Estimating Statewide Vehicle-Miles of Travel

State-of-the-Art Review

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Washington State Department of Transportation
Planning, Research and Public Transportation Division

in cooperation with the
United States Department of Transportation
Federal Highway Administration

ESTIMATING STATEWIDE VEHICLE-MILES OF TRAVEL: STATE OF THE ART REVIEW

Final Report

by

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TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

This study is concerned with developing a statistical basis for estimating statewide vehicle-miles of travel (VMT) that is consistent with available WSDOT resources, uses of the data collected and appropriate levels of accuracy. The study was conducted in conjunction with, and as a complement to, a more extensive Statewide Highway Data Rationalization Study. In this study, the nature of the problem is first established based on an investigation of users and uses of VMT data and documentation of existing data collection methods. A focused review of the literature is reported, and recommendations are made for a statistically-based methodology and set of procedures for sample design and development. The selection and detailed development and implementation of particular procedures and methodology was not a part of this study.

CONCLUSIONS AND RECOMMENDATIONS

As a result of this study, the following conclusions have been reached:

CONCLUSIONS

- There is no statistical basis for the estimation of statewide vehicle-miles of travel (VMT) by the Department, nor for the traffic counting program from which VMT estimates are derived.
- VMT data have important uses to the Department
- By employing improved statistical sampling methods that complement the HPMS sample in the State, a strong potential exists for significantly improving the effectiveness and quality of statewide VMT data, with little or no increase in the traffic counting budget.

In addition, the following recommendation is made:

RECOMMENDATION

- The Department should implement the recommendations of the recent Statewide Highway Data Rationalization Study with respect to volume counting and vehicle classification, in order to achieve the potential improvements in statewide VMT data noted above.

EXECUTIVE SUMMARY

This study is concerned with estimating statewide vehicle-miles of travel, using a statistical basis that is also consistent with available WSDOT resources, uses of the data collected and appropriate levels of accuracy. The study was conducted in conjunction with, and as a complement to, a more extensive Statewide Highway Data Rationalization Study.

This report addresses users and uses of VMT data, and user needs. Existing methods used by WSDOT for estimating statewide VMT are discussed; specifically, traffic count methods and fuel consumption methods. A focused review of the literature is then reported that emphasizes recent, statistically-based studies that are relevant to this study. Finally, a recommended approach is identified and implementation issues discussed.

It is concluded that:

- There is no statistical basis for the estimation of statewide vehicle-miles of travel (VMT) by the Department, nor for the traffic counting program from which VMT estimates are derived.
- VMT data have important uses to the Department.
- By employing improved statistical sampling methods that complement the HPMS sample in the State, a strong potential exists for significantly improving the effectiveness and quality of statewide VMT data, with little or no increase in the traffic counting budget.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

Each year the Washington State Department of Transportation (WSDOT) must estimate statewide vehicle-miles of travel (VMT) disaggregated into a number of categories including, for example, functional classifications of highway and urban and rural route sections. WSDOT expends considerable resources in collecting and processing these data. At present, there appears to be little or no statistical basis for estimation of VMT, nor for the traffic counting program from which VMT estimates are derived. This includes traffic count locations, duration, frequency and expansion of short-period counts to annual average daily traffic (AADT) volume estimates. As a result, the accuracy of statewide estimates of VMT is unknown.

1.2 Background Statement

Statewide estimates of VMT are required for a variety of purposes, including planning, design and operational analysis of highway facilities, revenue allocation and forecasting, as well as to comply with requirements and needs of other agencies; for example, at the federal level.

However, collection of large amounts of data is very costly. In a climate of increasing fiscal austerity at all levels of government and in all program areas, it is therefore important not only that the right type of data are collected, but that they are collected most efficiently. Moreover, the data should meet the needs of its users with respect to type, amount, form, accuracy and availability. A statewide highway data collection program should satisfy these criteria in an up-to-date and cost-effective manner. WSDOT has recently found it difficult to assess to what extent all these criteria are in fact being

met. Considerable concern has also existed about the appropriate level of resources that should be allocated to various data collection activities, and the fact that there is little statistical basis for these activities. The shifting emphasis in the Department's highway program from construction to maintenance, rehabilitation and reconstruction is another important factor.

In 1981, due to major budget cutbacks, the Department created an Organizational Review Team (the "Korf Committee") to review all planning functions. This included a review of the amount and types of highway data collected. The Committee recommended a sharp reduction in the level of traffic counting by the Department. This decision was based primarily on stated data needs by upper level management in the Department. The Committee did not, however, deal with the statistical validity and quality of the data being collected. Neither did the Committee attempt to integrate the remaining data collection effort.

The Department's Transportation Data Office currently consists of three branches: Travel Data, Roadway Inventory and Traffic Safety. The major data collection and related activities of these branches are summarized in Table 1.1 A number of these activities involve some form of sample survey (e.g., traffic counting), while others are 100% inventories (e.g., accident data). In either case, it is often not clear what an appropriate level of resource allocation is for each activity.

MAJOR PROGRAMS	DURATION OF ACTIVITY	PRODUCTS
TRAVEL DATA BRANCH		
- Traffic Counting for Projects	March through October	- Traffic Data Needed for Project Design
- Traffic Recording at Permanent Stations	Year 'round	- Monthly and Annual Traffic Trends - Annual Traffic Report
- Travel Analysis	Year 'round	- Operational and Economic Analyses of Travel Data for Project Planning and Design
- Transportation Trends	Year 'round	- Quarterly and Annual Transportation Trends Report
- 55 MPH Speed Monitoring	Year 'round	- Quarterly and Annual Reports to FHWA
- Railroad Grade Crossing Program	4-Year Program	- Data for Project Prioritization by DOT and Local Agencies
- Truck Weight and Vehicle Classification Counts	On Request	- Report to Materials Lab and FHWA for Pavement Management System
- Travel Data Equipment Support	Year 'round	- Installation, Maintenance and Repair of Traffic Monitoring and Air Quality Equipment
ROADWAY INVENTORY BRANCH		
- State Roadway Data	Year 'round	- Biennial Reports Provided to Materials Lab for Pavement Management System (PMS) and the Priority Array - Yearly Report to Highway Performance Monitoring System (HPMS) - SR Milepost Log & Control Section Manual Published Yearly

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- Road Life Data	Year 'round	- Biennial Reports to Materials Lab for PMS - Annual Reports to District Soils Engineers
- Pavement Evaluation	Biennially	- Biennial Reports to Materials Lab for PMS and Priority Array
- County-City Roadway Data	Year 'round	- Annual Reports to the State Aid Division for Disbursement of Gas Tax Monies to the Counties Midyear Report to HPMS
- Videolog	Summer months	- Current Tapes Provided to Districts & Headquarters on Two Year Cycle
- Federal Aid and Functional Class Systems	Year 'round	- Revisions of Federal-Aid and Functional Class Systems Provided Yearly to Headquarters, Districts, FHWA and Local Agencies
TRAFFIC SAFETY BRANCH		
- Accident Location Analysis	Year 'round	- Accident Listings Provided to Districts in Support of Project Development - Accident Report Published Annually
- Accident Analysis	Year 'round	- Accident Diagrams, Reports, Studies and Listings Provided to Develop the DOT's Construction Program
- Unknown Damage Claims	Year 'round	- Recovery of Damage to DOT Property by Public
- Safety Projects Evaluation	July through August	- Safety Evaluation Report to FHWA in Cooperation with Highway Development Office

Table 1.1 Data Collection Activities of the WSDOT Transportation Office

A major study concerned with rationalization of the Department's highway data collection activities was therefore clearly appropriate, and was begun in 1984. This study was called the Statewide Highway Data Rationalization Study (SHDRS), (Ritchie and Hallenbeck, 1986).

The present study addresses the problems noted above, in the narrower context of developing a statistical basis for estimating statewide VMT that is consistent with available WSDOT resources, uses of the data collected and appropriate levels of accuracy. This VMT study was conducted in conjunction with, and as a complement to, the SHDRS.

1.3 Study Objectives

The objectives of this study were basically to define and document current procedures for estimating VMT in Washington State, what basis there is for these procedures, what current needs exist and what alternative state-of-the-art procedures exist for satisfying these needs and fulfilling the objectives of collecting statewide VMT data. Broadly, the objectives of this study were therefore to define the problem, and identify potential solutions.

Given the close relationship of this study to the SHDRS, the emphasis was on collection of statistically-based traffic count data for estimation of statewide VMT. This was because the objectives of the SHDRS study were to perform an in-depth evaluation of the Department's highway data development and analysis activities, and to develop procedures and recommendations for a streamlined statewide highway data collection program. The program would be statistically-based and sensitive to both user needs and available WSDOT resources for data collection activities. The primary purpose of this program would be to satisfy internal needs of WSDOT, although all major users and uses would be identified. A rigorous statistical approach to program design and data collection is

necessary to permit estimation of data accuracy, and to provide a rational basis which could assist in allocating limited resources among the various possible data collection activities.

Accordingly, in this study the nature of the problem is first established based on an investigation of users of VMT data, uses of the data, the nature of categories for which data are required and documentation of existing data collection methods.

Second, a focused state-of-the-art review of the literature has been conducted. Based on this review, the most promising statistically-based methodologies and procedures for sample design and development are identified. The selection and detailed development and implementation of particular procedures and methodology was not a part of this study, but was to be undertaken as a subsequent activity, at the discretion of WSDOT.

1.4 Report Organization

This report is organized into a Conclusions and Recommendations section, Executive Summary, and five chapters in the body of the report and an Appendix. In addition to this Introduction, the chapters cover the following topics:

- users and uses of VMT data
- existing WSDOT methods for estimating statewide VMT
- review of the literature
- recommended approach
- implementation

CHAPTER 2. USERS AND USES OF VMT DATA

2.1 Users of VMT Data

Based on an extensive series of interviews with Department personnel, conducted as part of both this study and the SHDRS, the principal users of statewide VMT data were determined to be those listed in Table 2.1.

In addition, a variety of reports containing VMT data are produced by the Travel Data Branch of the WSDOT Transportation Data Office. In particular, the WSDOT Annual Traffic Report, which reports statewide VMT data in various categories, is received by various private sector firms such as billboard operators, land developers, oil companies and consultants. These firms are also believed to make some use of the VMT data.

2.2 Uses of VMT Data

The principal uses of statewide VMT data were determined to be as shown in Table 2.2.

2.3 User Needs

In general, users required estimates of average daily vehicle-miles of travel (DVMT), in the following principal categories, with cross-classifications amongst functional classes, vehicle classes and urban or rural areas being common:

- o four highway functional classifications
  - Interstates
  - Principal arterials
  - Minor arterials
  - Collectors

1. WSDOT:

   - Program Development Office
     - Priority and Project Development Branch
     - Long-Range Planning Branch

   - Transportation Planning Office
     - Systems Planning Branch
     - Economics Branch

   - Transportation Data Office
     - Safety Information Branch

2. Washington State Patrol

3. Traffic Safety Commission

4. Federal Highway Administration

Table 2.1 Principal Users of Statewide VMT Data

- Highway Systems Planning and Analysis
  - System level traffic forecasting
  - Long-range transportation systems planning
  - Highway Performance Monitoring System (for Federal Highway Administration)

- Traffic Safety
  - Accident analysis
  - Safety studies

- Economic analysis
  - Revenue allocation
  - Revenue forecasting

Table 2.2 Principal Uses of Statewide VMT Data

- o urban and rural areas
- o counties (39 in Washington State)
- o vehicle classification

In terms of trafffic counting activities, such estimates of course depend on traffic volume and vehicle classification information for a sample of highway segments throughout the highway network.

A statistically-based approach requires that appropriate statistical levels of confidence and precision be established to serve as objectives in the sample design process. In conjunction with the SHDRS, such data quality needs were elicited from all identified users of traffic information (not restricted to VMT data). It was soon realized that the vast majority of the data users could not articulate a need for a specific level of data precision for their analyses. The study team then reviewed all available literature in an attempt to learn if statistical standards had been suggested by other researchers. To a large extent, this also proved to be fruitless.

Because such sources failed to provide the needed guidance, the study team also undertook a selected number of sensitivity analyses and statistical derivations to examine the effect of data quality on the results of particularly important analyses. Among the analyses examined were:

- the priority array determination (see Glossary in Appendix A)
- pavement overlay calculations
- new pavement design
- bridge design
- pavement management system
- level of development determination.

To determine appropriate statistical data quality needs, as needed for the VMT

study, this information was supplemented by the small amount of guidance available from data users and published literature, and a large amount of professional judgment by SHDRS project and Technical Committee members. Further information in this regard is provided in Ritchie and Hallenbeck (1986).

CHAPTER 3. EXISTING WSDOT METHODS FOR ESTIMATING STATEWIDE VMT

3.1 Traffic Count Method

This section describes the use of short-period traffic counts by WSDOT for estimating statewide VMT.

The essence of this method involves determining average annual daily traffic (AADT) volumes at counting locations throughout the state road network (approximately 6,900 miles in length), interpolating AADT's for sections between counting locations, and then multiplying by each section length. Some counting locations involve permanent traffic recorders (63 locations in 1983) and others represent special short-period counts (2281 counts in 1983) of, usually, 48 to 72 hours duration. These short-period counts are converted to AADT's using existing, and in many cases outdated, empirically derived factors. Currently, most of the short-period counts are obtained on an "as needed" basis, for purposes not directly related to the need for VMT estimates.

There is essentially no statistical basis for this approach, nor for the number and location of the permanent traffic recorder stations. Accordingly, the accuracy, representativeness, and confidence inherent in these AADT volumes cannot be determined statistically, nor for the estimates of VMT for which they form the basis.

While it is possible that the historical evolution of the traffic counting program has resulted in a cost-effective process for estimating VMT, it is desirable to have a more rational and objective statistical basis for such important estimates, and particularly for the underlying traffic counts themselves.

3.2 Evaluation of Traffic Counting Procedures

Estimation of DVMT by vehicle type (e.g., 5-axle trucks) for a particular highway segment using the traffic count method necessitates having estimates of AADT and vehicle classification percentages for that segment.

To estimate the value of AADT, the Department requires:

- a short duration volume count
- an axle correction factor
- a seasonal travel correction factor, and, possibly
- a growth factor if the short count is not from the current year.

While the short duration volume count at a location is fairly easy to obtain, the other three factors are not readily obtained on a case-by-case basis. Therefore, the state needs an on-going process for collecting the raw data that can be used to calculate these last three factors, in addition to the ability to estimate or count volumes and axles at a location. For the most part, axle corrections, seasonal and growth factors are "system estimates"; that is, the actual values can not be determined for specific sites without an unreasonable amount of data collection. As a result, they are estimated on a system basis and applied to specific sites as necessary. The quality of these factors is particularly important because the Department uses them in the computation of almost all estimates of AADT, percentage of trucks, and other similar traffic estimates. Therefore, they contribute markedly to the quality of many of the analyses performed with traffic estimates.

The importance of computed factors means that the Department must collect sufficient information to produce valid estimates of these factors for all those analyses that use them. In the case of VMT estimation, the Department needs a statistically valid sample of the following pieces of data:

- 365 day-a-year traffic counts (for estimating seasonal and growth

factors)

- vehicle classification counts (for estimating axle correction factors and percentages of trucks and other vehicle types)
- short duration volume counts (for estimating statewide VMT and providing basic information on traffic volumes on state roads).

A detailed evaluation of the procedures used to collect and derive these data items is presented by Ritchie and Hallenbeck (1986), and will not be repeated here. However, a summary of the project team's findings are listed below:

- the Department generally has relatively good project level data, but an old and increasingly obsolete base traffic data file
- the Department does very little traffic counting other than at project locations
- an axle correction factor is not currently applied to raw axle counts (although this is being changed)
- ad hoc seasonal factors are applied manually, as opposed to a systematic and automated approach
- no HPMS data are collected by the WSDOT off the state highway system
- the state currently lacks an adequate vehicle classification database, although steps are being taken to obtain this
- the only vehicle weighings being performed for planning purposes are part of the Federal Long Term Pavement Monitoring Project (LTPM)
- it is unclear, to date, how statistically valid the data from these efforts are when used for analyses covering the entire state, as the data are not being collected in a statistically rigorous manner.

3.3 Fuel Consumption Method

In addition to the traffic count approach for estimating statewide VMT, it is understood that WSDOT has used a fuel consumption method for some analyses.

The essence of this method involves estimating gallons of fuel consumed from regional fuel tax receipts, estimating the average fuel efficiency (e.g., in miles per gallon) of the regional vehicle fleet, and estimating regional VMT directly.

Several significant difficulties occur in estimating VMT by the fuel consumption method, and relate to estimating the total fuel consumption in a region and the average fuel consumption rate. Inevitably, some travel occurs within a state using fuel purchased outside the state (e.g., local trips, through trips), and some travel occurs outside a state using fuel purchased inside the state. Also, it has been claimed that fuel tax data underestimate travel in rural areas because some untaxed fuel for farm use is used for highway travel. Finally, average fuel efficiency, or fuel consumption rates, of the vehicle fleet are difficult to estimate when fuel consumption characteristics are changing quickly, as has been the case in the last decade or so.

CHAPTER 4. REVIEW OF LITERATURE

4.1 Introduction

Historically, highway data and specifically traffic count data have been collected by state transportation agencies to support a wide range of programs and needs. For example, these have included the use of traffic count data to develop estimates of annual average daily traffic (AADT) and vehicle-miles of travel (VMT) for individual highway sections, functional classifications of highway and regional or other divisions of the state highway system. In addition, the Federal Highway Administration (FHWA) has required submission of various traffic and truck data and estimates for use by FHWA and other federal agencies. These have been required in order to establish national travel trends, prepare reports requested by Congress, plan for future transportation needs and assess the overall efficiency of various programs and policies.

Several recent reports have been published that relate to this study and general efforts to develop more cost-effective approaches to statewide highway data collection. These include the work of Hallenbeck and Bowman (1984), which proposed a general statewide traffic counting program based on the Highway Performance Monitoring System (HPMS) (1984); the study by Wright Forssen Associates (1983) which evaluated, and developed improvement recommendations for, the highway traffic data program of the Alaska Department of Transportation and Public Facilities; and work by the New York State Department of Transportation to streamline and reduce the cost of its traffic counting program (1983). While each of these studies provided useful background and guidance for this project, the conceptual basis of Hallenbeck and Bowman in utilizing the HPMS framework for purposes of statistically-based statewide highway data collection appeared particularly promising.

Accordingly, in this section a narrowly focused state-of-the-art literature review is presented. This review is focused in the sense of reviewing only the recent literature related to developing statistically-based estimates of statewide VMT.

4.2 Highway Performance Monitoring System

The HPMS was introduced by FHWA in 1978 to consolidate many previous federal data requirements and to strengthen the methods used by the states for collecting, estimating and reporting traffic count data. It involves a sample of highway sections that provide a basic set of traffic count locations for which geometric, operational and traffic volume data are to be available on a continuing basis.

In Washington, the sampled sections form "fixed" panels of highway sections which are monitored from year to year. The panels of sections have been established using an FHWA statistically-designed sampling plan based on the random selection of road sections within predetermined AADT volume groups or strata for each functional highway classification in the rural, small urban and urbanized areas of the state. FHWA states that the stratification of sections (or sampling units) into relatively homogenous AADT groups produces estimates of greater accuracy with respect to VMT, for a smaller number of samples at the functional class (summation) levels.

Recently, Hallenbeck and Bowman (1984) completed a study to identify ways of improving the cost-effectiveness of state traffic monitoring programs by developing a program based on the HPMS. The objectives of the study included:

- identification of the kinds of information required by the states and FHWA as well as the level of detail needed in the data
- development of a co-ordinated traffic monitoring program designed to

collect information for more than one purpose when possible

- identification of the capabilities of modern equipment to automatically collect data on vehicle classifications and weights as well as volumes, and
- development of central office analysis procedures incorporating statistical techniques, where appropriate.

Their report presents a cost-effective framework for collecting statewide traffic information. It provides a means of integrating vehicle classification, truck weight and traffic volume information, and includes procedures for determining the numbers of each of these types of monitoring sessions to provide data estimates within specified levels of precision.

By drawing on the conceptual basis of Hallenbeck and Bowman and employing statistical sampling methods that complement the HPMS sample, a strong potential appears to exist in Washington State for significantly improving highway data collection program efficiency by coordinating the collection of traffic count data, vehicle classification data and truck weight data. This approach was explored in the SHDRS as a possible basis for overall program design.

4.3 John Hamburg and Associates

In 1982 the firm of John Hamburg and Associates, Inc. published several reports on a National Co-operative Highway Research Program project entitled, "Improved Methods for Vehicle Counting and Determining Vehicle Miles of Travel" (1982a,b). The two reports referred to were subtitled Final Report on State of the Art, and Traffic Counting Program Design, respectively.

The State of the Art report documents and presents the results of a survey of (then) current state traffic counting programs. Three topic areas were surveyed - administration of the programs; data collection, processing and

presentation; and use of the data. The report presents and tabulates the aggregated responses of 43 states and Puerto Rico to a large number of questions about these topics. While all regions conducted traffic counting on a regular basis, there was found to be great disimilarity between the different program costs and procedures. One of the interesting results was also that for most types of volume and classification count, historical precedent was the overwhelming method used for selecting count locations. Statistical sampling was used only in a small number of states. With the exception of those states, the present methodologies were found to preclude the states from making any reliable estimate of precision at any confidence level.

The Traffic Counting Program Design report presented the design of an "ideal" statewide traffic counting program. The methods presented are said to represent the best of the existing state of the art as practiced by the various states, as well as innovative techniques developed by the consultant. However, it should be noted that this report and its procedures are effectively superceded by the development and publication of the 1984 HPMS guidelines by FHWA. Nevertheless, three major topics are discussed in detail - administration, inter-agency co-ordination and program design. Recommendations are made on sampling, count devices, data collection, data conversion and entry, factoring and presentation of the data. The authors present alternative procedures in recognition of the diversity of conditions, and the limitations that constrain count programs. Thus, no single idealized program was presented.

4.4 Guide to Urban Traffic Volume Counting

This manual, authored by Ferlis, Bowman and Cima (1980), is said to update and extend the methods contained in the original Guide to Urban Traffic Volume Counting (GUTVC) manual prepared in 1975. The original GUTVC is claimed to have

been rigorously tested by state and regional agencies around the country. The detailed procedures presented in this new (at the time) GUTVC therefore reflect experiences gained during that extensive testing program.

The manual presents methods by which urbanized areas can develop and implement integrated traffic counting programs to serve the volume data needs of local, regional and national agencies. Methods are presented for estimating volume at a single location, volume across a cordonline or cutline, VMT within a corridor or other small area, and also regional VMT. Statistical sampling concepts permit the collection of volume data at predetermined levels of precision and in a cost-effective manner. Some of the results of this study, particularly for estimating regional VMT in urban areas, appear to be a precursor to the subsequent report by Hallenbeck and Bowman (1984).

4.5 Related Studies

Several related studies of interest include a report from Oak Ridge National Laboratories by Greene and Loebl (1979), and papers by Rudman (1979) and Hoang and Poteat (1980). This last paper involved a field comparison of techniques discussed in the previous section in the Guide to Urban Traffic Volume Counting, with methods then used by the Florida Department of Transportation to estimate VMT. These methods involved a combination of fuel consumption and traffic counting approaches.

Green and Loebl (1979) report a comprehensive review of VMT statistics for air, highway and rail transportation of passengers and freight as a guide to those who use VMT data and need further information on the background of published VMT statistics. A survey they conducted of state practices in estimating VMT showed that states use one of three methods:

- fuel consumption method (11 states)
- traffic count method (23 states and the District of Columbia)
- a combination of the two (16 states)

An analysis of state VMT statistics using 1966-75 data showed that states using a combination or comparison of traffic count and fuel use methods arrive at consistently lower estimates of annual VMT per household, other things being equal, than states using exclusively one or the other method. Also, serious reservations were expressed about the validity of many states' VMT statistics. It was concluded that the selection of the best estimating method for statewide VMT would still require further, careful study.

CHAPTER 5. RECOMMENDED APPROACH

5.1 Introduction

This chapter identifies the recommended program structure for the Department to use in estimating statewide VMT. It is believed that this program will cost-effectively meet the needs of the Department's data users, while also meeting the budget constraints of the Department.

5.2 Overview of Program Structure

Based on the findings of this study and the SHDRS, it is recommended that the Department be guided by the detailed recommendations of Ritchie and Hallenbeck (1986) with respect to structuring HPMS short-duration volume counts, project counts, permanent traffic recorders and vehicle classification counts. This will permit the statistically-based estimation of statewide VMT, thereby meeting the objectives of this study. The budget impacts of these actions are minimal, while the cost-effectiveness improvements in collection, estimation and use of VMT data are expected to be significant.

The recommended program permits the straightforward estimation of AADT by vehicle type for any highway segment from the following equation:

$$AADT_c = VOL\ (F_s)\ (F_A)\ (F_G\ (P_c) \qquad (5.1)$$

where

$AADT_c$ = annual average daily traffic by vehicle type c on this segment.

VOL = average 24-hour volume from a standard WSDOT short-period weekday count.

F_s = seasonal factor for the count month.

F_A = weekday axle correction factor if VOL is in axles, not

vehicles; equal to 1, otherwise.

F_G = growth factor, if VOL is not a current year count; equal to 1, otherwise.

P_c = the appropriate vehicle proportion estimate

Extensive statistical analyses have permitted tabulation of the factors F_S, F_A, F_G and P_c for appropriate categories of urban and rural area, highway functional class, regions of the state, months of the year and, where appropriate, vehicle class. These tabulations, and discussions of their use, are presented in Ritchie and Hallenbeck (1986).

Estimation of annual average daily vehicle-miles of travel (DVMT), for any particular classification of highway and vehicle type, can then be estimated simply from:

$$DVMT = L\ (\overline{AADT}_c) \tag{5.2}$$

where

L = total length of highway segments in the desired category

$\overline{AADT}_c$ = the mean AADT for vehicle type c in this category of highway segments

$\overline{AADT}_c$ can be estimated as a simple average of the AADT's on segments in the desired category. It can also be estimated as a weighted average, where the weights are individual segment lengths. These methods are equivalent, of course, if all segments are of the same length. The weighted average effectively assumes that volumes are constant over the entire length of each segment, but is consistent with the notion of homogenous segments in HPMS. For most purposes, however, a simple averaging of AADT's across segments is probably adequate.

CHAPTER 6. IMPLEMENTATION

6.1 Implementation Overview

Implementation of the recommendations outlined in the previous chapter necessarily depends on implementation by the Department of the SHDRS recommendations. However, to provide assistance to the Department in doing so, Ritchie and Hallenbeck (1986) provide:

- step-by-step instructions for performing recommended data manipulations
- instructions on how to phase-in recommended changes to the existing data collection process
- instructions for determining the statistical precision of traffic estimates
- explanation of how to select recommended samples of vehicle classification data
- instructions for using the acquired information for updating the Department's counting samples and precision calculations
- suggested areas for further research

Reference should be made to the SHDRS Final Report by Ritchie and Hallenbeck (1986) for detailed implementation guidance.

REFERENCES

1. Ferlis, R.A., Bowman, L.A. and B.T. Cima (1980). "Guide to Urban Traffic Volume Counting." Peat, Marwick, Mitchell & Co., Final Report to Federal Highway Administration, Contract No. DOT-FH-11-9249.
2. Greene, D.L. and A.S. Loebl (1979). "Vehicle-Miles of Travel Statistics, Lifetime Vehicle-Miles of Travel and Current Methods of Estimating Vehicle-Miles of Travel." Oak Ridge National Laboratory, Contract No. W-7405-eng-26.
3. Hallenbeck, M.E. and L.A. Bowman (1984). "Development of a Statewide Traffic Counting Program Based on the Highway Performance Monitoring System." Final Report to FHWA, U.S. DOT, Contract No. DTFH61-82-C-00099.
4. John Hamburg & Associates (1982a). "Improved Methods for Vehicle Counting and Determining Vehicle-Miles of Travel - Final Report on State of the Art." Prepared for National Co-operative Highway Research Program.
5. John Hamburg & Associates (1982b). "Improved Methods for Vehicle Counting and Determining Vehicle-Miles of Travel - Traffic Counting Program Design." Prepared for National Co-operative Highway Research Program.
6. Hartgen, D.T. and J.H. Lemmerman (1983). "Streamlining Collection and Processing of Traffic Count Statistics." Transportation Research Record 779, pp. 6-10.
7. Highway Performance Monitoring System Field Manual for the Continuing Analytical and Statistical Data Base (1984). U.S. Department of Transportation, Federal Highway Administration, Office of Highway Planning.
8. Hoang, L.T. and V.P. Poteat (1980). "Estimating Vehicle Miles of Travel by Using Random Sampling Techniques." Transportation Research Record 779, pp. 6-10.

9. Ritchie, S.G. and M.E. Hallenbeck (1986). "Statewide Highway Data Rationalization Study." Final Report to Washington State Department of Transportation. Report No. WA-RD-83.1.

10. Rudman, L.M. (1979). "Vehicle Kilometers Traveled: Evaluation of Existing Data Sources." Transportation Research Record 726, pp. 19-28.

11. Wright Forssen Associates (1983). "Highway Traffic Data Study, Volume I: Final Report." Prepared for Alaska Department of Transportation and Public Facilities, Planning and Programming Division, Southeast Region, in association with Comsis Corporation and TRANSPO Group.

APPENDIX A: Glossary

1. AADT - Annual average daily traffic
2. DVMT - Average daily vehicle-miles of traffic
3. FHWA - Federal Highway Administration
4. HPMS - Highway Performance Monitoring System
5. Priority Array - The result of procedures used by WSDOT to objectively establish the need for highway system improvements, and rank order those improvements
6. SHDRS - Statewide Highway Data Rationalization Study - see Ritchie and Hallenbeck (1986)
7. VMT - Vehicle-miles of travel
8. WSDOT - Washington State Department of Transportation