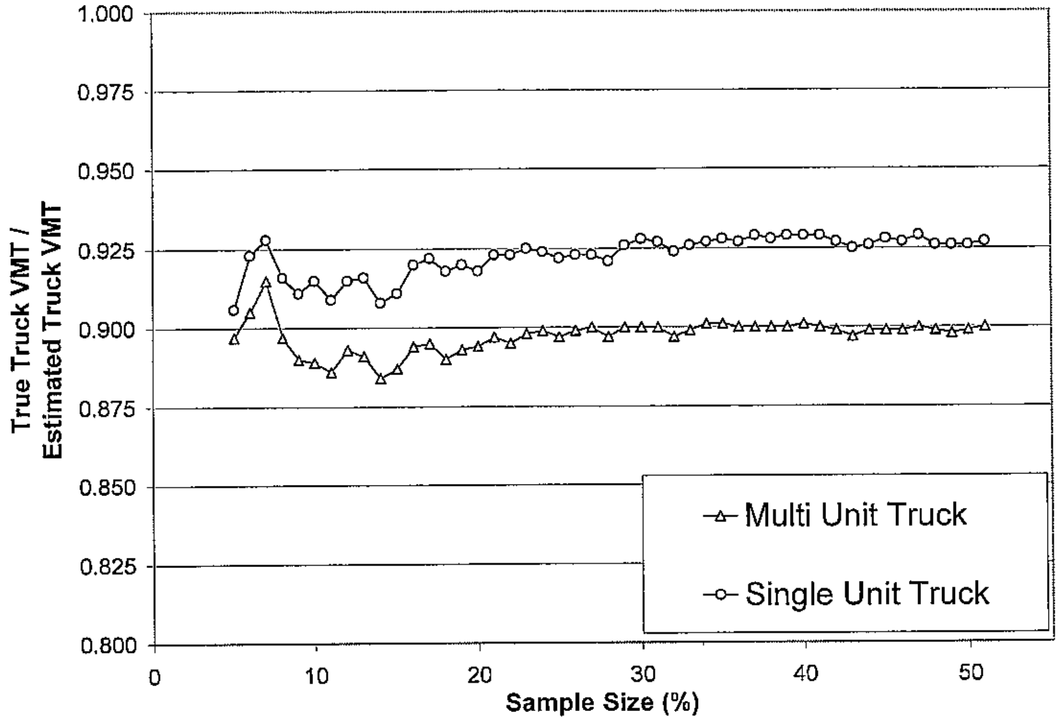
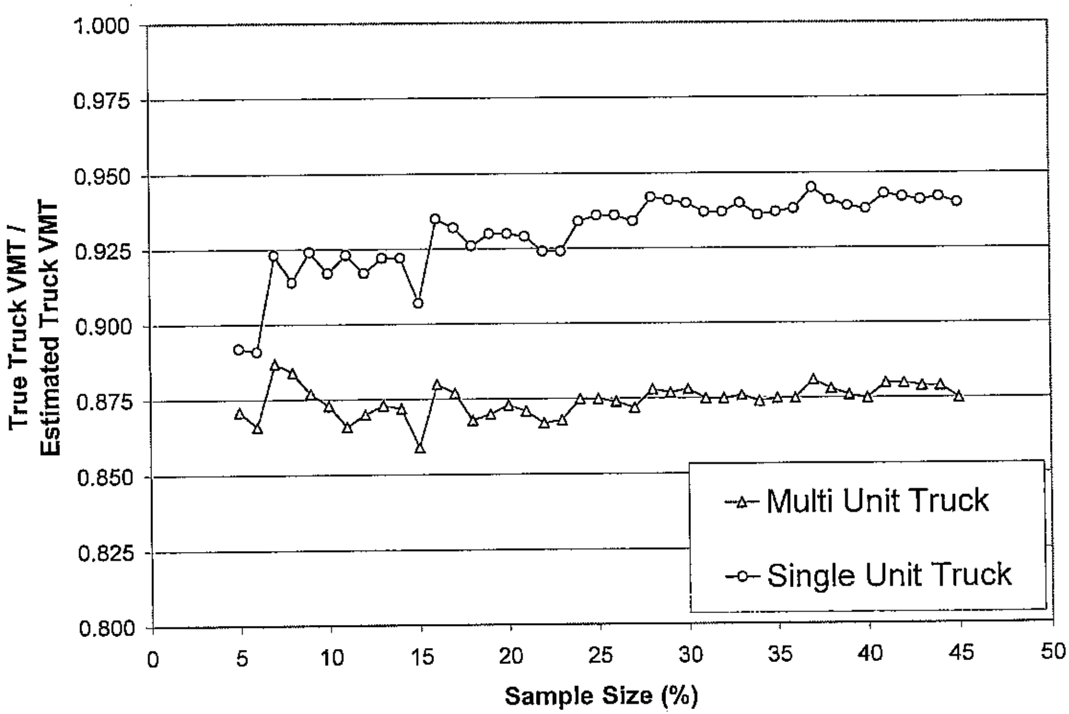


Figure 4.6 MAF (ATP Method) versus Sample Size: Interstate Rural Highways



To illustrate, suppose that a 25 % sample is taken from the roadway section on Interstate Urban Highways. Using the ASL method, the estimated Multi Unit truck VMT is 2,015 millions. According to Figure 4.1, the corresponding MAF for Multi Unit truck is 0.77 or 23 % overestimation. The calculated truck VMT is adjusted by multiplying it with the truck VMT Sample Factor, 0.77. Thus, the truck VMT becomes (2,015)(0.77)=1,552 millions. If the ATP method is used, the calculated truck VMT is 1,730 millions, and the MAF is 0.9 (see Figure 4.5). The adjusted truck VMT is (1,730)(0.9)=1,557 millions.

4.7 Summary of the Proposed Methodology

The current IDOT method for truck VMT calculation, overestimated VMT for multi-unit trucks on all eight functional classes except on the minor urban arterials. The overestimation for multi-unit trucks was 11.5 % and the range was from –10 % to +44 %. For single-unit trucks, the current method overestimated in five (interstate urban, freeway and expressway, other principal arterial rural, minor arterial rural, and major collector rural) and underestimated in three (interstate rural, other principal arterial urban, and minor arterial urban) functional classes. The range of under/overestimation was from -6 % to +35 %, but overall it was close to zero because the overestimates cancelled out the underestimates.

To calculate truck VMT more accurately, this study proposed a new methodology that stratifies the marked routes in Illinois not only by roadway functional class but also by traffic volume. For a given roadway functional class, the stratification by traffic volume is made such that the total section length in each volume group is approximately the same. The number of sections to be sampled from each volume group is proportional to the contribution of the volume group to the total VMT or truck VMT at the functional class level.

To obtain AADTT, the truck data obtained from short-term counts should be adjusted for temporal variation. Three categories (passenger cars and light trucks, single-units and conventional buses, combination vehicles) should be sufficient for Illinois. Developing the adjustment factors was beyond the scope of this study, so the study suggested how the factors should be computed from truck data collected at continuous classification count stations. The truck adjustment factors may be calculated using two different approaches as suggested in TMG 2000. The first approach, "specific roadway", requires a short-term truck data collected on a specific roadway be adjusted using factors from the nearest continuous classification counter on that roadway. The second approach requires that roadway sections be grouped according to roadway functional class and truck travel patterns. Using truck data collected from a set of continuous classification counters, "group truck factors" are then developed for that roadway. Since detailed truck travel pattern for Illinois is not available, roadway grouping based on the traffic volume is suggested. Thus, the adjustment factors should be calculated for each volume group, using either the "specific roadway" or "group truck factor" approaches, or a combination of the two. Specific road truck factors may be developed for the most important roads in the state, and group truck factors may be created for roadways without continuous classification count stations. Further studies are needed to determine which approach would be more suitable for Illinois conditions.

To calculate truck VMT for a roadway section, one can directly multiply the truck volume by the section length. This direct method can be used only when both truck volume and roadway section length data are known for an individual roadway section. When a complete set of information is not available, indirect methods are used to estimate truck VMT. This study proposed two different indirect methods to estimate truck VMT: average truck percentage (ATP) and average section length (ASL).

In the ATP method, truck VMT is calculated by multiplying the average truck percentage for a group of roadway sections by the total VMT of that group. The grouping of roadway sections is based on the functional class and traffic volume. The truck percentage for a given roadway section is the ratio of truck volume to the total traffic volume on that section. This method requires information on total traffic volume, truck volume, and total length of the sampled roadway sections. The idea for ATP method is similar to the current procedure IDOT uses (the HPMS method), but calculates truck VMT at volume group levels.

Three approaches to calculate the average truck percentages were examined. The first approach found the arithmetic average of truck percentages for all roadway sections that belonged to a volume group. The arithmetic average approach considered each section equally important regardless of the length of the section. The second approach found the average truck percentage weighted by the roadway section length. The second approach considered the section length, but not specifically the traffic volume on that section. The third approach found the average truck percentage weighted by traffic volume of each section. The third approach yields an average truck percentage that is the ratio of total truck volume to total volume of all vehicles for a given volume group. It is recommended to use the arithmetic approach because of its simplicity and sufficient accuracy.

The second method, ASL, uses the average section length. First, the total truck volume for the sampled sections is calculated. Then, the total truck volume is multiplied by the average roadway section length. To find the average roadway section length three approaches were examined: the average section length at roadway functional class, at sample, and at volume group levels. The average section length at roadway functional class level is easy to compute and it is simply the ratio of total roadway length to the total number of roadway sections in that functional class. The average section lengths for the sample and volume levels may not readily be available at the sampling time, so these approaches were not used in this study.

To obtain accurate truck VMT estimation, highways should be grouped into roadway functional class by the area type (urban and rural) and traffic volume level. For the marked routes eight functional classes are suggested: interstate urban, interstate rural, freeway and expressway, other principal urban arterial, other principal rural arterial, minor rural arterial, major rural collector, and minor urban arterial. The traffic volume levels should be selected such that the total length of roadway sections is approximately equally distributed among the volume groups. It is suggested that interstate highway systems be grouped into 14 volume groups, freeway and expressway systems into seven volume groups, other principal arterials into 16 volume groups, minor rural arterials into 20 volume groups, major rural collectors into 15 volume groups, and minor urban arterials into 10 volume groups.

Sample size influences the accuracy of truck VMT estimation and the decision on sample size must consider the error level that is acceptable. The study looked at the likely error, expressed as MAF, for each possible sample size. It is recommended to use the minimum sample size that yields more stable MAF. It is recommended to use the following sample sizes for different classes of roadways.

No	Roadway Functional Class	Sample Size (%)	No. of Sections Sampled	Total No. of Sections
1	Interstate Urban	16	158	986
2	Interstate Rural	16	73	451
3	Freeway and Expressway	12	10	78
4	Other Principal Arterial Urban	8	277	3,462
5	Other Principal Arterial Rural	10	143	1,435
6	Minor Arterial Rural	10	254	2,535
7	Major Collector Rural	11	74	672
8	Minor Arterial Urban	9	46	511
	Total		1,035	10,130

These roadway sections should be distributed among the volume groups. This study proposes two different ways to distribute the sample size. The first approach allows the sample distribution to be proportional to the total VMT distribution among volume groups. Thus, a greater number of sampled sections are taken from volume groups with a larger contribution to the total VMT. Instead of using the total VMT distribution, the second approach uses the truck

VMT distribution as the basis for distributing sampled sections. When historical data on truck VMT are available, the study verified that the second approach would provide better results. Furthermore, within a volume group, the sampled sections can be randomly selected from the sections that are in that volume group. The random selection can be replaced with more systematic selection if desired.

The ATP method should be used when the average truck percentages and the total VMT by volume groups are available. When the ATP method is used, a simple arithmetic average of truck percentages should be used. The ASL method should be used when the information required for ATP is not available or it is considered not reliable. This method only requires truck volume information by volume group. It is suggested to use the average section length at functional class level.

Once the truck VMT for the sampled sections is calculated, it should be expanded to obtain truck VMT on that highway functional class. The ideal expansion factor should consider the roadway lengths and volumes in that functional class and the sampled sections. However, finding this ideal expansion factor is not practical with less-than-complete-set of data that is available at the time of sampling. Thus, it is suggested to use the ratio of the number of total roadway sections in the functional class to the number of sampled sections from that functional class as the expansion factor.

The estimated truck VMT, using ATP and ASL methods, should further be adjusted by applying the methodology adjustment factors (MAF). The MAF is used because the ATP and ASL are indirect methods. A set of MAFs was developed for different roadway functional classes and truck types (single-unit and multi-unit trucks).

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Truck Data Collection

Over two-thirds of state DOTs, over half of the MPOs, and about one-fifth of the vendors/producers returned the survey. To compute truck VMT, most state DOTs responding to the survey collect traffic data by their staff. Several state DOTs use traffic counts and other sources in computing truck VMT. The majority of state DOTs collect data for the FHWA's 13 categories (F-13 scheme), but three state DOTs use fewer categories. Truck data are collected using machine classifiers unless certain conditions, such as congested highways, would demand collecting the data manually. The majority of DOTs use the number of axles and axle spacing to classify vehicles. A few DOTs use other variables such as vehicle length and weight.

The majority of state DOTs collect short-term vehicle classification data. The number of 24-hour or less classification stations ranged from 0 to 42 stations per 1,000 miles of total highway system. For short-term classifications, most state DOTs use portable devices with pneumatic road tubes, and some use the combination of the tubes with other sensors, such as loop detectors and piezoelectric and fiber optic sensors. Peek 1000/2000 and Peek 241 with a variety of sensor technologies dominate the market of portable classification devices. Illinois DOT uses Peek 241 and Hi-Star NC-97 devices in its vehicle classification program and prefers the Hi-Star NC-97 because of ease of installation and desirable performance. For continuous classifications, the majority of DOTs use permanent devices with loop detectors and piezoelectric sensors. The devices manufactured by Peek Traffic and Diamond Traffic Products are used by a considerable number of state DOTs.

The State DOTs used a variety of procedures to adjust truck data collected from the short-term classification counts. Most state DOTs develop their adjustment factors from continuous volume counts and use them for adjusting total volume and truck volume. Some state DOTs use adjustment factors for cars that are different than those for trucks.

5.2 Proposed Methodology To Estimate Truck VMT

The current IDOT method for truck VMT calculation overestimated VMT for multi-unit trucks on all eight functional classes except on the minor urban arterials. The overestimation for multi-unit trucks was 11.5 % and it ranged from –10 % to +44 %. For single-unit trucks, the current method overestimated in five (interstate urban, freeway and expressway, other principal arterial rural, minor arterial rural, and major collector rural) and underestimated in three (interstate rural, other principal arterial urban, and minor arterial urban) functional classes. The range of under/overestimation was from -6 % to +35 %, but overall it was close to zero because the overestimates cancelled out the underestimates.

To obtain AADTT, the truck data obtained from the short-term counts should be adjusted for temporal variation. Three vehicle categories (passenger cars and light trucks, single-units and conventional buses, combination vehicles) should be sufficient for Illinois. Developing the adjustment factors was beyond the scope of this study. The study suggested that the adjustment factors for single-unit and multi-unit trucks be calculated for each volume group. For the most important roads the "specific roadway" truck factors and for the remaining roads the "group truck factors" should be developed using data collected at continuous classification count stations. Further studies are needed to determine which approach would be more suitable for Illinois conditions.

To calculate truck VMT more accurately, this study proposed to stratify the marked routes in Illinois not only by roadway functional class but also by traffic volume. For a given roadway functional class, the stratification by traffic volume is made such that the total section length in each volume group is approximately equal. It is recommended to divide the marked routes in Illinois into eight functional classes and each class be divided into a number of volume groups. The functional classes are: interstate urban, interstate rural, freeway and expressway, other principal urban arterial, other principal rural arterial, minor rural arterial, major rural collector, and minor urban arterial. The traffic volume groups should be selected such that the total length of roadway sections is approximately equally distributed among the volume groups. The number of volume groups depends on the roadway functional class and the suggested numbers are: 14 groups for interstate urban, 14 for interstate rural, 7 for freeway/expressway, 16 for other principal urban arterial, 16 for other principal rural arterial, 20 for minor rural arterial, 15 for major rural collectors, and 10 for minor urban arterial.

This study proposed two different ways to distribute the sample size among the volume groups. The first approach allows the sample distribution to be proportional to the total VMT distribution among volume groups. Thus, a greater number of sampled sections are taken from volume groups with a larger contribution to the total VMT. The second approach uses the truck VMT distribution as the basis for distributing sampled sections. When historical data on truck VMT are available, the study verified that the second approach would provide better results. Furthermore, within a volume group, the sampled sections can be randomly selected from the sections that are in that volume group. The random selection can be replaced with more systematic selection if desired.

This study proposed two different methods for computing truck VMT: the Average Truck Percentage (ATP) and the Average Section Length (ASL). In the ATP method, truck VMT is calculated by multiplying the average truck percentage for a group of roadways by the total VMT of that group. The grouping of the roadways is based on the functional classes and traffic volume groups. It is recommended to use the simple arithmetic average of tuck percentages for each group. The second method (ASL) requires the information on the total truck volume for each roadway group and the average section length of the group. It was recommended to use the average section length at the roadway functional class level. The ATP method should be used when the average truck percentages and the total VMT by volume groups are available. The ASL method should be used when the information required for ATP is not available or it is considered not reliable.

Once the truck VMT for the sampled sections is calculated, it should be expanded to obtain the truck VMT on that highway functional class. It is suggested to use the ratio of the number of total roadway sections in the functional class to the number of sampled sections from that functional class as the expansion factor. The estimated truck VMT should be further adjusted by applying the methodology adjustment factors (MAF). The MAF is used because the ATP and ASL are indirect methods. A set of MAFs was developed for different roadway functional classes and truck types (single-unit and multi-unit trucks).

5.3 Recommendations

Truck VMT data are used for various purposes and an accurate estimation of truck VMT is essential. Recently, IDOT collects vehicle classification data for three categories (passenger cars, multi-unit, and single-unit trucks) at about 10,000 sections biennially. Vehicles are classified according to their length. This data collection program provides IDOT with a very rich database for truck classification and VMT calculation. This study recommends to:

1. Evaluate the accuracy and efficiency of truck VMT calculation using the recent data.
2. Investigate the merits of length-based vehicle classifications. The investigation should cover the quality and quantity of the data collected, safety issues, and costs.
3. Compare the proposed methodology with the recent data that IDOT has been collecting using the new traffic counting and classification devices.
4. Verify the results of the proposed methodology, which is based on the 1996 data, using the data for recent years.

5. Develop a user's manual for the proposed method because this report does not serve as a manual with step-by-step instruction.
6. Develop adjustment factors for multi-unit and single-unit trucks from the continuous classification count station. The factor should consider the functional classes and volume groups. In addition, it is necessary for IDOT to create database that specifically identify the characteristics of truck travel patterns on the marked routes, for example to identify major truck routes, local truck routes, etc.

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Appendix A

Vehicle Classification Equipment

Appendix A

Table A.1 shows several types of axle based classification equipment. These include TC/C 500, TC/C 540 from International Road Dynamics Inc. (IRD), IVS 2000 from International Development Corporation, MSC 3000 and 4000 from Mitron System Corporation, and Unicorn and Phoenix from Diamond Traffic Product. Some of these instruments are discussed below.

The TC/C 540 provides time interval classification counts for up to eight lanes with any type of axle sensors, sixteen lanes with inductive loops, and vehicle classification for up to eight lanes of traffic. The operation of TC/C 540 supports four road tube sensors, from two to eight remote inputs, from four to eight piezoelectric inputs, from four to eight DYNAX ® sensors, and four, eight, twelve, or sixteen presence inductive loops. Several sensor configurations are possible including two axle sensors, two presence sensors, two axle sensors and one presence sensor, and two presence sensors and one axle sensor. This equipment can be installed as either a portable or permanent unit. The portable equipment including installation is estimated to cost $20,000 to 25,000, and the permanent equipment to be $ 30,000 to 35,000.

IVS-2000 model is an intelligent vehicle sensor consisting of an inductive loop vehicle classifier and speed sensor. It can classify vehicles into 23 categories, which consist is that 13 FHWA classes and 10 additional classes. The additional classes include towing trailers, auto carries, tractors, and small buses. It operates by one or two loops per lane and can automatically switchover from two-loop to one-loop operation when a failure is detected.

MSC 3000 is a portable classifier and records traffic volume, speed, and the number of axles. The classifier consists of a traffic recorder, memory pack, translator, and programmer. It operates using pneumatic road tubes or piezoelectric sensors (two-cannel supports). It can record the 13 FHWA scheme or other optional schemes. The new version of MSC is called MSC 4000 Scout and provides more input sensors including a 20-channel modular traffic recorder. Moreover, this version can be used as either a portable or permanent classifier (rack-mount) and supports all type of sensors including loops, piezoelectric, and road tubes.

The Diamond Traffic Product manufactures two classifiers, Unicorn and Phoenix. Unicorn classifies vehicles in one or two lane sections of highways. This unit supports two or four road-tube air switches (32 counts per seconds), two or four multiplexing presence-loop detectors, four remote contact closures, and four piezoelectric sensors. Phoenix, on the other hand, is a multi-lane time interval classifier. This unit can classify vehicles from one to eight lanes of highways. It supports four road tube sensors, two to eight remote inputs, four to sixteen presence inductive loops, and four to eight piezoelectric sensor inputs. Lane sensor configurations are loop-loop, loop-axle-loop, axle-axle, and axle-loop-axle. This unit can classify the 13 FHWA scheme as a default classification, or user defined vehicle classification up to 30 types. The Phoenix Rax is a 19″ rack mounted unit and is a permanent version of the standard portable unit installed in a cabinet in a field.

Table A.2 shows sensor based classification equipment. These include the peek ADR family and NC 97 Hi-Star from Nu-Metrics. The peek ADR family is a multi-lane classifier that can be operated either remotely via telemetry or directly in the field via a computer with appropriate software. The peek ADR 2000, a portable unit, supports up to 24 piezoelectric sensor inputs, 24 loop inputs, or a combination of the two. The ADR 3000, a rack-based permanent instrument, supports up to 64 piezoelectric sensor inputs, 64 loop inputs, 64 electrical contact closures, or a combination of the three. The ADR 4000 instrument uses an improved algorithm to measure length accurately and consistently at all speeds even in congestion and regardless of the vehicle's lateral position in relation to the sensor site. Moreover, tailgating vehicles can be identified and discriminated from towing vehicles in all conditions, including congestion. Two similar vehicles in adjacent lanes can be differentiated from one vehicle straddling two lanes.

The portable NC-97 Hi-Star classifiers are very popular instruments. The HI-STAR® features patented Vehicle Magnetic Imaging (VMI) technology that records the volume, speed, and length classification of vehicles, road surface temperature, wet/dry surface condition, vehicle presence, and roadway occupancy. This instrument can classify vehicle length up to 8 Categories.

Table A.2 shows various types of visual based classification equipment. These include Autoscope 2004 system, TAS2, and IDET 100. The Autoscope 2004 detection system, available from Econolite Products, Inc., is an image processor -- a box that contains the microprocessor-based CPU, specialized image processing boards and software to analyze video images. Using a mouse, "virtual detectors" are placed on the video image displayed on a monitor. Each detector represents a zone. For most practical applications, there is virtually no limit to the number of detection zones (100 or more). These detection zones are distributed among the cameras to meet the needs of traffic applications. Once the system is set up, a detection signal is generated each time a vehicle crosses these virtual detectors. The system processor analyzes the incoming video images to generate traffic data such as volume, speed, occupancy, headways, queue lengths, and vehicle classification.

Table A.2 shows classification equipment using various new sensor technologies. These include the SmarTek System Acoustic Sensor (SAS-1) and the Automatic Vehicle Classification System (AVC). The SmarTek System Acoustic Sensor-version 1 (SAS-1), for example, uses the acoustic signals of vehicles for classification. This system uses non-contact passive acoustic sensors mounted on roadside structures and provides traffic volume per lane, occupancy, average vehicle speed, and 3 classes of vehicles (car/van, light, and semi). The Automatic Vehicle Classification System (AVC) of Transport Data Systems classifies vehicles and detects the presence of vehicles using the input sensors of a multi-beam vertical light curtain and a high frequency CW Doppler radar. This system provides basic information of vehicles that is fed to a processing computer system for classification. Various vehicles are then defined according to the length of vehicles, the number and relative position of axles, maximum and average height as well as height variations of vehicles, and other distinguishable patterns in vehicles' lateral profiles.

Table A.1 Axle Sensor Based Vehicle Classifiers

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
1	PAT Traffic Control Corp.	AVC 100	Piezoelectric-Loop-Piezoelectric or Loop-piezoelectric-Loop	Vehicle classification: 6 lanes (piezo-loop-piezo), 4 lanes (loop-piezo-loop)		Remote data acquisition, Remote control and programming Old and new (metric) TMG format, ASCII output files (comma delineated)	
2	Computer Enterprise	CE 2002	Loop and IR detectors	Vehicle classification	Nail gun-protective cover. 8 lane installed: $ 32,000. One-lane: equipment $ 35,000 - Installation $ 500, not including sensors	Serial messages format	ME
3	International Road Dynamics Inc. (IRD)	IRD TCC-500	Loop-Axle Sensor-Loop (Permanent of portable)	Traffic counts, 13 FHWA classification, speed, and gap between vehicles	Installation time per lane is 5 minutes (portable), 3 hours (permanent). On (in) pavement. Option for sensor arrays. Equipment: 1-lane $1,200-2,500 4-lane $1,500-4,000 Installation: 1-lane $100 – 1,000 4-lane $150 - 5,000	Remote data acquisition, Remote control and programming. Other Than TMG	US and Canada
		IRD TCC-540	Loop-Axle Sensor-Loop: 4 tubes, 4-16 loops, 4-8 piezoelectric, 4 and 8 DYNAX® sensors. (Permanent and portable)	Traffic counts (16 lanes), Classification (8 lanes)	Equipmmt and installation cost on one lane of a 4-lane highway: $ 30,000 - 35,000 (permanent), and $ 20,000-30,000 (portable)	Remote data acquisition, TAM (Take Away Memory) card.	Permanent: AZ, HI, IN, NJ, MI, TX. Portable: Canada

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
4	Intersection Development Corporation	IVS-2000	single/dual Loop	Traffic counts, vehicle classification (23 categories), including 13 FHWA class, speed, and gap between vehicles	Permanent: In-pavement, installation time per lane is approx. 4 hrs. Equipment: $3,000 Installation: $750-$1500	Remote data acquisition IDC software format	
5	International Traffic Corporation	ITC	Piezoelectric (Permanent or portable)	Traffic counts, FHWA 13 classification, speed of vehicles			AL, FL, IA, IL, IN, VA
6	Mitron System Corporation	MSC 3000	Pneumatic Tube-piezoelectric	Traffic counts, FHWA 13 classification, speed of vehicles	Portable: installation time per lane is 8 minute. On-(in) pavement Equipment: $ 739	Text, SDF format	
7	Mitron System Corporation	MSC SCOUT	Inductive Loops, piezoelectric, and pneumatic road tube	Traffic counts, FHWA 13 classification, speed of vehicles	Installation time per lane is 1 minute., On-(in) pavement.	Remote data acquisition Remote control and programming. Old and new (metric) TMG format	

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
	Mitron System Corporation	POPPS	Piezoelectric	Traffic counts, FHWA 13 classification, speed of vehicles, and gap between vehicles	Portable: installation time per lane is 10 minute. On- pavement Equipment: $ 199		NJ
8	Diamond Traffic Products	UNICORN	Road Tube Piezoelectric, loop Switch Closure - (axle-axle) (axle-loop, axle) or (loop axle loop) (Permanent or poprtable)	Traffic counts, FHWA's 13 classification, Speed of vehicles, Gap between vehicles, 30 user defined categories	Portable, Permanent, On-pavement In-pavement Equipment: 1-lane $1,072	Remote data acquisition, Remote control and programming. Old TMG* format, New (metric) TMG* format.	AL, CT, OK, NY, NV, SD
9	Diamond Traffic Products	Phoenix	Pneumatic road tube, piezoelectric, and Loop. Closure (Axle-Axle) (Axle Loop Axle) (Loop Axle Loop) (Permanent or portable)	Traffic counts, FHWA's 13 classification, Speed of vehicles, Gap between vehicles, 30 user defined bins per type classification	Portable, Permanent, installation time per lane is 1 - 2 Hrs for perm., On-pavement, In-pavement Equipment: 1-lane $1,560 Installation: Depends on Sensors	Remote data acquisition, Remote control and programming. Old TMG* format, New (metric) TMG* format, Diamond.	FL, AL, NY, OK, SD, MI, NC, CT, NV, CA, WA, WY, MT, ID, KY, TN

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
10	AMP Sensors	Roadtrax BL	Piezoelectric polymer in a coaxial configuration	Vehicle classification	Installed in a concrete cutting saw that can cut a 3/4" wide slot in a single pass. Sensors cost $250 - $300 for 6' Class II to $1000 for 12' Class IInstallation varies		Throughout the US, Canada, Europe, South America, Asia, Africa, New Zealand and Australia
		Roadtrax BLC	Piezoelectric polymer in a coaxial configuration	Vehicle classification	Installed in a concrete cutting saw that can cut a 3/4" wide slot in a single pass. Sensors range from $350 for 6' Class II to $1100 for 12' Class I		Throughout the US, Canada, and Europe.
11	JAMAR	TRAX II	Pneumatic road tubes	Collect raw data for volume, class, speed & gap.	1 and 4 lane: $1,000 per counter & installation per lane	Format: TDF, TPF & TRF binary files, ASCII, PRN, TMG, DFL	AL, CA, GA, NH, NY, PA, TX, VT

(This table was created based on the Vehicle Detector Clearing House, University of New Mexico, http://www.nmsu.edu/~traffic)

Table A.2 Length Based Vehicle Classifiers and Other Technologies

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
1	Peek Traffic	ADR 2000	Weigh-in-motion system (permanent or portable)	Multi lane Traffic counts, FHWA's 13 vehicle classification, speed, and gap between vehicles	On (in) Pavament	Remote data acquisition, remote control and programming	AR, DE, MD
		ADR 3000	Weigh-in-motion system (permanent or portable)		On (in) Pavament, Overhead, Pole-mounted		AR, CA, FL, AL
		ADR 4000	Weigh-in-motion system				WI
2	PAT Traffic Control Corporation	DAW 100	Weigh-in-motion system (Low profile bending plates, piezo, loops): Loop-2or1 bending plate-loop; Loop-bending plate-loop-bending plate; piezo-loop-piezo-piezo; loop-piezo-loop	Weighs and vehicle classification, interface with AVI		Remote data acquisition, remote control and programming	
		DAW 190	Weigh-in-motion system (bending plates, piezo, loops): Loop-2or1 bending plate-loop; Loop-bending plate-loop-bending plate; piezo-loop-piezo-piezo; loop-piezo-loop			Remote data acquisition, remote control and programming	

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
3	Electronique Controle Mesure	HESTIA	Weigh-in-motion system: multi-processor, rack mounted piezo-electric system (permanent or portable)	Traffic counts, FHWA's 13 vehicle classification, speed, and gap between vehicles	In-pavement: Equipment: 1-lane ($12,850); 4-lane ($24,915); Installation: 1-lane ($ 5,000); 4-lane ($ 15,000)	Remote data acquisition, remote control and programming; Old TMG format, New (metric) TMG format, SHRP, spread sheet compatible	ID, DE, MA, RI, TX
4	International Road Dynamics Inc. (IRD)	IRD Model 200	Weigh-in-motion system: Loop - bending plate - Dynax Axle sensor - Loop	Traffic counts, FHWA's 13 vehicle classification, speed of vehicles	Permanent option for sensor arrays. Installation time per lane os 1 day per lane; Equipment: 1-lane ($ 23,000); 4-lane ($ 60,000); Installation: 1-lane ($8,000-10,000); 4-lane ($15,000 - 25,000)	Remote data acquisition, remote control and programming. 1992 TMG format, 1992 TMG (metric). Other: customized	Throughout US and Canada
		IRD Model 1060p	Weigh-in-motion system: Piezoelectric + Loops in a Loop-piezo-piezo-Loop (permanent)	Traffic counts, FHWA's 13 vehicle classification, speed of vehicles	Permanent, installation time per lane is day per lane. Permanent equipment: 1-lane $13,000 4-lane $21,000 Installation: 1-lane $5,000| 4-lane $10,000	Remote data acquisition, remote control and programming. 1992 TMG format, 1992 TMG (metric). Other: customized	Throughout US and Canada

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
	International Road Dynamics Inc. (IRD)	IRD Model 1070	Weigh-in-motion system: Piezoelectric + Loops in a Loop-piezo-piezo-Loop (portable)	Traffic counts, FHWA's 13 vehicle classification, speed of vehicles	Portable on-pavement, in-pavement, installation time per lane is 10 minutes. Portable equipment: 1-lane $11,000 4-lane $13,000 Installation: 1-lane $500 4-lane $700	Remote data acquisition, remote control and programming. 1992 TMG format, 1992 TMG (metric). Other: customized	TX
		IRD Model 5000	Weigh-in-motion system: Loops-Single Lead Cell Scale-Axle Sensor-Loop	Traffic counts, FHWA's 13 vehicle classification, speed of vehicles	Permanent In-pavement, Installation time per lane is 3 days/lane, Option for sensor arrays Equipment: 1-lane $50,000 4-lane $175,000 Installation: 1-lane $15000 - 20,000 4-lane $35,000	Remote data acquisition, Remote control and programming 1992 TMG* 1995 TMG* (metric) Other: customized	Throughout U.S. and Canada
5	International Trafic Corporation	TEL-WIM	Weigh-in-motion system (permanent or portable)	Traffic counts, Vehicle classification, 13 FHWA classes, Speed of vehicles, Gap between vehicles	Portable, Permanent, installation time per lane depends on sensors, On-pavement, In-pavement, Overhead, Pole-mounted, Option for sensor arrays	Remote data acquisition, Remote control and programming. Old TMG* format, New (metric) TMG* format Other: By User	OH, NY, NM, PR, VA

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
6	International Trafic Corporation	Rak-Tel	Weigh-in-motion system: Rack Mounted System, All Solid State, Low Power, IZVDC System	Traffic counts, 13 FHWA classification, Speed of vehicles, Gap between vehicles	Permanent, installation time per lane depends on sensors, On-pavement, In- pavement, Option for sensor arrays Equipment and installation costs vary.	Remote data acquisition, Remote control and programming Old TMG* format, New (metric) TMG* format Other: By User	AL
7	Econolite Control Products, Inc.	Autoscope 2004, ECP	Video-image processing system, available in one, two, and four-image sensor input model.	Traffic counts, Vehicle classification, Speed of vehicles, Gap between vehicles	Overhead, Pole-mounted 1-4 lane: $12,350. Installation: varies with application	Remote data acquisition, Remote control and programming Non-TMG format	AZ, CA, CO, FL, IL, IN, MD, MI, MN, MO, NC, NJ, NM, NV, OR, TX, WA, WI
		Autoscope 2004, ISS	Video image sensor	Traffic counts, FHWA's 13 classification, Speed of vehicles	Permanent Overhead 4-lane: $21,000. Installation: $3,000 - $4,500	Remote data acquisition, Remote control and programming	CA, IN, GA, IL, NJ, MI
8	Nu-Metrics	Groundhog G-2WX	Vehicle magnetic imaging	Traffic counts, Vehicle classifiaction, Speed	Core drill, epoxy Equipment: $1800 - $7200 (1 and 4 lane) 8-lane installed: $14,400	915 ISM Spread Spectrum	CO, FL, NC
		NC-97 Hi-Star	Vehicle magnetic imaging	Traffic counts, Vehicle classifiaction, Speed	Equipment: 1 lane $975 4 lane $3900 8-lane installed $7800		AL, CA, AZ, CO, FL, IL, LA, OA, MO, NC, NV, PA

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
9	Computer Recognition Systems, Inc.	TAS2	Video Image Processing Systems Video: RS-170, CCIR, NTSC, PAL (Permanent or portable)	Traffic counts, Vehicle Classification, Speed of vehicles, Gap Between vehicles	Permanent Portable Overhead Pole-mounted Equipment: 1-lane and 4-lane $17,000 - $25,000	Remote data acquisition, Remote control and programming Non-TMG format	CA, MA
10	Sumitomo Electric Industries, Ltd.	IDET-100	Video image sensor				
11	International Road Dynamics Inc. (IRD)	IRD SmartSonic	Acoustic Sensor (Permanent and portable)	Traffic counts, FHWA's 13 classification, Speed of vehicles, Lane occupancy	Installation time per lane is 1 hour, overhead, Pole-mounted Equipment: 1-lane $ 1,500 4-lane $ 6,,000 Installation: 1-lane $500 4-lane $1,000	Remote data acquisition, Remote control and programming Hexadecimal format	AZ, MA, VA, TX
12	SmartTek Systems	SAS-1 Acoustic Sensor	Acoustic Sensor (Permanent and portable)	Vehicle classifiaction (3 classes: car/van, light truck, and semi)	Equipment and installation costs $ 3500 for 4 to 5 lanes		AZ, NC, NY, OH, VA
13	EIS Electrconic Intergrated System Inc.	RTMS Model X2	Multi-zone microwave radar presence detector/sensor	Traffic counts, Vehicle classification. Speed of vehicles, and Gap between vehicles	Portable and permanent Pole-mounted, Installation time per lane is 5 minutes Equipment: installed 1-lane: $1,000 (based on 4 lanes per unit), installed 8-lane $4,000	Remote data acquisition, Remote control and programming Other special-ASCII format	CA, GA, NJ, NY, OH, TX, WI

No.	Manufacturer	Equipment	Sensor Technology	Capabilities	Method and Cost of Installation	Telemetry and Data Output Format	States Currently Using
14	Scientific Technologies Inc.	Vehicle Scanner VS 6000	Inrared transmitter and controller	Vehicle classification, vehicle gaps	Permanent Pole-mounted. Option for sensor arrays. Equipment: 1-lane $ 7,200	Format: Non TMG proprietary RS-232-422 Relay + 8 bit parallel	CA, FL, KS, NJ, NY, ME, PA
15	International Traffic Corporation	SpeedStat	Laser beam	Traffic counts, Vehicle Classification, Speed of vehicles		Speed statistic format	AL, IA, IL, OH, MN, WI
16	Sumitomo Electric Industries, Ltd.	SDU-420	Ultrasonic transmitter and receiver	Traffic counts, Vehicle Classification, Speed of vehicles	Permanent, installation time per lane is 2 hours, Overhead, Pole-mounted Equipment: 1-lane $ 1,900 4-lane $ 7,600		
17	Transport Data Systems	Doppler Radar Based Automatic Vehicle Classifier	Dopler Radar	Traffic counts, Cehicle Classificaiton	Cost per installed lane $ 20,000		NJ

(This table was created based on the Vehicle Detector Clearing House, University of New Mexico, http://www.nmsu.edu/~traffic)

Appendix B
Copy of the Surveys and Interview Questions

SURVEY OF STATE DOTs ON EQUIPMENT, TECHNOLOGIES AND METHODOLOGIES FOR DETERMINING TRUCK VEHICLE MILES TRAVELED (VMT)

The University of Illinois at Urbana-Champaign is conducting this study for the Illinois Department of Transportation (DOT) to gather information on sources of truck VMT data, equipment and technologies used in truck classification, and methodologies for determining truck VMT. For any questions or comments, please contact Professor Ray Benekohal (217-244-6288, rbenekoh@uiuc.edu or Rob Robinson of Illinois DOT (217-785-2353, email robinsonre@nt.dot.state.il.us).

Thank you very much for your cooperation

Part I: General

1. Would you like to get a summary of this survey?
   a. Yes   b. No

2. Please provide the following Information:

   Your Name: ____________________
   Title: ____________________
   Address: ____________________
   ____
   ____
   Phone/ Fax: ____________________
   E-mail: ____________________

3. Is your truck classification data collected in-house, by contractors, or both?
   a. Almost all of it is collected by DOT staff
   b. Mostly by DOT, but some by contractor staff
   c. Almost all of it is collected by contractor staff
   d. Mostly by contractor, but some with DOT staff
   e. Other (specify) ____________________

4. Do you have a written procedure to collect truck classification data?
   a. Yes, (please include a copy.)
   b. No

5. To compute truck VMT, do you obtain truck classification data from any other agency within your state?
   a. Yes, (please provide name of the agency ____________________)
   b. No

6. To compute truck VMT which sources, other than truck volume, do you use? (Circle all that apply.)
   a. State Fuel Tax Report
   b. Truck Inventory and Use Survey (TIUS)
   c. Nationwide Truck Activity and Commodity Survey (NTACS)
   d. National Truck Trip Information Survey (NTTIS)
   e. International Registration Plan (IRP)
   f. Weigh station data
   g. Other (specify)____________________
   h. None

7. What variables do you use for automatic truck classification? (Circle all that apply.)
   a. Number of axles and axle spacing
   b. Total length of vehicle
   c. Axle spacing and length
   d. Axle spacing and weight
   e. Axle spacing, weight, and length
   f. Other (please specify) ____________________

Part II: Sample Size and Location for Truck Classification Counts

8. Every year, approximately in how many locations do you collect short-term (24-hours or less) truck classification data for each of the following road systems?

Road system	Number of locations
a. Interstate highways	_____
b. Arterials	_____
c. Collectors	_____
d. Local roads/streets	_____

9. What sources do you utilize to determine the number of locations (sample size) for truck classification? (Circle all that apply.)

   a. FHWA Traffic Monitoring Guide (TMG)
   b. AASHTO's guidelines
   c. Both FHWA and AASHTO guidelines
   d. Other (specify)

10. How do you determine the locations where truck classifications are conducted? (Circle all that apply.)

    a. Using FHWA Traffic Monitoring Guide (TMG)
    b. Using AASHTO's guidelines
    c. Using Both FHWA and AASHTO guidelines
    d. Other (specify)

11. What is the approximate number of permanent classification stations your agency maintains for each of the following road systems?

Road systems	number of stations
a. Interstates	__________
b. Arterials	__________
c. Collectors	__________
d. Local roads/streets	__________
e. Other (please specify)	__________

Part III: Highway Performance Monitoring System (HPMS) data

12. Approximately, how many of the permanent classification stations are on the HPMS sample sections? _________ stations

13. Annually, on how many HPMS sample sections do you collect short-term (48 hours) truck classification data? ________sections

Part IV: Field Data Collection for truck VMT

14. For how many truck categories do you collect classification data?

    a. FHWA scheme F-13 categories
    b. Other, (please list categories and define)______________________________

15. On congested roads, do you use any specific equipment and/or procedures to collect truck classification data?

    a. Yes, (please describe briefly or attach a copy of your procedure.)
    ____

    b. No

16. Annually, on how many non-HPMS sample sections do you collect short-term truck classification data?

    a. 12 hour................ _______stations
    b. 24 hour................ _______stations
    c. 48 hour................ _______stations
    d. Other (specify) .... _______stations

17. What is the classification count cycle for non-HPMS sections? ________ months

18. Do you perform manual truck classification counts to compute truck VMT?

    a. Yes   b. No

19. If "Yes" to previous question, what is the typical duration of the data collection period?
    a. 12 hour
    b. 24 hour
    c. 48 hour
    d. Other (specify) ____________

Part V: Data Collection Equipment for Truck VMT

20. Do you use the following equipment/technology for truck classification? If yes, how satisfied are you with it?

0= No opinion,
1= Very *unsatisfied*,
2= Somewhat *unsatisfied*,
3= Somewhat satisfied,
4= Very satisfied.

	Use it ?			(IF YES): How satisfied?				
Equipment or Technology	Yes	No	Don't know	Very *unsatisfied*	Somewhat *unsatisfied*	Somewhat satisfied	Very satisfied	No opinion
Road tube	__	__	__	1	2	3	4	0
Magnetic imaging	__	__	__	1	2	3	4	0
Electrical contact closure	__	__	__	1	2	3	4	0
Loop detector only	__	__	__	1	2	3	4	0
Loop detector plus axle sensors	__	__	__	1	2	3	4	0
Video image	__	__	__	1	2	3	4	0
Photoelectric sensor	__	__	__	1	2	3	4	0
Fiber optic	__	__	__	1	2	3	4	0
Laser/Lider	__	__	__	1	2	3	4	0
Acoustic	__	__	__	1	2	3	4	0
Microwave	__	__	__	1	2	3	4	0
Infrared	__	__	__	1	2	3	4	0
Ultrasonic	__	__	__	1	2	3	4	0
Radio Wave	__	__	__	1	2	3	4	0
WIM device	__	__	__	1	2	3	4	0
Other (specify)	__	__	__	1	2	3	4	0

21. Please briefly describe the main problem(s) you have had with the equipment/technology you specified in the previous question, and describe how do you dealt with them.

____
____
____
____
____
____
____
____
____
____
____

22. Do you use portable vehicle classification devices?

a. Yes (Which device and sensor type is used?)

Devices	Sensor Type
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________

b. No

23. Do you use permanent vehicle classification devices?

a. Yes (Which device and sensor type is used?)

Devices	Sensor Type
____________	____________
____________	____________
____________	____________
____________	____________
____________	____________

b. No

Part VI: Processing Field Data

24. For classification counts lasting less than 24 hours, do you apply adjustment factors to get daily volumes?

a. Yes, (please describe or attach a copy of your adjustment factors.)

____
____
____
____
____

b. No

25. Do you apply different expansion factors for trucks than cars when the count lasts less than 24 hours?

a. Yes, (please describe or attach a copy of your adjustment factors.)

____
____
____
____

b. No

26. For 24 hour or 48 hour classification counts, do you apply day-of-week adjustment factors?

   a. Yes, (please describe or attach a copy of your adjustment factors.)

   ____
   ____
   ____
   ____
   ____

   b. No

27. Do you apply seasonal adjustment factors for classification data?

   a. Yes, (please describe or attach a copy of your adjustment factors.)

   ____
   ____
   ____
   ____
   ____

   b. No

28. Do you use a different seasonal factor for trucks than cars?

   a. Yes, (please describe or attach a copy of your adjustment factors.)

   ____
   ____
   ____
   ____
   ____

   b. No

29. If you do not use seasonal adjustment factors, what compensation do you make for temporal variation of truck volume?

   ____
   ____

Part VII: Calculating and Reporting Truck VMT

30. Briefly describe or attach a copy of your procedures for computing Truck VMT.

   ____
   ____
   ____
   ____
   ____
   ____

31. What type of Truck VMT statistics does your agency publish? Please briefly describe the format or attach a copy.

____

____

____

____

____

____

32. Are the truck VMT statistics available on the Internet?

a. Yes, ______________________ (Please give internet address)

b. No

33. Do you have any additional comments/suggestions?

____

____

____

____

____

THANK YOU FOR YOUR PARTICIPATION IN THIS STUDY

Please return this survey and all attachments to:

Professor Ray Benekohal
1205 Newmark Civil Engineering Lab
University of Illinois
205 N. Mathews Ave
Urbana, IL 61801

SURVEY OF MPOs ON EQUIPMENT, TECHNOLOGIES AND METHODOLOGIES FOR DETERMINING TRUCK VEHICLE MILES TRAVELED (VMT)

The University of Illinois at Urbana-Champaign is conducting this study for the Illinois Department of Transportation (DOT) to gather information on sources of truck VMT data, equipment and technologies used in truck classification, and methodologies for determining truck VMT. For any questions or comments, please contact Professor Ray Benekohal (217-244-6288, rbenekoh@uiuc.edu *or Rob Robinson of Illinois DOT (217-785-2353, email robinsonre@nt.dot.state.il.us).*

Thank you very much for your cooperation

Part I: General

1. Would you like to get a summary of this survey?
   a. Yes b. No

2. Please provide the following Information:

   Your Name: ______________________
   Title: ______________________
   Address: ______________________
   ____
   ____
   Phone/ Fax: ______________________
   E-mail: ______________________

3. Does your organization collect truck classification data?
   a. Yes b. No (Please go to Question 21)

4. Is your truck classification data collected in-house, by contractors, or both?
   a. Almost all of it is collected by MPO staff
   b. Mostly by MPO, but some by contractor staff
   c. Almost all of it is collected by contractor staff
   d. Mostly by contractor, but some with MPO staff
   e. Other (specify) ______________________

5. Do you have a written procedure to collect truck classification data?
   a. Yes, (please include a copy.)
   b. No

6. What variables do you use for automatic truck classification? (Circle all that apply.)
   a. Number of axles and axle spacing
   b. Total length of vehicle
   c. Axle spacing and length
   d. Axle spacing and weight
   e. Axle spacing, weight, and length
   f. Other (please specify) ______________________

Part II: Sample Size and Location for Truck Classification Counts

7. Every year, approximately in how many locations do you collect <u>short-term</u> (24-hours or less) truck classification data for each of the following road systems?

Road system	Number of locations
a. Interstate highways	_____
b. Arterials	_____
c. Collectors	_____
d. Local roads/streets	_____

8. What sources do you utilize to determine the <u>number</u> of locations (sample size) for truck classification? (Circle all that apply.)
   a. FHWA Traffic Monitoring Guide (TMG)
   b. AASHTO's guidelines
   c. Both FHWA and AASHTO guidelines
   d. Other (specify)

9. How do you determine the <u>locations</u> where truck classifications are conducted? (Circle all that apply.)
   a. Using FHWA Traffic Monitoring Guide (TMG)
   b. Using AASHTO's guidelines
   c. Using Both FHWA and AASHTO guidelines
   d. Other (specify)

10. What is the approximate number of permanent classification stations your agency maintains for each of the following road systems?

Road systems	number of stations
a. Interstates	________
b. Arterials	________
c. Collectors	________
d. Local roads/streets	________
e. Other (please specify)	________

Part III: Field Data Collection for truck VMT

11. For how many truck categories do you collect classification data?
   a. FHWA scheme F-13 categories
   b. Other, (please list categories and define)____

12. On <u>congested</u> roads, do you use any specific equipment and/or procedures to collect truck classification data?
   a. Yes, (please describe briefly or attach a copy of your procedure.)
   ____

   b. No

13. Annually, on how many locations do you collect short-term truck classification data?

   a. 12 hour................ _______stations
   b. 24 hour................ _______stations
   c. 48 hour................ _______stations
   d. Other (specify) .... _______stations

18. Please briefly describe the main problem(s) you have had with the equipment/technology you specified in the previous question, and describe how do you dealt with them.

____
____
____
____
____
____
____
____
____
____
____

19. Do you use portable vehicle classification devices?

a. Yes (Which device and sensor type is used?)

Devices	Sensor Type
________	________
________	________
________	________
________	________
________	________

b. No

20. Do you use permanent vehicle classification devices?

a. Yes (Which device and sensor type is used?)

Devices	Sensor Type
________	________
________	________
________	________
________	________
________	________

b. No

Part V: Calculating Truck VMT

21. Does your organization compute truck VMT?

a. Yes

b. No (Please go to Question 31)

22. To compute truck VMT, do you obtain truck classification data from any other agency within your state?

   a. Yes, (please provide name of the agency ______________________________)
   b. No

23. Briefly describe or attach a copy of your procedures for computing Truck VMT.

____
____
____
____
____
____

24. For classification counts lasting less than 24 hours, do you apply adjustment factors to get daily volumes?

   a. Yes, (please describe or attach a copy of your adjustment factors.)

   ____
   ____
   ____
   ____
   ____

   b. No

25. Do you apply different expansion factors for trucks than cars when the count lasts less than 24 hours?

   a. Yes, (please describe or attach a copy of your adjustment factors.)

   ____
   ____
   ____
   ____

   b. No

26. For 24 hour or 48 hour classification counts, do you apply day-of-week adjustment factors?

   a. Yes, (please describe or attach a copy of your adjustment factors.)

   ____
   ____
   ____
   ____
   ____

   b. No

27. Do you apply seasonal adjustment factors for truck classification data?

a. Yes, (please describe or attach a copy of your adjustment factors.)

____
____
____
____
____

b. No

28. Do you use a different seasonal factor for trucks than cars?

a. Yes, (please describe or attach a copy of your adjustment factors.)

____
____
____
____
____

b. No

29. If you do not use seasonal adjustment factors, what compensation do you make for temporal variation of truck volume?

____
____

30. To compute truck VMT which sources, other than truck volume, do you use? (Circle all that apply.)

a. State Fuel Tax Report
b. Truck Inventory and Use Survey (TIUS)
c. Nationwide Truck Activity and Commodity Survey (NTACS)
d. National Truck Trip Information Survey (NTTIS)
e. International Registration Plan (IRP)
f. Weigh station data
g. Other (specify)______________________
h. None

Part VI: Utilizing Truck VMT

31. Do you use truck VMT statistics computed by another agency?

a. Yes, (please provide name of the agency ______________________)

b. No

32. What type of Truck VMT statistics does your agency publish? Please briefly describe the format or attach a copy.

____

33. Are the truck VMT statistics available on the Internet?

a. Yes, ______________________ (Please give internet address)

b. No

34. Do you have any additional comments/suggestions?

____

THANK YOU FOR YOUR PARTICIPATION IN THIS STUDY

Please return this survey and all attachments to:

Professor Ray Benekohal
1205 Newmark Civil Engineering Lab
University of Illinois
205 N. Mathews Ave
Urbana, IL 61801

INTERVIEW QUESTIONS FOR IDOT EMPLOYEES WHO USE TRUCK VMT DATA

1. What is the primary use of truck VMT data in your office?
2. Does your office use or plan on using truck VMT for other purposes? Please describe.
3. To what degree are you satisfied with the truck VMT data that is available to you?
4. Do you need any additional calculation (averaging, aggregation, etc.) of truck VMT data that is available to you before you use it? Please describe.
5. Where do you obtain truck Vehicle Mile Traveled (VMT) data?
6. If you have an access to different sources of truck VMT data, please specify them and how do you select the most suitable one for your purpose?
7. Do you validate or examine truck VMT data available to you for possible data error before you use it? Please describe.
8. What software and format do you use to store the VMT data you maintain?

INTERVIEW QUESTIONS FOR IDOT EMPLOYEES WHO COLLECT DATA FOR TRUCK VMT CALCULATION

1. In how many locations do you collect data (sample size)?
2. Why do you collect data in that many locations?
3. What is the frequency and duration of the data collection?
4. How do you select the sample locations and what criteria do you use for selection (i.e. highway functional classification, ADT, number of lanes, etc)?
5. How many truck types do you consider in data collection?
6. What equipment (including brand name) do you use to collect the data?
7. Do you have yearly data collection cost and labor involved?
8. In addition to current sources of data used for truck Vehicle Mile Traveled (VMT) calculation, do you consider other potential data sources? Please specify.
9. Do you have any suggestions or comments about the way in which truck traffic data currently collected?

INTERVIEW QUESTIONS FOR IDOT EMPLOYEES WHO CALCULATE /PUBLISH TRUCK VMT DATA

1. Does your office have or maintain a data file for truck VMT? Please provide a copy of data.
2. Please provide a copy of your procedure to calculate truck VMT.
3. What is the main purpose of calculating truck VMT? Please specify.
4. What sources of data do you use to calculate truck VMT? Please provide a copy of data sets you maintain.
5. How do you calculate truck VMT?
6. Do you use different sources of data to calculate VMT? Please explain.
7. What software and format do you use to store truck VMT estimate? Please explain.
8. Do you publish truck VMT?
9. Do you publish or report truck VMT by functional class? If yes what are the classes?
10. Do you publish or report truck VMT by AADT? If yes what are the AADT ranges?
11. Do you publish or report truck VMT by truck types? If yes what are truck types?
12. Do you publish or report truck VMT by other variables? Please specify.

Vehicle Classification Equipment Survey Form

(Please feel free to copy this form if necessary)

Please fill in the blank space and return the completed survey to Professor Ray Benekohal, 1205 Newmark Civil Engineering Lab., University of Illinois at Urbana-Champaign, 205 N. Mathews Ave., Urbana, IL 61801.

Company Name: ____________________ Ph: (___) __________ Fax: (___) ________
Internet Address: ____________________

A) Permanent Vehicle Classification Equipment

1. Equipment type and name ____________________
2. Names of States using the above-mentioned equipment ____________________
3. Cost of fully functioning system (equipment and installation cost) on one lane of a 4-lane interstate highway as shown on the sketch below (see Figure 1) ____________________
4. Number of such units sold in the USA in the past 5 years ____________________

B) Portable Vehicle Classification Equipment

1. Equipment type and name ____________________
2. Names of States using the above-mentioned equipment ____________________
3. Cost of fully functioning system on one lane of a 4-lane interstate highway as shown on the sketch below (see Figure 1) ____________________
4. Number of such units sold in the USA in the past 5 years ____________________

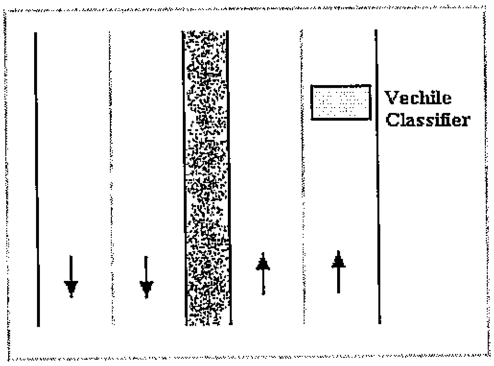


Figure 1 Vehicle classifier on one lane of a 4-lane interstate highway

Thank you for your cooperation

Appendix C

Names of DOTs, MPOs, and Equipment Vendors

Table C.1 State DOTs Returning the Survey

No	State	State Full Name	Street Address	City Address
1	AK	Alaska	Alaska DOT and Public Affairs, 3132 Channel Drive, Suite 200	Juneau, AK 99801 - 7898
2	AR	Arkansas	Arkansas Highway and Transportation Department, Planning and Research Division, PO Box 2261	Little Rock, AR 72203 - 2261
3	AZ	Arizona	206 S. 17th Ave MD 070R	Phoenix, AZ 85007
4	CA	California	1120 N. Street M.S. # 38, PO BOX 942874	Sacramento, CA 94274 - 0001
5	CO	Colorado	Colorado DOT, 4201 E. Arkansas Ave., DTD Empire Park Bldg	Denver, CO 80222
6	CT	Connecticut	Connecticut DOT, PO Box 317546	Newington, CT 06131 - 7546
7	HI	Hawaii	Department of Transportation, 869 Punchbowl Street	Honolulu, Hawaii 96813-5097

No	State	State Full Name	Street Address	City Address
8	IA	Iowa	800 Lincoln Way	Ames, IA 50010
9	ID	Idaho	State of Idaho Transportation Department, PO BOX 7129	Boise, ID 83707-1129
10	IL	Illinois	Illinois, DOT, 2300 South Dirksen Parkway.	Springfield, IL 62764
11	IN	Indiana	-	-
12	KS	Kansas	Kansas DOT, Docking State Office Bldg, # 830	Topeka, KS 66612
13	KY	Kentucky	Kentucky Transportation Cabinet, 125 Holmes St.	Frankfort, KY 40622
14	LA	Louisiana	Louisiana DOTD, PO BOX 94245	Baton Rouge, LA 70804-9245
15	MA	Massachusetts	Mass Highway Department., IO Park Plaza, #4150	Boston, MA 02116
16	MI	Michigan	Michigan Department of Transportation, 425 W. Ottawa Street, PO BOX 30050	Lansing, MI 48909

No	State	State Full Name	Street Address	City Address
17	MN	Minnesota	Minnesota DOT, 395 John Ireland Blvd, Mailstop 450	St. Paul, MN 55155
18	MT	Montana	2701 Prospect Avenue	Helena MT 59620-1001
19	NC	North Carolina	Traffic Survey Unit, 1554 Mail Service Center	Raleigh, NC 27699 - 1554
20	NE	Nebraska	Nebraska Dept. Of Roads, PO BOX 94759	Lincoln, NE 68509 - 4759
21	NH	New Hampshire	NHDOT, Bureau of Transportation Planning, 1 Hazen Drive, PO BOX 483	Concord, NH 03302-0483
22	NJ	New Jersey	1035 Parkway Avenue, PO BOX 612	Trenton, NJ 08625-0612
23	NV	Nevada	Nevada DOT, 1263 S. Stewart St.	Carson City, Nevada 89712
24	OK	Oklahoma	200 NE 21st	Okla City, OK 73105
25	OR	Oregon	555 13th Street NE	Salem, Oregon 97301 - 4178

No	State	State Full Name	Street Address	City Address
26	PA	Pennsylvania	Bureau of Planning and Research, Commenwealth of PA, 6th Floor Sorum Place, 555 Walnut St.	Harrisburg, PA 17101-1900
27	PR	Puerto Rico	PO BOX 42007	San Juan, PR 00940-2007
28	SC	South Carolina	SC DOT, PO BOX 191	Columbia, SC 29202
29	SD	South Dakota	700 E Broadway Ave E	Pievre, SD 57501
30	UT	Utah	450 / 80 2700 West	Salt Lake City, Utah 84119
31	VA	Virginia	Virginia DOT, 1401 East Broad St.	Richmond, VA 23219
32	VT	Vermont	Vermont AOT, National Life Bldg., Drawer 33	Montpelier, VT 05633
33	WA	Washington	318 E. State Avenue, m.s. 47380	Olympia, WA 98504-7380
34	WI	Wisconsin	Wisconsin DOT, 4802 Sheboygan Ave. Rm. 933	Madison, WI 53707 - 7913

No	State	State Full Name	Street Address	City Address
35	WV	West Virginia	West Virginia DOT, 1900 Kanawha Blvd. E. Building 5	Charleston, WV 25365
36	WY	Wyoming	Wyoming DOT, 5300 Bishop Blvd.	Cheyenne, WY 82009-3340

Table C.2 MPOs Returning the Survey

No	State	MPO	Street Address	City Address
1	AR	Metroplan	501W. Markham, Ste B	Little Rock, AR 72201
2	AZ	Maricopa Association of Governments	302 North 1st Avenue, Suite 300	Phoenix, Arizona 85003
3	CA	So. Cal. Ass. of Government	-	-
4	CO	DRCOG (Denver Regional Council of Governments	2480 W. 26th. Ave., Suite 200B	Denver, CO 80211
5	CT	South Central Regional Council of Goverments	127 Washington Ave. 4th Floor West	North Hang, CT 24473-1715
6	DC	Metropolitan Washington Council of Governments	Suite 300, 777 N. Capitol St. N.E.	Washington, D.C., 20002-4239
7	DE	Wilmapco	850 Library Avenue, Suite 100	Newark, DE 19711
8	FL	Miami - Dade MPO	111 NW 1st Street Suite 910	Miami, FL 33128
9	FL	Hillsborough County Metropolitan Planning Org.	601 E. Kennedy Blvd. 18th	Tampa, FL 33601

No	State	MPO	Street Address	City Address
10	HI	Oahu Metropolitan Planning Organization	Ocean View Center, Suite 200, 707 Richards Street	Honolulu, Hawaii 96813 - 4623
11	IL	Chicago Area Transportation Study	300 W. Adams	Chicago, IL 60606
12	IN	Metropolitan Development Division of Planing	200 E. Washington St. Suite 1841	Indianapolis, IN 46204
13	KY	KIPDA (Kentuckiana Regional Planning and Development Agency)	11520 Commenwealth Dr.	Louisville, KY 40299
14	MA	SRPEDD	88 Broadway	Taunton, MA 02780
15	MD	Baltimore Metropolitan Council	2700 Lighthouse Point East, Suite 310	Baltimore, MD 21224-4774
16	MI	Southeast Michigan Council of Governments	Semcog 660 Plaza Drive, Suite 1900	Detroit, MI 48226
17	NE	MAPA	MAPA, 2222 Cumming Street	Omaha, NE 68102-4328

No	State	MPO	Street Address	City Address
18	NJ	South Jersey Transportation Planning Org	1173 E. Landis Ave	Vineland, NJ 08360
19	NV	Regional Transportation Commission of Southern Nevada	600 S. Grand Central Pkwy	Las Vegas, NV 89106
20	OH	Ohio-Kentucky-Indiana (OKI) Regional Council of Governments	801 B. West Eight St.	Cincinnati, OH 45203
21	OK	Association of Central Oklahoma Government	ACOG, 21 E. MainSt. Ste. 100	OKC, OK 73104
22	OK	INCOG	201 W. 5th Street STE 600	Tulsa, OK 74103
23	OR	Metro, Transportation Department	600 NE Grand Ave.	Portland, OR 97232 - 2736
24	PA	Delaware Valley Regional Planning Commission	The Bourse Building 111 S. Independence Mall E.	Philadelphia, PA 19106
25	SC	Berkeley-Charleston-Dorchester Council of Governments	5290 Rivers Avenue, Suite 400	Charleston, SC 29406

No	State	MPO	Street Address	City Address
26	SC	Greenville County Planning Commission	301 University Ridge, Suite 400	Greenville, SC 29601-3660
27	TX	North Central Texas Council of Governemnts	616 Six Flags Drive, Suite 200	Arlington, Texas 76005
28	VA	Hampton Road Planning District Commission	723 Woodlake Dr.	Chesapeake, VA 23320
29	WA	PSRC	1011 Western Ave., #500	Seattle, WA 98104

Table C.3 Classification Equipment Vendors Returning the Survey

No	Company Name	Internet Address	Contact Person	Title	Phone No.	Fax No,	E-mail Address
1	International Road Dynamics Inc.	www.irdinc.com	Craig Lindsay	System Specialists	(306) 653 6600	(306) 242 5599	craig.lindsay@irdinc.com
2	Transport Data Systems	www.transportdatasystems.com	R.E. Hasselbring	-	(619) 226 2534	(619) 226 2534	rehasselbring@home.com
3	Scientific Technologies, Inc.	-	Charlie Strack	Product Manager	(510) 608 3411	-	charlie_strack@sti.com
4	Measurement Speciaties	www.msiusa.com	Donald Halverson	Director, Business Developmen	(610) 650 1580	(610) 650 1509	dhalvers@msiusa.com
5	Computer Recognition Systems	www.crs-its.com	Sal Desgrastino	-	(617) 491 7665	(617) 491 7753	-
6	Smartek Systems	www.smarteksys.com	-	-	(410) 315 9727	(410) 384 9264	gpieper@erols.com

Appendix D

Volume Groups

Table D Traffic Volume Groups for Various Functional Classes

No (1)	Volume Group (2)	Number of Sections (3)	Total Length (miles) (4)	Length-Section ratio (5)=(4)/(3)
	Interstate Urban			
1	0 - 5,000	0	0.00	0.000
2	5,000 - 10,000	6	9.17	1.528
3	10,000 - 15,000	25	15.97	0.639
4	15,000 - 20,000	50	33.09	0.662
5	20,000 - 25,000	39	34.04	0.873
6	25,000 - 30,000	42	44.32	1.055
7	30,000 - 35,000	26	24.52	0.943
8	35,000 - 40,000	48	56.67	1.181
9	40,000 - 60,000	118	96.26	0.816
10	60,000 - 80,000	53	40.97	0.773
11	80,000 - 100,000	36	36.03	1.001
12	100,000 - 120,000	67	51.21	0.764
13	120,000 - 140,000	124	57.54	0.464
14	140,000 - larger	352	91.30	0.259
	Total	986	591.09	0.599
	Interstate Rural			
1	0 - 5,000	12	42.09	3.507
2	5,000 - 10,000	53	147.05	2.775
3	10,000 - 15,000	77	250.70	3.256
4	15,000 - 20,000	165	383.61	2.325
5	20,000 - 25,000	87	267.93	3.080
6	25,000 - 30,000	42	104.21	2.481
7	30,000 - 35,000	7	21.92	3.131
8	35,000 - 40,000	8	21.19	2.649
	Total	451	1238.70	2.747
	Freeway and Expressway Urban			
1	0 - 10,000	13	11.11	0.855
2	10,000 - 20,000	29	30.03	1.036
3	20,000 - 30,000	9	7.11	0.790
4	30,000 - 40,000	10	10.39	1.039
5	40,000 - 50,000	4	3.91	0.978
6	50,000 - 60,000	4	4.29	1.073
7	60,000 - Larger	9	6.31	0.701
	Total	78	73.15	0.938

No (1)	Volume Group (2)	Number of Sections (3)	Total Length (miles) (4)	Length-Section ratio (5)=(4)/(3)
	Other Principal Arterial Urban			
1	0 - 2,000	14	4.24	0.303
2	2,000 - 4,000	137	45.11	0.329
3	4,000 - 6,000	290	130.27	0.449
4	6,000 - 8,000	364	162.45	0.446
5	8,000 - 10,000	326	159.47	0.489
6	10,000 - 12,000	340	168.54	0.496
7	12,000 - 14,000	342	184.37	0.539
8	14,000 - 16,000	293	157.56	0.538
9	16,000 - 18,000	195	127.42	0.653
10	18,000 - 20,000	206	121.52	0.590
11	20,000 - 25,000	365	243.84	0.668
12	25,000 - 30,000	236	179.9	0.762
13	30,000 - 35,000	160	144.87	0.905
14	35,000 - 40,000	92	73.46	0.798
15	40,000 - 45,000	47	43.55	0.927
16	45,000 - Larger	55	55	1.000
	Total	3462	2001.57	0.578
	Other Principal Arterial Rural			
1	0 - 2,000	94	224.75	2.391
2	2,000 - 4,000	461	881.1	1.911
3	4,000 - 6,000	378	643.23	1.702
4	6,000 - 8,000	220	261.76	1.190
5	8,000 - 10,000	142	135.69	0.956
6	10,000 - 12,000	60	60.15	1.002
7	12,000 - 14,000	35	31.28	0.894
8	14,000 - 16,000	23	33.83	1.471
9	16,000 - 18,000	12	10.75	0.896
10	18,000 - 20,000	6	3.93	0.655
11	20,000 - 22,000	4	2.85	0.713
	Total	1435	2289.32	1.595

No (1)	Volume Group (2)		Number of Sections (3)	Total Length (miles) (4)	Length-Section ratio (5)=(4)/(3)
	Minor Arterial Rural				
1	0 -	250	1	1.06	1.060
2	250 -	500	12	22.03	1.836
3	500 -	750	45	113.44	2.521
4	750 -	1,000	98	256.42	2.617
5	1,000 -	1,250	102	263.04	2.579
6	1,250 -	1,500	128	324.71	2.537
7	1,500 -	1,750	144	319.39	2.218
8	1,750 -	2,000	148	360.6	2.436
9	2,000 -	2,500	333	663.84	1.994
10	2,500 -	3,000	277	520.95	1.881
11	3,000 -	3,500	230	351.72	1.529
12	3,500 -	4,000	204	266.1	1.304
13	4,000 -	4,500	156	201.51	1.292
14	4,500 -	5,000	114	108.33	0.950
15	5,000 -	6,000	160	167.74	1.048
16	6,000 -	7,000	135	138.41	1.025
17	7,000 -	8,000	83	84.94	1.023
18	8,000 -	9,000	56	54.58	0.975
19	9,000 -	10,000	36	22.94	0.637
20	10,000 -	Larger	73	60.47	0.828
	Total		2535	4302.22	1.697
	Major Collector Rural				
1	0 -	250	1	1.5	1.500
2	250 -	500	12	40.02	3.335
3	500 -	750	26	70.06	2.695
4	750 -	1,000	38	98.3	2.587
5	1,000 -	1,250	63	143.22	2.273
6	1,250 -	1,500	52	101.71	1.956
7	1,500 -	1,750	45	89.15	1.981
8	1,750 -	2,000	48	88.53	1.844
9	2,000 -	2,500	83	128.56	1.549
10	2,500 -	3,000	64	85.11	1.330
11	3,000 -	3,500	36	58.57	1.627
12	3,500 -	4,000	50	69.49	1.390
13	4,000 -	4,500	42	54.33	1.294
14	4,500 -	5,000	30	35.35	1.178
15	5,000 -	Larger	82	71.1	0.867
	Total		672	1135	1.689

No (1)	Volume Group (2)			Number of Sections (3)	Total Length (miles) (4)	Length-Section ratio (5)=(4)/(3)
	Minor Arterial Urban					
1	0	-	2,500	12	5.17	0.431
2	2,500	-	5,000	57	28.64	0.502
3	5,000	-	7,500	92	52.87	0.575
4	7,500	-	10,000	89	48.01	0.539
5	10,000	-	15,000	121	71.9	0.594
6	15,000	-	20,000	62	70.99	1.145
7	20,000	-	25,000	35	38.13	1.089
8	25,000	-	30,000	22	25.44	1.156
9	30,000	-	35,000	12	14.81	1.234
10	35,000	-	larger	9	10.79	1.199
	Total			511	366.75	0.718

Appendix E.1

Methodology Adjustment Factor (MAF) for the Average Section Length (ASL) Method

Notations

AveSection	= Average number of section
Size	= Percentage of the total number of section used as a sample size
Section	= The number of section in a group
Length	= The total length of the section in a group (in miles)
RatioLS	= The ratio of "Length" to "Section"
MuVMT1	= The true Multi Unit truck VMT
MuVol	= Multi Unit truck volume
MuVMT2	= The estimated Multi Unit truck VMT
expMuVMT2	= The estimated Multi Unit truck VMT expanded to population level
RMuVMT2	= The Multi Unit truck VMT Methodology Adjustment Factor (MAF)
SuVMT1	= The true Single Unit truck VMT
SuVol	= Single Unit truck volume
SuVMT2	= The estimated Single Unit truck VMT
expSuVMT2	= The estimated Single Unit truck VMT expanded to population level
RSuVMT2	= The Single Unit truck VMT Methodology Adjustment Factor (MAF)

APPENDIX E1

TRUCK VMT METHODOLOGY ADJUSTMENT FACTOR (MAF) FOR THE ASL METHOD

Interstate Urban
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
50	5	50	29.591	0.592	88.010	473.229	101.660	2004.742	0.777	27.783	158.848	34.124	672.928	0.714
60	6	60	35.645	0.594	103.907	564.983	121.371	1994.530	0.781	32.814	188.451	40.484	665.281	0.722
67	7	68	39.574	0.582	116.034	647.935	139.191	2018.271	0.772	36.976	218.027	46.837	679.138	0.707
80	8	80	47.154	0.589	139.359	764.727	164.281	2024.759	0.770	44.167	256.339	55.068	678.707	0.708
87	9	87	51.400	0.591	152.389	833.850	179.130	2030.137	0.768	48.329	279.477	60.038	680.430	0.706
101	10	100	59.861	0.599	175.959	949.833	204.046	2011.890	0.775	55.345	317.369	68.178	672.235	0.714
110	11	108	64.884	0.601	191.207	1026.484	220.512	2013.193	0.774	60.323	343.637	73.821	673.958	0.713
118	12	118	69.975	0.593	206.876	1124.064	241.474	2017.743	0.772	65.436	376.760	80.937	676.301	0.710
129	13	129	76.506	0.593	226.693	1225.296	263.221	2011.909	0.775	71.645	408.659	87.789	671.008	0.716
138	14	137	81.459	0.595	242.301	1309.713	281.356	2024.941	0.770	76.861	438.639	94.230	678.178	0.708
150	15	149	88.649	0.595	262.081	1421.531	305.377	2020.816	0.771	83.213	476.180	102.294	676.927	0.709
157	16	157	92.971	0.592	274.150	1495.612	321.291	2017.790	0.772	86.829	500.496	107.518	675.240	0.711
166	17	167	98.228	0.588	290.830	1596.093	342.877	2024.410	0.770	92.143	534.266	114.772	677.638	0.709
178	18	178	105.013	0.590	311.366	1700.907	365.393	2024.032	0.770	98.341	567.520	121.916	675.333	0.711
185	19	186	109.477	0.589	324.720	1779.258	382.225	2026.203	0.769	102.602	595.647	127.958	678.317	0.708
194	20	196	114.659	0.585	341.807	1881.445	404.177	2033.257	0.766	108.342	630.566	135.460	681.446	0.705
206	21	207	121.731	0.588	360.444	1973.814	424.020	2019.728	0.772	114.002	660.192	141.824	675.549	0.711
218	22	218	128.598	0.590	379.828	2080.017	446.835	2021.005	0.771	120.023	695.142	149.332	675.420	0.711
225	23	226	132.849	0.588	393.121	2157.091	463.392	2021.701	0.771	124.333	721.151	154.920	675.888	0.710
234	24	236	138.316	0.586	409.745	2253.156	484.029	2022.256	0.771	129.961	754.836	162.156	677.482	0.709
245	25	246	144.809	0.589	428.449	2345.143	503.790	2019.255	0.772	135.825	785.485	168.740	676.331	0.710
253	26	254	149.215	0.587	441.725	2424.803	520.902	2022.086	0.771	140.209	814.012	174.868	678.819	0.707
263	27	265	155.467	0.587	460.134	2530.718	543.655	2022.809	0.770	146.196	849.801	182.556	679.248	0.707
274	28	275	161.989	0.589	478.888	2621.855	563.234	2019.449	0.772	152.141	880.029	189.050	677.831	0.708
286	29	287	168.835	0.588	497.718	2730.628	586.601	2015.290	0.773	157.973	915.319	196.631	675.534	0.711
295	30	296	174.038	0.588	512.545	2818.089	605.389	2016.600	0.773	162.804	943.991	202.791	675.512	0.711
305	31	305	180.020	0.590	528.820	2904.194	623.887	2016.893	0.773	167.957	974.035	209.245	676.444	0.710
316	32	315	186.324	0.592	548.227	2999.237	644.304	2016.773	0.773	174.066	1005.252	215.951	675.961	0.710
327	33	326	192.719	0.591	565.496	3100.610	666.081	2014.589	0.774	179.645	1039.350	223.276	675.307	0.711
336	34	336	197.947	0.589	580.907	3199.428	687.309	2016.926	0.773	184.777	1073.052	230.516	676.454	0.710
347	35	346	204.385	0.591	598.809	3287.628	706.257	2012.628	0.774	190.247	1101.420	236.610	674.270	0.712
355	36	355	209.137	0.589	614.875	3382.945	726.733	2018.476	0.772	195.648	1134.260	243.665	676.770	0.710
367	37	366	216.309	0.591	634.083	3478.745	747.313	2013.253	0.774	201.382	1164.545	250.171	673.957	0.713
376	38	376	221.784	0.590	652.085	3576.924	768.404	2015.017	0.773	207.032	1198.222	257.405	675.004	0.711

386	39	386	227.825	0.590	668.907	3670.224	788.447	2014.012	0.774	212.284	1228.301	263.867	674.023	0.712
394	40	394	231.978	0.589	682.236	3750.022	805.589	2016.018	0.773	216.841	1256.695	269.966	675.601	0.711
406	41	405	239.043	0.590	702.241	3852.735	827.655	2014.981	0.773	222.864	1291.379	277.417	675.391	0.711
415	42	414	244.429	0.590	718.666	3941.350	846.691	2016.516	0.773	228.249	1321.167	283.817	675.950	0.710
427	43	425	251.335	0.591	739.921	4046.747	869.333	2016.852	0.773	234.818	1356.448	291.396	676.038	0.710
432	44	432	254.408	0.589	751.002	4121.764	885.448	2020.953	0.771	238.345	1381.487	296.775	677.361	0.709
445	45	444	261.934	0.590	770.897	4228.007	908.271	2017.017	0.773	244.593	1415.857	304.158	675.450	0.711
454	46	454	267.731	0.590	788.327	4328.037	929.760	2019.259	0.772	250.351	1450.002	311.493	676.503	0.710
462	47	462	272.005	0.589	800.607	4403.732	946.021	2018.997	0.772	254.196	1475.142	316.894	676.314	0.710
476	48	475	280.561	0.591	825.068	4523.653	971.783	2017.217	0.773	262.019	1514.831	325.420	675.503	0.711
483	49	483	284.759	0.590	839.110	4606.499	989.580	2020.137	0.771	266.598	1542.427	331.348	676.417	0.710
493	50	492	290.138	0.590	854.881	4692.503	1008.056	2020.209	0.771	271.591	1572.061	337.714	676.801	0.710
501	51	501	294.866	0.589	868.401	4778.684	1026.569	2020.354	0.771	276.169	1601.234	343.981	676.977	0.709

Interstate Rural

Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
22	5	22	60.204	2.737	100.133	104.017	104.000	2132.001	0.849	16.170	14.993	14.991	307.306	0.927
28	6	28	76.953	2.748	128.286	132.191	132.169	2128.870	0.851	20.745	19.211	19.208	309.383	0.921
32	7	32	88.462	2.764	142.977	146.810	146.785	2068.757	0.875	22.861	21.189	21.186	298.589	0.954
35	8	35	96.209	2.749	156.704	161.731	161.704	2083.675	0.869	25.315	23.600	23.596	304.053	0.937
40	9	40	109.539	2.738	180.058	186.780	186.749	2105.596	0.860	28.962	26.926	26.921	303.536	0.939
45	10	45	123.747	2.750	203.374	210.351	210.316	2107.829	0.859	32.903	30.481	30.476	305.433	0.933
50	11	50	138.459	2.769	227.991	232.770	232.731	2099.231	0.863	36.421	33.396	33.391	301.184	0.946
54	12	54	149.053	2.760	245.166	250.973	250.931	2095.739	0.864	39.732	36.475	36.469	304.582	0.936
59	13	59	162.458	2.754	266.474	273.984	273.938	2093.999	0.865	43.474	39.951	39.944	305.335	0.933
62	14	62	170.557	2.751	281.015	288.535	288.487	2098.508	0.863	45.619	42.008	42.001	305.526	0.933
67	15	67	185.624	2.771	307.675	313.925	313.873	2112.784	0.857	50.346	45.864	45.856	308.674	0.923
73	16	73	202.485	2.774	326.968	334.467	334.411	2066.019	0.876	53.102	48.537	48.529	299.815	0.951
76	17	76	210.244	2.766	341.357	349.722	349.663	2074.975	0.873	55.361	50.800	50.792	301.409	0.946
84	18	83	230.365	2.775	376.222	384.087	384.022	2086.676	0.868	60.710	55.609	55.600	302.115	0.943
87	19	86	238.840	2.777	389.012	397.132	397.066	2082.287	0.870	62.571	57.353	57.343	300.718	0.948
91	20	90	249.998	2.778	405.879	413.880	413.811	2073.651	0.873	65.386	59.949	59.939	300.363	0.949
96	21	95	263.240	2.771	428.777	438.393	438.319	2080.862	0.870	69.379	63.449	63.439	301.167	0.946
101	22	100	277.832	2.778	453.110	462.251	462.173	2084.401	0.869	73.439	67.020	67.009	302.211	0.943
104	23	104	287.490	2.764	470.703	481.944	481.863	2089.618	0.867	76.336	69.941	69.929	303.251	0.940
108	24	108	298.249	2.762	485.051	497.109	497.026	2075.542	0.872	78.363	71.884	71.872	300.132	0.950
114	25	114	314.634	2.760	511.707	525.812	525.724	2079.836	0.871	82.917	76.007	75.994	300.643	0.948
117	26	117	322.779	2.759	526.341	540.370	540.279	2082.616	0.870	84.947	78.005	77.992	300.637	0.948
122	27	122	335.858	2.753	549.088	565.719	565.624	2090.956	0.866	88.970	81.816	81.802	302.399	0.942
127	28	127	349.588	2.753	568.034	585.065	584.967	2077.325	0.872	91.830	84.428	84.414	299.770	0.951

130	29	130	357.243	2.748	582.464	600.557	600.456	2083.121	0.869	94.135	86.703	86.688	300.741	0.948
136	30	136	373.287	2.745	608.798	628.130	628.025	2082.641	0.870	98.644	90.946	90.931	301.542	0.945
140	31	140	385.467	2.753	629.430	647.008	646.899	2083.939	0.869	101.751	93.567	93.551	301.369	0.946
144	32	144	395.571	2.747	646.744	666.323	666.211	2086.536	0.868	104.667	96.484	96.468	302.131	0.943
149	33	149	409.621	2.749	667.919	688.125	688.010	2082.500	0.870	107.978	99.470	99.453	301.029	0.947
154	34	154	424.493	2.756	692.612	711.475	711.356	2083.258	0.869	111.897	102.985	102.968	301.548	0.945
158	35	158	434.116	2.748	709.282	730.844	730.722	2085.794	0.868	114.695	105.925	105.908	302.306	0.943
161	36	161	442.896	2.751	722.815	743.934	743.809	2083.590	0.869	116.850	107.759	107.741	301.808	0.944
167	37	167	457.953	2.742	744.280	768.355	768.226	2074.670	0.873	120.381	111.284	111.265	300.483	0.948
171	38	171	469.120	2.743	765.661	789.185	789.053	2081.069	0.870	123.642	114.249	114.230	301.274	0.946
177	39	177	485.280	2.742	793.832	819.084	818.947	2086.696	0.868	128.550	118.613	118.593	302.177	0.943
181	40	181	496.445	2.743	811.568	837.392	837.252	2086.191	0.868	131.716	121.476	121.455	302.632	0.942
183	41	184	503.535	2.737	821.029	848.690	848.548	2079.864	0.871	133.103	123.015	122.995	301.470	0.945
189	42	190	520.145	2.738	848.093	876.149	876.002	2079.353	0.871	137.424	127.066	127.045	301.565	0.945
193	43	193	529.567	2.744	863.055	889.456	889.307	2078.121	0.871	139.619	128.880	128.859	301.116	0.946
197	44	197	539.406	2.738	880.745	909.248	909.096	2081.230	0.870	142.400	131.654	131.632	301.350	0.946
202	45	202	553.332	2.739	906.892	935.708	935.552	2088.781	0.867	146.436	135.283	135.260	301.992	0.944

Freeway and Expressway

Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
4	5	4	3.503	0.876	2.701	8.961	2.877	56.109	0.733	2.083	7.291	2.341	45.652	0.524
4	6	4	3.503	0.876	2.701	8.961	2.877	56.109	0.733	2.083	7.291	2.341	45.652	0.524
5	7	5	4.576	0.915	4.462	13.461	4.322	67.428	0.610	2.552	8.491	2.726	42.533	0.562
5	8	5	4.576	0.915	4.462	13.461	4.322	67.428	0.610	2.552	8.491	2.726	42.533	0.562
8	9	8	7.048	0.881	6.675	20.546	6.597	64.321	0.639	4.189	14.034	4.506	43.934	0.544
8	10	8	7.048	0.881	6.675	20.546	6.597	64.321	0.639	4.189	14.034	4.506	43.934	0.544
9	11	9	8.091	0.899	7.014	21.373	6.863	59.477	0.691	4.396	14.599	4.688	40.627	0.588
10	12	10	8.722	0.872	7.825	24.773	7.954	62.044	0.663	5.067	17.473	5.610	43.762	0.546
10	13	10	8.722	0.872	7.825	24.773	7.954	62.044	0.663	5.067	17.473	5.610	43.762	0.546
11	14	11	9.783	0.889	8.378	26.075	8.372	59.368	0.693	5.400	18.357	5.894	41.796	0.572
12	15	12	10.428	0.869	9.208	29.406	9.442	61.372	0.670	6.090	21.182	6.801	44.208	0.541
12	16	12	10.428	0.869	9.208	29.406	9.442	61.372	0.670	6.090	21.182	6.801	44.208	0.541
13	17	13	11.573	0.890	9.581	30.202	9.698	58.186	0.707	6.298	21.674	6.959	41.756	0.573
13	18	13	11.573	0.890	9.581	30.202	9.698	58.186	0.707	6.298	21.674	6.959	41.756	0.573
15	19	15	13.204	0.880	10.929	34.756	11.160	58.031	0.709	7.266	25.031	8.037	41.793	0.572
16	20	16	14.276	0.892	12.690	39.256	12.605	61.448	0.669	7.736	26.231	8.422	41.059	0.582
16	21	16	14.276	0.892	12.690	39.256	12.605	61.448	0.669	7.736	26.231	8.422	41.059	0.582
17	22	17	14.978	0.881	13.586	42.652	13.695	62.836	0.654	8.485	29.112	9.348	42.889	0.557
18	23	18	16.037	0.891	14.122	43.904	14.097	61.087	0.673	8.815	29.982	9.627	41.716	0.573
19	24	19	17.050	0.897	14.443	44.720	14.359	58.948	0.698	9.012	30.556	9.811	40.278	0.594

20	25	20	17.711	0.886	15.281	48.090	15.441	60.220	0.683	9.717	33.428	10.733	41.860	0.571
20	26	20	17.711	0.886	15.281	48.090	15.441	60.220	0.683	9.717	33.428	10.733	41.860	0.571
22	27	22	19.480	0.885	16.560	51.641	16.581	58.788	0.699	10.598	36.024	11.567	41.010	0.583
23	28	23	20.233	0.880	17.518	55.052	17.677	59.947	0.686	11.406	38.931	12.500	42.393	0.564

Other Principal Arterial Urban
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
174	5	175	123.730	0.707	36.489	117.724	30.507	603.510	0.651	39.669	126.553	32.795	648.771	0.658
206	6	206	146.142	0.709	43.057	138.542	35.902	603.356	0.651	46.911	149.398	38.715	650.632	0.656
241	7	241	171.568	0.712	50.670	162.421	42.089	604.620	0.650	55.219	175.491	45.476	653.273	0.653
278	8	278	197.589	0.711	57.976	186.175	48.245	600.807	0.654	63.381	201.807	52.296	651.253	0.655
310	9	310	220.554	0.711	64.925	208.220	53.958	602.585	0.652	71.006	225.704	58.488	653.183	0.653
348	10	347	247.476	0.713	73.003	233.861	60.602	604.626	0.650	79.749	253.117	65.592	654.410	0.652
383	11	382	272.212	0.713	80.230	256.788	66.543	603.072	0.651	87.553	277.866	72.005	652.573	0.654
415	12	415	295.287	0.712	86.539	277.611	71.939	600.131	0.655	94.679	300.988	77.997	650.668	0.656
449	13	449	319.356	0.711	93.622	300.850	77.962	601.121	0.654	102.465	326.041	84.490	651.454	0.655
485	14	485	344.578	0.710	101.172	325.241	84.282	601.619	0.653	110.681	352.243	91.280	651.567	0.655
520	15	520	369.687	0.711	108.682	348.604	90.337	601.433	0.653	118.823	377.385	97.795	651.088	0.656
555	16	554	394.487	0.712	116.380	372.375	96.496	603.015	0.652	127.055	402.707	104.357	652.134	0.654
588	17	588	418.248	0.711	123.358	394.969	102.351	602.620	0.652	134.727	427.293	110.728	651.937	0.655
623	18	623	443.160	0.711	130.892	418.762	108.517	603.027	0.651	142.747	452.670	117.304	651.856	0.655
658	19	659	467.837	0.710	137.490	440.879	114.249	600.195	0.655	150.269	477.552	123.752	650.119	0.657
689	20	690	489.877	0.710	143.412	460.252	119.269	598.418	0.657	156.864	498.652	129.220	648.346	0.658

Other Principal Arterial Rural
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
70	5	70	105.407	1.506	14.014	26.161	14.369	294.568	0.962	8.248	15.373	8.444	173.098	0.933
87	6	87	130.411	1.499	17.548	33.298	18.290	301.675	0.940	10.515	19.983	10.976	181.041	0.892
100	7	101	150.602	1.491	20.594	39.021	21.433	304.515	0.931	12.324	23.420	12.864	182.771	0.884
114	8	115	171.498	1.491	23.218	44.000	24.168	301.571	0.940	13.831	26.284	14.437	180.147	0.897
128	9	129	191.552	1.485	26.039	49.377	27.121	301.695	0.940	15.418	29.350	16.121	179.332	0.901
144	10	144	215.931	1.500	29.304	54.875	30.141	300.362	0.944	17.299	32.568	17.889	178.266	0.906
158	11	159	238.025	1.497	32.218	60.419	33.186	299.511	0.946	19.026	35.941	19.741	178.168	0.907
173	12	172	259.667	1.510	35.034	65.235	35.831	298.941	0.948	20.728	38.703	21.259	177.360	0.911
187	13	186	280.810	1.510	37.960	70.501	38.724	298.758	0.949	22.325	41.679	22.893	176.618	0.915
202	14	200	303.843	1.519	41.105	75.724	41.593	298.429	0.950	24.055	44.637	24.518	175.915	0.918
216	15	215	324.616	1.510	44.292	81.944	45.009	300.410	0.944	25.937	48.382	26.575	177.370	0.911
230	16	229	346.429	1.513	47.012	87.130	47.858	299.894	0.945	27.507	51.474	28.273	177.169	0.912

245	17	244	368.467	1.510	50.152	92.930	51.043	300.194	0.944	29.301	54.864	30.135	177.228	0.911
261	18	260	392.345	1.509	53.333	99.121	54.444	300.488	0.943	31.375	58.809	32.302	178.281	0.906
272	19	272	409.437	1.505	55.646	103.686	56.951	300.461	0.943	32.746	61.522	33.792	178.279	0.906
288	20	288	432.874	1.503	58.831	109.670	60.238	300.145	0.944	34.632	65.075	35.744	178.097	0.907
301	21	301	452.764	1.504	61.427	114.420	62.847	299.621	0.946	36.199	67.855	37.271	177.685	0.909
315	22	315	473.869	1.504	64.160	119.476	65.624	298.955	0.948	37.701	70.718	38.843	176.952	0.913
330	23	330	496.442	1.504	67.238	125.115	68.722	298.834	0.949	39.483	73.968	40.628	176.671	0.914
345	24	345	519.091	1.505	70.489	131.137	72.029	299.600	0.946	41.412	77.573	42.608	177.225	0.911
357	25	357	538.297	1.508	72.858	135.341	74.338	298.811	0.949	42.733	79.956	43.917	176.529	0.915
373	26	372	561.300	1.509	76.022	141.008	77.451	298.769	0.949	44.544	83.193	45.695	176.270	0.916
386	27	386	581.527	1.507	79.038	146.915	80.696	299.995	0.945	46.327	86.813	47.683	177.269	0.911
402	28	402	605.637	1.507	82.473	153.169	84.131	300.317	0.944	48.320	90.627	49.778	177.691	0.909
416	29	416	627.357	1.508	85.350	158.459	87.036	300.234	0.944	49.994	93.598	51.410	177.340	0.911
431	30	432	650.130	1.505	88.608	164.984	90.620	301.019	0.942	52.018	97.664	53.644	178.191	0.906
445	31	445	670.586	1.507	91.113	169.559	93.133	300.329	0.944	53.480	100.251	55.065	177.568	0.910
459	32	460	692.320	1.505	94.223	175.506	96.400	300.725	0.943	55.300	103.810	57.019	177.875	0.908
473	33	473	712.695	1.507	96.829	179.970	98.852	299.899	0.945	56.747	106.457	58.473	177.398	0.911
486	34	487	732.316	1.504	99.571	185.288	101.772	299.884	0.945	58.359	109.586	60.192	177.363	0.911
502	35	503	756.935	1.505	102.842	191.250	105.047	299.687	0.946	60.278	113.025	62.081	177.109	0.912

Minor Arterial Rural
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
127	5	126	196.161	1.557	13.586	26.099	14.822	298.198	0.907	9.550	18.602	10.564	212.534	0.881
153	6	153	235.564	1.540	16.320	31.769	18.042	298.930	0.905	11.532	22.786	12.940	214.406	0.873
177	7	177	273.528	1.545	18.981	36.622	20.798	297.867	0.908	13.422	26.303	14.938	213.937	0.875
201	8	201	310.431	1.544	21.470	41.513	23.575	297.330	0.910	15.139	29.697	16.865	212.703	0.880
225	9	225	346.650	1.541	24.037	46.434	26.370	297.098	0.911	16.983	33.324	18.925	213.219	0.878
253	10	253	390.893	1.545	27.026	52.192	29.640	296.986	0.911	19.127	37.516	21.305	213.472	0.877
279	11	279	430.726	1.544	29.715	57.602	32.712	297.223	0.910	20.987	41.424	23.525	213.748	0.876
301	12	302	465.469	1.541	32.167	62.357	35.412	297.254	0.910	22.726	44.814	25.450	213.628	0.876
330	13	330	509.766	1.545	35.222	68.145	38.700	297.283	0.910	24.844	48.937	27.792	213.490	0.877
353	14	353	545.597	1.546	37.712	72.825	41.357	296.999	0.911	26.636	52.323	29.714	213.388	0.877
381	15	381	588.533	1.545	40.647	78.621	44.649	297.074	0.911	28.728	56.546	32.112	213.662	0.876
405	16	406	625.612	1.541	43.347	84.049	47.731	298.027	0.908	30.610	60.375	34.287	214.082	0.874
429	17	430	663.562	1.543	46.040	89.086	50.592	298.257	0.907	32.483	63.920	36.300	214.003	0.875
457	18	457	707.147	1.547	48.982	94.702	53.782	298.329	0.907	34.569	67.966	38.598	214.106	0.874
481	19	481	743.563	1.546	51.502	99.485	56.498	297.759	0.908	36.378	71.397	40.546	213.691	0.876
506	20	507	783.423	1.545	54.333	105.089	59.680	298.400	0.907	38.387	75.452	42.850	214.248	0.874
533	21	534	825.333	1.546	57.252	110.828	62.939	298.785	0.905	40.445	79.519	45.159	214.379	0.873
556	22	558	861.269	1.543	59.844	115.816	65.772	298.803	0.905	42.293	83.211	47.256	214.684	0.872

582	23	583	901.828	1.547	62.682	120.944	68.684	298.654	0.906	44.218	86.778	49.281	214.284	0.874
606	24	606	938.119	1.548	65.208	125.655	71.359	298.508	0.906	45.988	90.125	51.182	214.102	0.874
634	25	634	982.683	1.550	68.157	131.240	74.531	298.008	0.908	48.067	94.187	53.489	213.872	0.875
660	26	660	1023.280	1.550	70.937	136.543	77.543	297.835	0.908	50.016	98.004	55.657	213.773	0.876
684	27	684	1059.663	1.549	73.504	141.546	80.384	297.916	0.908	51.914	101.699	57.755	214.048	0.875
710	28	710	1100.882	1.551	76.320	146.888	83.418	297.836	0.908	53.840	105.464	59.893	213.845	0.875
733	29	734	1136.992	1.549	78.910	151.850	86.236	297.832	0.908	55.673	109.067	61.940	213.919	0.875
760	30	760	1178.062	1.550	81.721	157.228	89.290	297.829	0.908	57.664	112.949	64.144	213.954	0.875
785	31	786	1217.609	1.549	84.478	162.645	92.366	297.898	0.908	59.614	116.908	66.392	214.127	0.874
814	32	813	1262.078	1.552	87.463	167.987	95.400	297.466	0.909	61.675	120.662	68.524	213.664	0.876
838	33	837	1299.567	1.553	90.106	173.027	98.262	297.604	0.909	63.490	124.180	70.522	213.589	0.876
862	34	862	1337.871	1.552	92.774	178.167	101.181	297.557	0.909	65.395	127.886	72.627	213.583	0.876
888	35	888	1379.236	1.553	95.612	183.572	104.251	297.608	0.909	67.419	131.806	74.853	213.684	0.876
913	36	914	1417.773	1.551	98.458	189.222	107.459	298.041	0.908	69.433	135.921	77.190	214.088	0.874
938	37	938	1457.136	1.553	101.053	193.942	110.140	297.660	0.909	71.230	139.240	79.075	213.704	0.876
962	38	962	1494.457	1.553	103.618	198.819	112.910	297.533	0.909	73.074	142.811	81.102	213.716	0.876
991	39	989	1539.217	1.556	106.579	204.197	115.964	297.238	0.910	75.142	146.591	83.249	213.384	0.877
1016	40	1014	1578.675	1.557	109.353	209.477	118.962	297.406	0.910	77.143	150.442	85.436	213.590	0.876
1045	41	1043	1624.469	1.557	112.515	215.602	122.441	297.591	0.909	79.354	154.853	87.941	213.741	0.876
1066	42	1065	1657.145	1.556	114.924	220.234	125.071	297.705	0.909	81.019	158.090	89.780	213.701	0.876
1091	43	1091	1696.350	1.555	117.656	225.756	128.207	297.896	0.908	82.959	162.069	92.039	213.858	0.875
1114	44	1114	1733.203	1.556	120.267	230.454	130.875	297.817	0.908	84.796	165.406	93.934	213.755	0.876
1141	45	1141	1774.731	1.555	123.153	236.141	134.105	297.946	0.908	86.843	169.513	96.267	213.879	0.875
1166	46	1166	1814.173	1.556	125.908	241.269	137.017	297.889	0.908	88.794	173.204	98.363	213.850	0.875

Major Collector Rural

Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
34	5	34	51.748	1.522	1.799	3.579	1.998	39.489	0.891	1.909	3.780	2.110	41.703	0.866
40	6	41	62.145	1.516	2.210	4.383	2.447	40.100	0.877	2.318	4.589	2.562	41.989	0.860
48	7	48	74.448	1.551	2.600	5.072	2.831	39.635	0.888	2.719	5.304	2.961	41.452	0.872
52	8	53	80.521	1.519	2.885	5.710	3.187	40.414	0.871	2.995	5.946	3.320	42.089	0.858
59	9	60	91.225	1.520	3.222	6.366	3.554	39.800	0.884	3.384	6.693	3.736	41.847	0.863
64	10	65	98.477	1.515	3.546	6.977	3.895	40.264	0.874	3.660	7.282	4.065	42.027	0.860
73	11	74	111.905	1.512	4.016	7.963	4.446	40.370	0.872	4.182	8.317	4.643	42.160	0.857
77	12	78	118.430	1.518	4.251	8.370	4.673	40.256	0.874	4.406	8.774	4.898	42.197	0.856
92	13	91	142.048	1.561	4.976	9.626	5.374	39.682	0.887	5.118	9.997	5.581	41.211	0.877
95	14	94	145.456	1.547	5.132	10.007	5.587	39.938	0.881	5.295	10.416	5.815	41.569	0.869
102	15	101	155.957	1.544	5.559	10.774	6.014	40.017	0.879	5.691	11.180	6.241	41.525	0.870
110	16	109	169.656	1.556	5.953	11.493	6.416	39.556	0.890	6.156	12.003	6.700	41.308	0.875
114	17	114	175.737	1.542	6.224	12.097	6.753	39.807	0.884	6.435	12.668	7.072	41.685	0.867

123	18	122	188.641	1.546	6.695	12.964	7.237	39.864	0.883	6.897	13.502	7.537	41.516	0.870
128	19	128	196.944	1.539	7.068	13.659	7.625	40.031	0.879	7.258	14.228	7.943	41.699	0.866
136	20	135	208.581	1.545	7.465	14.418	8.049	40.065	0.878	7.620	14.926	8.332	41.476	0.871
145	21	143	221.917	1.552	7.840	15.134	8.449	39.702	0.886	8.041	15.736	8.784	41.280	0.875
148	22	147	226.814	1.543	8.116	15.713	8.772	40.098	0.877	8.287	16.292	9.095	41.575	0.869
156	23	155	239.431	1.545	8.544	16.516	9.220	39.973	0.880	8.732	17.138	9.567	41.478	0.871
162	24	162	248.406	1.533	8.929	17.375	9.699	40.234	0.875	9.129	18.020	10.060	41.729	0.866
170	25	169	260.234	1.540	9.255	17.997	10.046	39.948	0.881	9.490	18.702	10.440	41.514	0.870
175	26	175	269.274	1.539	9.617	18.670	10.422	40.022	0.879	9.851	19.406	10.833	41.599	0.869
182	27	182	280.036	1.539	9.994	19.413	10.837	40.014	0.879	10.247	20.164	11.256	41.561	0.869
185	28	186	284.707	1.531	10.189	19.874	11.094	40.082	0.878	10.445	20.672	11.540	41.693	0.867
196	29	196	300.487	1.533	10.788	20.998	11.722	40.189	0.876	11.005	21.753	12.143	41.635	0.868
202	30	201	309.901	1.542	11.031	21.409	11.952	39.957	0.881	11.280	22.233	12.411	41.494	0.871
209	31	209	320.495	1.533	11.511	22.387	12.497	40.182	0.876	11.731	23.234	12.970	41.703	0.866
217	32	217	332.878	1.534	11.926	23.174	12.937	40.062	0.878	12.171	24.085	13.445	41.636	0.868
220	33	220	337.003	1.532	12.048	23.458	13.095	39.999	0.880	12.345	24.463	13.656	41.713	0.866
231	34	230	353.749	1.538	12.602	24.445	13.646	39.871	0.882	12.891	25.476	14.222	41.552	0.870
235	35	235	360.387	1.534	12.816	24.914	13.908	39.770	0.885	13.179	26.084	14.561	41.638	0.868
238	36	239	365.172	1.528	13.030	25.423	14.192	39.903	0.882	13.385	26.609	14.854	41.765	0.865
248	37	249	380.271	1.527	13.539	26.384	14.728	39.749	0.885	13.928	27.637	15.428	41.638	0.868
256	38	256	393.041	1.535	13.956	27.148	15.155	39.782	0.884	14.271	28.367	15.835	41.568	0.869
265	39	264	406.098	1.538	14.357	27.907	15.579	39.654	0.887	14.719	29.194	16.297	41.484	0.871
270	40	270	414.533	1.535	14.760	28.694	16.018	39.867	0.883	15.067	29.925	16.705	41.578	0.869
278	41	277	426.006	1.538	15.119	29.354	16.386	39.753	0.885	15.484	30.688	17.131	41.559	0.869
283	42	282	434.007	1.539	15.386	29.893	16.687	39.766	0.885	15.763	31.234	17.436	41.550	0.870
289	43	289	443.689	1.535	15.845	30.770	17.177	39.941	0.881	16.174	32.066	17.900	41.623	0.868
295	44	295	452.686	1.535	16.154	31.360	17.506	39.878	0.882	16.505	32.714	18.262	41.601	0.868
304	45	304	465.901	1.533	16.721	32.454	18.117	40.048	0.879	17.056	33.798	18.867	41.707	0.866
310	46	309	474.930	1.537	16.975	32.907	18.370	39.950	0.881	17.314	34.282	19.137	41.619	0.868
319	47	318	488.578	1.536	17.468	33.950	18.952	40.049	0.879	17.793	35.258	19.683	41.593	0.869
326	48	325	499.423	1.537	17.879	34.666	19.352	40.013	0.879	18.177	35.986	20.089	41.537	0.870
330	49	330	505.987	1.533	18.165	35.282	19.696	40.107	0.877	18.478	36.612	20.438	41.620	0.868
334	50	334	511.981	1.533	18.400	35.720	19.940	40.119	0.877	18.736	37.115	20.719	41.686	0.867
344	51	344	528.056	1.535	18.937	36.735	20.507	40.060	0.878	19.277	38.168	21.307	41.622	0.868
348	52	349	533.847	1.530	19.237	37.435	20.898	40.238	0.874	19.539	38.798	21.658	41.703	0.866
358	53	358	548.916	1.533	19.745	38.298	21.380	40.131	0.877	20.055	39.676	22.148	41.575	0.869
361	54	362	553.607	1.529	20.027	38.912	21.722	40.323	0.873	20.298	40.244	22.466	41.705	0.866
367	55	368	562.836	1.529	20.312	39.497	22.048	40.262	0.874	20.613	40.873	22.817	41.665	0.867
379	56	378	580.175	1.535	20.910	40.510	22.614	40.203	0.875	21.159	41.844	23.359	41.527	0.870
383	57	383	586.725	1.532	21.157	41.068	22.926	40.224	0.875	21.438	42.462	23.704	41.590	0.869
388	58	389	595.347	1.530	21.401	41.654	23.253	40.169	0.876	21.733	43.141	24.083	41.603	0.868
395	59	396	604.684	1.527	21.812	42.511	23.731	40.272	0.874	22.111	43.972	24.547	41.655	0.867

403	60	404	617.494	1.528	22.223	43.263	24.151	40.172	0.876	22.516	44.765	24.989	41.566	0.869
407	61	409	624.006	1.526	22.507	43.868	24.489	40.236	0.874	22.799	45.361	25.322	41.605	0.868
412	62	414	630.679	1.523	22.798	44.444	24.810	40.272	0.874	23.072	45.971	25.663	41.656	0.867
424	63	424	649.393	1.532	23.353	45.361	25.322	40.134	0.877	23.620	46.918	26.191	41.511	0.870
431	64	430	659.687	1.534	23.655	45.951	25.651	40.088	0.878	23.941	47.524	26.530	41.461	0.871
439	65	439	672.618	1.532	24.178	46.991	26.232	40.155	0.876	24.488	48.615	27.139	41.543	0.870
444	66	444	679.550	1.531	24.436	47.516	26.525	40.146	0.876	24.745	49.177	27.452	41.549	0.870
451	67	451	691.044	1.532	24.781	48.167	26.888	40.064	0.878	25.167	49.919	27.867	41.522	0.870
455	68	456	697.414	1.529	25.047	48.770	27.225	40.121	0.877	25.448	50.549	28.218	41.585	0.869

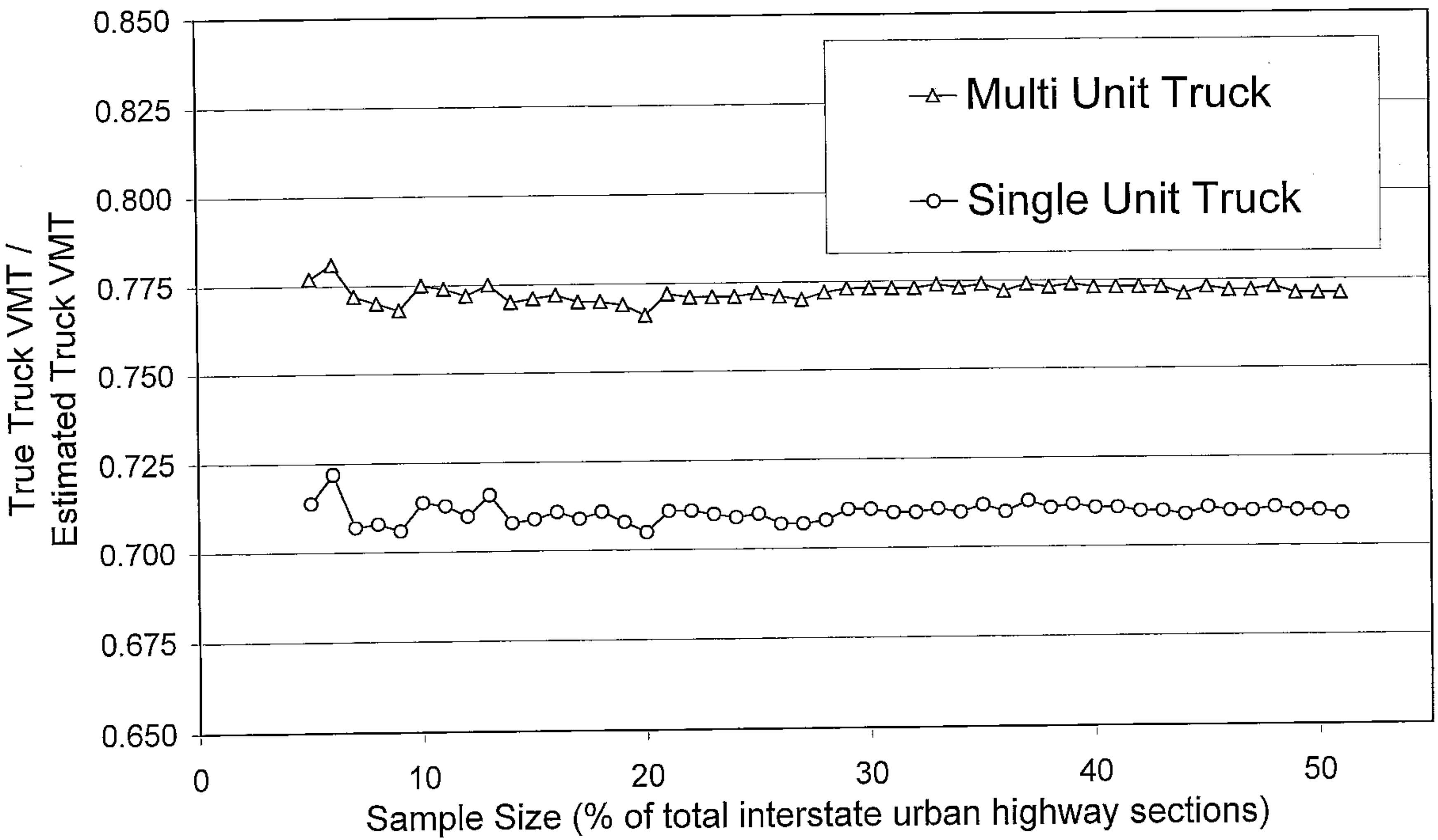
Minor Arterial Urban
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
26	5	26	24.646	0.948	4.636	11.287	3.975	78.129	0.633	5.446	13.580	4.783	93.999	0.647
31	6	31	29.856	0.963	5.662	13.687	4.821	79.461	0.623	6.684	16.583	5.840	96.273	0.632
37	7	37	35.349	0.955	6.724	16.440	5.790	79.969	0.619	7.893	19.745	6.954	96.042	0.633
41	8	41	38.834	0.947	7.382	17.980	6.333	78.925	0.627	8.706	21.698	7.642	95.245	0.639
47	9	47	44.803	0.953	8.583	20.964	7.384	80.277	0.616	10.123	25.214	8.880	96.549	0.630
51	10	51	48.650	0.954	9.343	22.806	8.032	80.480	0.615	10.998	27.382	9.644	96.627	0.629
55	11	55	52.501	0.955	10.163	24.825	8.743	81.234	0.609	11.958	29.792	10.493	97.486	0.624
62	12	62	58.756	0.948	11.336	27.772	9.781	80.618	0.614	13.306	33.227	11.703	96.453	0.631
66	13	66	62.980	0.954	12.194	29.726	10.469	81.059	0.611	14.320	35.574	12.529	97.006	0.627
70	14	70	66.816	0.955	12.994	31.749	11.182	81.628	0.606	15.233	37.869	13.338	97.364	0.625
78	15	78	74.332	0.953	14.345	34.948	12.309	80.638	0.614	16.853	41.834	14.734	96.525	0.630
81	16	81	77.342	0.955	14.911	36.322	12.793	80.705	0.613	17.502	43.421	15.293	96.476	0.630
87	17	87	83.240	0.957	16.094	39.119	13.778	80.924	0.612	18.881	46.708	16.451	96.623	0.630
92	18	92	87.876	0.955	16.924	41.183	14.505	80.563	0.614	19.924	49.335	17.376	96.511	0.630
96	19	97	92.373	0.952	17.773	43.446	15.302	80.609	0.614	20.951	51.969	18.304	96.424	0.631
101	20	101	97.219	0.963	18.844	45.727	16.105	81.481	0.607	22.167	54.663	19.252	97.406	0.624
108	21	107	103.160	0.964	19.954	48.230	16.986	81.122	0.610	23.457	57.720	20.329	97.085	0.627
114	22	113	109.037	0.965	21.104	51.080	17.990	81.355	0.608	24.827	61.080	21.513	97.282	0.625

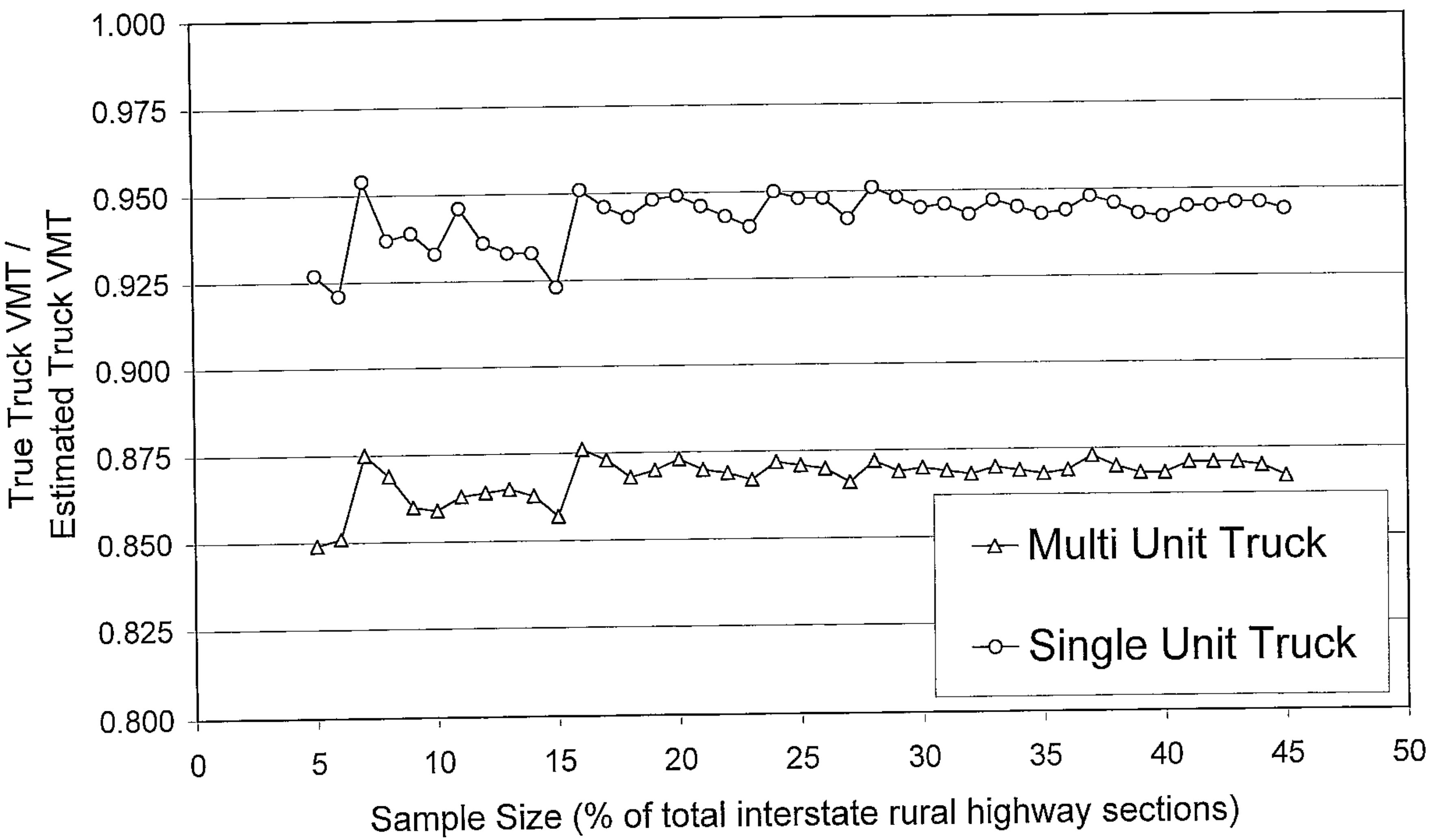
Appendix E.2

Plot of Methodology Adjustment Factor (MAF) for the Average Section Length (ASL) Method

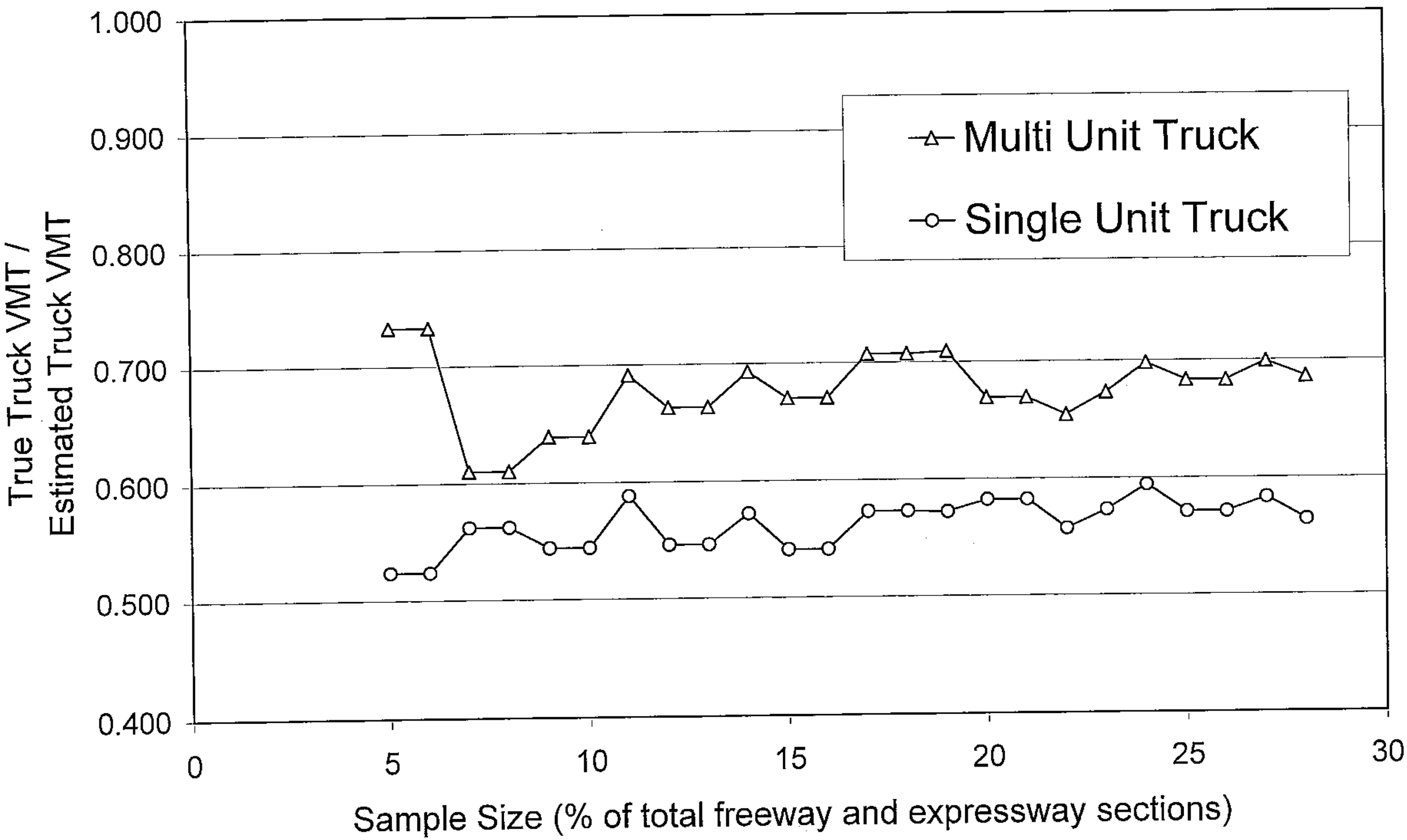
MAF (ASL Method) for Interstate Urban Highways



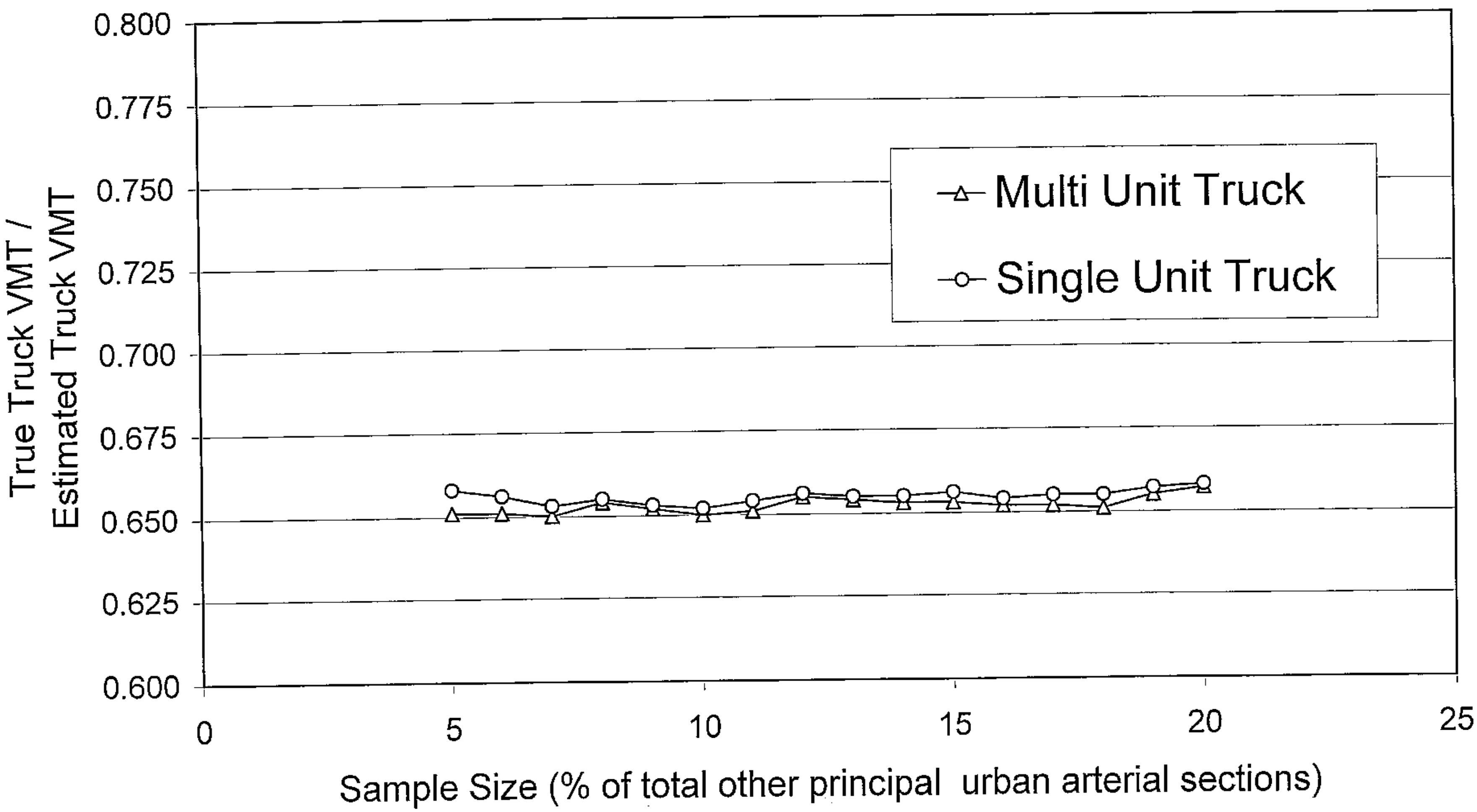
MAF (ATP Method) for Interstate Rural Highways

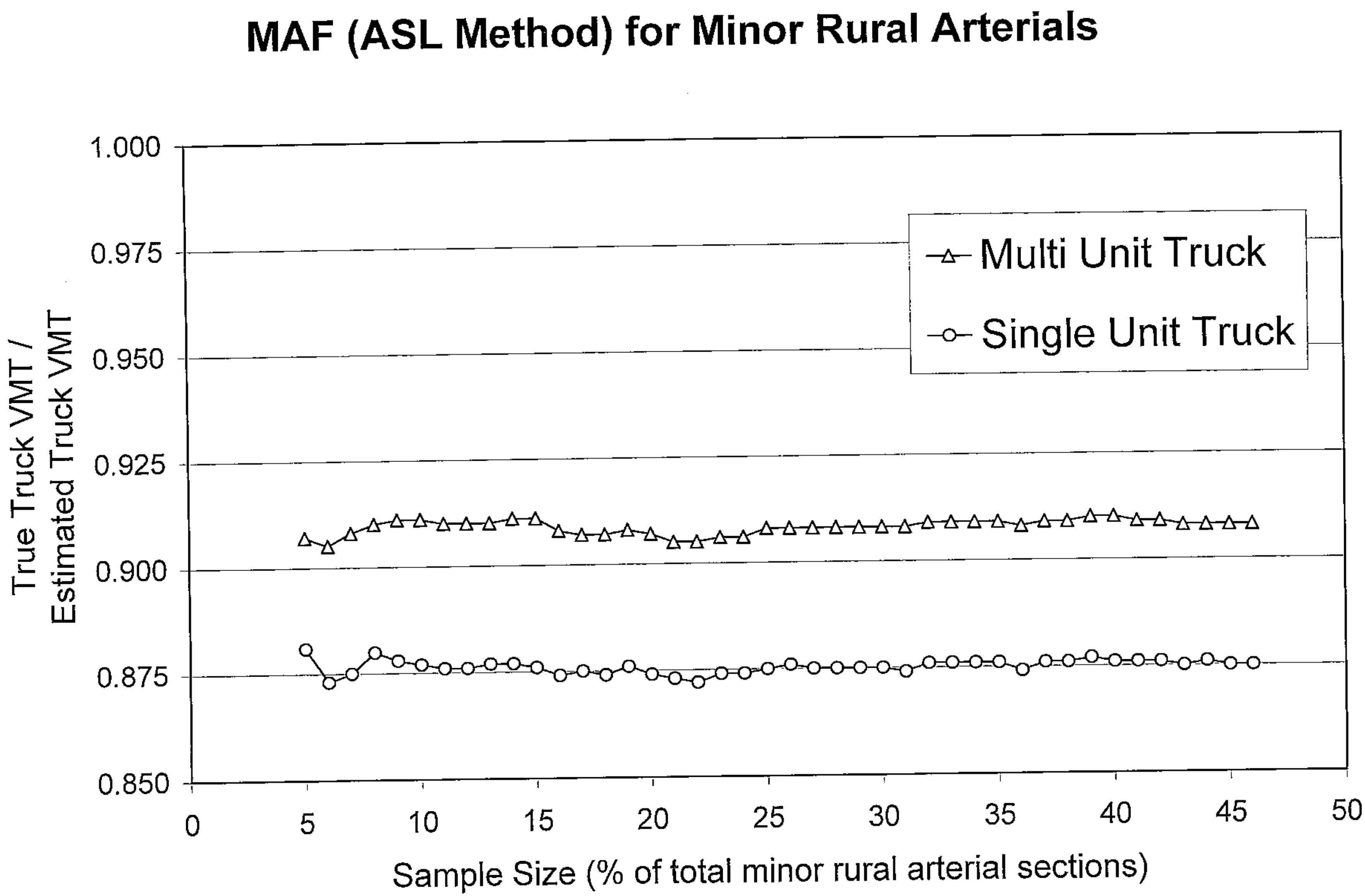


MAF (ASL Method) for Freeways and Expressways



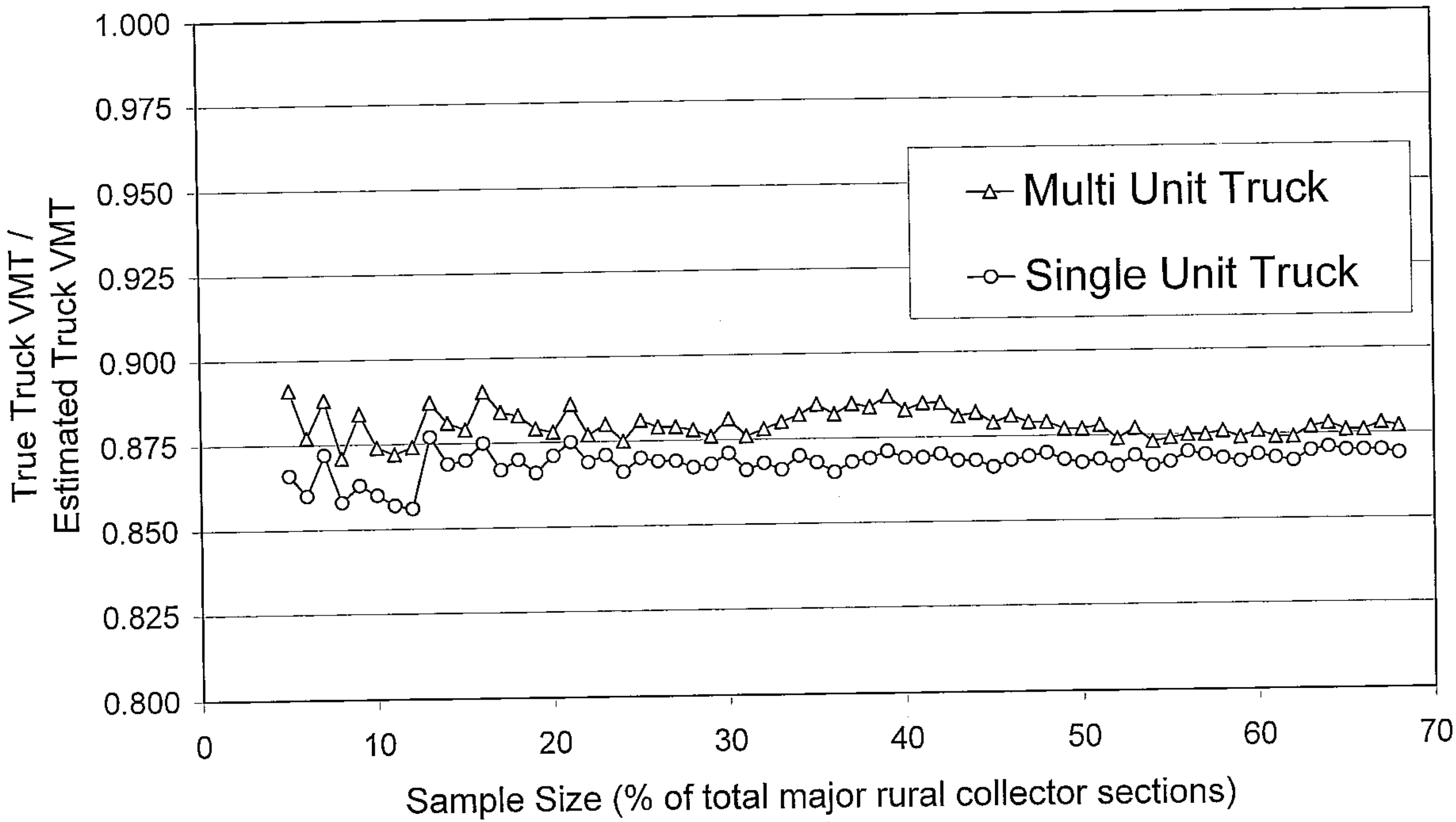
MAF (ASL Method) for Other Principal Urban Arterials



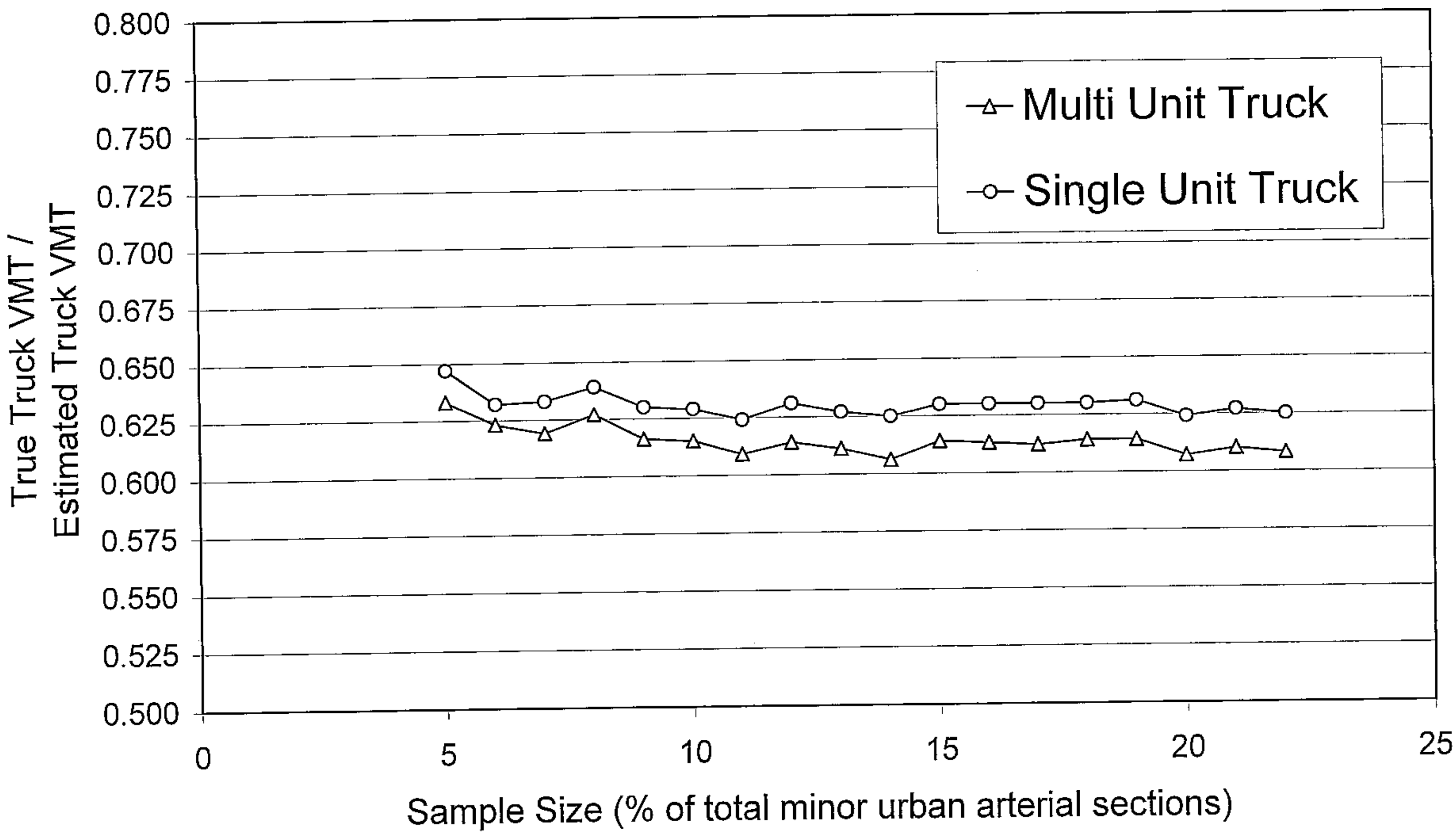


MAF (ASL Method) for Minor Rural Arterials
True Truck VMT / Estimated Truck VMT
1.000
0.975
0.950
0.925
0.900
0.875
0.850
0
5
10
15
20
25
30
35
40
45
50
Sample Size (% of total minor rural arterial sections)
Multi Unit Truck
Single Unit Truck

MAF (ASL Method) for Major Rural Collectors



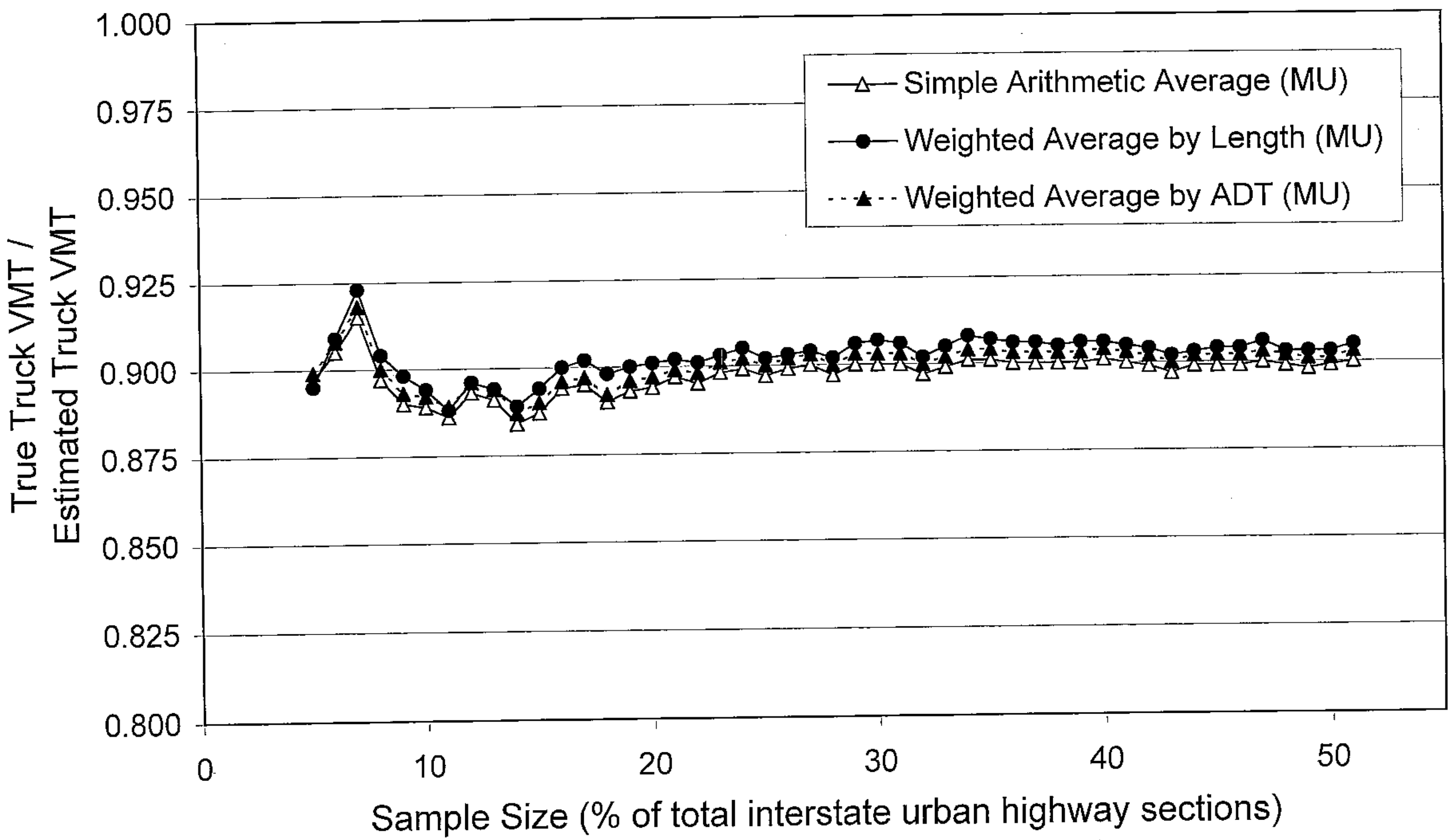
MAF (ASL Method) for Minor Urban Arterials



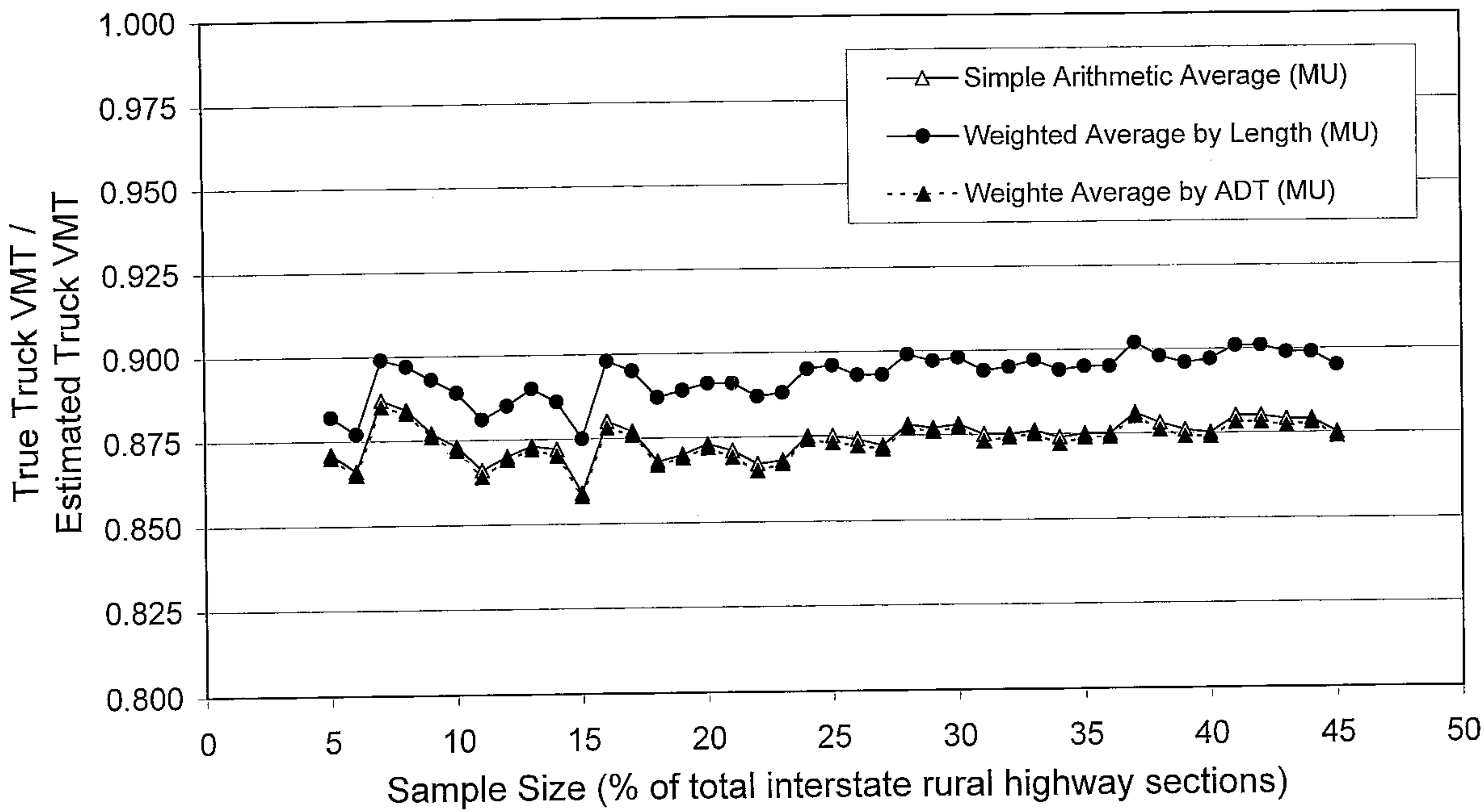
Appendix F.1

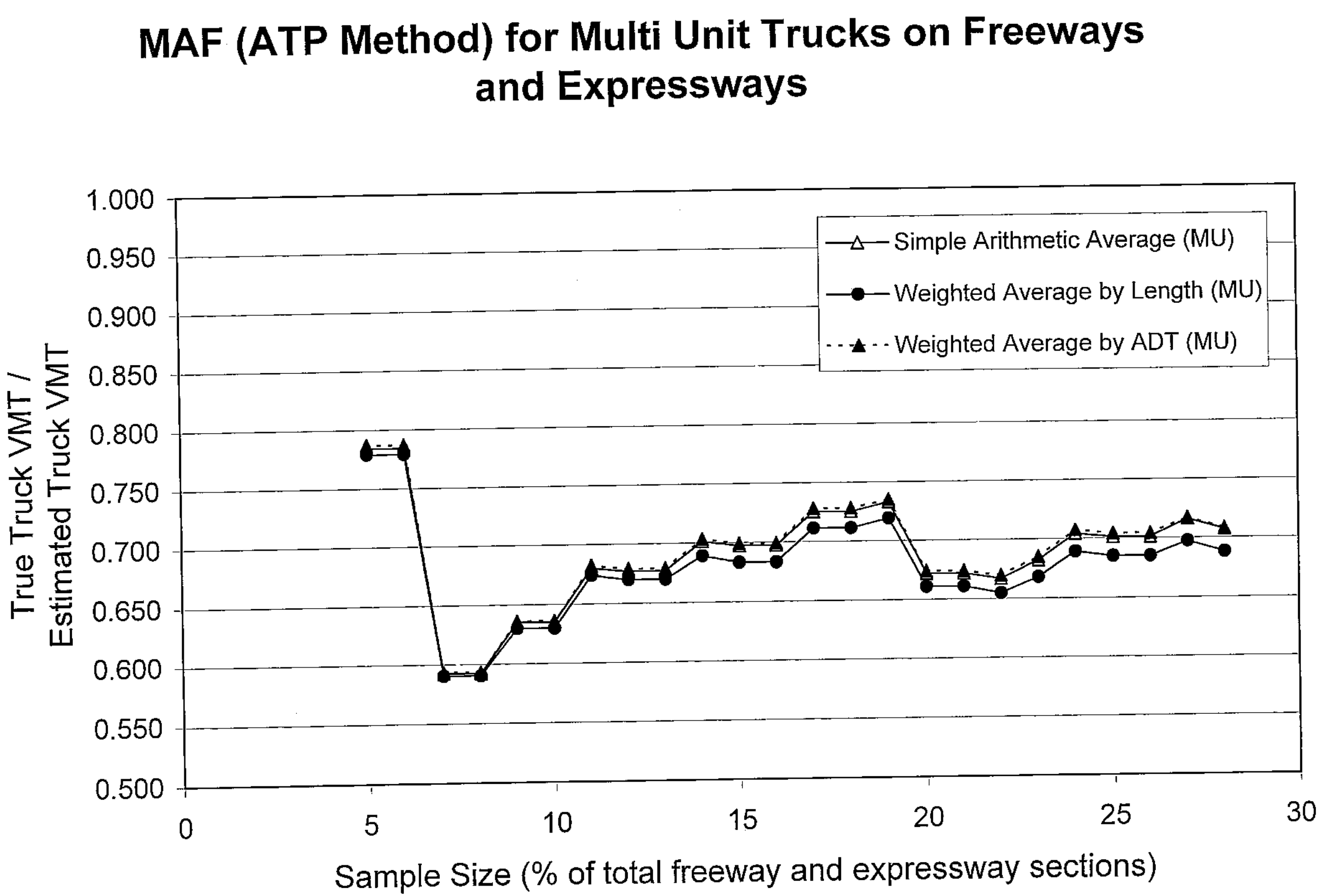
Comparison of Methodology Adjustment Factor (MAF) for the Average Truck Percentage (ATP) Method Using Three different ATP Factors

MAF (ATP Method) for Multi Unit Trucks on Interstate Urban Highways



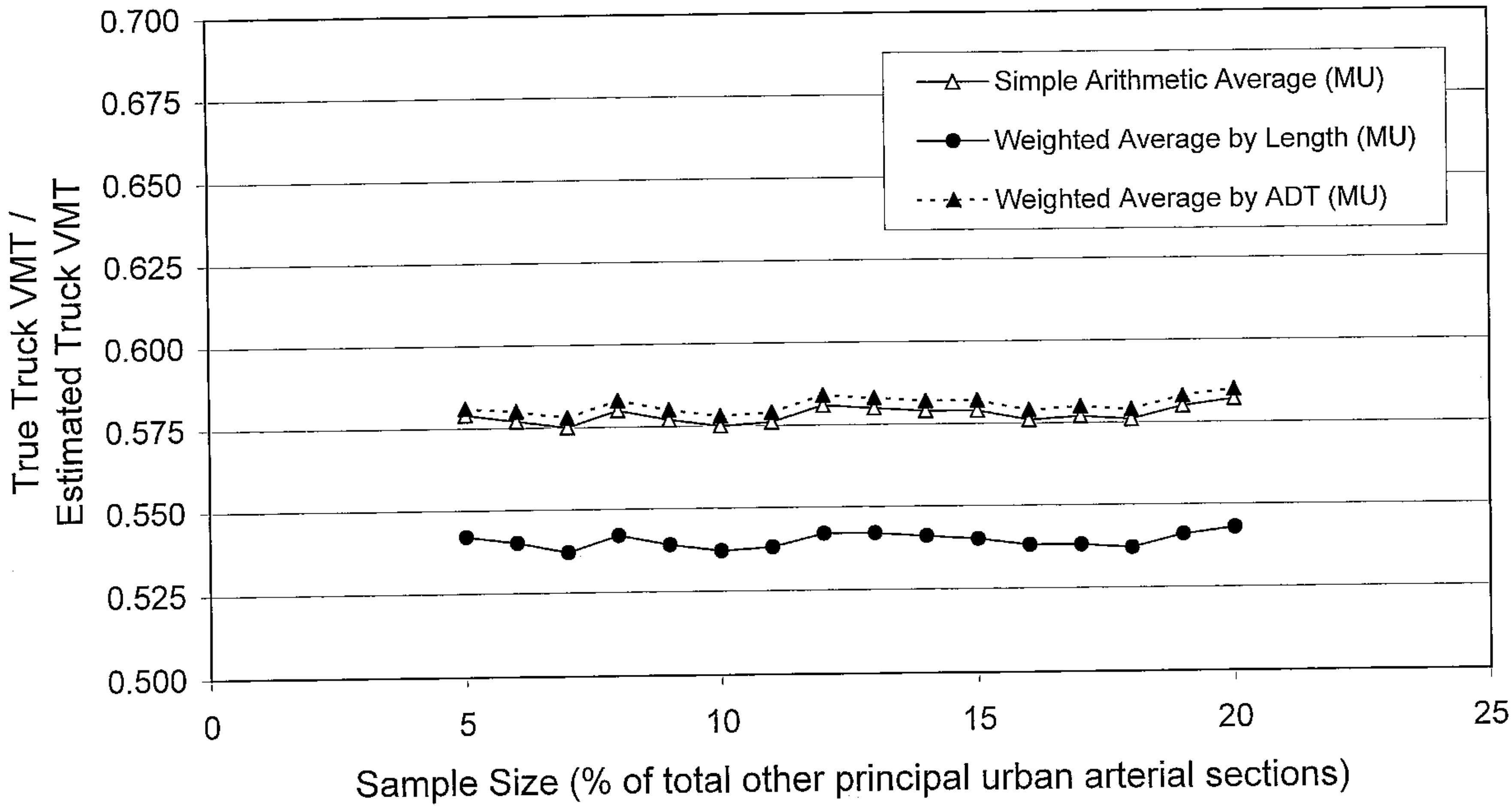
MAF (ATP Method) for Multi Unit Trucks on Interstate Rural Highways



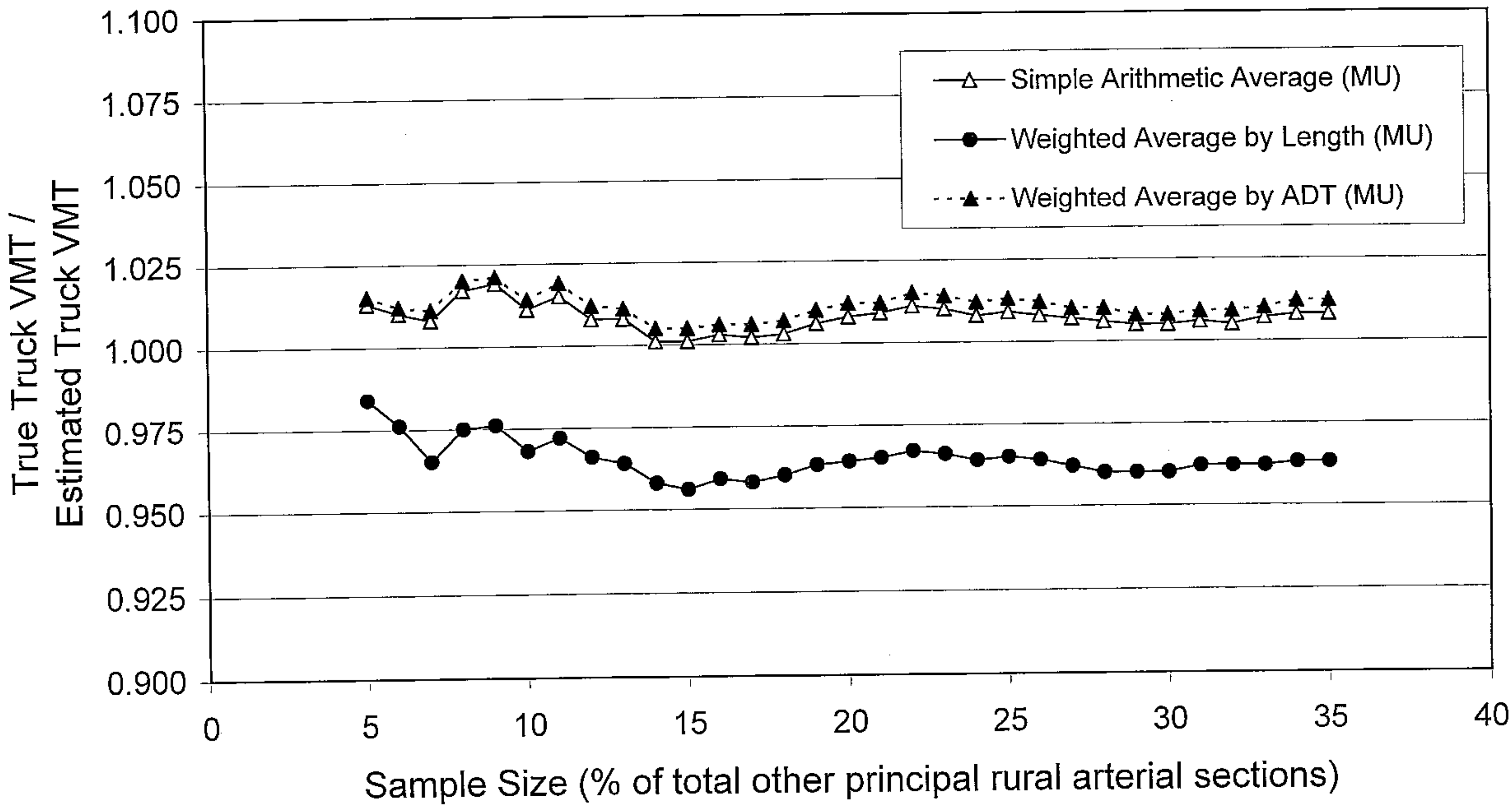


MAF (ATP Method) for Multi Unit Trucks on Freeways and Expressways
True Truck VMT / Estimated Truck VMT
1.000
0.950
0.900
0.850
0.800
0.750
0.700
0.650
0.600
0.550
0.500
0
5
10
15
20
25
30
Sample Size (% of total freeway and expressway sections)
Simple Arithmetic Average (MU)
Weighted Average by Length (MU)
Weighted Average by ADT (MU)

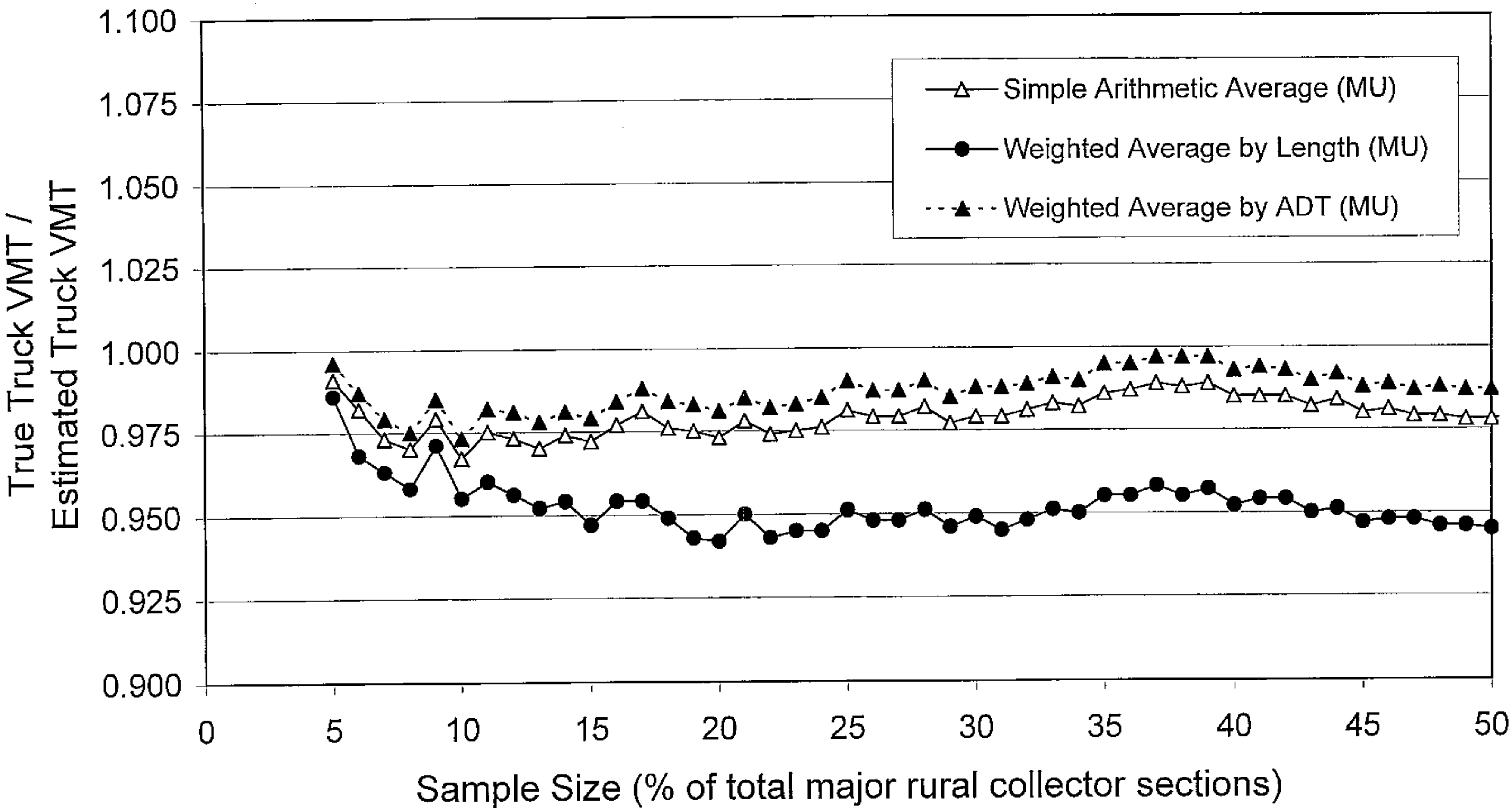
MAF (ATP Method) for Multi Unit Trucks on Other Principal Urban Arterials



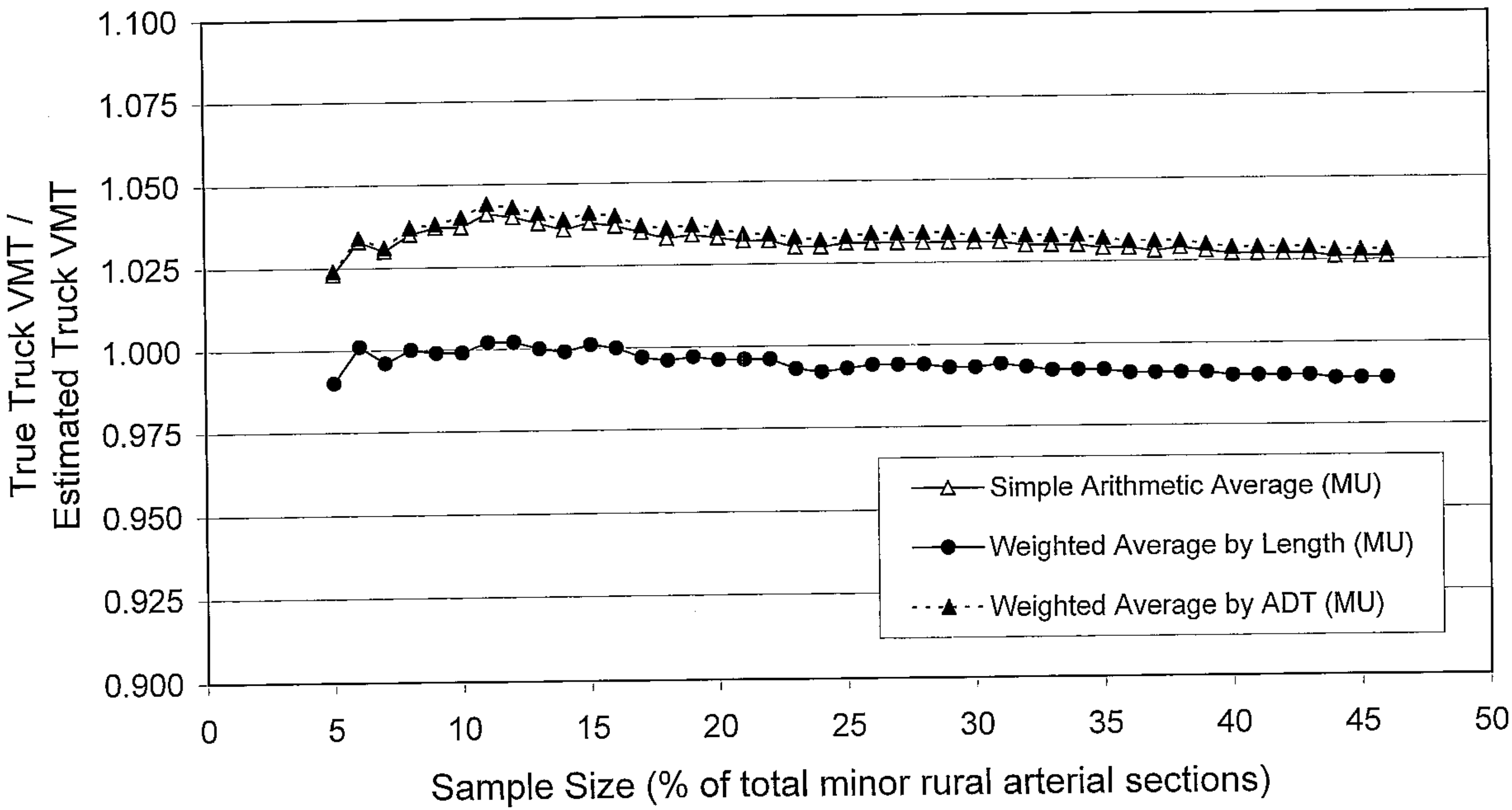
MAF (ATP Method) for Multi Unit Trucks on Other Principal Rural Arterials



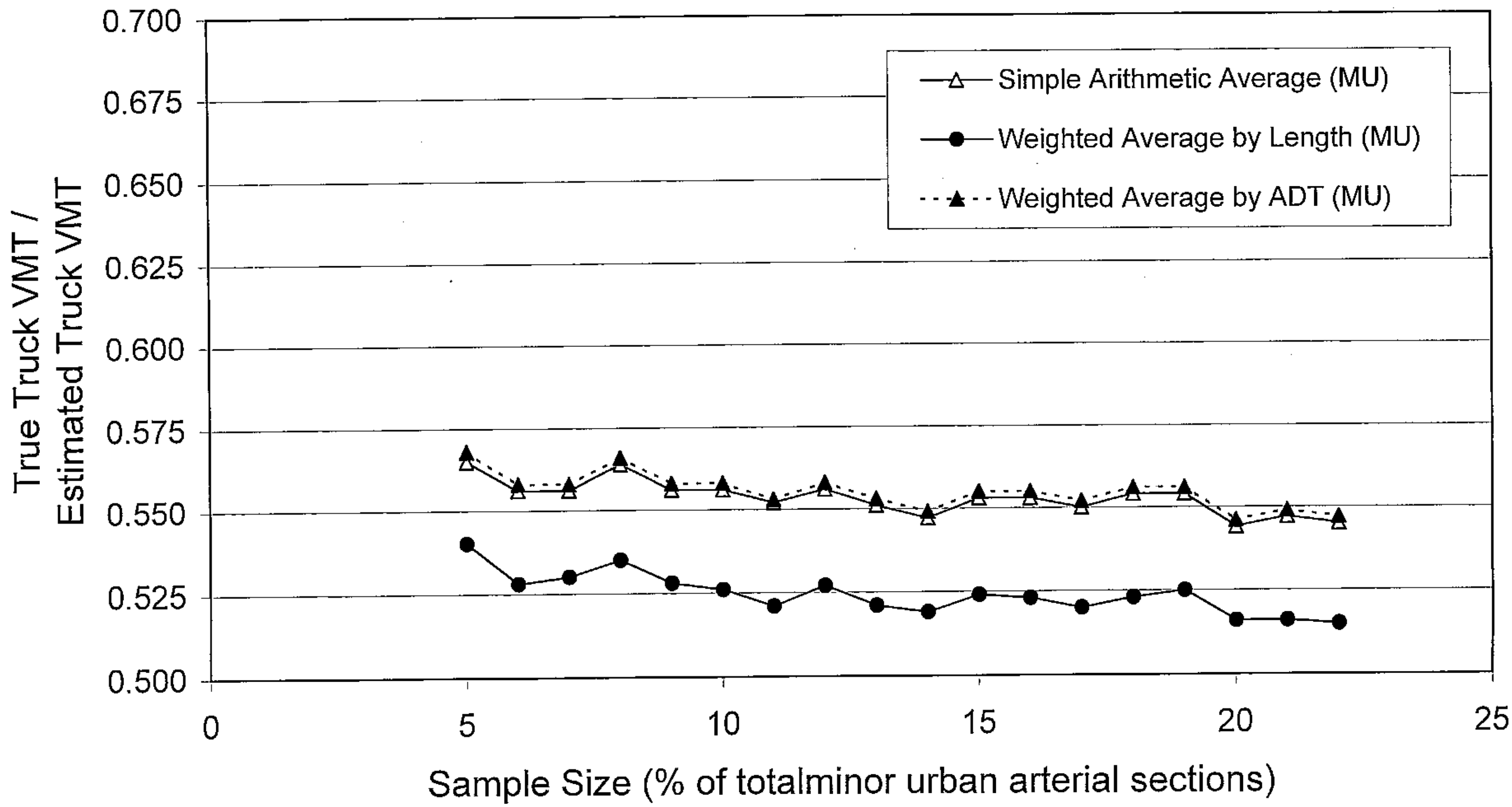
MAF (ATP Method) for Multi Unit Trucks on Major Rural Collectors



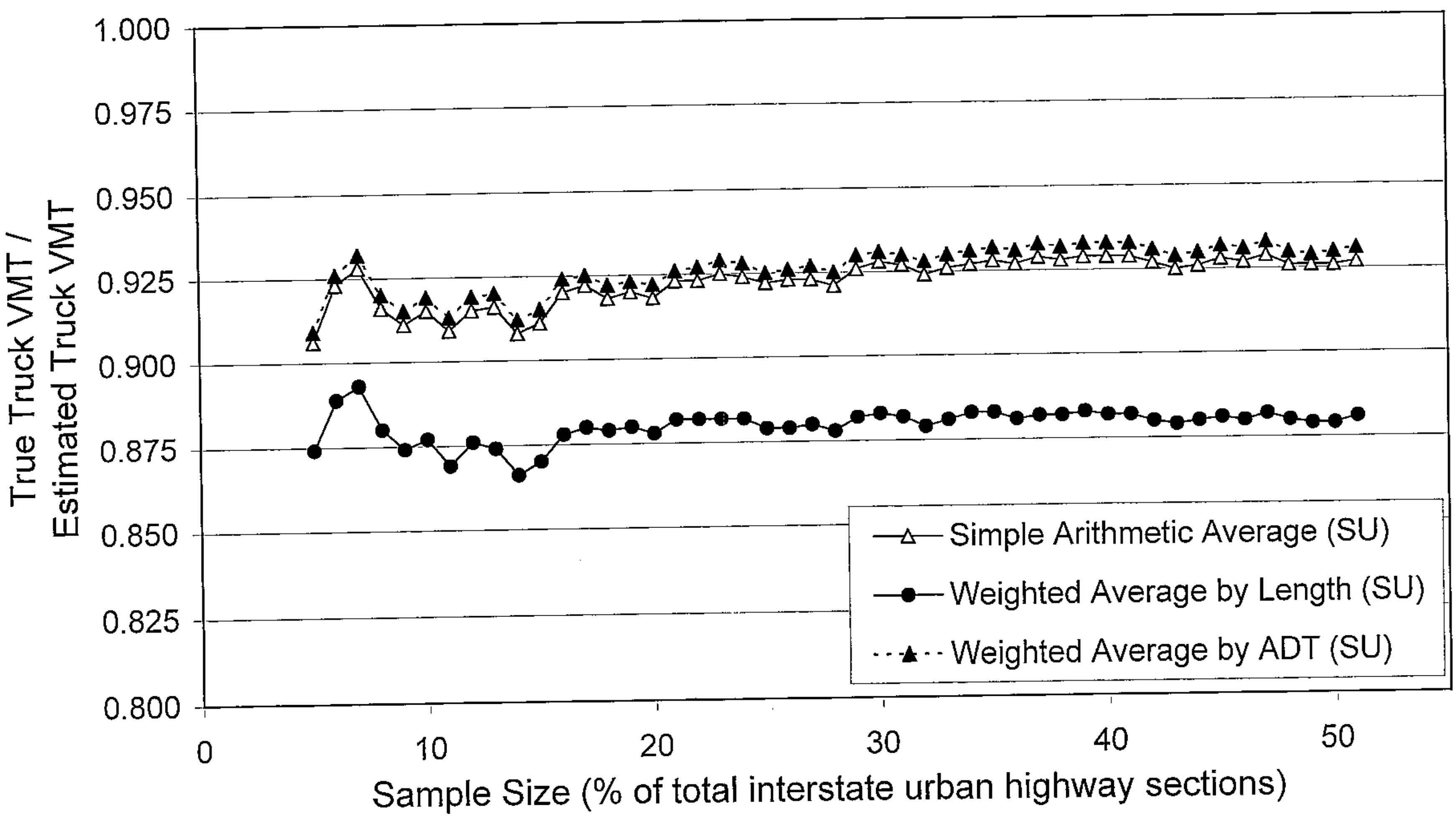
MAF (ATP Method) for Multi Unit Trucks on Minor Rural Arterials



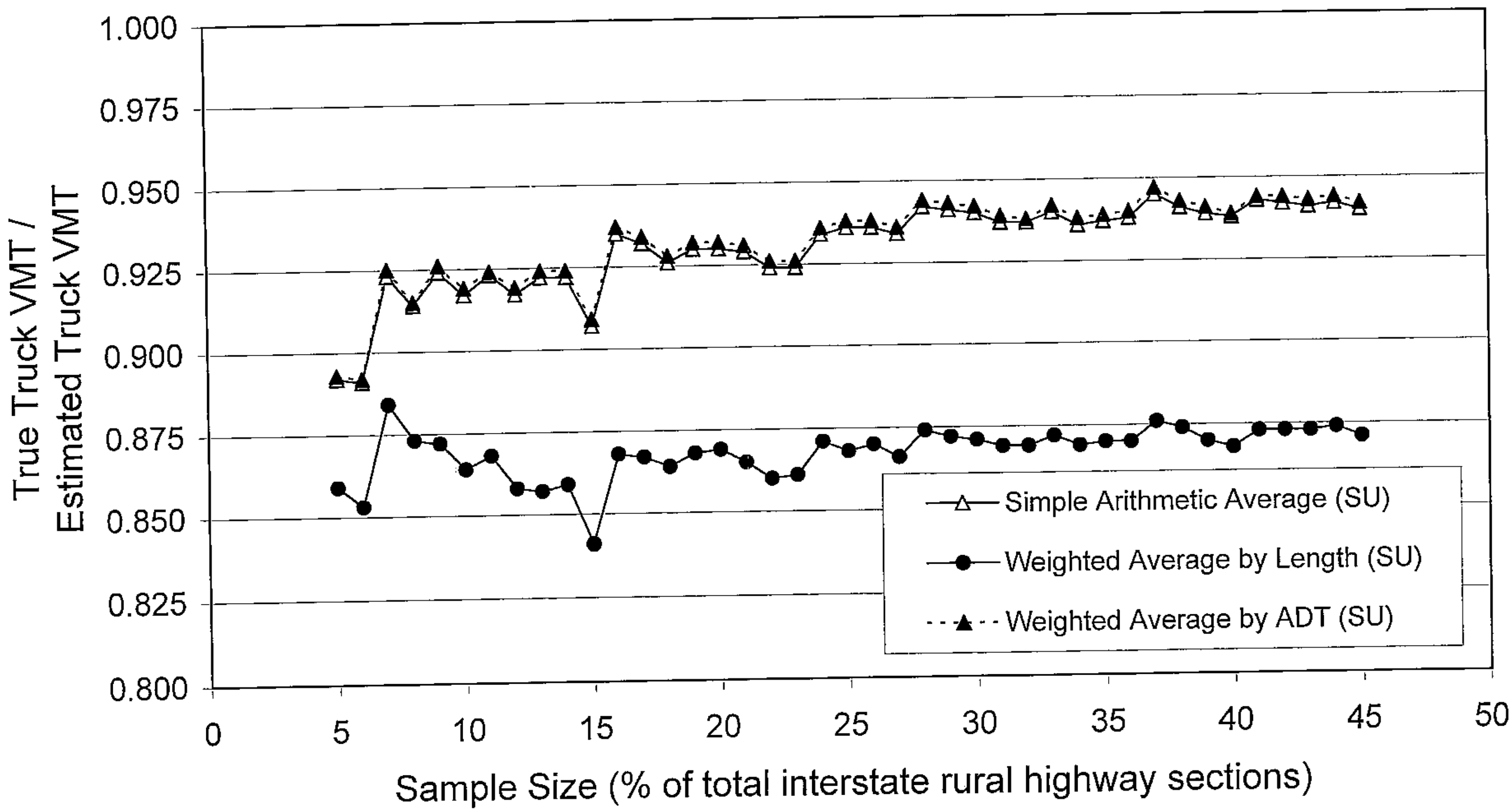
MAF (ATP Method) for Multi Unit Trucks on Minor Urban Arterials



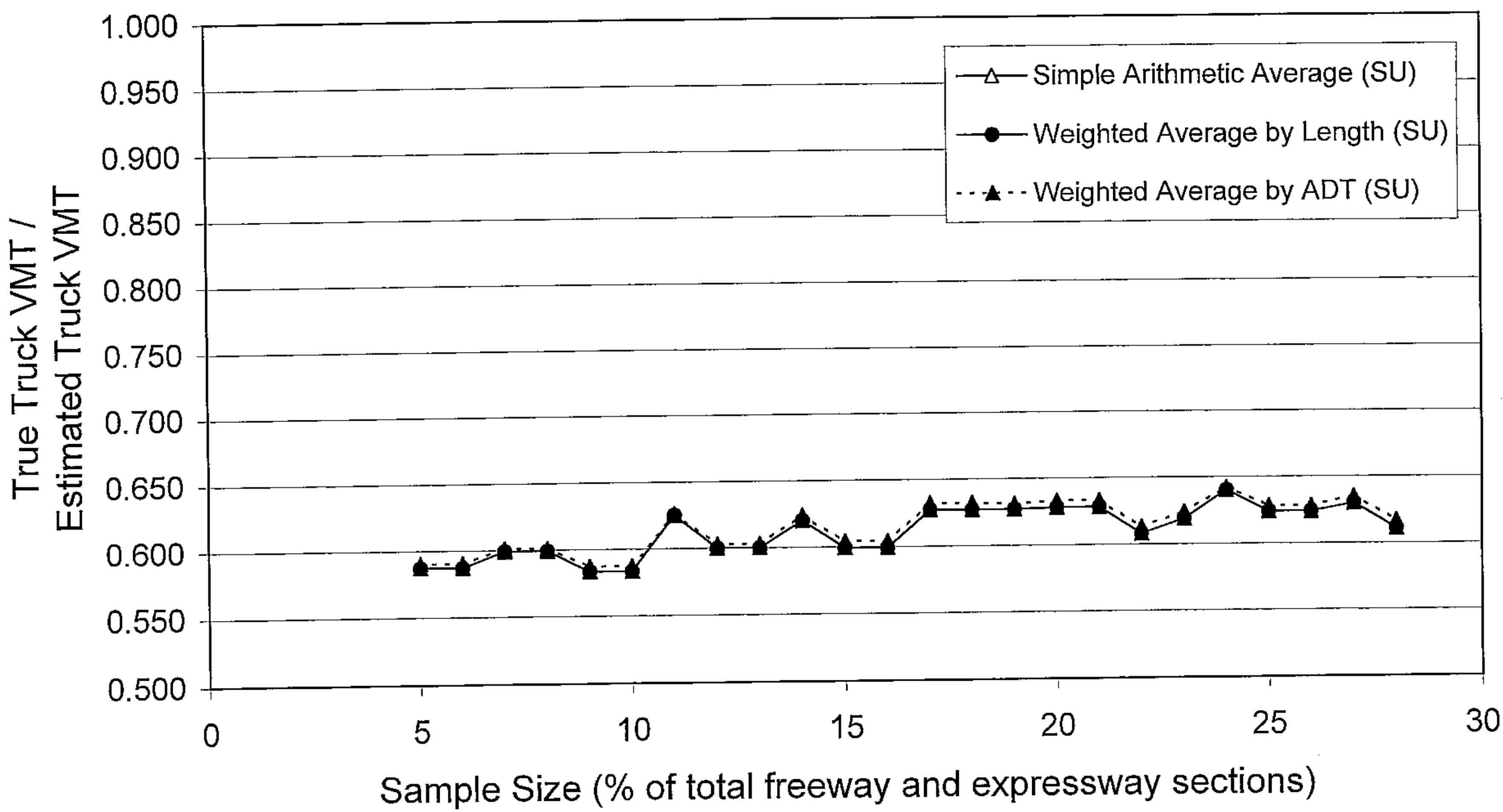
MAF (ATP Method) for Single Unit Trucks on Interstate Urban Highways



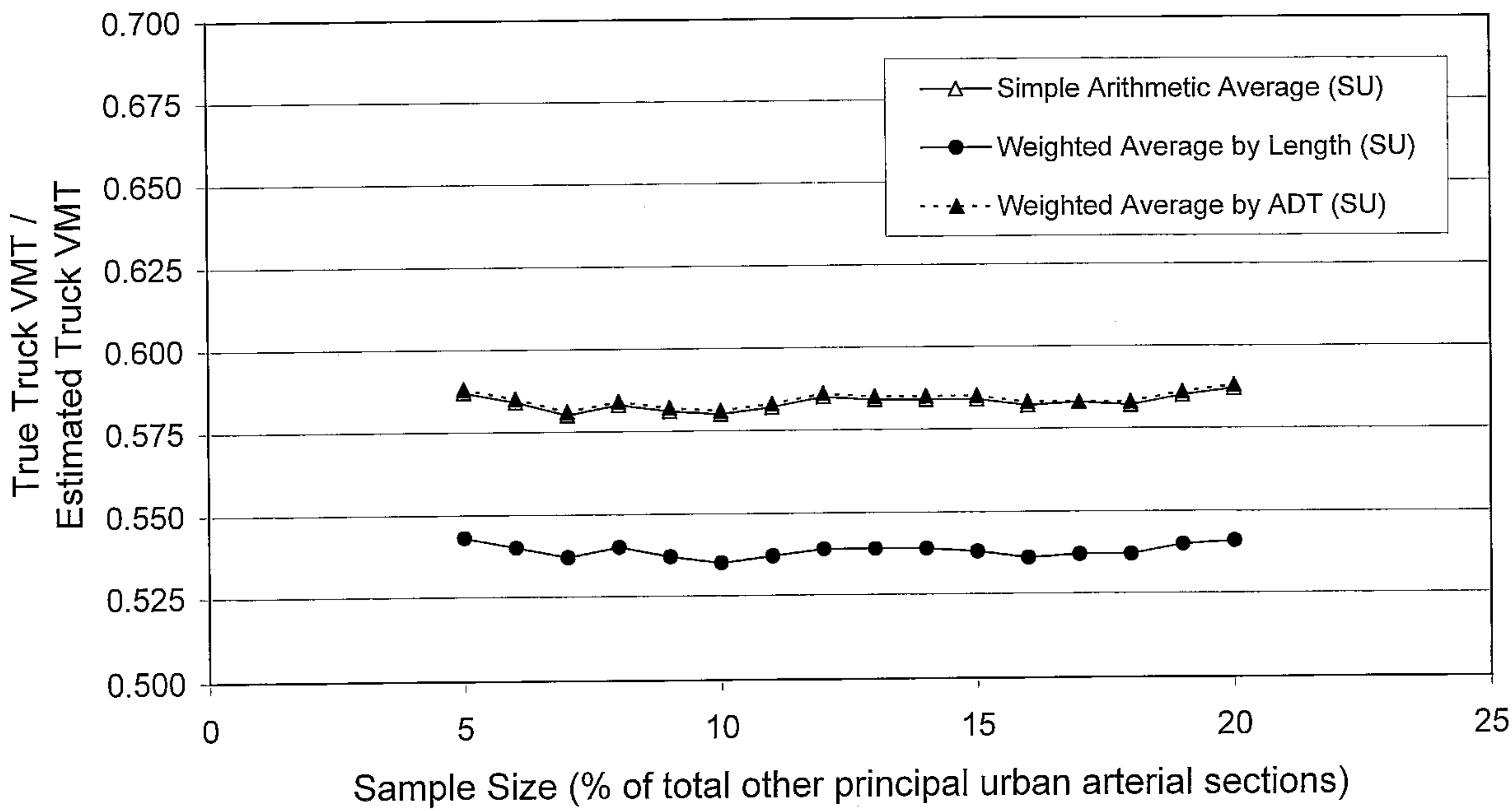
MAF (ATP Method) for Single Unit Trucks on Interstate Rural Highways

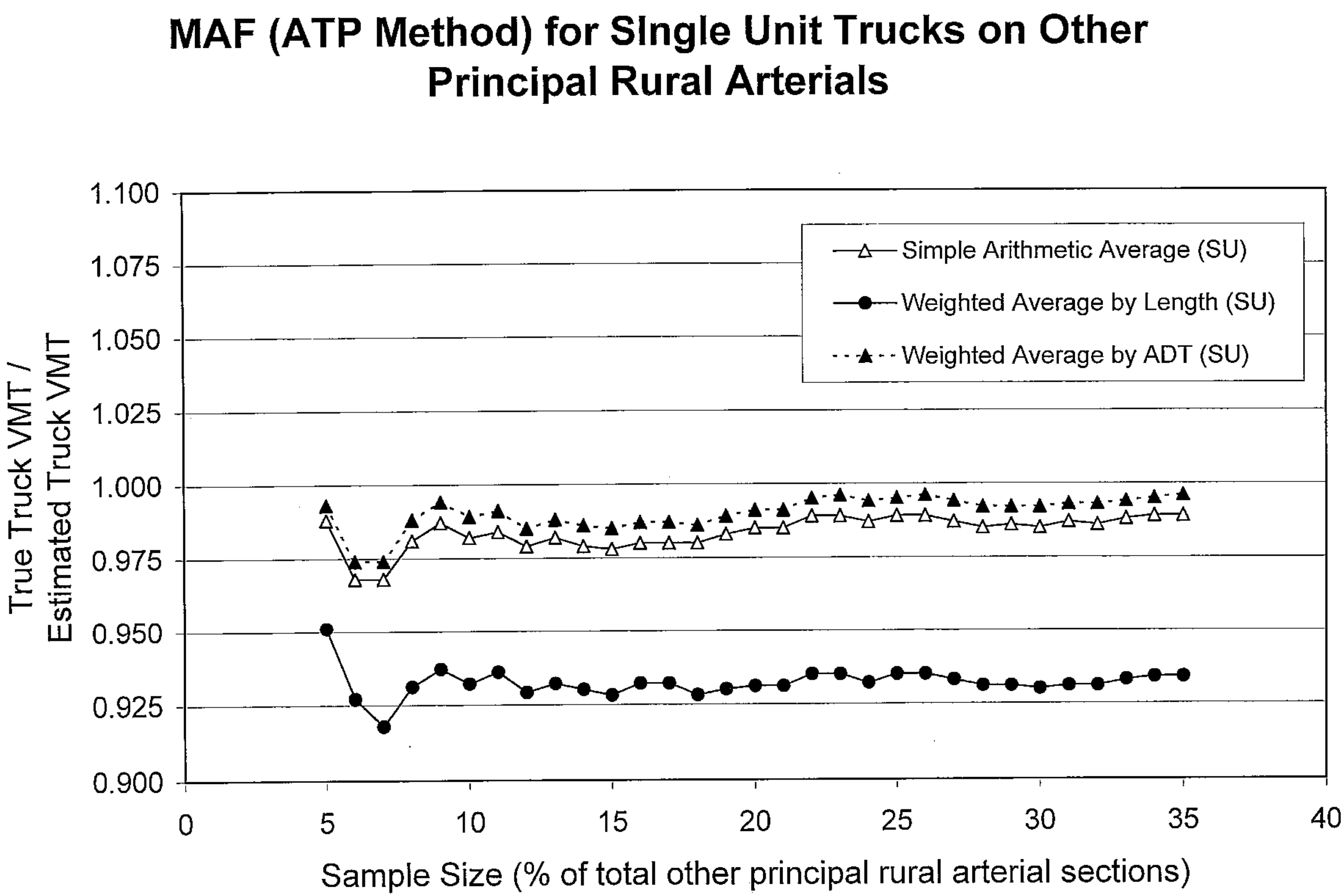


MAF (ATP Method) for Single Unit Trucks on Freeways and Expressways

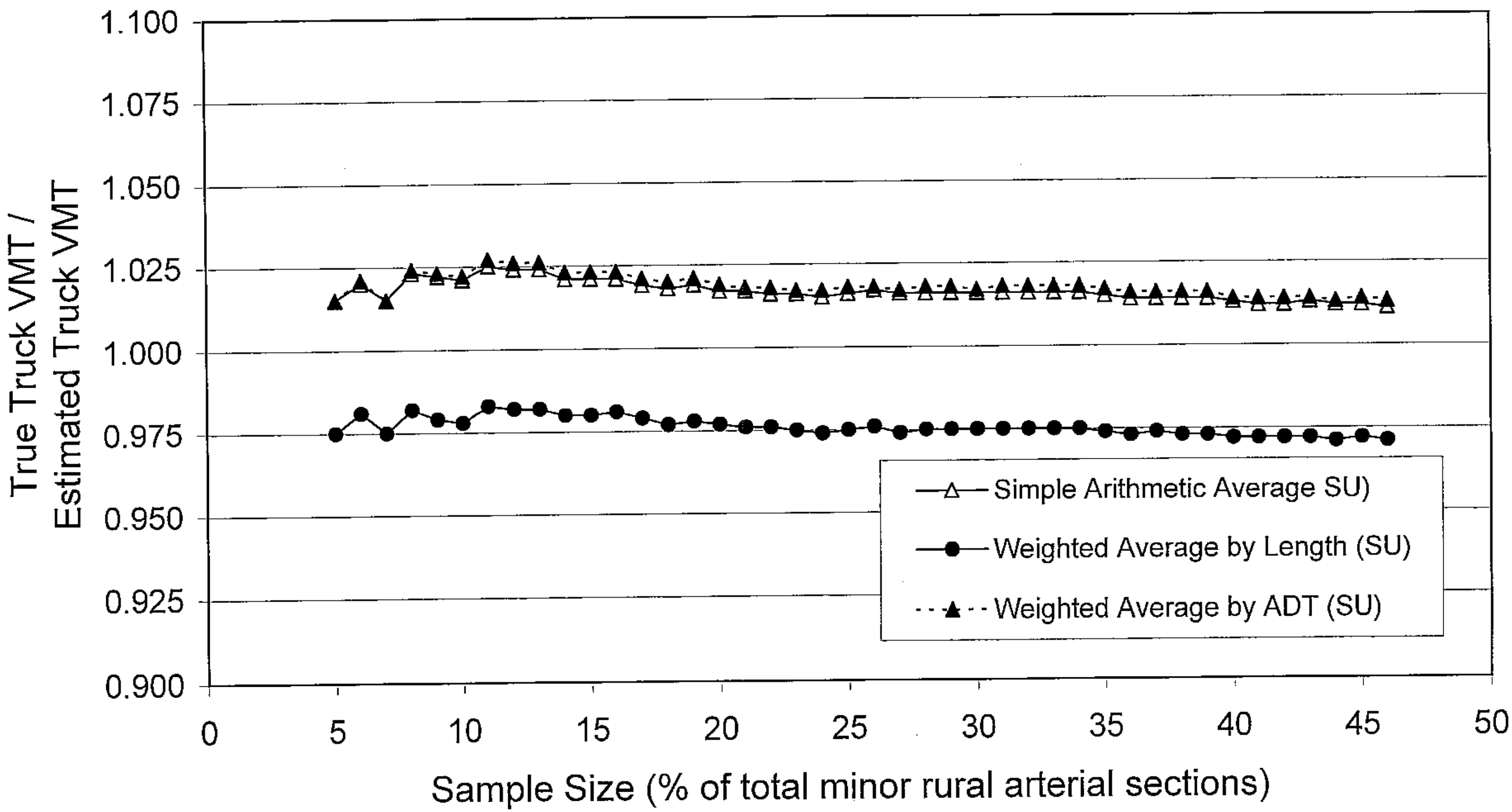


MAF (ATP Method) for Single Unit Trucks on Other Principal Urban Arterials

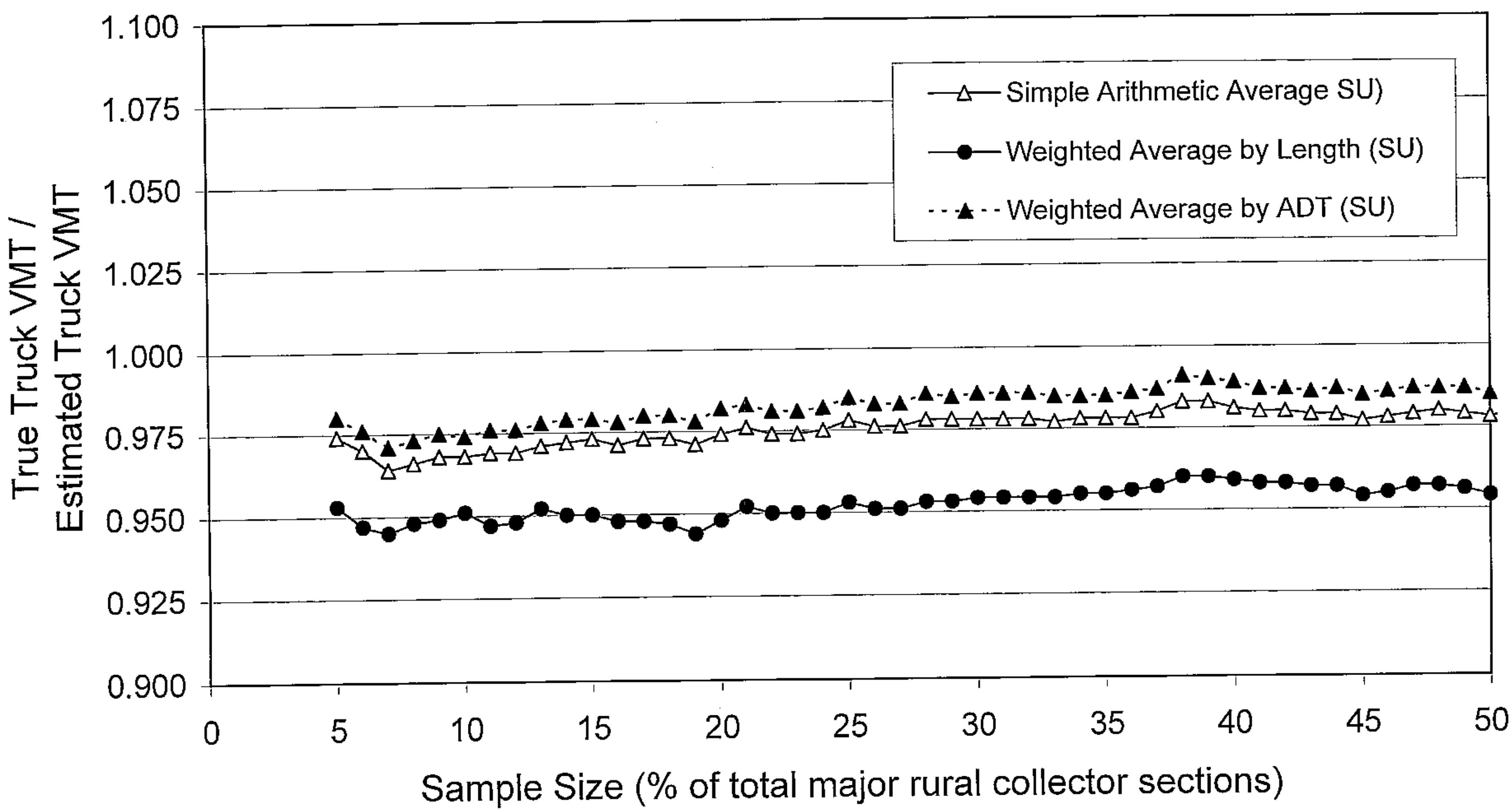



MAF (ATP Method) for Single Unit Trucks on Other Principal Rural Arterials
1.100
1.075
1.050
1.025
1.000
0.975
0.950
0.925
0.900
True Truck VMT / Estimated Truck VMT
0
5
10
15
20
25
30
35
40
Sample Size (% of total other principal rural arterial sections)
Simple Arithmetic Average (SU)
Weighted Average by Length (SU)
Weighted Average by ADT (SU)

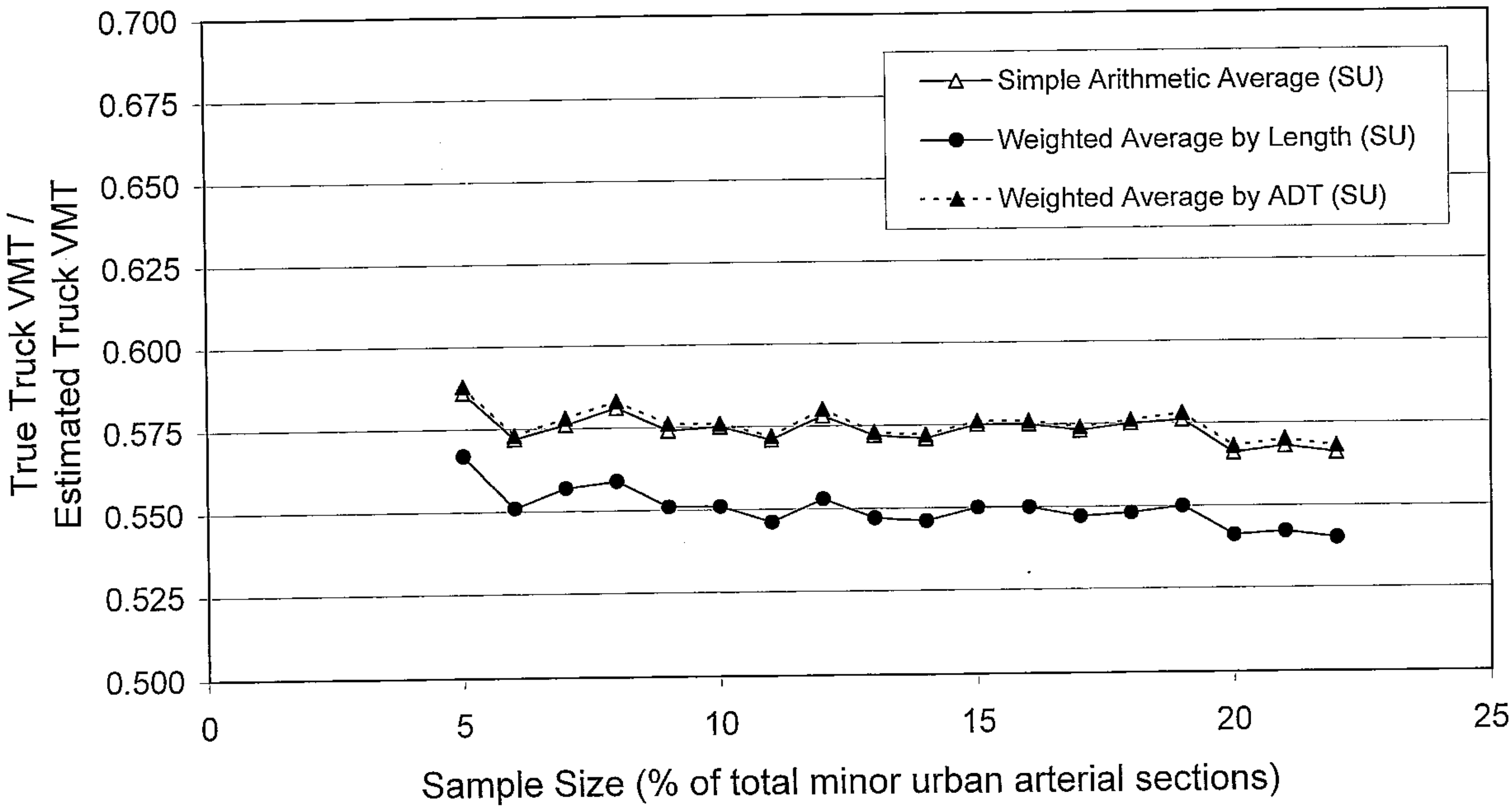
MAF (ATP Method) for Single Unit Trucks on Minor Rural Arterials



MAF (ATP Method) for Single Unit Trucks on Major Rural Collectors



MAF (ATP Method) for Single Unit Trucks on Minor Urban Arterials



Appendix F.2

Methodology Adjustment Factor (MAF) for the Average Truck Percentage (ATP) Method

Notations

AveSection	= Average number of section
Size	= Percentage of the total number of section used as a sample size
Section	= The number of section in a group
Length	= The total length of the section in a group (in miles)
RatioLS	= The ratio of "Length" to "Section"
MuVMT1	= The true Multi Unit truck VMT
MuVol	= Multi Unit truck volume
MuVMT2	= The estimated Multi Unit truck VMT
expMuVMT2	= The estimated Multi Unit truck VMT expanded to population level
RMuVMT2	= The Multi Unit truck VMT Methodology Adjustment Factor (MAF)
SuVMT1	= The true Single Unit truck VMT
SuVol	= Single Unit truck volume
SuVMT2	= The estimated Single Unit truck VMT
expSuVMT2	= The estimated Single Unit truck VMT expanded to population level
RSuVMT2	= The Single Unit truck VMT Methodology Adjustment Factor (MAF)

APPENDIX F2

TRUCK VMT METHODOLOGY ADJUSTMENT FACTOR (MAF) FOR THE ATP METHOD
(the simple arithmetic truck percentage is used)

Interstate Urban
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
50	5	50	29.591	0.592	88.010	473.229	88.095	1737.237	0.897	27.783	158.848	26.886	530.185	0.906
60	6	60	35.645	0.594	103.907	564.983	104.744	1721.285	0.905	32.814	188.451	31.672	520.477	0.923
67	7	68	39.574	0.582	116.034	647.935	117.462	1703.202	0.915	36.976	218.027	35.683	517.399	0.928
80	8	80	47.154	0.589	139.359	764.727	140.962	1737.362	0.897	44.167	256.339	42.541	524.320	0.916
87	9	87	51.400	0.591	152.389	833.850	154.546	1751.516	0.890	48.329	279.477	46.491	526.893	0.911
101	10	100	59.861	0.599	175.959	949.833	177.824	1753.344	0.889	55.345	317.369	53.243	524.977	0.915
110	11	108	64.884	0.601	191.207	1026.484	192.735	1759.598	0.886	60.323	343.637	57.884	528.457	0.909
118	12	118	69.975	0.593	206.876	1124.064	208.831	1744.977	0.893	65.436	376.760	62.819	524.912	0.915
129	13	129	76.506	0.593	226.693	1225.296	228.906	1749.621	0.891	71.645	408.659	68.552	523.973	0.916
138	14	137	81.459	0.595	242.301	1309.713	244.817	1761.968	0.884	76.861	438.639	73.495	528.946	0.908
150	15	149	88.649	0.595	262.081	1421.531	265.456	1756.644	0.887	83.213	476.180	79.624	526.906	0.911
157	16	157	92.971	0.592	274.150	1495.612	277.694	1743.990	0.894	86.829	500.496	83.076	521.738	0.920
166	17	167	98.228	0.588	290.830	1596.093	295.036	1741.947	0.895	92.143	534.266	88.244	521.012	0.922
178	18	178	105.013	0.590	311.366	1700.907	316.247	1751.796	0.890	98.341	567.520	94.412	522.980	0.918
185	19	186	109.477	0.589	324.720	1779.258	329.142	1744.808	0.893	102.602	595.647	98.497	522.139	0.920
194	20	196	114.659	0.585	341.807	1881.445	346.406	1742.633	0.894	108.342	630.566	103.947	522.918	0.918
206	21	207	121.731	0.588	360.444	1973.814	364.910	1738.169	0.897	114.002	660.192	109.279	520.526	0.923
218	22	218	128.598	0.590	379.828	2080.017	384.899	1740.872	0.895	120.023	695.142	115.027	520.259	0.923
225	23	226	132.849	0.588	393.121	2157.091	397.945	1736.167	0.898	124.333	721.151	118.990	519.133	0.925
234	24	236	138.316	0.586	409.745	2253.156	414.748	1732.801	0.899	129.961	754.836	124.380	519.654	0.924
245	25	246	144.809	0.589	428.449	2345.143	433.321	1736.806	0.897	135.825	785.485	130.015	521.116	0.922
253	26	254	149.215	0.587	441.725	2424.803	446.401	1732.880	0.899	140.209	814.012	134.088	520.517	0.923
263	27	265	155.467	0.587	460.134	2530.718	465.378	1731.556	0.900	146.196	849.801	139.805	520.179	0.923
274	28	275	161.989	0.589	478.888	2621.855	484.491	1737.121	0.897	152.141	880.029	145.379	521.250	0.921
286	29	287	168.835	0.588	497.718	2730.628	504.197	1732.190	0.900	157.973	915.319	150.911	518.460	0.926
295	30	296	174.038	0.588	512.545	2818.089	519.796	1731.482	0.900	162.804	943.991	155.420	517.716	0.928
305	31	305	180.020	0.590	528.820	2904.194	535.594	1731.461	0.900	167.957	974.035	160.311	518.250	0.927
316	32	315	186.324	0.592	548.227	2999.237	555.171	1737.772	0.897	174.066	1005.252	166.066	519.814	0.924
327	33	326	192.719	0.591	565.496	3100.610	572.958	1732.933	0.899	179.645	1039.350	171.388	518.369	0.926
336	34	336	197.947	0.589	580.907	3199.428	589.360	1729.492	0.901	184.777	1073.052	176.443	517.776	0.927
347	35	346	204.385	0.591	598.809	3287.628	606.982	1729.723	0.901	190.247	1101.420	181.506	517.239	0.928
355	36	355	209.137	0.589	614.875	3382.945	623.243	1731.036	0.900	195.648	1134.260	186.558	518.158	0.927
367	37	366	216.309	0.591	634.083	3478.745	642.825	1731.763	0.900	201.382	1164.545	191.888	516.944	0.929

376	38	376	221.784	0.590	652.085	3576.924	660.136	1731.102	0.900	207.032	1198.222	197.282	517.342	0.928
386	39	386	227.825	0.590	668.907	3670.224	678.102	1732.146	0.900	212.284	1228.301	202.408	517.031	0.929
394	40	394	231.978	0.589	682.236	3750.022	691.061	1729.408	0.901	216.841	1256.695	206.570	516.948	0.929
406	41	405	239.043	0.590	702.241	3852.735	710.921	1730.784	0.900	222.864	1291.379	212.363	517.013	0.929
415	42	414	244.429	0.590	718.666	3941.350	728.024	1733.892	0.899	228.249	1321.167	217.597	518.238	0.927
427	43	425	251.335	0.591	739.921	4046.747	748.676	1736.928	0.897	234.818	1356.448	223.806	519.229	0.925
432	44	432	254.408	0.589	751.002	4121.764	759.615	1733.750	0.899	238.345	1381.487	227.149	518.446	0.926
445	45	444	261.934	0.590	770.897	4228.007	780.349	1732.937	0.899	244.593	1415.857	233.045	517.528	0.928
454	46	454	267.731	0.590	788.327	4328.037	798.350	1733.862	0.899	250.351	1450.002	238.597	518.187	0.927
462	47	462	272.005	0.589	800.607	4403.732	810.915	1730.653	0.900	254.196	1475.142	242.283	517.081	0.929
476	48	475	280.561	0.591	825.068	4523.653	835.429	1734.175	0.899	262.019	1514.831	249.713	518.352	0.926
483	49	483	284.759	0.590	839.110	4606.499	849.859	1734.910	0.898	266.598	1542.427	254.128	518.779	0.926
493	50	492	290.138	0.590	854.881	4692.503	865.420	1734.358	0.899	271.591	1572.061	258.826	518.703	0.926
501	51	501	294.866	0.589	868.401	4778.684	880.107	1732.107	0.900	276.169	1601.234	263.292	518.175	0.927

Interstate Rural
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
22	5	22	60.204	2.737	100.133	104.017	101.419	2079.088	0.871	16.170	14.993	15.583	319.452	0.892
28	6	28	76.953	2.748	128.286	132.191	129.789	2090.527	0.866	20.745	19.211	19.857	319.833	0.891
32	7	32	88.462	2.764	142.977	146.810	144.901	2042.192	0.887	22.861	21.189	21.908	308.772	0.923
35	8	35	96.209	2.749	156.704	161.731	159.001	2048.844	0.884	25.315	23.600	24.201	311.848	0.914
40	9	40	109.539	2.738	180.058	186.780	183.073	2064.148	0.877	28.962	26.926	27.357	308.452	0.924
45	10	45	123.747	2.750	203.374	210.351	206.938	2073.978	0.873	32.903	30.481	31.008	310.774	0.917
50	11	50	138.459	2.769	227.991	232.770	231.938	2092.083	0.866	36.421	33.396	34.246	308.901	0.923
54	12	54	149.053	2.760	245.166	250.973	249.169	2081.025	0.870	39.732	36.475	37.204	310.723	0.917
59	13	59	162.458	2.754	266.474	273.984	271.225	2073.264	0.873	43.474	39.951	40.423	308.996	0.922
62	14	62	170.557	2.751	281.015	288.535	285.621	2077.662	0.872	45.619	42.008	42.495	309.120	0.922
67	15	67	185.624	2.771	307.675	313.925	313.208	2108.309	0.859	50.346	45.864	46.661	314.092	0.907
73	16	73	202.485	2.774	326.968	334.467	333.124	2058.068	0.880	53.102	48.537	49.314	304.664	0.935
76	17	76	210.244	2.766	341.357	349.722	347.842	2064.170	0.877	55.361	50.800	51.517	305.712	0.932
84	18	83	230.365	2.775	376.222	384.087	383.803	2085.482	0.868	60.710	55.609	56.629	307.709	0.926
87	19	86	238.840	2.777	389.012	397.132	396.843	2081.117	0.870	62.571	57.353	58.405	306.289	0.930
91	20	90	249.998	2.778	405.879	413.880	413.923	2074.213	0.873	65.386	59.949	61.131	306.332	0.930
96	21	95	263.240	2.771	428.777	438.393	438.083	2079.742	0.871	69.379	63.449	64.620	306.776	0.929
101	22	100	277.832	2.778	453.110	462.251	463.254	2089.276	0.867	73.439	67.020	68.406	308.511	0.924
104	23	104	287.490	2.764	470.703	481.944	480.897	2085.429	0.868	76.336	69.941	71.141	308.506	0.924
108	24	108	298.249	2.762	485.051	497.109	495.630	2069.714	0.875	78.363	71.884	73.062	305.100	0.934
114	25	114	314.634	2.760	511.707	525.812	523.199	2069.849	0.875	82.917	76.007	76.997	304.610	0.936
117	26	117	322.779	2.759	526.341	540.370	537.738	2072.821	0.874	84.947	78.005	79.000	304.522	0.936
122	27	122	335.858	2.753	549.088	565.719	561.574	2075.984	0.872	88.970	81.816	82.547	305.154	0.934

127	28	127	349.588	2.753	568.034	585.065	580.564	2061.689	0.878	91.830	84.428	85.174	302.469	0.942
130	29	130	357.243	2.748	582.464	600.557	595.057	2064.390	0.877	94.135	86.703	87.265	302.741	0.941
136	30	136	373.287	2.745	608.798	628.130	621.730	2061.765	0.878	98.644	90.946	91.444	303.243	0.940
140	31	140	385.467	2.753	629.430	647.008	642.696	2070.399	0.875	101.751	93.567	94.433	304.209	0.937
144	32	144	395.571	2.747	646.744	666.323	660.608	2068.988	0.875	104.667	96.484	97.156	304.286	0.937
149	33	149	409.621	2.749	667.919	688.125	682.569	2066.032	0.876	107.978	99.470	100.123	303.058	0.940
154	34	154	424.493	2.756	692.612	711.475	707.589	2072.226	0.874	111.897	102.985	103.919	304.336	0.936
158	35	158	434.116	2.748	709.282	730.844	724.798	2068.886	0.875	114.695	105.925	106.529	304.079	0.937
161	36	161	442.896	2.751	722.815	743.934	738.647	2069.129	0.875	116.850	107.759	108.465	303.837	0.938
167	37	167	457.953	2.742	744.280	768.355	760.855	2054.764	0.881	120.381	111.284	111.713	301.691	0.945
171	38	171	469.120	2.743	765.661	789.185	782.159	2062.888	0.878	123.642	114.249	114.809	302.800	0.941
177	39	177	485.280	2.742	793.832	819.084	811.670	2068.154	0.876	128.550	118.613	119.096	303.459	0.939
181	40	181	496.445	2.743	811.568	837.392	830.201	2068.623	0.875	131.716	121.476	122.003	303.996	0.938
183	41	184	503.535	2.737	821.029	848.690	839.752	2058.305	0.880	133.103	123.015	123.348	302.337	0.943
189	42	190	520.145	2.738	848.093	876.149	867.048	2058.097	0.880	137.424	127.066	127.431	302.481	0.942
193	43	193	529.567	2.744	863.055	889.456	882.105	2061.293	0.879	139.619	128.880	129.568	302.773	0.941
197	44	197	539.406	2.738	880.745	909.248	899.980	2060.361	0.879	142.400	131.654	132.143	302.521	0.942
202	45	202	553.332	2.739	906.892	935.708	926.720	2069.063	0.875	146.436	135.283	135.812	303.224	0.940

Freeway and Expressway

Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
4	5	4	3.503	0.876	2.701	8.961	2.688	52.422	0.784	2.083	7.291	2.089	40.739	0.587
4	6	4	3.503	0.876	2.701	8.961	2.688	52.422	0.784	2.083	7.291	2.089	40.739	0.587
5	7	5	4.576	0.915	4.462	13.461	4.450	69.418	0.592	2.552	8.491	2.559	39.919	0.599
5	8	5	4.576	0.915	4.462	13.461	4.450	69.418	0.592	2.552	8.491	2.559	39.919	0.599
8	9	8	7.048	0.881	6.675	20.546	6.645	64.791	0.635	4.189	14.034	4.196	40.915	0.584
8	10	8	7.048	0.881	6.675	20.546	6.645	64.791	0.635	4.189	14.034	4.196	40.915	0.584
9	11	9	8.091	0.899	7.014	21.373	6.978	60.478	0.680	4.396	14.599	4.429	38.382	0.623
10	12	10	8.722	0.872	7.825	24.773	7.781	60.695	0.677	5.067	17.473	5.115	39.898	0.599
10	13	10	8.722	0.872	7.825	24.773	7.781	60.695	0.677	5.067	17.473	5.115	39.898	0.599
11	14	11	9.783	0.889	8.378	26.075	8.269	58.632	0.701	5.400	18.357	5.441	38.581	0.620
12	15	12	10.428	0.869	9.208	29.406	9.076	58.992	0.697	6.090	21.182	6.133	39.864	0.600
12	16	12	10.428	0.869	9.208	29.406	9.076	58.992	0.697	6.090	21.182	6.133	39.864	0.600
13	17	13	11.573	0.890	9.581	30.202	9.449	56.696	0.725	6.298	21.674	6.357	38.144	0.627
13	18	13	11.573	0.890	9.581	30.202	9.449	56.696	0.725	6.298	21.674	6.357	38.144	0.627
15	19	15	13.204	0.880	10.929	34.756	10.794	56.131	0.733	7.266	25.031	7.341	38.174	0.626
16	20	16	14.276	0.892	12.690	39.256	12.549	61.179	0.672	7.736	26.231	7.809	38.070	0.628
16	21	16	14.276	0.892	12.690	39.256	12.549	61.179	0.672	7.736	26.231	7.809	38.070	0.628
17	22	17	14.978	0.881	13.586	42.652	13.432	61.631	0.667	8.485	29.112	8.565	39.298	0.608
18	23	18	16.037	0.891	14.122	43.904	13.903	60.248	0.682	8.815	29.982	8.909	38.604	0.619

19	24	19	17.050	0.897	14.443	44.720	14.222	58.384	0.704	9.012	30.556	9.143	37.533	0.637
20	25	20	17.711	0.886	15.281	48.090	15.035	58.635	0.701	9.717	33.428	9.841	38.380	0.623
20	26	20	17.711	0.886	15.281	48.090	15.035	58.635	0.701	9.717	33.428	9.841	38.380	0.623
22	27	22	19.480	0.885	16.560	51.641	16.199	57.433	0.716	10.598	36.024	10.686	37.887	0.631
23	28	23	20.233	0.880	17.518	55.052	17.151	58.163	0.707	11.406	38.931	11.504	39.015	0.613

Other Principal Arterial Urban
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
174	5	175	123.730	0.707	36.489	117.724	34.322	678.979	0.579	39.669	126.553	36.760	727.209	0.587
206	6	206	146.142	0.709	43.057	138.542	40.493	680.516	0.577	46.911	149.398	43.499	731.029	0.584
241	7	241	171.568	0.712	50.670	162.421	47.570	683.350	0.575	55.219	175.491	51.193	735.391	0.580
278	8	278	197.589	0.711	57.976	186.175	54.408	677.559	0.580	63.381	201.807	58.740	731.498	0.583
310	9	310	220.554	0.711	64.925	208.220	60.916	680.299	0.577	71.006	225.704	65.745	734.221	0.581
348	10	347	247.476	0.713	73.003	233.861	68.489	683.307	0.575	79.749	253.117	73.796	736.255	0.580
383	11	382	272.212	0.713	80.230	256.788	75.197	681.494	0.576	87.553	277.866	80.948	733.613	0.582
415	12	415	295.287	0.712	86.539	277.611	81.102	676.565	0.581	94.679	300.988	87.493	729.883	0.585
449	13	449	319.356	0.711	93.622	300.850	87.865	677.484	0.580	102.465	326.041	94.753	730.593	0.584
485	14	485	344.578	0.710	101.172	325.241	95.000	678.126	0.579	110.681	352.243	102.366	730.700	0.584
520	15	520	369.687	0.711	108.682	348.604	101.995	679.054	0.579	118.823	377.385	109.813	731.098	0.584
555	16	554	394.487	0.712	116.380	372.375	109.172	682.225	0.576	127.055	402.707	117.378	733.505	0.582
588	17	588	418.248	0.711	123.358	394.969	115.720	681.329	0.577	134.727	427.293	124.439	732.666	0.583
623	18	623	443.160	0.711	130.892	418.762	122.733	682.023	0.576	142.747	452.670	131.875	732.826	0.582
658	19	659	467.837	0.710	137.490	440.879	128.910	677.218	0.580	150.269	477.552	138.833	729.346	0.585
689	20	690	489.877	0.710	143.412	460.252	134.454	674.608	0.582	156.864	498.652	144.850	726.769	0.587

Other Principal Arterial Rural
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
70	5	70	105.407	1.506	14.014	26.161	13.648	279.775	1.013	8.248	15.373	7.978	163.557	0.988
87	6	87	130.411	1.499	17.548	33.298	17.023	280.777	1.010	10.515	19.983	10.118	166.881	0.968
100	7	101	150.602	1.491	20.594	39.021	19.799	281.298	1.008	12.324	23.420	11.744	166.852	0.968
114	8	115	171.498	1.491	23.218	44.000	22.327	278.600	1.017	13.831	26.284	13.192	164.607	0.981
128	9	129	191.552	1.485	26.039	49.377	25.015	278.271	1.019	15.418	29.350	14.710	163.639	0.987
144	10	144	215.931	1.500	29.304	54.875	28.128	280.301	1.011	17.299	32.568	16.500	164.430	0.982
158	11	159	238.025	1.497	32.218	60.419	30.928	279.127	1.015	19.026	35.941	18.184	164.111	0.984
173	12	172	259.667	1.510	35.034	65.235	33.699	281.148	1.008	20.728	38.703	19.786	165.073	0.979
187	13	186	280.810	1.510	37.960	70.501	36.453	281.235	1.008	22.325	41.679	21.327	164.540	0.982
202	14	200	303.843	1.519	41.105	75.724	39.456	283.094	1.001	24.055	44.637	22.997	165.001	0.979
216	15	215	324.616	1.510	44.292	81.944	42.420	283.131	1.001	25.937	48.382	24.742	165.139	0.978

230	16	229	346.429	1.513	47.012	87.130	45.116	282.711	1.003	27.507	51.474	26.293	164.762	0.980
245	17	244	368.467	1.510	50.152	92.930	48.085	282.792	1.002	29.301	54.864	28.028	164.840	0.980
261	18	260	392.345	1.509	53.333	99.121	51.183	282.492	1.003	31.375	58.809	29.865	164.829	0.980
272	19	272	409.437	1.505	55.646	103.686	53.405	281.749	1.006	32.746	61.522	31.152	164.351	0.983
288	20	288	432.874	1.503	58.831	109.670	56.411	281.076	1.008	34.632	65.075	32.917	164.015	0.985
301	21	301	452.764	1.504	61.427	114.420	58.943	281.009	1.009	36.199	67.855	34.395	163.974	0.985
315	22	315	473.869	1.504	64.160	119.476	61.532	280.312	1.011	37.701	70.718	35.858	163.353	0.989
330	23	330	496.442	1.504	67.238	125.115	64.517	280.552	1.010	39.483	73.968	37.560	163.328	0.989
345	24	345	519.091	1.505	70.489	131.137	67.573	281.063	1.008	41.412	77.573	39.344	163.649	0.987
357	25	357	538.297	1.508	72.858	135.341	69.887	280.917	1.009	42.733	79.956	40.646	163.379	0.989
373	26	372	561.300	1.509	76.022	141.008	72.870	281.097	1.008	44.544	83.193	42.341	163.330	0.989
386	27	386	581.527	1.507	79.038	146.915	75.727	281.522	1.007	46.327	86.813	44.024	163.663	0.987
402	28	402	605.637	1.507	82.473	153.169	78.923	281.728	1.006	48.320	90.627	45.931	163.958	0.985
416	29	416	627.357	1.508	85.350	158.459	81.756	282.020	1.005	49.994	93.598	47.513	163.898	0.986
431	30	432	650.130	1.505	88.608	164.984	84.934	282.131	1.005	52.018	97.664	49.372	164.003	0.985
445	31	445	670.586	1.507	91.113	169.559	87.409	281.869	1.006	53.480	100.251	50.772	163.724	0.987
459	32	460	692.320	1.505	94.223	175.506	90.380	281.946	1.005	55.300	103.810	52.516	163.826	0.986
473	33	473	712.695	1.507	96.829	179.970	92.788	281.502	1.007	56.747	106.457	53.915	163.567	0.988
486	34	487	732.316	1.504	99.571	185.288	95.407	281.129	1.008	58.359	109.586	55.441	163.363	0.989
502	35	503	756.935	1.505	102.842	191.250	98.550	281.152	1.008	60.278	113.025	57.249	163.325	0.989

Minor Arterial Rural
Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
127	5	126	196.161	1.557	13.586	26.099	13.139	264.350	1.023	9.550	18.602	9.171	184.521	1.015
153	6	153	235.564	1.540	16.320	31.769	15.808	261.919	1.033	11.532	22.786	11.072	183.450	1.020
177	7	177	273.528	1.545	18.981	36.622	18.342	262.702	1.030	13.422	26.303	12.880	184.473	1.015
201	8	201	310.431	1.544	21.470	41.513	20.716	261.269	1.035	15.139	29.697	14.509	182.985	1.023
225	9	225	346.650	1.541	24.037	46.434	23.161	260.949	1.037	16.983	33.324	16.260	183.198	1.022
253	10	253	390.893	1.545	27.026	52.192	26.031	260.824	1.037	19.127	37.516	18.304	183.403	1.021
279	11	279	430.726	1.544	29.715	57.602	28.607	259.923	1.041	20.987	41.424	20.109	182.710	1.025
301	12	302	465.469	1.541	32.167	62.357	30.993	260.153	1.040	22.726	44.814	21.778	182.802	1.024
330	13	330	509.766	1.545	35.222	68.145	33.918	260.550	1.038	24.844	48.937	23.802	182.842	1.024
353	14	353	545.597	1.546	37.712	72.825	36.349	261.036	1.036	26.636	52.323	25.529	183.330	1.021
381	15	381	588.533	1.545	40.647	78.621	39.178	260.674	1.038	28.728	56.546	27.554	183.335	1.021
405	16	406	625.612	1.541	43.347	84.049	41.772	260.818	1.037	30.610	60.375	29.365	183.353	1.021
429	17	430	663.562	1.543	46.040	89.086	44.341	261.407	1.035	32.483	63.920	31.156	183.676	1.019
457	18	457	707.147	1.547	48.982	94.702	47.197	261.803	1.033	34.569	67.966	33.153	183.902	1.018
481	19	481	743.563	1.546	51.502	99.485	49.628	261.552	1.034	36.378	71.397	34.864	183.743	1.019
506	20	507	783.423	1.545	54.333	105.089	52.373	261.867	1.033	38.387	75.452	36.806	184.031	1.017
533	21	534	825.333	1.546	57.252	110.828	55.231	262.193	1.032	40.445	79.519	38.791	184.150	1.017

556	22	558	861.269	1.543	59.844	115.816	57.704	262.149	1.032	42.293	83.211	40.556	184.246	1.016
582	23	583	901.828	1.547	62.682	120.944	60.383	262.556	1.030	44.218	86.778	42.380	184.277	1.016
606	24	606	938.119	1.548	65.208	125.655	62.804	262.721	1.030	45.988	90.125	44.073	184.364	1.015
634	25	634	982.683	1.550	68.157	131.240	65.621	262.381	1.031	48.067	94.187	46.070	184.206	1.016
660	26	660	1023.280	1.550	70.937	136.543	68.281	262.262	1.031	50.016	98.004	47.937	184.121	1.017
684	27	684	1059.663	1.549	73.504	141.546	70.762	262.254	1.031	51.914	101.699	49.731	184.309	1.016
710	28	710	1100.882	1.551	76.320	146.888	73.451	262.251	1.031	53.840	105.464	51.595	184.217	1.016
733	29	734	1136.992	1.549	78.910	151.850	75.948	262.301	1.031	55.673	109.067	53.349	184.249	1.016
760	30	760	1178.062	1.550	81.721	157.228	78.666	262.393	1.031	57.664	112.949	55.261	184.324	1.016
785	31	786	1217.609	1.549	84.478	162.645	81.326	262.293	1.031	59.614	116.908	57.146	184.308	1.016
814	32	813	1262.078	1.552	87.463	167.987	84.189	262.507	1.030	61.675	120.662	59.110	184.310	1.016
838	33	837	1299.567	1.553	90.106	173.027	86.693	262.566	1.030	63.490	124.180	60.831	184.239	1.016
862	34	862	1337.871	1.552	92.774	178.167	89.303	262.624	1.030	65.395	127.886	62.656	184.262	1.016
888	35	888	1379.236	1.553	95.612	183.572	92.066	262.823	1.029	67.419	131.806	64.611	184.447	1.015
913	36	914	1417.773	1.551	98.458	189.222	94.805	262.943	1.029	69.433	135.921	66.542	184.557	1.014
938	37	938	1457.136	1.553	101.053	193.942	97.322	263.018	1.028	71.230	139.240	68.280	184.532	1.014
962	38	962	1494.457	1.553	103.618	198.819	99.775	262.921	1.029	73.074	142.811	70.035	184.552	1.014
991	39	989	1539.217	1.556	106.579	204.197	102.677	263.181	1.028	75.142	146.591	72.028	184.622	1.014
1016	40	14	1578.675	1.557	109.353	209.477	105.350	263.375	1.027	77.143	150.442	73.956	184.889	1.013
1045	41	43	1624.469	1.557	112.515	215.602	108.400	263.464	1.027	79.354	154.853	76.107	184.978	1.012
1066	42	65	1657.145	1.556	114.924	220.234	110.699	263.494	1.027	81.019	158.090	77.682	184.905	1.012
1091	43	91	1696.350	1.555	117.656	225.756	113.366	263.412	1.027	82.959	162.069	79.557	184.856	1.013
1114	44	114	1733.203	1.556	120.267	230.454	115.861	263.651	1.026	84.796	165.406	81.302	185.010	1.012
1141	45	141	1774.731	1.555	123.153	236.141	118.629	263.563	1.026	86.843	169.513	83.257	184.976	1.012
1166	46	166	1814.173	1.556	125.908	241.269	121.285	263.685	1.026	88.794	173.204	85.129	185.079	1.011

Major Collector Rural

Expansion factor = (the number of sections in a population/the number of sections in a sample)

AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
34	5	34	51.748	1.522	1.799	3.579	1.796	35.503	0.991	1.909	3.780	1.877	37.089	0.974
40	6	41	62.145	1.516	2.210	4.383	2.187	35.840	0.982	2.318	4.589	2.274	37.266	0.970
48	7	48	74.448	1.551	2.600	5.072	2.582	36.148	0.973	2.719	5.304	2.676	37.467	0.964
52	8	53	80.521	1.519	2.885	5.710	2.862	36.284	0.970	2.995	5.946	2.949	37.394	0.966
59	9	60	91.225	1.520	3.222	6.366	3.208	35.933	0.979	3.384	6.693	3.332	37.315	0.968
64	10	65	98.477	1.515	3.546	6.977	3.519	36.378	0.967	3.660	7.282	3.611	37.331	0.968
73	11	74	111.905	1.512	4.016	7.963	3.976	36.105	0.975	4.182	8.317	4.106	37.289	0.969
77	12	78	118.430	1.518	4.251	8.370	4.198	36.164	0.973	4.406	8.774	4.330	37.303	0.969
92	13	91	142.048	1.561	4.976	9.626	4.910	36.256	0.970	5.118	9.997	5.036	37.193	0.971
95	14	94	145.456	1.547	5.132	10.007	5.054	36.130	0.974	5.295	10.416	5.199	37.164	0.972
102	15	101	155.957	1.544	5.559	10.774	5.442	36.206	0.972	5.691	11.180	5.584	37.151	0.973
110	16	109	169.656	1.556	5.953	11.493	5.844	36.026	0.977	6.156	12.003	6.034	37.202	0.971

114	17	114	175.737	1.542	6.224	12.097	6.087	35.881	0.981	6.435	12.668	6.301	37.144	0.973
123	18	122	188.641	1.546	6.695	12.964	6.545	36.052	0.976	6.897	13.502	6.745	37.151	0.973
128	19	128	196.944	1.539	7.068	13.659	6.872	36.076	0.975	7.258	14.228	7.090	37.221	0.971
136	20	135	208.581	1.545	7.465	14.418	7.261	36.145	0.973	7.620	14.926	7.450	37.084	0.974
145	21	143	221.917	1.552	7.840	15.134	7.659	35.994	0.978	8.041	15.736	7.881	37.035	0.976
148	22	147	226.814	1.543	8.116	15.713	7.903	36.128	0.974	8.287	16.292	8.115	37.095	0.974
156	23	155	239.431	1.545	8.544	16.516	8.325	36.093	0.975	8.732	17.138	8.557	37.097	0.974
162	24	162	248.406	1.533	8.929	17.375	8.688	36.037	0.976	9.129	18.020	8.934	37.058	0.975
170	25	169	260.234	1.540	9.255	17.997	9.016	35.850	0.981	9.490	18.702	9.293	36.951	0.978
175	26	175	269.274	1.539	9.617	18.670	9.361	35.946	0.979	9.851	19.406	9.643	37.030	0.976
182	27	182	280.036	1.539	9.994	19.413	9.739	35.958	0.979	10.247	20.164	10.027	37.021	0.976
185	28	186	284.707	1.531	10.189	19.874	9.922	35.848	0.982	10.445	20.672	10.226	36.945	0.978
196	29	196	300.487	1.533	10.788	20.998	10.506	36.019	0.977	11.005	21.753	10.780	36.961	0.978
202	30	201	309.901	1.542	11.031	21.409	10.745	35.923	0.979	11.280	22.233	11.048	36.936	0.978
209	31	209	320.495	1.533	11.511	22.387	11.174	35.928	0.979	11.731	23.234	11.490	36.944	0.978
217	32	217	332.878	1.534	11.926	23.174	11.586	35.878	0.981	12.171	24.085	11.929	36.942	0.978
220	33	220	337.003	1.532	12.048	23.458	11.719	35.795	0.983	12.345	24.463	12.103	36.970	0.977
231	34	230	353.749	1.538	12.602	24.445	12.262	35.826	0.982	12.891	25.476	12.650	36.960	0.978
235	35	235	360.387	1.534	12.816	24.914	12.473	35.668	0.986	13.179	26.084	12.923	36.955	0.978
238	36	239	365.172	1.528	13.030	25.423	12.680	35.651	0.987	13.385	26.609	13.133	36.927	0.978
248	37	249	380.271	1.527	13.539	26.384	13.178	35.566	0.989	13.928	27.637	13.662	36.870	0.980
256	38	256	393.041	1.535	13.956	27.148	13.566	35.610	0.988	14.271	28.367	13.997	36.743	0.983
265	39	264	406.098	1.538	14.357	27.907	13.979	35.584	0.989	14.719	29.194	14.444	36.767	0.983
270	40	270	414.533	1.535	14.760	28.694	14.356	35.732	0.985	15.067	29.925	14.793	36.818	0.981
278	41	277	426.006	1.538	15.119	29.354	14.718	35.705	0.985	15.484	30.688	15.203	36.883	0.980
283	42	282	434.007	1.539	15.386	29.893	14.989	35.719	0.985	15.763	31.234	15.478	36.883	0.980
289	43	289	443.689	1.535	15.845	30.770	15.410	35.832	0.982	16.174	32.066	15.876	36.917	0.979
295	44	295	452.686	1.535	16.154	31.360	15.705	35.775	0.984	16.505	32.714	16.195	36.892	0.979
304	45	304	465.901	1.533	16.721	32.454	16.244	35.909	0.980	17.056	33.798	16.727	36.975	0.977
310	46	309	474.930	1.537	16.975	32.907	16.496	35.876	0.981	17.314	34.282	16.986	36.940	0.978
319	47	318	488.578	1.536	17.468	33.950	17.007	35.938	0.979	17.793	35.258	17.458	36.893	0.979
326	48	325	499.423	1.537	17.879	34.666	17.379	35.935	0.979	18.177	35.986	17.835	36.878	0.980
330	49	330	505.987	1.533	18.165	35.282	17.660	35.962	0.978	18.478	36.612	18.119	36.897	0.979
334	50	334	511.981	1.533	18.400	35.720	17.878	35.971	0.978	18.736	37.115	18.364	36.947	0.978
344	51	344	528.056	1.535	18.937	36.735	18.398	35.941	0.979	19.277	38.168	18.894	36.910	0.979
348	52	349	533.847	1.530	19.237	37.435	18.680	35.969	0.978	19.539	38.798	19.146	36.866	0.980
358	53	358	548.916	1.533	19.745	38.298	19.179	36.001	0.977	20.055	39.676	19.650	36.884	0.980
361	54	362	553.607	1.529	20.027	38.912	19.439	36.086	0.975	20.298	40.244	19.885	36.914	0.979
367	55	368	562.836	1.529	20.312	39.497	19.730	36.028	0.977	20.613	40.873	20.188	36.865	0.980
379	56	378	580.175	1.535	20.910	40.510	20.304	36.096	0.975	21.159	41.844	20.736	36.864	0.980
383	57	383	586.725	1.532	21.157	41.068	20.550	36.056	0.976	21.438	42.462	21.015	36.873	0.980
388	58	389	595.347	1.530	21.401	41.654	20.813	35.954	0.979	21.733	43.141	21.308	36.809	0.982

395	59	396	604.684	1.527	21.812	42.511	21.204	35.983	0.978	22.111	43.972	21.684	36.796	0.982
403	60	404	617.494	1.528	22.223	43.263	21.599	35.928	0.979	22.516	44.765	22.092	36.747	0.983
407	61	409	624.006	1.526	22.507	43.868	21.861	35.918	0.980	22.799	45.361	22.352	36.725	0.984
412	62	414	630.679	1.523	22.798	44.444	22.129	35.920	0.980	23.072	45.971	22.631	36.734	0.984
424	63	424	649.393	1.532	23.353	45.361	22.658	35.911	0.980	23.620	46.918	23.176	36.732	0.984
431	64	430	659.687	1.534	23.655	45.951	22.988	35.926	0.979	23.941	47.524	23.508	36.738	0.983
439	65	439	672.618	1.532	24.178	46.991	23.479	35.941	0.979	24.488	48.615	24.027	36.780	0.982
444	66	444	679.550	1.531	24.436	47.516	23.728	35.912	0.980	24.745	49.177	24.288	36.760	0.983
451	67	451	691.044	1.532	24.781	48.167	24.092	35.898	0.980	25.167	49.919	24.694	36.795	0.982
455	68	456	697.414	1.529	25.047	48.770	24.355	35.892	0.980	25.448	50.549	24.968	36.795	0.982

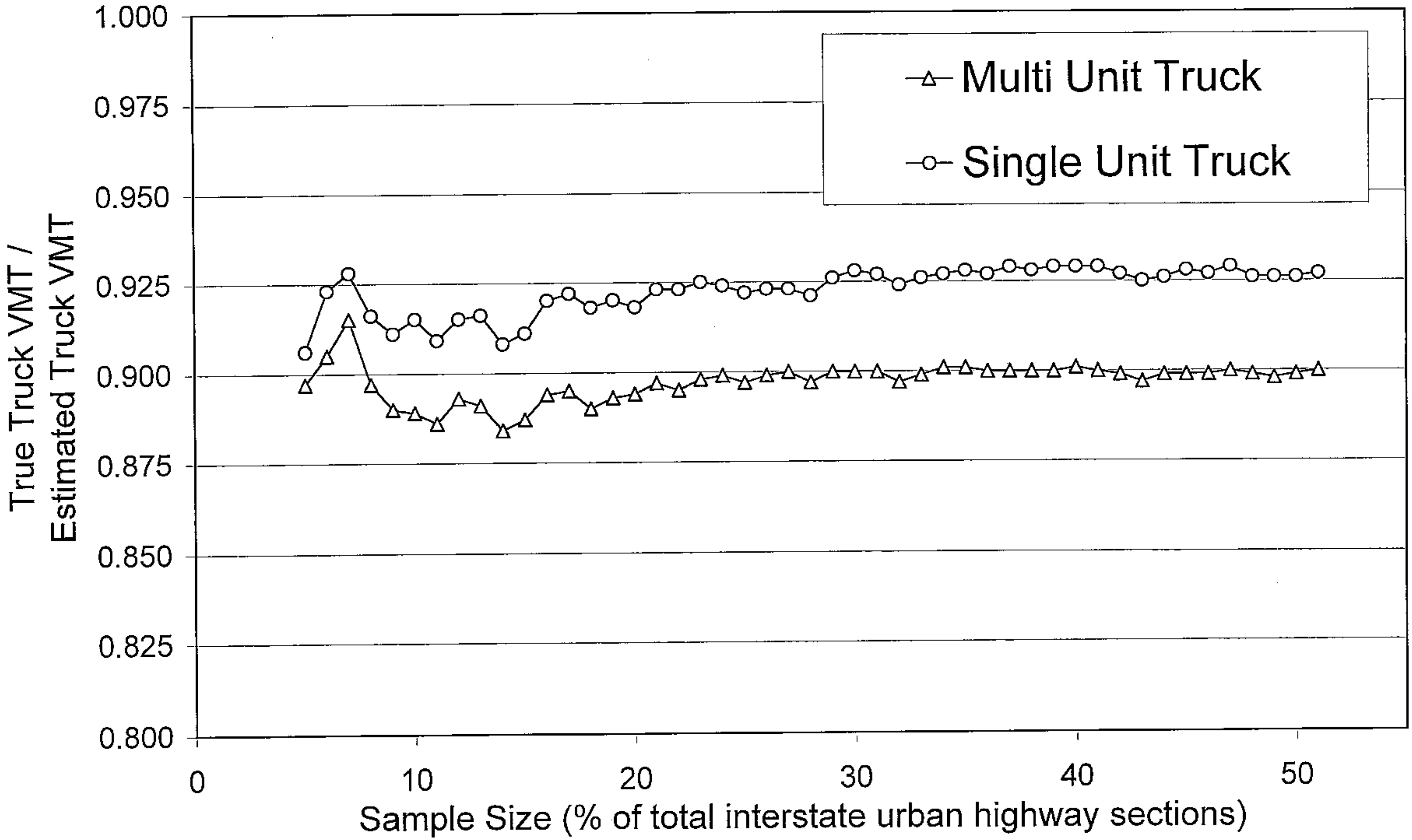
Minor Arterial Urban
Expansion factor = (the number of sections in a population/the number of sections in a sample)

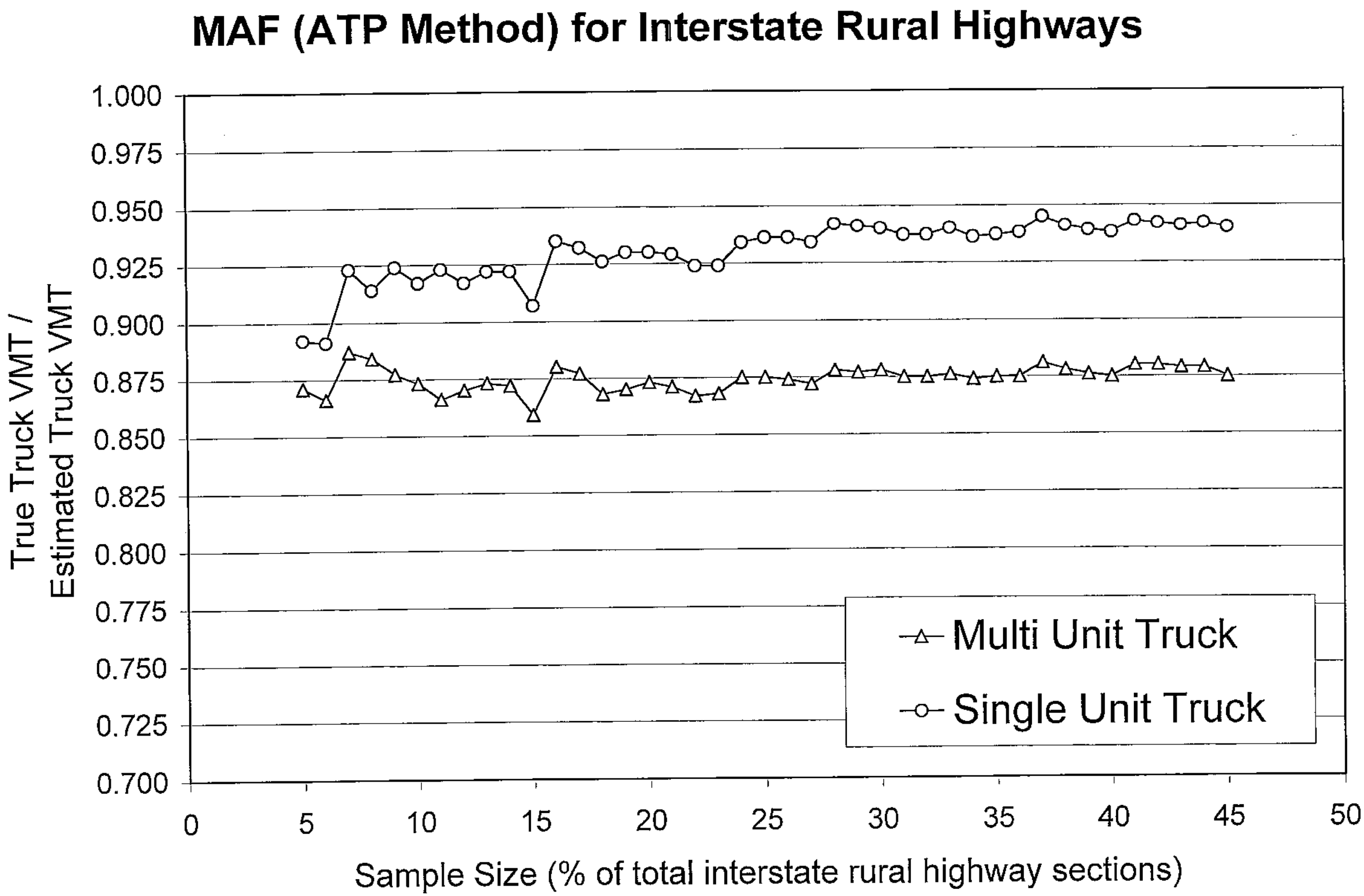
AveSection	size	section	length	ratioLS	MuVMT1	MuVol	MuVMT2	expMuVMT2	RMuVMT2	SuVMT1	SuVol	SuVMT2	expSuVMT2	RSuVMT2
26	5	26	24.646	0.948	4.636	11.287	4.459	87.640	0.565	5.446	13.580	5.277	103.721	0.586
31	6	31	29.856	0.963	5.662	13.687	5.401	89.033	0.556	6.684	16.583	6.455	106.409	0.572
37	7	37	35.349	0.955	6.724	16.440	6.448	89.048	0.556	7.893	19.745	7.644	105.575	0.576
41	8	41	38.834	0.947	7.382	17.980	7.041	87.758	0.564	8.706	21.698	8.402	104.713	0.581
47	9	47	44.803	0.953	8.583	20.964	8.189	89.031	0.556	10.123	25.214	9.745	105.953	0.574
51	10	51	48.650	0.954	9.343	22.806	8.885	89.024	0.556	10.998	27.382	10.565	105.852	0.575
55	11	55	52.501	0.955	10.163	24.825	9.658	89.731	0.552	11.958	29.792	11.474	106.607	0.571
62	12	62	58.756	0.948	11.336	27.772	10.804	89.045	0.556	13.306	33.227	12.763	105.188	0.578
66	13	66	62.980	0.954	12.194	29.726	11.600	89.814	0.551	14.320	35.574	13.738	106.366	0.572
70	14	70	66.816	0.955	12.994	31.749	12.383	90.398	0.547	15.233	37.869	14.603	106.601	0.571
78	15	78	74.332	0.953	14.345	34.948	13.651	89.430	0.553	16.853	41.834	16.152	105.817	0.575
81	16	81	77.342	0.955	14.911	36.322	14.188	89.505	0.553	17.502	43.421	16.772	105.809	0.575
87	17	87	83.240	0.957	16.094	39.119	15.322	89.995	0.550	18.881	46.708	18.076	106.172	0.573
92	18	92	87.876	0.955	16.924	41.183	16.093	89.384	0.554	19.924	49.335	19.059	105.859	0.575
96	19	97	92.373	0.952	17.773	43.446	16.966	89.378	0.554	20.951	51.969	20.046	105.602	0.576
101	20	101	97.219	0.963	18.844	45.727	17.971	90.924	0.544	22.167	54.663	21.243	107.475	0.566
108	21	107	103.160	0.964	19.954	48.230	18.956	90.528	0.547	23.457	57.720	22.433	107.136	0.568
114	22	113	109.037	0.965	21.104	51.080	20.092	90.860	0.545	24.827	61.080	23.756	107.430	0.566

Appendix F.3

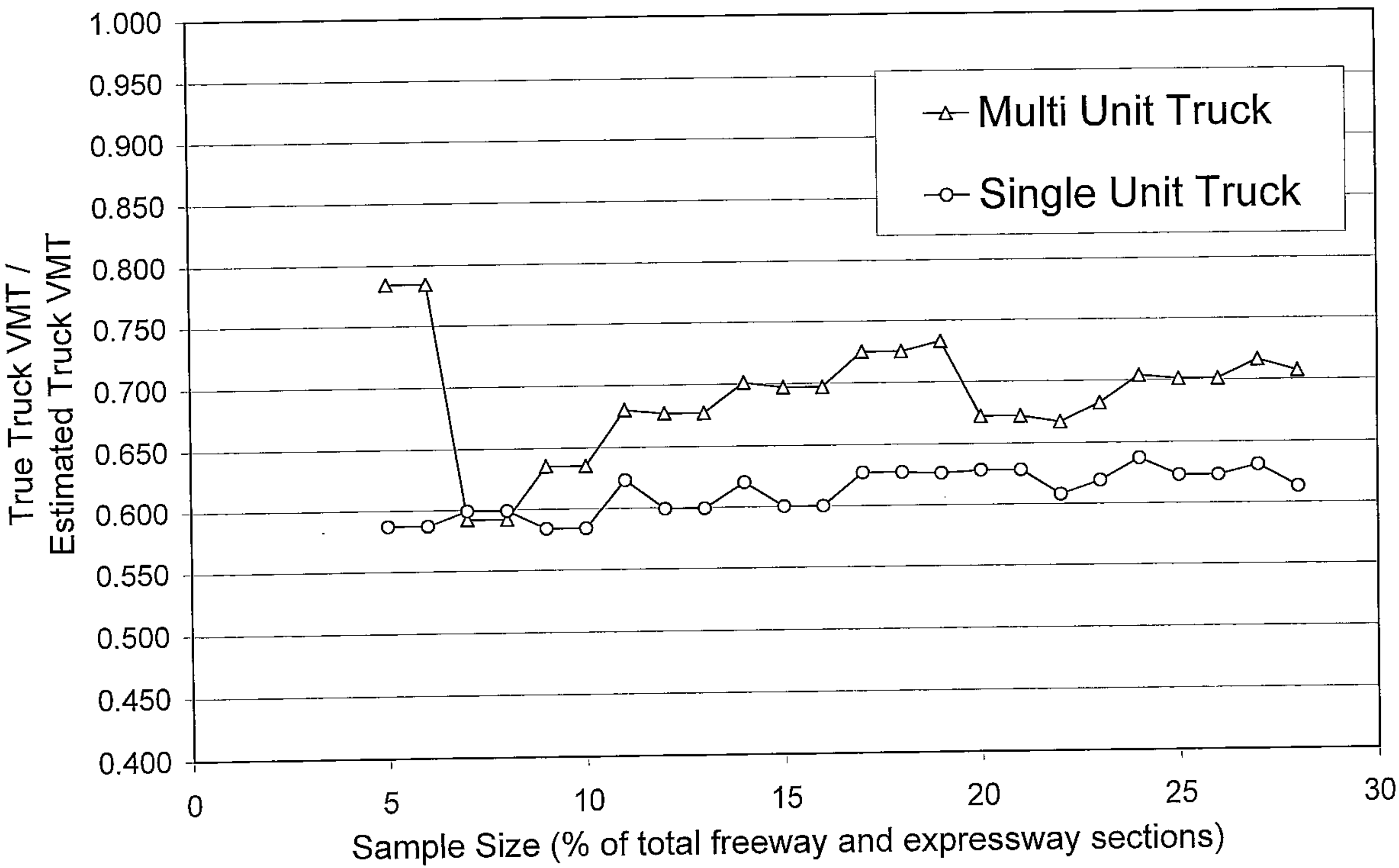
Plot of Methodology Adjustment Factor (MAF) for the Average Truck Percentage (ATP) Method

MAF (ATP Method) for Interstate Urban Highways

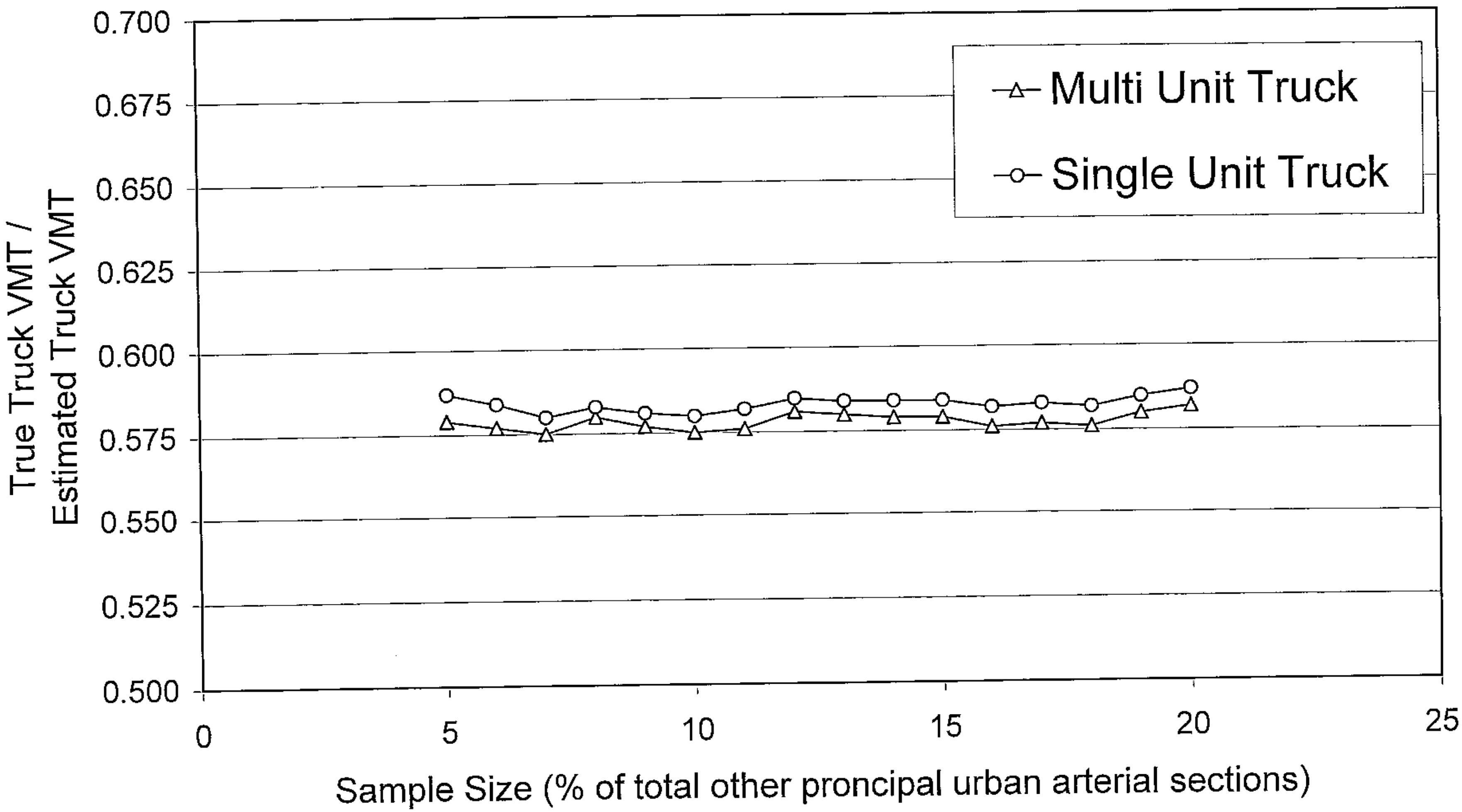



MAF (ATP Method) for Interstate Rural Highways
True Truck VMT / Estimated Truck VMT
1.000
0.975
0.950
0.925
0.900
0.875
0.850
0.825
0.800
0.775
0.750
0.725
0.700
0
5
10
15
20
25
30
35
40
45
50
Sample Size (% of total interstate rural highway sections)
Multi Unit Truck
Single Unit Truck

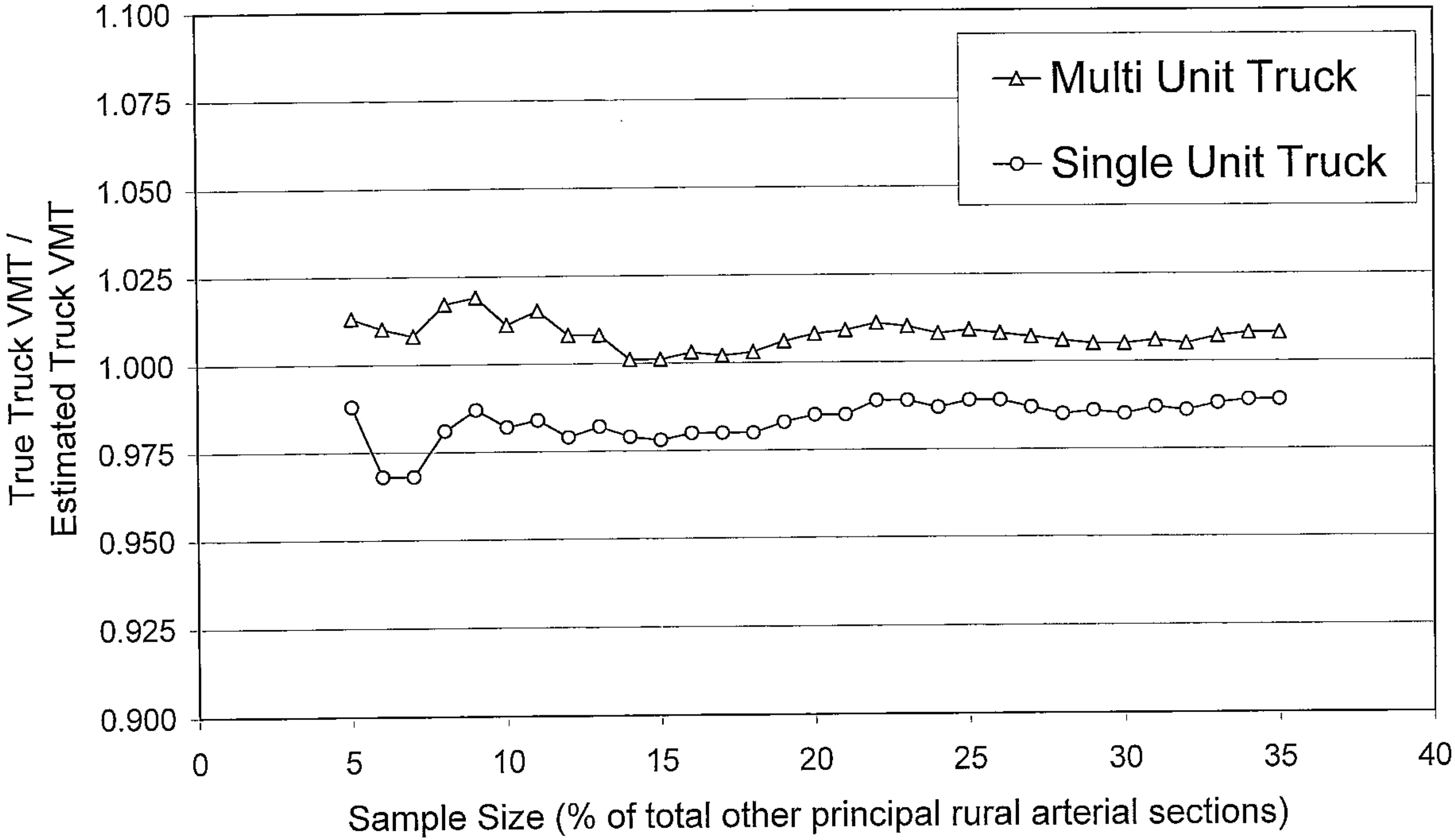
MAF (ATP Method) for Freeways and Expressways



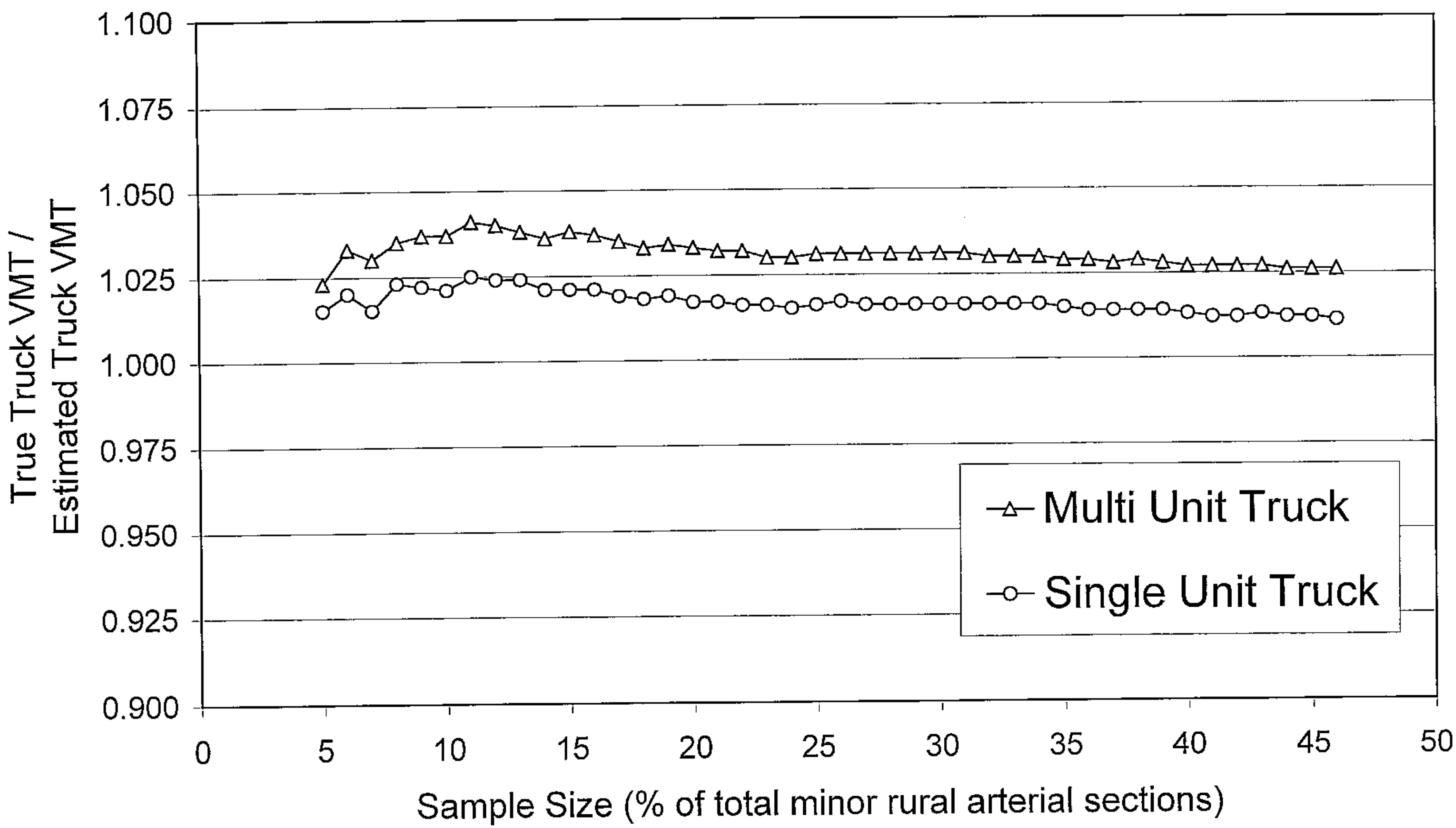
MAF for the ATP Method: Other Principal Urban Arterials



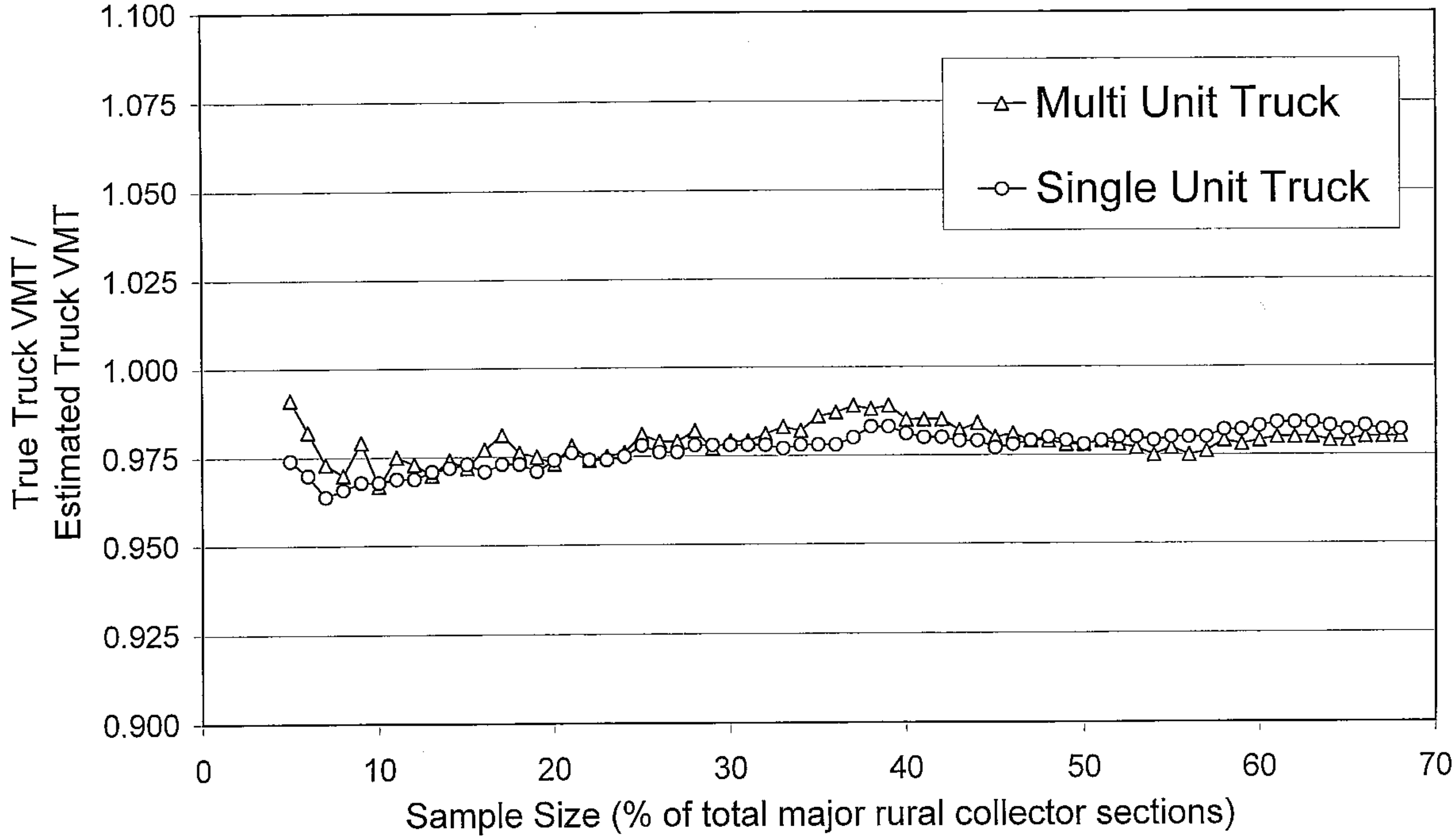
MAF (ATP Method) for Other Principal Rural Arterials



MAF (ATP Method) for Minor Rural Arterials



MAF (ATP Method) for Major Rural Collectors



MAF (ATP Method) for Minor Urban Arterials