STATEWIDE HIGHWAY DATA RATIONALIZATION STUDY

Final Report

by

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16. Abstract

This study involved an in-depth evaluation of the Washington State Department of Transportation highway data development and analysis activities. It developed statistically-based procedures and recommendations for a streamlined highway data collection program. Opportunities to reduce manpower and equipment costs, streamline work activities, improve the quality of data collected and provide accurate and timely data for the various users were identified. Given the focus on highway data, the major effort was devoted to the Department's traffic counting program. However, many data items and programs were considered, with the following receiving particular attention: traffic volume counting, including estimation of annual average daily traffic at any location throughout the state highway system; associated seasonal, axle and growth factors; vehicle classification; truck weights; and the relationship between the statistical sampling requirements recommended for these items and those associated with the FHWA Highway Performance Monitoring System in the state.

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ABSTRACT

This study involved an in-depth evaluation of the Washington State Department of Transportation highway data development and analysis activities. It developed statistically-based procedures and recommendations for a streamlined highway data collection program. Opportunities to reduce manpower and equipment costs, streamline work activities, improve the quality of data collected and provide accurate and timely data for the various users were identified. Given the focus on highway data, the major effort was devoted to the Department's traffic counting program. However, many data items and programs were considered, with the following receiving particular attention: traffic volume counting, including estimation of annual average daily traffic at any location throughout the state highway system; associated seasonal, axle and growth factors; vehicle classification; truck weights; and the relationship between the statistical sampling requirements recommended for these items and those associated with the FHWA Highway Performance Monitoring System in the state.

CONCLUSIONS AND RECOMMENDATIONS

After an extensive review of the Department's traffic counting program, the project team has reached the following conclusions:

CONCLUSIONS

- The number of volume counts currently being taken in a given year is roughly equal to the number required by the Department. However, some adjustment in where those counts are taken needs to be made.
- The Department currently lacks an adequate vehicle classification database, and its existing program is insufficient to significantly improve that database.
- The truck weight information collected by the Department does not provide the necessary unbiased information needed for cost effective pavement design.
- The Department does not utilize an axle correction factor for its mechanical volume counts. This lack of a factor results in a systematic over-estimation of vehicular traffic on state highways.
- The seasonal factoring process used by the Department is overly dependent on professional judgement and lacks a basis in statistics.

RECOMMENDATIONS

To improve the cost-effectiveness of the Department's counting program, the project team makes the following recommendations, with costs associated with those changes being shown in Table CR.1.

- The Department needs to collect volume data on HPMS sample segments as specified by the FHWA Traffic Volume Counting Manual. As a result, 483 short duration counts per year will be needed.
- Volume counts should also be made to fulfill specific project needs, where the cost of volume counting is warranted by the benefit the new information will provide. This results in the need for approximately 1,300 additional counts each year (this number depends on a year's project needs).
- Volume counts should be made for 48 hours at a location.
- Existing PTR counters should have their capabilities expanded to allow their use in collecting vehicle length data needed to improve the traffic information used in the design process.
- Until further data is collected defining the seasonal variability of this data, 20 existing PTR locations should be enabled to collect this type of information. Once that data is available, the number of PTR count locations required to obtain a desired level of precision for vehicle classification estimation can be more accurately estimated.
- Collect 452 short duration vehicle classification counts over a three year period to provide information on percent of travel by vehicle type throughout the state highway system. This will yield the percent of travel by 5-axle truck ± 15% with a 90% level of confidence.
- Purchase automatic vehicle classification equipment to reduce the cost of vehicle classification data collection.
- Purchase an unobtrusive truck weighing device(s).

TABLE CR.1

COMPARISON OF DATA COLLECTION COSTS

Type of Count	FTE (a) Current (c)	FTE (a) Proposed	FTE (a) Change	BUDGET (b) Current (c)	BUDGET (b) Proposed	BUDGET (b) Annual Change	BUDGET (b) One Time Charge
Volume Counts							
PTRs	0.00	0.00	0.00	25,000 (d)	25,000 (d)	0	0
Short Counts	3.50	3.50	0.00	159,000	159,000 (e)	0	0
Vehicle Classification							
PTRs	0.00	0.00	0.00	0	0	0	15,000 (f)
Short Counts	0.35	0.75	0.40	25,000 (g)	45,000	20,000	25,000 (k)
Truck Weighing	1.00 (i)	0.60	-0.40	68,000	42,000 (h)	(26,000)	125,000 (j)
TOTAL	4.85	4.85	0.00	277,000	271,000	(6,000)	165,000

(a) FTEs are for data collection only, they do not include necessary office processing or report production.

(b) Budget includes: cost of FTEs shown, coding, travel expenditures, per diem and supervision. It does not include report preparation.

(c) Based on the current FY-'86 budget. "Current" values are estimated, as the actual budget does not use these categories.

(d) Estimated annual telephone charges for telemetry system.

(e) This cost should be shared with project budgets and will vary with project needs.

(f) One time cost of three additional Golden River counters.

(g) Existing HPMS counting budget.

(h) Does not include the one time cost of purchasing WIM equipment

(i) Vehicle classification counts for the LTPM study are included under vehicle classification short counts.

(j) One time cost for WIM equipment ($85,000 - $100,000) and training.

(k) Cost of ten additional vehicle classifiers.

- Collect truck weights at 15 locations throughout the state, with a minimum of 200 five axle combination trucks being weighed at each location. This will provide an accurate procedure for estimating mean five-axle combination truck weights for each strata at roughly ± 10% with a 95% level of confidence.
- Apply an axle correction factor to volume counts collected by axle-sensing mechanical traffic counters.
- Calculate and apply seasonal factors based on the functional classification and geographic location of PTRs and individual road segments.
- Maintain the existing speed monitoring program as it directly fulfills requirements for monitoring the 55 mph speed limit.
- Continue to collect accident information from the State Patrol. A separate study is currently underway to determine if the Department should request a change in the types of data collected by the Patrol.

EXECUTIVE SUMMARY

INTRODUCTION

The objectives of this project were to perform an in-depth evaluation of the Washington State Department of Transportation highway data development and analysis activities, and to develop statistically-based procedures and recommendations for a streamlined highway data collection program. This summary presents the project findings. It describes the recommended program structure, lists the amount of data collection that the project team recommends the Department undertake, and indicates roughly what that data collection should cost.

After briefly reviewing the structure of the counting program, this summary addresses the basic types of traffic monitoring that the Department performs:

- volume counting
- vehicle classification
- truck weights

Each of these topics contains several issues. This summary provides only highly condensed explanations of the level of recommended data collection. Tables E.1 and E.2, pages 2 and 3 contain tables summarizing the recommendations. Table CR.1, page xv, summarizes costs and manpower. Chapter 6 contains a complete explanation of the recommendations.

TABLE E.1

Summary of Recommendations

Type of Count	Action	Financial Impact*	Comments
Volume Counts			
PTRs	Slightly reduce the number of PTRs being used for seasonal factoring	Negligable Change	Use a systematic method for applying seasonal factors based on functional class and geographic location
Short Counts	Collect at 345 HPMS volume sections and those counts which are paid for by project funds (roughly 1,300 locations)	Costs similar to current costs	If project counts increase significantly over time, more FTEs may be needed
Vehicle Classification			
PTRs	Upgrade existing PTRs to collect vehicle length data a minimum of 20 locations	Cost of software upgrade and minor installation costs ($9,000 for three new counters)	Data collection via telemetry, will provide seasonality for vehicle class data Such data is needed for pavement design
Short counts	Collect 151 vehicle class counts/year Purchase and use automatic counters for data collection	Reduction in cost per 24 hr count of 66 percent, offset by increase in the number of counts per year and cost of new equipment.	Supplies data for non-project related needs. (Trends, forecasting, reporting)
Truck Weighing	Purchase unobtrusive WIM system Collect data at 15 locations Collect weights for 200 five axle combination vehicles per location	Depends on system purchased, most likely will decrease manpower costs (bridge WIM = $85,000) (application now pending for WIM funds with FHWA)	Needs research into equipment capabilities, seasonality of data, and variability of truck weights. (project underway)
Miscellaneous			
	Apply an axle Correction Factor to mechanically collected (axle) counts	None	Will give a better traffic volume estimate
	Calculate and apply seasonal factors based on functional classification and geographic area	None	Will give a better traffic volume estimate

* Equipment costs only, manpower costs are described in Table CR.1, pg. xv

TABLE E.2

PROGRAM ELEMENT SUMMARY

ELEMENT	SUBELEMENT	COUNT PERIOD	NUMBER OF COUNTS	DESIGN PRECISION
Volume Counts				
	PTRs	365 Days	49	90-10 (mean seasonal factor)*
	Short Counts	48 hours	1,650/year	90-15 (AADT estimates on rural interstates)*
Vehicle Classification				
	PTRs	365 Days	20 (initially)	N/A**
	Short Counts	48 hours	151 locations/year	90-15 (5 axle combinations on interstates)***
Truck Weighing				
	(none)	200 five axle combinations vehicles/location	15 locations/year	95-10 (5 axle combinations)***

*   Actual precision achieved depends on the month the count is taken in, and for AADT on the precision of the axle correction factor.

** No data exists to accurately estimate the precision of seasonal correction factors for vehicle classifications

*** Precisions vary by vehicle classification and functional classification.

PROGRAM STRUCTURE

The traffic counting program is structured in such a manner as to provide the state with two levels of traffic information. The first level is site specific information. This is information taken on particular road sections specifically for use at that location. It is collected as warranted for particular projects.

The second level of information encompasses systemwide estimates. These estimates are used whenever site specific estimates are not available or when system (i.e. statewide or functional classification) estimates are more appropriate than site specific information. System estimates are used in a majority of the pavement overlay designs performed by the Department. Other examples of such situations would include:

- trend analysis of truck VMT (vehicle miles of travel) for the state highway system or interstate system
- estimation of vehicle weights per truck type for use in pavement design calculations
- calculation and application of seasonal and axle correction factors.

Finally, system estimates are required for converting short duration site-specific counts into AADT and other estimates needed by the Department.

VOLUME COUNTING

Volume counting consists of two basic types of activities, short duration counts (24 to 72 hours in length) and permanent traffic recorder (PTR) stations (365 day per year count locations). Both parts are integral to the estimation of Annual Average Daily Traffic (AADT) and other volume estimates used in the design of roads, pavements and structures. PTRs and short counts will be discussed separately below.

Short Duration Counts

AADT is the most frequently required traffic estimate of all data collected by the Department. AADT estimates are required for:

- pavement designent projects
- geometric design
- interstate 4R appropriations by the federal government
- priority array calculation
- highway performance monitoring system (HPMS) submittal
- most other roadway related analyses performed by the Department.

Of the above, the first two most significantly affect the expenditure of Department funds (especially construction funds), while the HPMS submittal is a reporting requirement of the FHWA, and is used in the Interstate 4R appropriation calculation. The recommended short duration volume counting program will provide the Department with reliable volume estimates for all of these tasks. Furthermore, a decision was made by the Department to limit the collection of other counts that did not have immediate financial implications to the Department. The recommended program, therefore, consists of project counts and those additional counts required for providing reliable system estimates, including the annual updating of the HPMS.

Using the project and HPMS data needs as the base, the project team determined that the field data collection needs for short duration volume counts can be met by a field crew equal to roughly 3.5 full time equivalents (FTE), which is equivalent to the current level of employment for traffic data collection within the Department.

The data actually needed by most users are estimates of AADT. These can be estimated from the short duration counts by multiplying each count by an axle correction factor and a seasonal adjustment. Axle corrections are dealt with under the heading "Vehicle Classification," seasonal adjustments are dealt with immediately below under "Permanent Traffic Recorders."

Permanent Traffic Recorders

The current level of PTR counting is slightly higher than needed for estimation of seasonal adjustment factors used in AADT calculations. However, the project team recommends that the Department continue to maintain more PTRs than are necessary strictly to provide seasonal factors. This recommendation is made because of:

- the very limited number of short duration traffic counts being recommended
- the current use of telemetry for PTR data collection, with its attendant low cost
- the imminent capability of the State to collect vehicle classification data from PTR locations.

As the primary use of PTR data is still seasonal factoring, the proposed factoring process and its need for PTRs will be detailed first.

The project team recommends that the Department use a linear regression variation of the FHWA seasonal factor procedure. Data for 1980 through 1984 from PTR stations indicates that the following seasonal factor groups should be used:

- Rural Interstates
- Urban Roads
- Other Rural Roads in the Northeast part of the State
- Other Rural Roads in the Southeast part of the State
- Other Rural Roads in the Northwest part of the State
- Other Rural Roads in the Southwest part of the State
- Central mountain passes.

A list of counties falling into each grouping is provided in Chapter 5.

Several other seasonal factor approaches were also considered, but had deficiencies that caused the recommended approach to be preferred.

The project team does recommend that one adjustment be made to the FHWA seasonal factoring approach. We recommend that a factor from a specific PTR can be used in place of the group factor for a specific road section in those cases where that factor can be considered more accurate than the group seasonal factor. The implementation section of the report includes a complete description of when this exception applies.

Number of PTRs

The Department should maintain the same approximate number of PTRs as they are currently operating although not all of these machines are necessary for estimating seasonal factors. As needs for new PTR locations occur, existing machines not needed for seasonal factoring can be transferred to the newly desired location. This will alleviate the need for the Department to purchase new PTR equipment in the near future for volume counting purposes.

By following this study's statistical analysis and the

FHWA guidelines, the appropriate number of PTRs for the Department is 49. This would mean that 10 counters could be removed as shown in the following table:

Group	Number of PTRs as of May, 1984	Recommended Number of PTRs for Seasonal Factoring
Rural Interstates	9	8
Urban Roads	11	8
NW Rural	9	8
SE Rural	13	8
SW Rural	6	6
NE Rural	4	4
Mountains	7	7
	59	49

The removal of 1 rural interstate, 3 urban, 1 NW rural, and 5 SE rural counters would have little effect on the precision of group seasonal factors, particularly as they are applied to individual volume counts.

Given that the vast majority of these locations are on the telemetry system, the cost savings to be made by removing the counters are fairly small. (The only significant costs for data collection from these points are telephone charges of $6 to $50 per month.) Also, given the State's paucity of information regarding the seasonal variation of truck travel, it is advisable to keep the majority of the extra stations, and convert all PTRs into stations capable of recording traffic by vehicle length. This will probably provide better information than could be achieved via any other manner for the same amount of money, and at the same time will help fill one of the major gaps in the State's traffic database.

The Department may also wish to use the counters not needed for calculating seasonal factors for special project counting needs although these "extra" counters should be included in the seasonal factor process. For example, the Department reactivated a PTR at the Custer Rest Stop on I-5, to monitor traffic levels before, during and after the World's Fair in Vancouver. Similarly, the Department might wish to specifically place PTRs on rural roads being affected by railroad abandonment to better estimate the changing levels of truck travel that result from that abandonment. These counts would be considered "special project counts," as opposed to those used for seasonal factoring.

VEHICLE CLASSIFICATION COUNTS

The biggest weakness in the existing Department traffic counting program is the lack of vehicle classification information. The Department does not have good data describing truck travel on its highways. Neither does it have data that could tell it how that travel varies throughout the year. Both of these are serious weaknesses given the significance of vehicle classification information in the design of projects and its requirement in the annual HPMS submittal. The project team, therefore, recommends that the Department take steps to improve the vehicle classification information that the State is currently collecting.

The first step in the recommended program is to permit the PTR stations to collect traffic volumes by vehicle length category. The Department needs to either obtain the software that will enable the existing equipment to collect this information, or it should develop such software itself. This expanded PTR capability is the most cost-efficient method for obtaining an understanding of the seasonal changes in truck travel. As an initial step, the project team recommends 20 PTR locations capable of collecting vehicle length data, be established at existing PTR sites. The 20 counters should be divided so that four counters are in each of the following categories:

- rural interstates,
- urban interstates,
- rural principal arterials,
- urban principal and minor arterials and collectors, and
- rural minor arterials and collectors.

Once the enhanced PTRs have been operating for a year, enough information will be available on daily and seasonal variation of truck travel to more accurately select sample sizes, for both PTRs and manual, short-duration classification counts. The final system design (including PTRs) would be very similar to the volume counting scheme presented above. The majority of vehicle classification counts would be taken to fulfill project needs. A smaller number of counts would be taken on a statistical sample of HPMS locations to provide estimates of statewide travel, and travel by functional class of highway within specified levels of precision. Some of the HPMS sample counts would likely be made as a result of project needs, the remaining counts would have to be specifically scheduled by the Data Office.

In the time before the PTRs become operational for vehicle classification, the State must be aware of the following conclusions the study team drew from available WSDOT data:

- a single, weekday vehicle classification count will probably <u>overestimate</u> annual average truck travel at a location, because truck travel (as a percent of total travel) is consistently higher on weekdays than on weekends

- the combination of daily and seasonal variation makes the percentage of truck travel highly variable both at a location and across functional classes.

These two conclusions mean that the Department needs a fairly large number of counts preferably spread out over the calendar year in order to reasonably estimate truck travel either at a location, or for a functional classification of roadway.

The project team recommends, as a temporary measure, that the Department perform 452 vehicle classification counts, spread over three years. These counts should be distributed between functional classes as shown in the following Table. The Department's project counts would contribute in some cases towards the necessary HPMS counts.

****

Table E.3 Recommended Vehicle Classification Count Program

Roadway Category	Number of Counts	Precision	Level of Confidence
Rural Interstates	104	±15%	90%
Urban Interstates	99	±15%	90%
Rural Principal Arterials	99	±20%	80%
Rural Minor Arterials and Collectors	83	±20%	80%
Urban Principal & Minor Arterials and Collectors	67	±20%	80%

*In estimating the average percent of travel by 5-axle combination trucks on the stated roadway category.

Finally, the Department is encouraged to investigate and purchase a limited number of portable automatic vehicle classification counters in addition to their PTRs capable of collecting vehicle length data. Use of these machines or similar devices would allow the Department to begin collecting 24 or 48 hour vehicle classification information at sites instead of 4 or 6 hour manual counts. Not only will this provide a more lengthy and therefore better count, it will reduce the cost of performing vehicle classification counts considerably. Further, it would allow the Department to move away from 72 hour project counts, toward 48 hour traffic counts, which would also reduce the cost of traffic counting. At this time, the 72 hour counts are preferable to 48 hour counts, in that the added time allows for a vehicle classification count in addition to two manual intersection counts and the necessary number of machine axle counts. If the classification count can be performed by machine, it may reduce the need for the extra day of traffic counting in many cases.

In the meantime, the Department should continue its current project counting procedures.

AXLE CORRECTION FACTORS

The above vehicle classification program should also be used to estimate axle correction factors. With the proposed vehicle classification scheme, the mean axle correction factors for all functional classes can be estimated with a relative precision of 0.4% with 90% confidence. (i.e. the average axle correction factor for rural interstates might be estimated as 2.35 ± 0.01 with a 90 percent chance of being correct.)

Until the new program is operational, the Department can use the

1980/81 HPMS case study database as a basis for estimating mean axle correction factors for each functional class of roadway. This database results in the following levels of precision at a 90% confidence level.

Functional Class	Precision %
Rural Interstates	± 10.2
Rural Principal Arterials	± 8.8
Rural Minor Arterials	± 4.8
Rural Collectors	± 10.7
Urban Interstates	± 3.9
Urban Principal Arterials	± 6.8
Urban Minor Arterials	± 2.1
Urban Collectors	± 1.6

TRUCK WEIGHTS

Statewide average truck weight information is used by the materials laboratory in its pavement depth calculations. The Department does not have the capability at this time to select in a statistically valid manner, truck weight locations from the HPMS sample, due to limitations in available equipment. Furthermore, the weight data the state has suffers from statistical bias due to the avoidance of all scales by many overweight trucks (through no fault of the Department). This limited data inhibits the ability of the project team to make definitive statements concerning the appropriate truck weight sample.

Given the above, the available data was used to estimate truck weight location sample sizes. It was not possible, with the available information, to estimate daily or seasonal variation. It was possible to estimate the variation in mean truck weight per vehicle type for an average of locations and between locations. This allows a sampling plan similar to that used by Wisconsin DOT, where the sample sizes chosen are based on the number of trucks weighed, as opposed to the number of days of weighing performed.

For vehicle weights, the recommended functional class groups for collecting truck weights are Rural Interstates, Other Rural Roads and Urban Roads.

The recommended sampling plan for each functional class group, based on available information, is as follows:

****

Table E.4 Recommended Truck Weighing Program for Rural Interstates

Type of Vehicle	Number of Locations	Number of Vehicles	Relative Precision	Confidence Level
2 axle, 4 T trucks	5	200	35%	80
2 axle, 6 T	5	200	16%	80
3 axle SU	5	200	20%	80
3 axle Com.	5	200	19%	80
4 axle Com.	5	200	10%	80
5 + axle Com.	5	200	10%	95
5 axle Double	5	200	11%	95
6 + axle Double	5	200	14%	95

****

As can be seen from the above table, the most important truck weights are for the heavier trucks (5 axles and greater). In actual operation, the truck weighing crew would stay at a location weighing all vehicles that came by until they had weighed the appropriate number of trucks for a specified category (usually 5 axle combinations, or if on an interstate, 6 axle doubles). In this manner, the appropriate precision is gained for these "most important" vehicle types. If more than the desired number of vehicles of another vehicle type are weighed, then the weight for that vehicle type is known with better precision than shown above. If less than the desired number of vehicles is weighed, then the precision is less than indicated above. The above precision estimates are based on estimates for rural interstates. Sample sizes and precision estimates for the other two functional class groups are similar.

Growth Estimation

The project team recommends that the Department continue to use its PTRs as the primary resource for estimating growth factors in the State. Because the Department does not directly collect data on over 50% of the HPMS sections, and currently cannot ascertain the quality of the data collected for it by the location jurisdictions, it is recommended that growth estimates from the HPMS system be used only as a secondary source for estimating growth.

CHAPTER 1. INTRODUCTION

1.1 Problem Statement

For many years, the Washington State Department of Transportation (WSDOT) has had responsibility for collecting a large amount of data across the state. This has been undertaken to assist the planning, design and operations function of the Department, 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. For example, estimates of statewide vehicle-miles of travel (VMT) are obtained by 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

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
- 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

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.

A study concerned with rationalization of the Department's highway data collection activities is therefore clearly appropriate. The issues identified above are of added significance given current development of the new Transportation Information and Planning Support (TRIPS) system. TRIPS is essentially a computerized, on-line, database management system for assembling, maintaining and reporting information about the State's highway network [1]. Accordingly, the focus of this Data Rationalization Study is limited to highway-related data.

1.2 Study Objectives

The basic objectives of this 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.

This study was to identify opportunities to reduce manpower and equipment costs, streamline work activities, improve the quality of data collected and provide accurate and timely data for the various users.

Given the focus on highway related data, a major effort has naturally been devoted to the Department's traffic counting program. However, a number of data items and programs must be considered, and the following received particular attention:

- traffic counting, including estimation of seasonal ,axle correction and growth factors
- vehicle classification
- truck weights
- vehicle speeds
- other Highway Performance Monitoring System (HPMS) [2] and Pavement Management System (PMS) data.

Vehicle speed information was dropped from the analysis when it was determined that the Department was performing speed studies as mandated by federal regulation and had no desire to refine or expand this data collection process. Pavement and roadway condition data were not included in the scope of this project.

An in-depth evaluation was to build on work already underway at the WSDOT Transportation Data Office and the University of Washington, and relate to:

- data requirements of actual and potential users
- sampling plans for the various components
- data collection, count processing and data management and storage procedures

count and processing equipment requirements and costs

- staffing requirements
- overall manpower and equipment costs
- procedures for implementing study recommendations.

1.3 Overview of Previous Work

Historically, highway data and specifically traffic count data have been collected by state transportation agencies to support a wide range of programs and needs. These have included the use of traffic count data to develop estimates of annual average daily traffic (AADT), vehicle-miles of travel (VMT) and design hour volume (DHV) 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 [3], which proposed a general statewide traffic counting program based on the Highway Performance Monitoring System (HPMS) [2]; the study by Wright Forsenn Associates [4] 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 [5]. While each of these studies provided useful background and guidance for this project, the conceptual basis of Hallenbeck and Bowman [3] in utilizing the HPMS framework for purposes of statewide highway data collection appeared particularly promising.

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. By employing statistical sampling methods that complement the HPMS sample, a strong potential appeared to exist 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 this study as a possible basis for overall program design.

Other relevant and useful works in the general area include Peat, Marwick and Mitchell [6]; DiRenzo, Bowman and Hallenbeck [7]; John Hamburg and Associates [8a,b,c]; Hoang and Poteat [9], Rudman [10]; Greene and Loebl [11]; and Mahoney [12].

1.4 Report Organization

This report is organized into a Conclusions and Recommendations section, seven chapters in the body of the report and several appendices. In addition to this introduction, the chapters cover the following topics:

- study approach
- users of Department data and their needs
- review of the existing Department database and data collection program
- statistical analysis and program design
- recommended data collection program
- implementation plan

The appendices contain a glossary of terms and other technical discussions relating to the main body of the report.

CHAPTER 2. STUDY APPROACH

2.1 Introduction

This chapter describes the study approach and methodology used to perform this project. In addition, regular and frequent meetings were held with two Departmental committees, a senior management Steering Committee, and a Technical Committee.

The objectives of the study have been discussed in section 1.2, and basically involve the following:

- determine the need for data within the Department
- evaluate the existing data collection process in light of that need
- provide a statistical basis for traffic estimates provided by the data collection process
- determine ways in which the Department could change its data collection strategies to more economically meet its needs.

2.2 Research Tasks

Specifically, the project was originally structured as twelve tasks. Elements of, and emphasis on, these tasks evolved over time through consultation with the Study Steering and Technical Committees. The original tasks, however, served as the basis of the project and were as follows:

Task 1 Identify data users.

Task 2 Identify data uses and special user requirements.

Task 3 Finalize specific data items to be addressed in this study, including those items currently collected and those desired. Prioritize, if necessary, due to project time and budget constraints. High priority data items will include:

* traffic count program design, including
  - coverage counts, if any
  - permanent traffic recorder (PTR) counts
  - seasonal factors
  - estimation of AADT, VMT and DHV
* vehicle classification studies
* truck weight studies
* vehicle speed monitoring

Other HPMS, pavement management systems (PMS) and relevant data items may be considered, as specifically agreed upon.

Task 4 Determine how to elicit statistical inputs from data users, as necessary and appropriate, e.g., allowable errors and desired levels of confidence for collected, derived and desired data items.

Task 5 Obtain statistical inputs from users, recognizing that compromise and/or prioritization may be necessary among uses, users and data error and confidence levels. Default values will be proposed for the last two items when they cannot be supplied by the users.

Task 6 Study and evaluate effectiveness of existing data collection activities with respect to user needs and requirements (including statistical aspects). This will include evaluation of data requirements of actual and potential users; existing sampling plans, if any, for the various components; data collection, count processing and data management and storage procedures; count and processing equipment costs and requirements; staffing requirements; overall manpower and equipment costs.

Task 7 Identify and evaluate existing statistical literature and methods relevant to developing recommendations and procedures for both overall and specific data collection program designs, that are also sensitive to WSDOT resource levels, that utilize the HPMS framework wherever possible and appropriate, and are consistent with the TRIPS system.

Task 8 Recommend potential statewide highway data collection methods for possible implementation.

Task9 Have WSDOT officials review and approve these potential methods prior to detailed analysis and investigation for purposes of developing specific, cost-effective procedures for implementation.

Task 10 To determine which potential methods should be implemented, conduct detailed analyses and sample designs (utilizing existing data when appropriate for establishing sample design variability measures). Document expected benefits and improvements for WSDOT and others in Final Report.

Task 11 Develop documentation to assist WSDOT personnel in implementing the study recommendations and procedures.

Task 12 a. Prepare and submit draft final report.

b. Prepare and submit final report.

2.3 Approach Overview

Data uses, users and their needs were determined by building on work previously performed by the Korf Committee. This also involved reviewing available literature on the subject of statewide traffic data collection. The two primary literature sources were the following:

- FHWA's Draft Traffic Counting Guide [13]

- the technical basis for that guide, "Development of a Statewide Traffic Monitoring Guide Based on the Highway Performance Monitoring System" [3].

The results of this investigation are included in Chapter 3 of this report, and were used throughout the remainder of the project as a basis for the majority of the analyses.

The specific data items to be addressed in the study were determined to be the "system" traffic data estimates (and not project-level estimates) collected by the Data Office of the Department's Planning, Research and Public Transportation Division. Roadway information and pavement condition data were excluded from the analysis.

One of the most difficult tasks in the study was the attempt to establish appropriate, statistical levels of confidence and precision to serve as objectives in the sample design process. The study team went back to all identified users of traffic information to elicit their data quality needs. As a result of this effort, 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 provied 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.

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 project and Technical Committee members.

While the investigation of data needs proceeded, the project team reviewed the current activities of the Data Office. In particular, the team examined:

- data being collected
- methods for determining locations of data collection
- manipulations performed on the data collected before being provided to users.

This information was then later compared with the data needs determined in the beginning of the project to investigate the strengths and weaknesses of the existing data collection procedures.

The project team also obtained information from both the Department and FHWA to assist in assessing the variability of data (i.e. the variation in traffic volumes, truck travel, etc., between days, locations and seasons). Current costs of the data collection process were also gathered. This information was used to estimate the sample sizes needed to meet the Department's accuracy (precision) needs and to determine the approximate cost of meeting those needs.

After this information was gathered, several alternatives were developed to meet the identified needs of the Department. This information was presented to the Steering and Technical Committees for review. The program recommended in this final report includes the preferred alternative and reflects comments and changes recommended by these two committees.

CHAPTER 3. DATA USERS AND USER NEEDS

3.1 Introduction

This chapter summarizes the information collected on user needs by the project team. It is intended to clarify the uses of Department traffic information, with the further intent of clarifying the need for those data and the level at which they should be collected.

This chapter considers the Department's data needs from two different perspectives:

- expressed user needs
- data to be collected and manipulated.

In the first section of this chapter, the data requested from the Data Office are explored. This section is based primarily on an extensive series of interviews with Department personnel and other data users identified during the course of the study. Use was also made of several documents produced during the Korf Committee review of the data collection process.

The second section of this chapter details the difference between the data that is requested and the raw data that needs to be collected, and describes the various manipulation steps that must be performed to turn that raw information into the form requested by data users. It then details what raw data the Department must collect to meet the expressed user needs.

3.2 User Needs

A total of 45 major uses of traffic information were identified by the project team with the assistance of the Transportation Data Office. These uses were broken into 11 user categories, shown in Table 3.1. In all, 14 types of traffic information were identified and can be further

Table 3.1

Users Data Needs

USES	AVERAGE ANNUAL DAILY TRAFFIC	AVERAGE DAILY TRUCK TRAVEL	DESIGN HOURLY VOLUME	PEAK HOUR FRACTION	DIREC-TIONAL SPLIT	TRUCK PERCENTAG	PEAK HOUR VOLUME	EQUIVALENT AXLE LOADINGS	TRUCK WEIGHTS	TURNING MOVEMENTS	VEHICLE CLASS. PERCENTAGE	VEHICLE MILES OF TRAVEL	SPEEDS	ACCIDENTS
1 Project Level Traffic Forecast	1		1	1	1	1	1			1	1			
2 Highway Geometric Design	2		2	2	2	2	2			2				2
3 Highway Pavement Design	3					3		3	3		3			
4 Project Level Bridge Design	4	4												
5 Signal Warrants	5									5	5			5
6 Intersection Design	6									6				
7 Traffic Eng. Control & Operation	7												7	7
8 Speed Study Analysis	8												8	
9 Vehicle Weight Enforcement	9					9			9					
10 System Level Traffic Forecasting	10											10		
11 System Level Bridge Design	11													
12 Long-Range Trans. Syst. Plan.	12											12		
13 Capacity Needs Analysis	13			13	13	13	13							
14 Highway Perf. Monitoring Syst.	14			14	14	14					14	14	14	14
15 Pavement Management System	15					15								
16 Model Calibration & Validation	16		16											
17 Survey Control	17													
18 Freight Analysis Movement	18			18	18	18	18							
19 VMT Determination	19											19		
20 Flow Maps	20													
21 Priority Array	21			21	21	21								21
22 Project Level Invest. Anal.	22						22							22
23 Maintenance Programing	23													
24 Maintenance Scheduling	24													

Continued overpage ...

Table 3.1
(Continued)
Users Data Needs

	AVERAGE ANNUAL DAILY TRAFFIC	AVERAGE DAILY TRUCK TRAVEL	DESIGN HOURLY VOLUME	PEAK HOUR FRACTION	DIREC-TIONAL SPLIT	TRUCK PERCENTAG	PEAK HOUR VOLUME	EQUIVALENT AXLE LOADINGS	TRUCK WEIGHTS	TURNING MOVEMENTS	VEHICLE CLASS. PERCENTAGE	VEHICLE MILES OF TRAVEL	SPEEDS	ACCIDENTS
25 Accident Analysis	25											25		25
26 Safety Studies	26											26		26
27 Air Quality	27					27					27		27	
28 Water Quality	28													
29 Noise Quality	29						29				29		29	
30 Economic Impact of Development	30													
31 Energy Consumption	31										31			
32 Economic Studies & Analyses	32										32		32	32
33 Revenue											33	33		
34 State Patrol	34											34	34	34
35 Traffic Safety Commission	35											35	35	35
36 Commerce & Economic Devl.	36													
37 AAA	37													
38 Motel Chains	38													
39 Service Station Chains	39													
40 Chamber of Commerce	40													
41 Outdoor Advertising	41													
42 Litigation Tort Claims	42		42	42	42	42	42			42	42		42	42
43 Damage Recovery														43
44 Construction Manpower Planning	44													
45 Maintenance Manpower Planning	45													

categorized as belonging to the following five groups (Table 3.2):

- traffic volumes (daily, hourly, directional, etc.)
- vehicle classifications (truck percentages and distributions)
- truck weights
- speeds, and
- accident data.

Each of these types of information will be discussed below.

3.3 Volume Data

The information most frequently desired is (not surprisingly) Annual Average Daily Traffic (AADT), a volume estimate. It was requested in 43 of the 45 listed data uses. From our estimates, under half of these uses would be readily satisfied with general estimates of volumes (i.e. something less than a specific volume count on a specified state highway, at a specified milepost). An example of this type of estimate might be the need for volumes for travel model calibration.

The remaining volume requests are point-specific. That is, the data request is for a specified roadway at a specified milepost. These requests range from project level needs (AADT and hourly distributions of traffic) for design purposes, to AADT estimates for accident rate calculations in the priority array calculation, to requests made by private citizens for use in the location of outdoor advertising (billboards).

The users of this information would all prefer to use data that directly relates to a traffic count taken at a specific location, although most of the users of this information would be satisfied with an AADT estimate based on a traffic count on that road in the general

Volumes

Average Annual Daily Traffic	(AADT)
Design Hourly Volume	(DHV)
Peak Hour Traffic Percentage	(K)
Directional Split	(D)
Peak Hour Volume Turning Movements	(Peak Hour)
Vehicle Miles of Travel	(VMT)

Vehicle Classifications

Average Daily Truck Traffic	(ADTT)
Percentage of Trucks in Peak	(T)
Percentage by Vehicle Class	(Veh. Class)

Truck Weights

Truck Weights	
Equivalent 18 Kip Axle Loads	(EAL)

Speed Data

Percentage of Vehicles by Speed Range

Accident Data

State Highway Patrol Accident Reports

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Table 3.2. Categories of Traffic Information

vicinity of the specified milepost. Few of the data users were able to respond to questions about the statistical reliability needed in the data they used.

Each of the uses of volume data is sensitive to the variation inherent in the traffic estimates (the changes in volumes on a day-to-day basis). This sensitivity changes from analysis to analysis, as does the Department's need for reliability from the various analyses. For example, a 100 percent under-estimation of trucks in a pavement overlay calculation in most cases will have a significant effect on the amount of overlay being placed. This will have a significant effect on the expenditure of Department resources both now and in the future, and therefore the Department should be very sensitive to the quality of data used in this type of analysis. However, a similar error during a water quality analysis for a roadway improvement study has considerably less impact on the Department and its resources, and therefore, data for this analysis may be of less importance to the Department.

This does not mean that the Department should ignore the need for truck volume data for water quality analyses (or similar analyses), or that these analyses would not be better served with higher quality, site-specific data, but only that the state cannot afford to collect all potential data and that these data should have a lower priority because of their smaller impact on the fiscal responsibilities of the Department.

Unfortunately, it is not within the scope and resources of this statewide data study to derive the sensitivity to data inputs of each of the 43 listed uses of AADT data. However, because the study team was unable to extract this type of information from the data users, several sensitivity analyses were performed, primarily based on the following:

- the financial impact of the various analyses on the Department's resources
- the amount of data required for the analyses
- the cost of the acquiring those data
- the sensitivity of the results of a selected number of analyses to a selected range of data inputs.

The information obtained from this sensitivity review was used to develop the primary structure of the data collection program, described in Chapter 6.

3.4 Volume Needs

The data needs for the various volume estimates were divided into three basic categories:

- project-oriented, site-specific estimates - those data uses which require and warrant data specifically collected for particular projects
- network-level, site-specific estimates - those network-based analyses that need point-specific data, but whose data collection costs imply that data collection specifically for that purpose may be unwarranted (i.e. the cost of collecting the requested counts is too high in relation to the financial impact of the analysis
- system estimates - those data uses for which a general traffic estimate based on averages (e.g., statewide, functional class-specific, or other) computed from previously collected data is sufficient to meet the user's requirements.

Table 3.3 shows how the project team has divided the 43 identified

	PROJECT ORIENTED	NETWORK LEVEL SITE SPECIFIC	SYSTEM ESTIMATES
Project Level Traffic Forecasts	X		
Highway Geometric Design	X		
Highway Pavement Design	X		
Project Level Bridge Design	X		
Signal Warrants	X		
Intersection Design	X		
Traffic Engineering Control and Operations	X		
Speed Study Analysis			X
Vehicle Weight Enforcement		X	
System Level Traffic Forecasting			X
System Level Bridge Design			X
Long Range Transportation Systems Planning			X
Capacity/Needs Analysis	X	X	
Highway Performance Monitoring System		X	X
Pavement Management System		X	
Model Calibration & Validation			X
Survey Control			X
Freight Movement Analysis			X
VMT Determination			X
Flow Maps			X
Priority Array		X	
Project Level Investment Analysis		X	
Maintenance Programing		X	
Maintenance Scheduling		X	
Accident Analysis		X	
Safety Studies		X	
Air Quality Analysis		X	X
Water Quality Analysis		X	X

Continued on following pg....
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Table 3.3. Volume Data Uses by Data Requirements

	PROJECT ORIENTED	NETWORK LEVEL SITE SPECIFIC	SYSTEM ESTIMATES
Noise Quality Analysis		X	X
Impacts of Development		X	
Energy Consumption		X	X
Economic Studies & Analysis		X	X
Revenue			X
State Patrol		X	X
Traffic Safety Commission		X	X
Commerce & Economic Development			X
AAA			X
Motel Chains			X
Service Station Chains			X
Chamber of Commerce			X
Other			X
Litigation (Tort Claims)	X	X	
Construction Manpower Planning			X
Maintenance Manpower Planning			X

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Table 3.3. Volume Data Uses by Data Requirements (Continued)

user needs among these categories. It should be noted that this table is intended only to define the needs of data users as a whole, and is not intended to limit the data that can be used in any of these analyses.

3.5 Vehicle Classification

Vehicle classification needs are roughly equivalent to volume needs, although fewer analyses need vehicle classification information as an input. The project team stratified vehicle classification needs in the same manner and in the same categories that were used for volume estimates. Table 3.4 shows the analyses that users indicated needed vehicle classification data, and how the project team believes those estimates can be met.

As with volume estimates, the vehicle classification estimates can be divided into the three basic categories:

- project-specific
- network-level site-specific
- system estimates.

Project estimates are appropriate for those projects in which the cost of collecting vehicle classification information, which is better than that which already exists from other sources, is outweighed by the financial benefits of using that information (primarily construction related design).

At the other extreme, the state has a distinct need for maintaining a statistically valid estimate of total travel by vehicle type within the state. This type of estimate is particularly important for establishing trends for forecasting (which has a significant effect on pavement design) and for potential use in allocating funds both from

	PROJECT ORIENTED	NETWORK LEVEL SITE SPECIFIC	SYSTEM ESTIMATES
Project Level Traffic Forecast	X		
Highway Geometric Design	X		
Highway Pavement Design	X		
Project Level Bridge Design	X		
Signal Warrants	X		
Vehicle Weight Enforcement		X	
Capacity/Needs Analysis	X	X	
Highway Performance Monitoring System			X
Pavement Management System		X	
Freight Movement Analysis			X
VMT Determination			X
Priority Array		X	
Air Quality Analysis		X	X
Noise Quality Analysis		X	X
Energy			X
Economic Studies & Analysis		X	X
Revenue			X
Litigation (Tort Claims)	X	X	

Table 3.4. Vehicle Classification Uses by Data Requirements

federal sources (i.e. between states) and within the state.

3.6 Truck Weights

Truck weights are not needed in a large number of analyses, but in the calculations for which they are used they have significant effects on the expenditure of Department funds. Unlike volumes and vehicle classification, truck weight data needs do not fall into the three previously mentioned categories. In almost all cases, truck weights are used as statewide averages.

Data are unavailable to determine whether site-specific vehicle weight data are warranted for project design purposes. In any case, at this point, the collection of vehicle weight data other than on a systemwide basis is impractical. This is primarily due to the truck weighing equipment the Department has available.

The Washington State Transportation Center (TRAC) and the Department are currently scheduled to begin testing WIM systems in July, 1985. This testing may lead to a limited capability to weigh vehicles on a project basis. It may also provide sufficient information to determine whether truck weights vary by region of the state, by functional classification of road, or by other parameters. This information would enable the Department to make more rational decisions about the need to expand on a weighing program designed to provide statewide information.

3.7 Speed Data

The Department has one significant, recurring need for speed information: the required federal speed enforcement survey. The conduct of this study is set forth in legislative statute and is followed by the Department. All other needs for speed information should be met on a project basis, as the data needed are very site-specific, and system estimates (of speed ranges) are not appropriate for these uses.

3.8 Accident Data

Accident information used by the Department is collected by the State Highway Patrol. The Department does not collect its own accident data, except for special projects. These procedures should be continued.

3.9 Collected Versus Derived Data

This section examines the issue of what specific data items the Department needs to collect, how those data must be manipulated, and how they should be combined to produce the traffic estimates requested by data users. For example, to produce a value of AADT on any given section of roadway, the Department needs:

- 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 (or axles) at a location.

Thus, the data needs of the Department can be divided into the following two basic categories:

- raw data to be collected, and
- factors and estimates derived from that raw data.

Specific data items within these two categories are discussed below.

3.9.1 Collected data

The data needs in this category are items collected directly by the Department. The specific data identified include:

- volumes (including daily and peak hour data)
- vehicle classification estimates
- truck weights
- accident data
- speeds.

This information is sometimes used in its raw form, but is more commonly manipulated in some fashion before being used in WSDOT analyses. Raw data serve as the basis for all calculated factors. To that end, the need for raw data can be described as the combination of the needs for raw data itself (volumes at a location on a given day, the number of accidents at a location, etc.) plus the raw data needed to determine the calculated factors.

Raw data are needed to supply the Department with the project-specific, network-level site-specific, and system estimates described earlier for volume and vehicle classification counting. To meet these needs, the Department needs a two-tiered data collection approach.

In the first tier of data collection, the Department needs to be able to collect the site-specific data that are warranted by its most important analyses (i.e. those that have the largest financial or political impact). This means that the Department needs to be able to collect volume and vehicle classification information at particular sites, as requested by engineers directing the project designs in question. These requests should be routed to the Data Office with a sufficient lead time to allow effective manpower scheduling by that group.

The primary data uses that will warrant this site specific data collection include:

- pavement and overlay design
- geometric modification
- intersection signal warrants
- special point-specific accident studies.

Accident data (the description of all traffic accidents on all state highways) are also collected on a point-specific basis. This data collection is essentially free to the Department (with the exception of data processing costs, which are fairly low), so it should continue to be collected in the existing manner.

The second tier of data collection includes those counts necessary to provide system estimates for the Department. In addition to the needs listed in Tables 3.3 and 3.4, these estimates are used as defaults for network-level site-specific and project-specific data needs when site-specific counts, or other more site-specific data are not available (i.e. a volume count within a mile or two of the road section in question). It should be noted that currently, a majority of the Department's pavement overlay designs are performed based on these default estimates.

This second tier of data collection, in particular, needs to form a statistically valid sample. This provides the Department with a rational means for understanding the quality of the data it is using for factors and defaults in all of its analyses. The Department's sample is most appropriately taken as part of the FHWA's HPMS database.

While the HPMS sample has distinct limitations, it does provide the most cost-effective basis for choosing samples for statistically valid data collection.

Unlike the first tier of data collection where only volume and vehicle classification data are collected, the second tier should collect volume, vehicle classification, truck weight, and speed data. The Department's volume counting locations already exist in the form of the HPMS volume sample. The vehicle classification locations should be taken as a subset of that collection of volume count locations. The truck weight sample should in turn be taken as a subsample from the vehicle classification sample. The procedures for selecting these locations and the number of locations that should be selected for each of these samples are discussed in the following two chapters of this report.

The speed survey currently performed by the Department is already a statistically valid sample. The data collected fulfills a special federal requirement. Its collection should be continued as it is currently performed. The Department should ensure that the data collected as part of this sample is entered into the traffic database.

It is recommended that the statistically valid sample be taken on a three year cycle. That is, only one third of the total number of sample locations should be counted in any given year. This cycle length is recommended by FHWA because:

- traffic changes (on a systemwide level) occur very slowly, and little change is expected over the three year cycle
- the three year cycle is reasonable in terms of the amount of data that needs to be collected in any given year.

This recommendation applies to all HPMS counts (volume, vehicle classification and truck weights), but does not include the speed survey, whose sampling plan is based on a one year cycle.

Finally it should be noted that the Department may wish to supplement the HPMS sample slightly. It is deemed advisable by the project team that a limited number (10 to 25) of volume counts be taken by the Department each year on particular roads, in addition to the HPMS sample counts. These counts are suggested because the HPMS sample, being randomly selected, does not have any counts on some state highways, and it is in the interest of the Department to have at least one or two counts every count cycle on all State Highways. Appendix B presents a list of the count sections that the project team recommends be added to the three year HPMS count cycle.

3.9.2 Calculated factors and estimates

An example of calculated data is well represented by AADT. It comprises the combination of several pieces of raw information, usually by multiplying a raw estimate by one or more factors which are themselves computed from raw data. The primary factors the Department requires for providing calculated estimates include the following:

- axle correction factors
- seasonal correction factors
- growth factors.

For the most part, these values 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 particular, the Department needs a statistically valid sample of the following pieces of data:

- 365 day-a-year traffic counts (for estimating peak hour, seasonal and growth factors)
- vehicle classification counts (for estimating axle correction factors and truck percentages)
- short duration volume counts (for estimating statewide VMT and providing basic information on traffic volumes on state roads)
- truck weights.

It was also concluded that the state is in need of 365 day-a-year vehicle classification counters to supply the Department with information on the seasonal variation in truck travel in the state. It is believed that this information will lead to considerably more accurate pavement design calculations.

CHAPTER 4. EVALUATION OF EXISTING TRAFFIC COUNTING PROCEDURES

4.1 Introduction

This chapter documents and evaluates the existing Department highway data collection and manipulation procedures. It describes the raw data collected, the procedures used, and the strengths and weaknesses of the program as a whole. This evaluation does not deal specifically with the implementation of TRIPS, the Department's new roadway information database, but will point out areas in which the existing procedures will be significantly affected by this new system. Note that some changes in the data collection and manipulation procedures have already been planned because of TRIPS, while other areas concerning its implementation have not yet been addressed.

The chapter is organized into the following two sections:

- a brief description of the existing data collection and manipulation procedures
- an evaluation of the strengths and weaknesses of the data collection and manipulation process as it currently exists.

4.2 Description of Existing Data Collection and Manipulation Process

This section provides a description of the data currently being collected by the Department and gives a brief overview of the existing data collection methodology. As discussed earlier, the procedures used to manipulate much of the data collected will change with the implementation of TRIPS. As a result, the emphasis of this section will be on describing the data collected and the steps performed in data manipulation rather than on the physical methods currently being used to manipulate the data.

As indicated in Chapter 3, the vast majority of traffic data collected by the Department falls under one of the following categories:

- permanent traffic recorder (PTR) data
- short duration volume counts
- vehicle classification data
- truck weight data
- speed data
- accident data.

The individual data items within each of these categories are discussed below.

4.2.1 PTR data

The Department currently operates about 80 pieces of PTR equipment to collect data year-round at approximately 65 locations (n.b. these numbers can change as the Department moves counters to gain information on particular travel movements). More than one counter is necessary at some locations to handle multiple lanes or several different legs of intersecting roadways. The actual number of operating PTR stations has increased in recent years as the Department has attempted to maximize its anticipated data collection efforts and statewide traffic knowledge while minimizing the cost of the collection.

The PTR data provides information for calculating the following:

- seasonal adjustment factors for converting short duration counts to AADT estimates
- estimated design hour (and other design) factors for non-PTR locations
- growth trends.

PTRs also provide volume information for the sections of highway on which they are located.

Currently, these data are collected using a telemetry system, to which the Department recently converted. This conversion has reduced the amount of manpower needed to collect and manipulate PTR data. It could also improve the quality of data gathered because the telemetry system can speed up the detection of malfunctioning traffic counters, provided the polling of PTRs is performed more often than the previous manual visits. At this time, the Department only polls PTR stations once per month, which is essentially the same rate as the manual data collection from PTRs.

The equipment at all PTR stations uses magnetic inductance loops embedded in the pavement to sense the presence of passing vehicles. Because these counters operate throughout the year, and actually count vehicles rather than axles, the data from the counters can be used directly (i.e. without the need for an axle correction factor) to calculate AADT and other volume measures.

4.2.2 Short duration counts

The majority of traffic volume counts taken by the Department fall under this category. Short duration axle counts usually last 72 hours, but may also be of 48- and 24-hour lengths. At this time, the Department collects short period counts only when requested for specific projects or when manpower is available to place and retrieve counters while performing other tasks.

The data collected from these counts are seasonally adjusted and entered into the existing traffic volume database for future reference. Volume data already in the database and not replaced by a new volume count are adjusted annually to reflect VMT growth in the state. The seasonal factors applied to each raw count are derived from available PTR data. A transportation data office engineer or technician determines the particular PTR(s) used for the factor based on his knowledge of the following:

- the road being counted
- the roads which contain PTR stations
- a book containing previous estimates of seasonal factors for various road sections (based on old PTRs, old control counts, and professional judgment).

In most cases, an axle correction factor has not been applied to the raw axle counts, although the Department has instituted changes to this policy.

The Department prefers to take 72-hour, machine, axle counts. Shorter counts (i.e. 48- or 24-hour counts), are acceptable, and are used when time or manpower limitations prevent the use of longer counts.

In most cases, traffic counting is the responsibility of the Planning, Research and Public Transportation Division of WSDOT. Districts perform only limited amounts of counting and, instead, usually request specific counts from the Travel Data Branch of the above division (it should be noted that District 1 is an exception to this rule).

4.2.3 Vehicle classification counts

The Department collects vehicle classification data as part of the following two different program elements:

- project-specific data
- data at PTR locations.

For project-specific counts, vehicle classification counts are either 6 hour

hour manual counts, or part of 4 hour manual intersection counts. These project data are also used for other purposes when available. The Department does have several hundred of these counts in paper form in filing cabinets. It is hoped that this information will be put onto TRIPS so that it is more readily available to data users.

At PTR stations, the Department is currently performing manual counts on a quarterly basis to better understand the vehicle mix present on the state highway system. At this time, however, the Department's usable vehicle classification database is insufficient to estimate seasonal or locational variation in truck travel for most of the state highway system.

The Department is considering using the actual PTR stations for collecting volume data by vehicle length category (i.e. cars, small trucks and large trucks), using the capabilities of the new PTR counting devices and two inductance loops in each lane of traffic. This could provide a significant data resource at a limited cost to the Department. However, the variability and applicability of the PTR vehicle length data have not been tested at this time.

The principal vehicle classification need for the department appears to be the number (or percentage) of trucks in each of the following categories:

- 2 axle trucks (not including pickups)
- 3 axle trucks
- 4 axle trucks
- 5 axle trucks
- 6 or more axle trucks.

These categories are more aggregate than the "standardized" categories recently accepted and published by FHWA for use in future data submittals(See Table 4.1) and the manual classification categories actually collected by Department field crews. An example of a form used by the Department for vehicle classification data collection is shown in Figure 4.1.

4.2.4 Truck weight data

Currently, truck weight data for purposes other than enforcement are collected as part of the FHWA's long-term pavement monitoring program (LTPM). These weighings are being used in lieu of truck weighings that would normally be performed as part of the federal biennial truck weight survey. The truck survey has been temporarily suspended by FHWA pending the outcome of on-going research into various weigh-in-motion strategies. LTPM Study truck data are collected using low speed WIM scales at ten specific sites.

Data resulting from this effort are sent to FHWA. After analyzing the data, FHWA provides vehicle weight, average Equivalent Axle Load (EAL) and Equivalent Wheel Load (EWL) data to the Department for use in construction and pavement management functions.

4.2.5 Speed Data

The Department collects traffic speed data at specified locations throughout the state to demonstrate compliance with the 55 MPH speed limit. The data to be collected and the data collection methodology are specifically detailed by federal regulation. These instructions are followed by the Department.

4.2.6 Accident data

The Department collects data on highway accidents on all state highways. The data are pulled from computer tapes provided by the

Motorcyles (Optional)

Passenger Cars with/without Trailers

2-axle, 4-tire pickups, vans and motorhomes

Buses

2-axle, 6-tire single units

3-axle single unit

4-or-more-axle single unit

4-or-less-axle double unit

5-axle double unit

6-or-more-axle double unit

5-or-less-axle multi-unit

6-axle multi-unit

7-or-more-axle multi-unit

Table 4.1 Recommended FHWA Vehicle Classification Categories

Figure 4.1 WSDOT Vehicle Classification Field Sheet

Washington State Department of Transportation

MANUAL COUNT SHEET

LOCATION ______________________ Sheet ___ of ___

Recorder's Name | SR No. (1) | SR MP (4) | Control Section (9) | Station No. (13 – 16) | Mo (19) – Day (21) – Year (23) | Day of Week (25) | Time Begin (26)

PASSENGER CARS	CAR/w Trailer	VANS AND PICKUPS	V or P w/Trailer	BUSES	Motor-cycles	SINGLE UNIT TRUCKS			TRUCK-TRAILER			TRACTOR SEMI-TRAILER					TRAINS (2 TRAILERS)				OTHER	Total Lanes This Direction	Direction	Lane(s) Counted
						Medium 2-Axle	Heavy 3-Axle	LTD's	4-Axle	5-Axle	6-Axle	3-Axle	4-Axle	5-Axle Log Trk	5-Axle	6-Axle	5 Axle	6-Axle	7-Axle	8-Axle				
30	34	36	40	42	44	46	49	51	53	55	57	59	61	63	65	68	70	73	75	77	79	82	83	84

← TO

TURN BACK DENOMINATORS EVERY SHEET

INDICATE NORTH

TO →

PASSENGER CARS	CAR/w Trailer	VANS AND PICKUPS	V or P w/Trailer	BUSES	Motor-cycles	SINGLE UNIT TRUCKS			TRUCK-TRAILER			TRACTOR SEMI-TRAILER					TRAINS (2 TRAILERS)				OTHER	Total Lanes This Direction	Direction	Lane(s) Counted
						Medium 2-Axle	Heavy 3-Axle	LTD's	4-Axle	5-Axle	6-Axle	3-Axle	4-Axle	5-Axle Log Trk	5-Axle	6 Axle	5-Axle	6-Axle	7-Axle	8-Axle				
30	34	36	40	42	44	46	49	51	53	55	57	59	61	63	65	68	70	73	75	77	79	82	83	84

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Washington State Patrol. The information contained on the tapes is compiled from traffic accident reports written by State Patrol or other law enforcement officers responding to the scene of reported accidents. The Department performs no additional data collection for accident analysis other than to combine the patrol accident data with other data already available at the Data Office (i.e. volume estimates, geometric information, pavement condition, etc.).

4.3 Evaluation of the Data Collection Process

In a limited sense, the existing data collection program fulfills the majority of the Department's current data needs. The program can be characterized as the lowest possible level of volume data collection permissible to meet immediate project data needs with insufficient amounts of vehicle classification and truck weight information being collected. This low level of data collection results in the lowest immediate cost to the Department, but it also causes some data deficiencies that conceivably could cost the state more money than is being saved.

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.

These issues are dealt with in more detail below.

4.3.1 Volume counting

As stated earlier, the Department primarily performs project-related traffic counting. The vast majority of counts taken are specified as a result of project needs. The remaining volume information is gathered as manpower permits. This means that non-project-related counts tend to cluster around project locations, since field crews do not have the time or travel allowance to move away from the project area when collecting these counts.

In terms of user satisfaction with the data, this data collection strategy should be an acceptable resource for important and specific projects. This is because those projects that result in the expenditure of significant Department resources (and therefore have the budgets that allow for data collection) have the ability to request whatever traffic information is believed necessary for project design. At the same time, however, the Department can put less emphasis (and planning funds) into smaller projects that have less of an effect on the expenditures of funds. These analyses must rely on available data, and in turn, the

Department must be prepared to accept whatever imprecision results from the lack of information being collected for these analyses. In other words, it would appear that the Department has concentrated its rescources on those areas which most significantly affect its finances.

Because this project does not deal with the statistical quality of data collected for specific project analyses, it is not possible to determine whether the current level of data collection for projects is optimal. That topic must be addressed by further research.

A problem with the existing traffic counting process is that while any one non-project data need might not be that "important", when taken as a whole, the combined impact of these analyses can be significant. Further, because traffic counting is centered around project sites, those parts of the state not involved in major projects will have little or no traffic counting performed. As the counts in these areas grow older, users of those data start to question (sometimes rightly) the validity of the available traffic estimates. Considering that these estimates are included in such analyses as the Priority Array, the HPMS submittal (which includes the information used to apportion Interstate 4R funds), and other non-site-specific analyses, the state has a need for maintaining the quality of traffic information on road sections that are not project locations. In addition, in recent years system level data have been used for pavement overlay design purposes when location-specific data could not be collected in time. This represents a very significant use of system data.

The project team performed several sensitivity analyses to determine the effects of data quality on analyses such as those listed above. The conclusions drawn from those analyses are the following:

- errors on the order of 25 percent in volume estimates have only minor significance in most analyses (with the exception of pavement overlay design)

- the state has a definite need for maintaining a statistically valid estimate of total travel on the state system.

The existing data collection program is not providing sufficient information to keep volume estimate errors near 25 percent on the average or provide reasonable estimates of VMT on the State Highway System. It is therefore the conclusion of the project team that the Department needs to improve its systemwide counting effort by meeting the HPMS volume sample guidelines outlined in the FHWA's draft traffic counting manual [13].

4.3.2 Factoring and data manipulation

Currently, most of the factoring and data manipulation performed by the Department is done manually. The Department supplies traffic estimates in terms of auto equivalents, and does supply an estimate of the percentage of truck travel, but it does not automatically apply an axle correction factor.

The current seasonal factor process also requires a considerable amount of judgmental intervention. While this intervention sometimes results in better factoring (when the engineer's knowledge of a particular road is especially good), this type of procedure tends to result in biases in the reported AADTs because of the perceptions (right or wrong) of the individuals performing the factoring. Further, it leads to inconsistencies because two different engineers or technicians using the same volume counts might develop considerably different AADT estimates based on their individual perceptions of what the "correct" seasonal factor should be.

The project team has concluded that the Department needs to develop and use a consistent, statistically valid, seasonal factoring procedure. This procedure should specify the following:

- what data will be used to compute seasonal factors
- when and where those factors should be applied
- when exceptions to those factors are permissible
- how those exceptions should be noted.

A potential solution to these requirements may be found in the TRIPS system currently being developed and installed for the Department. TRIPS provides the ideal tool for automatically performing all neccessary factoring procedures for converting raw data into useful traffic estimates.

The data for calculating the necessary factors are already collected as part of the on-going traffic counting program. The raw data for these calculations are already to be included in the TRIPS system. However, at this time little or no effort has been made to determine how TRIPS should manipulate this information to produce the desired results. Further work in this area of TRIPS should be done during the design and installation phases yet to be completed. Guidelines for much of this work can be taken from the next three chapters. Areas to be determined for TRIPS include the following:

- the data to be used to calculate these factors must be specified
- routines must be developed to estimate the appropriate factors from these data
- storage areas must be set up to contain the factors
- computerized routines must then be developed which allow these stored data to be readily applied to any raw traffic count within the automated TRIPS system.

The study team suggests that these data could best be stored and utilized as a series of tables created within TRIPS. These tables could then be used on a look-up basis for application to any raw traffic count. Preliminary instructions on how to perform these tasks are included in the implementation section of this report.

4.3.3 Vehicle classification

The Department collects very little vehicle classification data. Some of this information is collected in the form of six-hour manual counts for projects and 4-hour, intersection turning movement counts. In addition, the Department has recently undertaken a program to perform, on a quarterly schedule (subject to funds availability), 24-hour manual vehicle classification counts at PTR stations. The majority of these data are not currently stored in a manner that makes them available to most users of Department data.

This data collection effort is insufficient to meet the Department's needs. Although the 6-hour counts for project locations are providing data requested by project engineers, it is probable that these data are not statistically accurate enough for their purposes.

The biggest difficulty with the existing data collection effort is that the Department has no knowledge of how truck travel changes on its highway system from month to month or day to day. Because this knowledge is lacking, short duration counts (e.g. six-hour manual counts at project sites) cannot be expanded to an average annual total with any degree of accuracy or confidence. The designs based on the collected data are therefore not likely to be as accurate as they should be.

A further problem with the current data collection method is that no statistically valid estimate can be made of truck travel in the state, or on the state highway system. This becomes a very serious problem when viewed in conjunction with traffic forecasting for pavement design. The pavement design process allows for the changing of truck travel percentages over time (e.g., if truck travel is expected to grow, more Equivalent Axle Loads will be applied to the pavement over its design life, and the pavement will need to be correspondingly thicker). At this time, the Department has no knowledge of how those percentages have changed, and consequently, has little basis for forecasting such travel into the future.

4.3.4. Truck weighing

The Department's truck weighing consists of the LTPM data collection described in Chapter 3. This data collection is probably insufficient for the Department's needs, but appropriate given the equipment and resources currently available to the Department.

The biggest problem with this data collection procedure is that it cannot account for biases that are apparent in every above-ground weighing system. Heavy and overweight trucks tend to avoid scales, even when those scales are not used for enforcement purposes. As a result, the truck weights that are obtained tend to underestimate the average weight of trucks on the highway system.

In combatting this problem, the use of the Department's "PAT" slow-speed WIM (weigh-in-motion) equipment is far superior to the use of State Highway Patrol static scales. The Department field crews are more likely to gather a valid database using the PAT scales because truckers associate the static scales with weight enforcement efforts, and the PAT scales offer significant advantages in terms of the time necessary to weigh vehicles and the crew needed to operate them. However, in order to collect the data really needed, the Department will need to acquire a weighing system that is unobtrusive to the truckers so that avoidance of the scales is not a problem.

Once the equipment is available, the state can then expand on the LTPM sample for weighing. The LTPM sites are a good start for an appropriately sized sample, but the existing sample size is relatively small for estimating statewide averages.

4.3.5 Speed data

The Department collects the appropriate amount of vehicle speed information in the appropriate manner at the present time.

4.3.6 Accident information

The Department does not perform the field data collection for accident analyses. This information is supplied by the State Patrol on computer tape. The existing procedures and data are sufficient to meet the Department's needs.

CHAPTER 5. STATISTICAL ANALYSIS AND PROGRAM DESIGN

5.1 Introduction

This chapter describes the statistical framework used for analysis of existing WSDOT highway traffic data, and presents the results of those analyses which provide the basis for designing elements of the recommended data collection program discussed in the next chapter.

The major focus of this chapter is the statistical estimation of the following statewide, system-level data items:

- AADT, including seasonal factors, axle correction factors and growth factors
- vehicle classification
- truck weights.

5.2 Statistical Reporting of Results

Because sampling plays such a central role in a statistically based approach to data collection, it is worthwhile to clarify, through a simple example, some basic concepts.

Essentially, sampling involves making inferences about the characteristics of an entire population, based on the characteristics of a carefully selected subset of elements. In most cases, we are attempting to estimate a true value, such as an AADT or truck percentage, based on our sample. Because we have a sample (i.e. less than 100% of the possible or population observations), we have variability or sampling error associated with the results. This sampling error can be expressed through the relative precision level achieved, with a given level of confidence, such as 90%.

For example, if an estimated sample parameter (such as an AADT estimate) has a resulting precision of 15% at a 90% confidence level, this means that we can be 90% sure that the true mean (or true AADT) us estimated within ± 15% error by the sample value.

In practice, some decision must be made about the acceptable limits of error for the sample. This can be done more formally by specifying that the sample mean for a data item should be within some percentage, 100d%, of the true average value for a certain percentage of values. This latter percentage is called the level of confidence, and is denoted by 100 $(1 - \alpha)$% where α is the fraction of the area under the probability distribution curve of the data item that falls outside the confidence limits. Thus, for a 95% confidence level, $\alpha = .05$.

As an example, suppose that daily traffic volumes on a segment are normally distributed. It can be shown that the simple random sample size required to achieve a precision of 100d% with 100 $(1 - \alpha)$ level of confidence is:

$$n = \left[\frac{Z_{\alpha/2}\, cv}{d} \right]^2 \tag{5.1}$$

where n = sample size

cv = coefficient of variation of the population distribution (ratio of standard deviation to the mean)

$Z_{\alpha/2}$ = standard normal statistic corresponding to the $1 - \alpha$ confidence level (found in tables of any statistics book).

Suppose further that it is desired to estimate the mean daily volume within 5% of the true value and with 95% confidence, and that $cv = 0.2$. Then:

$$n = \left[\frac{1.96\ (0.2)}{.05} \right]^2$$

$$= 62 \text{ days of counts}$$

If each day of counting costs $100, the total data collection cost would be $6200. However, if instead it is deemed acceptable to achieve 10% precision with a 90% level of confidence, the required sample size would be:

$$n = \left[\frac{1.645(0.2)}{.10}\right]^2$$

$$= 11 \text{ days}$$

and the total data collection cost would be reduced to only $1100, a reduction of 82%.

Although this example is simplistic, and ignores various regional, seasonal and other factors that could be important, the point to note is that the desired precision and confidence level have a major impact on sample design and cost. There is little point collecting more precise sample data at a higher level of confidence than is required by the data users, particularly when very considerable cost savings can be realized from smaller sample sizes. Conversely, when resources are limited, and insufficient for the desired sample size, trade-offs between precision and level of confidence are explicit. A comprehensive account of sampling theory as it has been developed for use in sample surveys is given by Cochran [14].

5.3 Annual Average Daily Traffic (AADT)

5.3.1 Basic model

The basic model used for estimating AADT for a particular highway segment, based on a single, short-duration count, is as follows:

$$AADT = VOL\ (F_S)\ (F_A)\ (F_G) \tag{5.2}$$

where:

VOL = average 24-hour volume from a standard WSDOT 72-hour Tuesday - Thursday short 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.

In order to determine the relative precision of an estimated AADT from equation (5.2), the coefficient of variation (ratio of standard deviation to mean) must be found. This can be obtained from the following approximate expression:

$$cv^2(AADT) = cv^2(F_S) + cv^2(F_A) + cv^2(F_G) \quad (5.3)$$

where each cv^2 is the squared coefficient of variation of each variable. Thus, the coefficient of variation of the AADT estimate is:

$$cv(AADT) = [cv^2(F_S) + cv^2(F_A) + cv^2(F_G)]^{0.5} \quad (5.4)$$

The relative precision (%) at a 100 $(1 - \alpha)$% confidence level is then given approximately by:

$$\text{precision }(AADT) = \pm\ 100\, Z_{\alpha/2}\ cv(AADT)\ \% \quad (5.5)$$

where $Z_{\alpha/2}$ is the same standard normal statistic used in equation (5.1).

Also, a 100 $(1 - \alpha)$% confidence interval is defined as:

$$AADT \pm Z_{\alpha/2} AADT\ cv(AADT) \quad (5.6)$$

The Z statistics corresponding to 95%, 90% and 80% confidence levels are 1.96, 1.645 and 1.282, respectively.

5.3.2 Seasonal factor analysis

5.3.2.1 Factor groupings

The data for analyzing seasonal factors were basically obtained from the Department's Annual Traffic Reports [15 a,b,c,d,e], which list the monthly PTR traffic volumes throughout each year.

Several alternative methods for performing seasonal factoring were evaluated. The primary ones considered were:

- continued use of existing Data Office procedures.
- cluster analysis of PTRs
- procedures suggested in the FHWA draft counting guide [13]
- a revised FHWA procedure using linear regression.

The chosen strategy was the fourth of those choices. This approach uses the basic method recommended by FHWA. The state highway system is stratified by geographic region and functional classification of highway system. These strata are then examined to determine which strata have similar seasonal patterns and which, therefore, might be combined. The project team used Departmental PTR data from 1980 through 1984 to calculate the appropriate factor groups. The chosen groups are:

- rural interstates
- urban roads
- other rural roads in the Northeast part of the State
- other rural roads in the Southeast part of the State
- other rural roads in the Northwest part of the State
- other rural roads in the Southwest part of the State
- central mountain passes.

With the exception of the Central Mountain group, each factor group is defined by functional class of road and county boundaries. (Note that the Urban group contains all urban classified state highways regardless of the county they are in). A list of the counties assigned to each factor group is presented in Table 5.1.

The advantages of the adopted approach are as follows:

- the seasonal factors are statistically valid, meaning that the precision associated with any AADT estimate based on these factors can be calculated.
- the overall errors associated with this approach are equal to or smaller than the errors associated with any other seasonal factoring approach considered.
- the factoring procedure is transparent to any user of volume information, thus allowing the recalculation of the raw traffic count at some later point in time if it is desired.

Each of the other seasonal factor procedures had drawbacks that the project team could not accept. For example, in the case of cluster analysis:

- the clusters computed were not consistent across years (i.e., PTRs changed groups from year to year, meaning that roads should change groups as well, but no method was available to make that adjustment each year.
- individual road sections are not easily or accurately assigned to cluster groups, irrespective of the difficulties mentioned above.
- the total error in the AADT estimate (including seasonal variation, daily variation, and variation in the axle correction factor) was only marginally better than by the recommended approach, prior to including the indeterminate

Northwest Group	
Whatcom	Skagit
Snohomish	King
Pierce	Thurston
Grays Harbor	Clallam
Jefferson	Mason
Island	Kitsap
Southwest Group	
Pacific	Lewis
Wahkiakum	Cowlitz
Clark	Skamania
Klickitat	
Southeast Group	
Yakima	Benton
Franklin	Walla Walla
Columbia	Garfield
Asotin	Whitman
Adams	Kittitas
Grant	Lincoln
Spokane	Douglas
Chelan	
Northeast Group	
Ferry	Stevens
Okanogan	Pend Oreille

Table 5.1 Assignment of Counties to Seasonal Factor Groups

error that is present as a result of the first two points.

5.3.2.2 Basic model

Seasonal factors for each month of the year were therefore derived for each of the seven factor groups described earlier. The modified FHWA approach adopted basically involved a regression analysis for each factor group for each month, of AADT versus the average 24-hour short count volumes that could be formed for each PTR from 72-hour Tuesday-Thursday counts in that month. The resulting regression coefficient of the short count volume is then the derived seasonal factor for that factor group and month. This approach corresponds to the manner in which short counts are actually taken and converted to AADT estimates by the Department.

The first seasonal factor regression model estimated was as follows (note the constant term is suppressed):

$$AADT = \beta \; VOL + u \qquad (5.7)$$

where AADT and VOL are as defined previously, β is the regression coefficient (seasonal factor) to be estimated and u is the error term. Such an equation would typically be estimated by ordinary least squares [16]. However, one of the required assumptions of that method is homoscedasticity, which means that the variance of the error term, u, is constant regardless of the magnitude of VOL. It often happens that this assumption is not valid (the case of heteroscedasticity) and the model must be reduced (by a transformation) to a form where the error term does have a constant variance.

Estimation of equation (5.7) revealed the presence of heteroscedasticity for some factor group and monthly traffic count datasets. Further, a consequence of this problem was that estimated variances would be biased and would underestimate the true variance. To address this issue, a commonly used transformation was employed to reduce equation (5.7) to a homoscedatic form. It was assumed that the variance of the error term was known up to a multiplicative constant:

$$\text{var}(u) = \sigma^2 \; VOL^2 \tag{5.8}$$

Dividing through equation (5.7) by VOL, we have:

$$\frac{AADT}{VOL} = \beta + \frac{u}{VOL} \tag{5.9}$$

Substituting $e = \frac{u}{VOL}$, we have:

$$\frac{AADT}{VOL} = \beta + e \tag{5.10}$$

where $\text{var}(e) = (1/VOL^2)\ \text{var}(u)$

$= (1/VOL^2) \quad \sigma^2 \quad VOL^2$

$= \sigma^2$

Thus, the variance of the error term, e, in equation (5.10) is constant, σ^2, and ordinary least squares estimation methods can be applied. The form of equation (5.10) is now so simple that computerized regression packages are not required. The estimation results can be obtained as follows:

$$\hat{\beta} = \sum_{i=1}^{n} \frac{AADT_i}{VOL_i} \; / \; n \tag{5.11}$$

$$\hat{\sigma}^2 = \left[\Sigma \left(\frac{AADT_i}{VOL_i} - \hat{\beta} \right)^2 \right] / \; (n-1) \tag{5.12}$$

$$\text{var}(\hat{\beta}) = \hat{\sigma}^2 / n \tag{5.13}$$

and the t-statistic on $\hat{\beta}$ is:

$$t_{\hat{\beta}} = \hat{\beta} \sqrt{n} / \hat{\sigma} \qquad (5.14)$$

In equations (5.11) and (5.12), the subscript i refers to each short count in the month for the factor group, and n represents the number of counts.

Finally, we must derive the relative precision of our AADT estimates. In applying the seasonal factors from equation (5.10) to counts in the following year, we are actually forecasting the value of the ratio $\frac{AADT}{VOL}$ in the equation. Therefore, the appropriate variance measure is the variance of the prediction error for the forecast ratio of $\frac{AADT}{VOL}$. It can be shown that this variance is given by:

$$\hat{\sigma}^2 (1 + 1/n) \qquad (5.15)$$

for each factor group and month. The required coefficient of variation for equation (5.4) is then:

$$cv(F_s) = \hat{\sigma} (1 + 1/n)^{0.5} / \hat{\beta} \qquad (5.16)$$

It is interesting to note that this theoretically derived result is equivalent to that obtained by more qualitative reasoning in the FHWA draft counting guide [13].

5.3.2.3 Results

The seasonal factors for 1984, derived using the procedures above, are presented in Table 5.2 for April through September (the period when the Department performs the vast majority of its traffic counting), and Table 5.3 for October through March.

The coefficients of variation, based on equation (5.16) are presented in Table 5.4. These have been used to calculate relative

Group	April	May	June	July	Aug.	Sept.
Rural Int.	1.132	1.126	0.960	0.907	0.849	0.990
Urban	0.966	0.952	0.903	0.894	0.878	0.907
NW	1.023	0.995	0.921	0.848	0.812	0.957
SW	1.087	1.055	0.935	0.823	0.769	0.925
SE	1.137	1.077	0.956	0.896	0.855	0.979
NE	1.025	0.927	0.895	0.754	0.779	0.882

Table 5.2 1984 Seasonal Factors for April - September.

Group	Oct.	Nov.	Dec.	Jan.	Feb.	March
Rural Int.	1.274	1.220	1.116	1.554	1.425	1.238
Urban	1.045	1.006	0.935	1.088	1.033	0.988
NW	1.236	1.124	1.067	1.296	1.558	1.075
SW	1.467	1.283	1.067	1.408	1.259	1.145
SE	1.500	1.318	1.043	1.595	1.472	1.259
NE	1.339	1.176	0.981	1.200	1.184	1.163

Table 5.3 1984 Seasonal Factors for October - March

Month	Factor Group					
	Rural Int.	Urban	NW	SW	SE	NE
Jan.	0.172	0.090	0.149	0.216	0.196	0.074
Feb.	0.150	0.073	0.105	0.154	0.190	0.100
March	0.113	0.057	0.102	0.147	0.180	0.146
April	0.109	0.062	0.095	0.132	0.144	0.123
May	0.089	0.070	0.078	0.108	0.138	0.080
June	0.064	0.057	0.095	0.082	0.118	0.077
July	0.057	0.063	0.092	0.077	0.115	0.104
Aug.	0.064	0.042	0.090	0.143	0.090	0.097
Sept.	0.090	0.059	0.069	0.129	0.112	0.086
Oct.	0.167	0.112	0.150	0.217	0.239	0.176
Nov.	0.255	0.090	0.130	0.186	0.250	0.115
Dec.	0.078	0.073	0.084	0.114	0.088	0.083

Table 5.4 Coefficients of Variation of 1984 Seasonal Factors, $cv(F_S)$

precision levels of April - September AADT estimates, as shown in Table 5.5, without incorporating axle correction or growth factors.

It is also interesting to see how the AADT precision levels vary as a function of the number of PTRs in each factor group. This is shown in Figure 5.1, for the month of June. It can be seen that these curves are relatively flat beyond about 6-8 PTRs per group. Thus, in terms of statistical precision of AADT estimates only, little is gained by having additional PTRs. However, as discusssed in Chapter 6, there may be other reasons for maintaining larger numbers of PTRs in any group.

5.3.3 Axle correction factor analysis

Axle correction factors are required to convert short count volumes into AADT estimates when those short counts are obtained using equipment that records axles rather than vehicles. Calculation of the factors requires vehicle classification information (percent vehicles in each class), as well as knowledge of the number of axles per vehicle in each vehicle class, as discussed in section 5.4.

The average number of axles per vehicle, A_V, in a given factor group (typically highway functional class) is given by:

$$A_V = \sum_C (Axles_C)(P_C) \qquad (5.17)$$

where $Axles_C$ = number of axles per vehicle in class C

P_C = proportion of vehicles in class C (system-level estimate).

The variance of A_V is then given by

$$\text{var}(A_V) = \sum_C (Axles_C)^2 \, \text{var}(P_C) \qquad (5.18)$$

where $\text{var}(P_C)$ is the variance of vehicle class C proportion, from a

Month	Factor Group					
	Rural Int.	Urban	NW	SW	SE	NE
April	18	10	16	22	24	20
May	15	12	13	18	23	13
June	11	9	16	13	19	13
July	9	10	15	13	19	17
August	11	7	15	24	15	16
September	15	10	11	21	18	14

Note: 90% Confidence Level

Table 5.5 Relative Precision (%) of Seasonally Adjusted AADT Estimates From Short Counts in Each Month (Without Incorporating Axle Correction or Growth Factors).

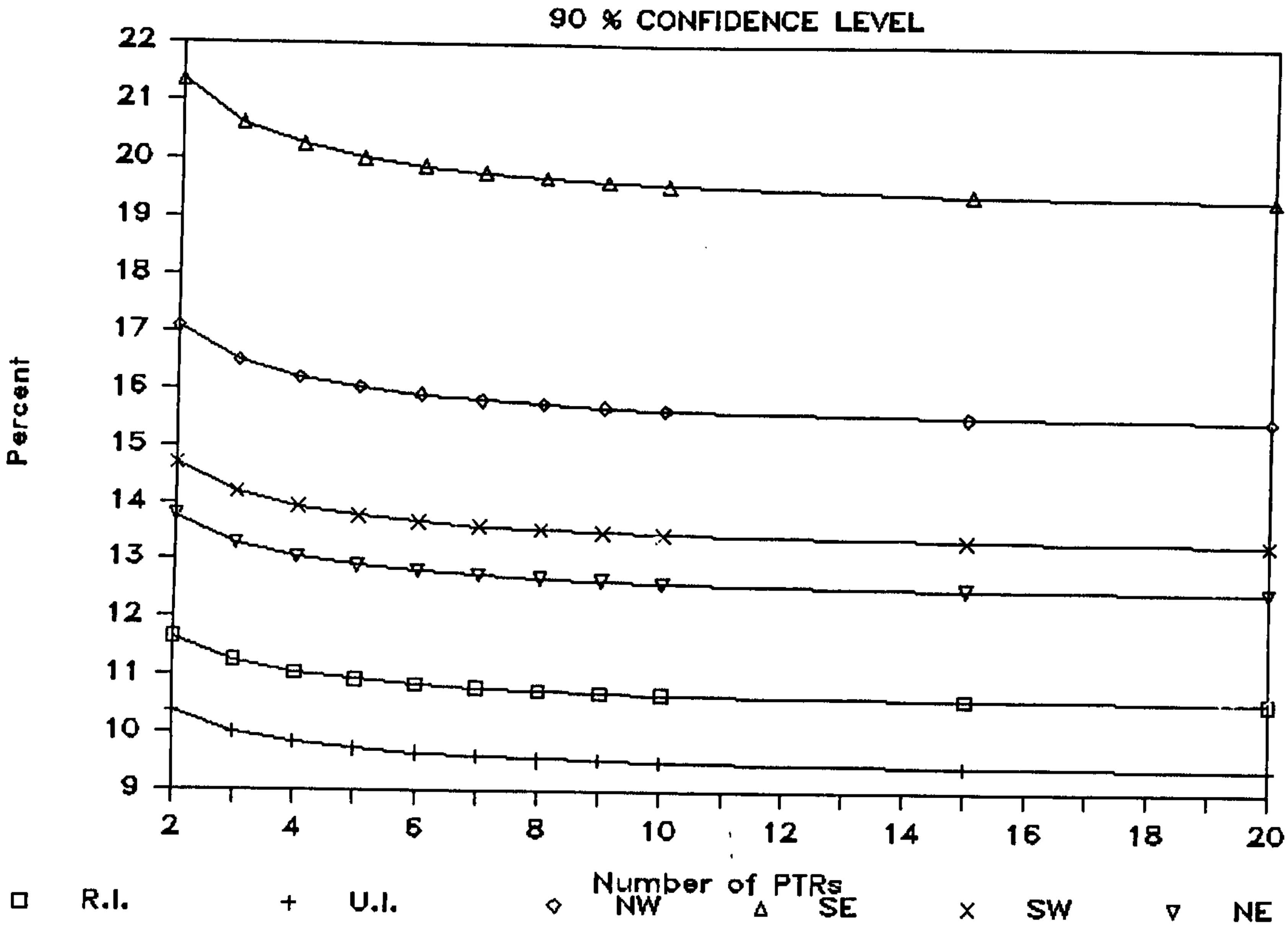


Figure 5.1 AADT precision levels (%), based on June seasonal factors alone, versus number of PTRs

vehicle classification study.

Thus, the coefficient of variation of A_V is:

$$cv(A_V) = [\sum_C (Axles_C)^2 \, var(P_C)]^{0.5} \, / \, [\sum_C (Axles_C)(P_C)] \quad (5.19)$$

However, the desired axle correction factor, F_A, is actually the inverse of A_V:

$$F_A = A_V^{-1} \quad (5.20)$$

It can be shown by a first-order Taylor series approximation that:

$$cv(F_A) = cv(A_V) \quad (5.21)$$

This result permits the coefficient of variation of the axle correction factor to be derived readily from equation (5.19), for insertion into equation (5.4).

Table 5.6 presents the estimated axle corrections factor for eight functional classes of highway, together with relative precisions and coefficients of variation.

5.3.4 Growth factors

As is discussed in Chapter 6, growth factors represent a relatively minor part of the factoring process to obtain AADT estimates from short counts. However, at times an old count must be converted to a more recent AADT by means of a growth factor. Several methods exist for estimating growth factors. In general, the approaches are fairly crude ways of attempting to account for traffic growth or decline over time. The analysis discussed in this section was exploratory only, although the results appear reasonable.

Simple growth factors were estimated for each of the previously identified seasonal factor groups, for the periods 1982-83 and 1983-84. The factors were obtained by forming the ratio of AADT in the more

Functional Class	F_A*	% Precision**	$cv(F_A)$
Rural Interstate	0.423	10.2	0.062
Rural Principal Arterial	0.461	8.8	0.053
Rural Minor Arterial	0.471	4.8	0.029
Rural Collector	0.459	10.7	0.066
Urban Interstate	0.454	3.9	0.023
Urban Principal Arterial	0.463	6.8	0.041
Urban Minor Arterial	0.482	2.1	0.013
Urban Collector	0.495	1.6	0.010

* weekday factors

** 90% confidence level

Table 5.6 Axle Correction Factors

recent year to that in the earlier year for each PTR in a group, and applying the same regression analysis procedure as discussed in section 5.3.2.2. In one group there was one PTR, and in a second group, no PTR, for both years, so that coefficients of variation of the factors, F_G, could not be formed. Table 5.7 presents the estimated growth factors for each period, together with their coefficients of variation.

5.4 Vehicle Classification

5.4.1 Data analysis

Because of the limited nature of vehicle classification counts taken by the Department in recent years, the best available dataset for statistical analysis was from a 1980-81 study for FHWA in the state. Unlike volume counting, which has a system of PTR stations for continuous monitoring, it is not presently possible to derive vehicle classification seasonal factors for conversion of a single (say 24-hour) classification count to an annual average estimate for a given highway segment. Rather, the data available only permit an approximate systemwide plan to be developed for an annual counting program on different functional classes, in order to derive annual average vehicle classification results. Improvements to the Department's current vehicle classification activities are discussed more fully in Chapters 6 and 7.

The 1980-81 data consists of 248 manual 24-hour vehicle classification counts. The data were collected at 31 locations across the state, with 4 weekday counts (one per season) and 4 weekend counts (one per season) at each location. For analysis purposes, the data were reduced to six vehicle types:

- cars
- 2 axle trucks

Group	Period			
	1982 - 83		1983 - 84	
	F_G	$cv(F_G)$	F_G	$cv(F_g)$
Rural Int.	1.065	0.020	1.024	0.037
Urban	1.175	0.306	1.046	0.066
NW	1.052	0.110	1.016	0.055
SW	1.059	--	1.094	--
SE	1.041	0.060	1.041	0.042
NE	--	--	--	--

Table 5.7 Growth factors

- 3 axle trucks, and buses
- 4 axle trucks
- 5 axle trucks
- 6+ axle trucks

In addition, a slightly more detailed set of functional classifications was retained for initial analyses than was used in the seasonal factor development. These functional classes consisted of eight groups: interstates, principal arterials, minor arterials and collectors, for both rural and urban locations.

The principal analysis method used was a 2-stage cluster sampling approach with multiple strata. The first set of strata corresponded to functional classes. Within strata, the primary sampling units or clusters were possible count locations, and the secondary or elementary sampling units were days at each location (required to be the same at each location in a stratum). The second stratification was introduced with respect to weekdays and weekend days because vehicle classifications were noticeably different across these strata, with truck percentages often being considerably lower on weekend count days. The population sizes for each stage were taken to be the number of HPMS population sections in each functional class in the case of locations, and at the second stage simply the number of weekdays and/or weekend days in a year. Allowance was also made in the analysis for the fact that the second stage units were not of equal size (as is often assumed in cluster analysis) due to the daily variations in traffic volume throughout the year.

Within each functional class, and for each vehicle class C, the average (weighted) vehicle proportion, P_C, was estimated as follows:

$$P_c = \left(\sum_{i=1}^{n} p_i \right) / n \qquad (5.22)$$

where

$p_i = w_1 p_{i1} + w_2 p_{i2}$

p_i = proportion at location i

p_{i1} = weekend proportion at location i.

$$= \left(\sum_{k=1}^{m_1} C_{ik1} \right) / \left(\sum_{k=1}^{m_1} X_{ik1} \right)$$

p_{i2} = weekday proportion at location i

$$= \left(\sum_{j=1}^{m_2} C_{ij2} \right) / \left(\sum_{j=1}^{m_2} X_{ij2} \right)$$

C_{ik1} = total number of vehicles of type C at station i on weekend day k

C_{ij2} = total number of vehicles of type C at station i on weekday j

X_{ik1} = total number of vehicles at station i on weekend day k

X_{ij2} = total number of vehicles at station i on weekday j.

p_{i1k} = proportion observed on weekend day k.

p_{i2j} = proportion observed on weekday j.

m_1 = number of weekend days at each location

m_2 = number of weekdays at each location

w_1 = 2/7, w_2 = 5/7

n = number of count locations.

The variance was obtained from:

$$\text{var}(P_c) = (1-f_1)(s_1^2/n) + [w_1^2(1-f_{21})s_{21}^2/(nm_1) + w_2^2(1-f_{22})s_{22}^2/(nm_2)] \quad (5.23)$$

where $f_1 = n/N$

N = population size of HPMS segments for functional class

$$f_{21} = m_1/104$$

$$f_{22} = m_2/261$$

$$s_{21}^2 = (\sum_{i=1}^{n} s_{21i}^2)/n$$

$$s_{21i}^2 = \sum_{k=1}^{m_1} (P_{i1k} - P_{i1})^2 / (m_1 - 1)$$

$$s_{22}^2 = (\sum_{i=1}^{n} s_{22i}^2)/n$$

$$s_{22i}^2 = (p_{i2j} - p_{i2})^2/(m_2 - 1)$$

$$s_1^2 = \sum_{i=1}^{n} (p_i - P_c)^2 / n - 1$$

Thus, the coefficient of variation of the estimate is:

$$cv(P_c) = [var(P_c)]^{0.5}/P_c \qquad (5.24)$$

The relative precision (%) at a 100 $(1 - \alpha)$% confidence level is then given approximately by:

$$precision\ (P_c) = \pm\ 100\ Z_{\alpha/2}\ cv(P_c) \qquad (5.25)$$

In addition to the analysis approach above, which distinguishes between counts on weekdays and weekends by introducing sample stratification, estimates for P_c were also calculated without this stratification by pooling weekday and weekend counts at each location. For this simpler formulation, P_c is calculated from:

$$P_c = \left(\sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij}\right) / \left(\sum_{i=1}^{n} \sum_{j=1}^{m} X_{ij}\right) \qquad (5.26)$$

where C_{ij} = total number of vehicles of type C at station i on day j

X_{ij} = total number of vehicles atstation i on day j

f_2 = m/365

m = number of days sampled at each station.

The variance of P_c is then calculated from:

$$var(P_c) = (1 - f_1)(s_1^2/n) + f_1(1-f_2)(s_2^2/mn) \qquad (5.27)$$

where $s_2^2 = \sum_{i=1}^{n} \sum_{j=1}^{m} (pij - \bar{p}i)^2 / [n(m-1)]$

$\bar{p}i = \sum_{j=1}^{m} C_{ij} / \sum_{i=1}^{m} X_{ij}$

$p_{ij} = C_{ij} / X_{ij}$

The coefficient of variation and precision of P_c are then calculated as before by equations (5.24) and (5.25) respectively.

5.4.2 Results

Table 5.8 presents the classification count results for each functional class. These averages are based on the weighted weekday and weekend counts. Table 5.9 shows the relative precision of these results at a 90% confidence level. Clearly, the precision of the estimates for large trucks (5 or more axles) is relatively poor, although this was not unexpected given the limited nature of the counts and the inherent variability of truck travel as a percentage of total daily volume. Table 5.10 gives the coefficients of variation for each vehicle class proportion.

5.4.3 Estimating annual average daily truck volumes

The estimation of annual average daily truck traffic volume, AADTT, can be accomplished readily by applying the analysis results above and extending the AADT estimation equations in section 5.3.1:

$$AADTT = VOL\ (F_S)(F_A)(F_G)(P_C) \qquad (5.28)$$

where P_C = the appropriate vehicle proportion estimate from Table 5.8,

Functional Class	Vehicles Class 1	2	3	4	5	6+
Rural Int.	87.0	3.1	0.6	0.3	8.3	0.8
Rural P. A.	90.3	3.2	1.0	0.1	5.0	0.3
Rural M. A.	92.2	2.9	0.9	0.1	3.5	0.5
Rural Col.	89.3	3.5	3.0	0.3	3.6	0.3
Urban Int.	91.1	2.8	0.7	0.4	4.5	0.4
Urban P.A.	90.8	3.1	0.6	0.2	4.9	0.4
Urban M.A.	94.4	2.8	0.8	0.2	1.7	0.2
Urban Col.	95.1	3.4	0.4	0.1	0.9	0.1

Table 5.8 % Vehicles by Type in Each Functional Class

Functional Class	Vehicle Class					
	1	2	3	4	5	6+
Rural Interstates	4	11	13	35	35	33
Rural Principal Arterials	3	7	50	43	43	48
Rural Minor Arterials	2	9	22	45	33	68
Rural Collectors	7	29	82	62	91	69
Urban Interstates	1	8	13	22	20	14
Urban Principal Arterials	3	17	22	39	41	40
Urban Minor Arterials	1	26	31	67	19	44
Urban Collectors	1	25	35	43	34	86

Note: 90% Confidence Level

Table 5.9 Relative Precision (%) of Vehicle Classification Results

Functional Class	Vehicle Class 1	2	3	4	5	6+
Rural Interstates	0.024	0.068	0.079	0.213	0.215	0.201
Rural Principal Arterials	0.018	0.044	0.303	0.263	0.259	0.294
Rural Minor Arterials	0.010	0.057	0.134	0.271	0.201	0.416
Urban Interstates	0.007	0.050	0.077	0.131	0.119	0.088
Urban Principal Arterials	0.018	0.103	0.134	0.237	0.247	0.241
Urban Minor Arterials	0.008	0.157	0.187	0.405	0.114	0.266
Urban Collectors	0.007	0.150	0.216	0.260	0.207	0.522

Table 5.10 Coefficients of Variation for Vehicle Proportions in Table 5.8

and all other notation is as defined previously. It must be remembered that this AADTT estimate is based on system-level vehicle classification data, and not a specific truck count for the section where the volume count, VOL, was taken.

The coefficient of variation can be obtained from:

$$cv(AADTT) = [cv^2(F_S)+cv^2(F_A)+cv^2(F_G)+cv^2(P_C)]^{0.5} \qquad (5.29)$$

where $cv(P_C)$ is given by Table 5.10. The relative precision at a $100(1-\alpha)\%$ confidence level is then given approximately by:

$$\text{precision}\ (AADTT) = \pm\ 100\ Z_{\alpha/2}\ cv(AADTT)\% \qquad (5.30)$$

As an example, consider the calculation of an annual average daily 5-axle truck volume on a rural interstate segment, based on a short duration axle count in June.

Average 24 hour volume VOL = 50,000 axles.

F_S = 0.960 (Table 5.2)

F_A = 0.423 (Table 5.6)

F_G = 1.0 (since this is a current year count)

P_C = 0.083 (Table 5.8)

$cv(F_S)$ = 0.064 (Table 5.4)

$cv(F_A)$ = 0.062 (Table 5.6)

$cv(F_G)$ = 0.0 (since we do not use an estimated factor)

$cv(P_C)$ = 0.215 (Table 5.10)

Thus, from equation 5.22, the estimate of daily 5-axle trucks is:

$$AADTT = 50{,}000\ (0.960)(0.423)(1.0)(0.083)$$
$$= 1{,}685 \text{ 5-axle trucks.}$$

From equation 5.23, the coefficient of variation of this estimate is:

$$CV(AADTT) = [(0.064)^2 + (0.062)^2 + (0.0)^2 + (0.215)^2]^{0.5}$$
$$= 0.233$$

Finally, from equation (5.24), the relative precision of this estimate at a 90% confidence level is:

$$\text{precision (AADTT)} = \pm 100\ (1.645)(0.233)\%$$
$$= \pm 38.3\%$$

which means that we can be 90% confident the true value of AADTT is within about 40% of the estimate of 1,685 5-axle trucks per day.

5.4.4 Vehicle classification sample design

The results obtained from these analyses of vehicle classification data provided some basis for developing the study recommendations for this data item in Chapter 6. This section presents some of the findings related to design of a sample for collecting vehicle classification data.

Of particular interest is how the statistical precision of classification estimates is affected by sample size and choice of confidence level. To gain further insight into these relationships, a number of tabular and graphic reports were generated. Several of these are presented in this section as background information.

Table 5.11 shows the variation in precision achieved with a number of different sample designs, in the case of rural interstates. These results are based on a cluster-analysis, as before, but with pooled weekend and weekday counts, without stratification. It can be seen that the precision levels are more sensitive to the number of locations chosen than the number of days surveyed per location. For a given

No. Loc.	No. Days	No. Counts	Vehicle Class					
			Auto	2	3	4	5	6
2	1	2	9	37	81	95	105	105
2	5	10	6	23	39	68	71	69
4	1	4	7	26	57	67	74	74
4	5	20	4	16	27	48	50	49
8	1	8	5	18	40	47	52	52
8	5	40	3	11	19	34	35	34
20	1	20	3	12	25	29	33	33
20	5	100	2	7	12	20	21	21
40	1	40	2	9	18	20	23	23
40	5	200	1	5	8	13	14	14

Note: 90% confidence level.

Table 5.11 Relative Precision (%) of Rural Interstate Vehicle Classifications for Different Sample Designs number of classification counts, the results indicate that it is better to take all those counts at different locations, with only one count per location, on randomly chosen days during the year.

To avoid the added complexity, and cost, to the Department of having to take at least two counts per location (one weekday, one weekend) at every sampled location, as required by the stratified cluster analysis procedure, it was decided that for purposes of sample design and implementation, a pooled cluster analysis approach should be used without stratification by day of week. All this would mean in practice is that the count day(s) at a location would be chosen randomly from all days in the year. Given the nature of the data on which the analyses were based and the interim nature of any recommended manual count program (due to introduction of automatic vehicle classifiers by the Department; see Chapter 6), this approach was judged appropriate. Thus, the remaining results reported in this section pertain to the pooled weekday and weekend classification data.

Figure 5.2 illustrates the effect of both confidence level and number of counts (or locations counted) on the precision of 5-axle truck proportions for rural interstates. Clearly, both smaller precision levels and higher confidence levels require that more counts be taken, but it is interesting to note that the major benefit in resulting precision comes from taking around 20 counts, and that the improvement in precision for successive counts is relatively small. However, the magnitude of the precision is still high, and the implication is that to achieve precise results, a much larger number of vehicle classification counts is required (than the Department currently collects). Finally, Figures 5.3 and 5.4 show the effect, at a 90% confidence level, of varying sample sizes for rural and urban counts, respectively, on the

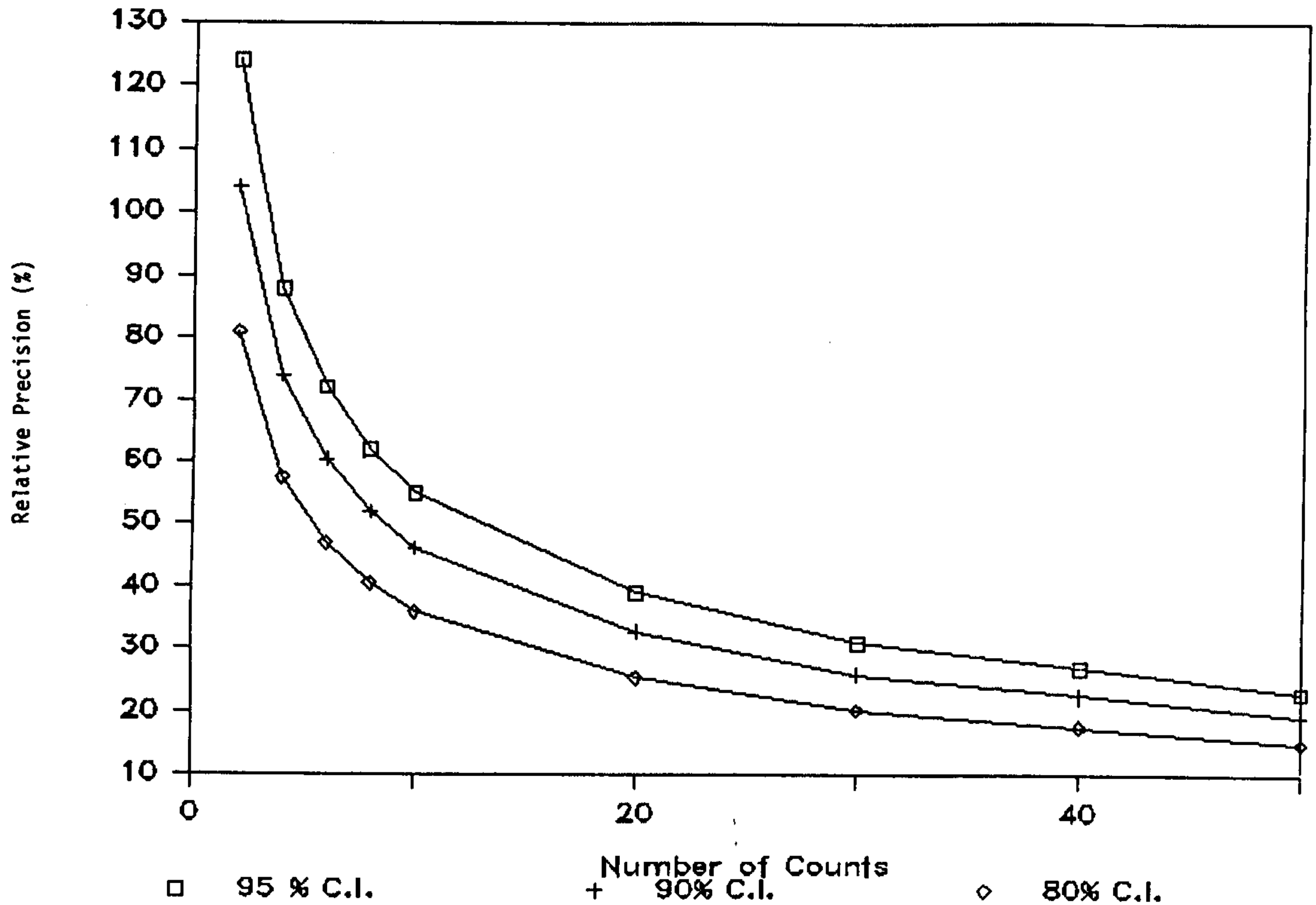
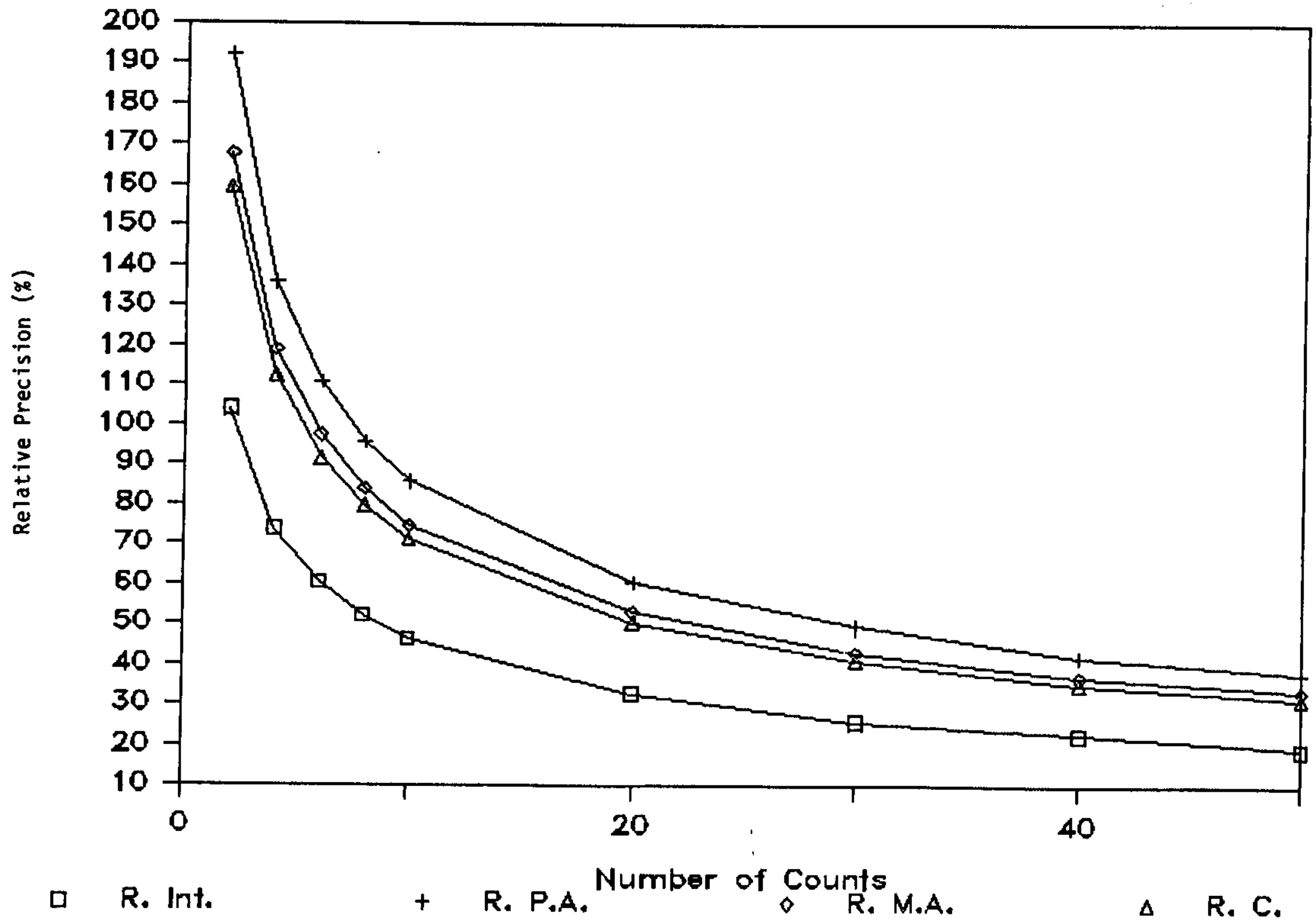
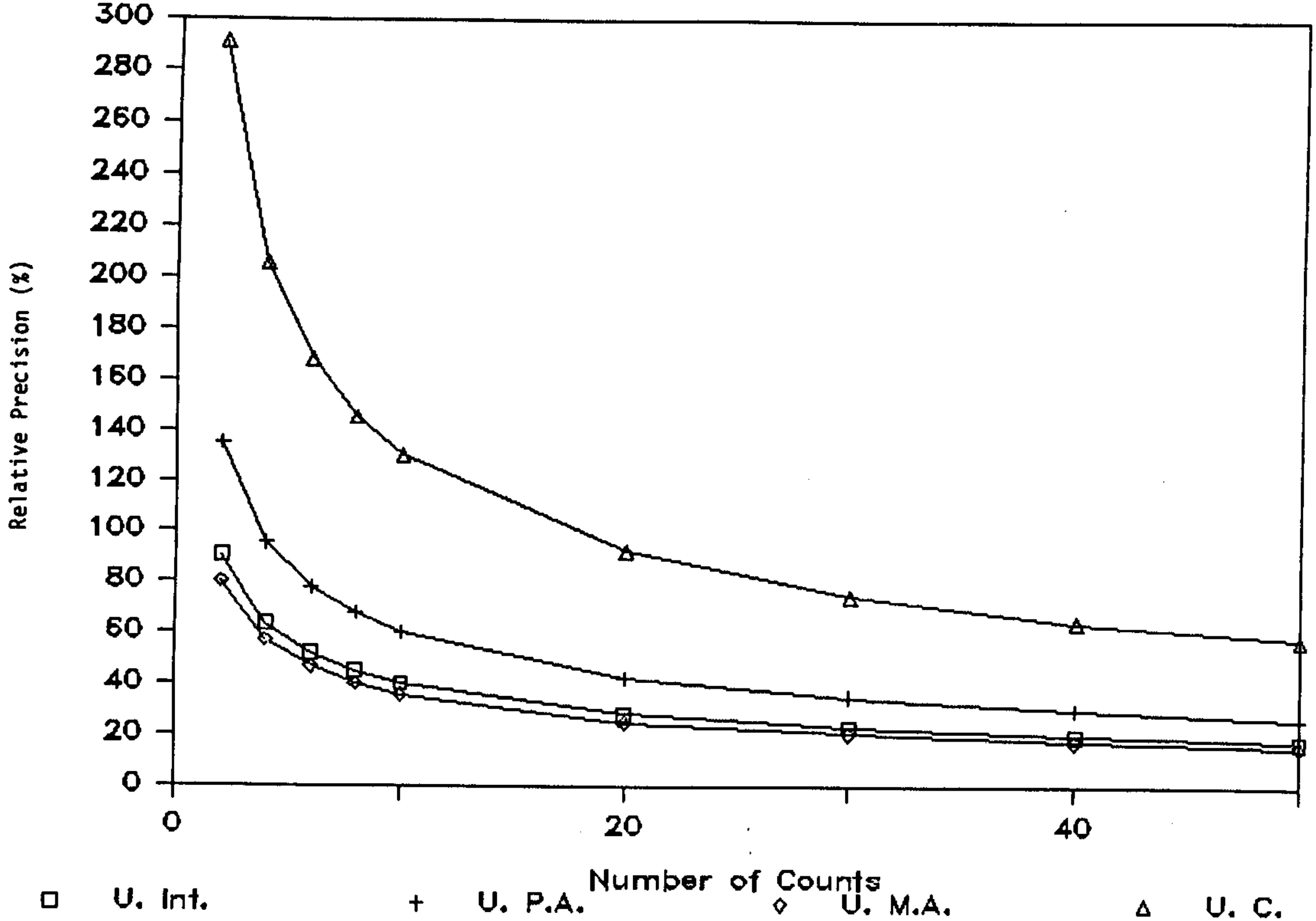


Figure 5.2 Effect of confidence level and number of counts on relative precision of 5-axle truck proportion for rural interstates



Note: 90% confidence level

Figure 5.3 Effect of sample size on relative precision for estimating 5-axle truck proportion on rural highways



Note: 90% confidence level

Figure 5.4 Effect of sample size on relative precision for estimating 5-axle truck proportion on urban highways precision of 5-axle truck proportions.

5.5 Truck Weights

This section describes the statistical analysis of truck weight data.

The truck weight analysis and sample design differs significantly from the volume and vehicle classification analyses described earlier. Both of the previous analyses were centered on the ability of the Department to collect information for a short period of time (a day or more) and then convert that information to an estimate of average annual conditions using factors obtained primarily from PTR stations. At this time, and for the forseable future, the Department does not have the capability to collect truck weight information on a year-round basis. As a result, the state does not have the information necessary to treat the truck weight data collection process in a manner similar to that for volume and vehicle class data (i.e applying seasonal and day-of-week adjustment factors).

To allow for the above realities, the project team took a practical approach to truck weight data collection, and followed an approach first used by Wisconsin DOT, which fits well within the statistical framework of the program already defined. In this approach, the Department must weigh a specified number of vehicles (as opposed to weighing for a specified time period) at a specified number of locations.

The intent of this type of sample design is to determine and account for two major sources of variation in truck weight:

- variation in weights between trucks of similar configuration (variation within truck types) at a location called VARIATION

(type)

- variation in mean weights between locations of trucks with similar configurations called VARIATION (location).

The procedure assumes that seasonal variation of truck weights is negligable and that no consistent time of day affects are present in the weight of vehicles (i.e. trucks running at night are not heavier than trucks running during the day time.)

By determining the magnitudes of these two sources of variation, the sample size (consisting of the number of trucks to be weighed at each location and the number of locations to be used) necessary to achieve a specified level of precision can be calculated from the following formula:

$$d^2 = \frac{cv_{(location)}^2 \; Z_{\alpha/2}^2}{n_{(location)}} + \frac{cv_{(type)}^2 \; Z_{\alpha/2}^2}{n_{(type)}} \quad (5.31)$$

where

d	=	relative precision of the mean EAL estimate for each truck type
$cv_{(location)}$	=	coefficient of variation across locations of the EAL for each truck type
$cv_{(type)}$	=	coefficient of variation between vehicles of the same type or axle configuration
$n_{(location)}$	=	the number of locations where weighing takes place
$n_{(type)}$	=	the number of vehicles of each type that are weighed at each location.

5.5.1 Data analysis

The primary sources of truck weight data available to the project team were the truck weight tables sent to the Department by FHWA as a result of the LTPM data submittal, and the biennial truck weight survey performed by the Department until 1982. Available from these reports were distributions of axle loadings by vehicle type, by weigh station. The information was not available on a truck by truck basis.

Both of these data bases suffer from a bias problem that exists because overweight trucks by-pass convential scale operations. The sample collected thus tends to present an under-estimation of the true axle weights. In addition, neither of these two studies had sites that were selected in a statistically valid manner. As a result, the information available has some serious flaws in terms of its statistically rigorous use. The first of these flaws will only be corrected by the use of inconspicuous weighing equipment, while a valid sampling plan will take care of the second problem.

The data analysis was performed using the available axle weights in terms of Equivalent Axle Loadings (EALs) for flexible pavement. (Rigid pavement EALs would also have been acceptable.) EALs were chosen over actual axle weights for the following reasons:

- EALs are used, and play a significant role, in pavement design;
- the axle weight to EAL conversion is a fourth order polynomial (i.e. EALs are roughyl equal to axle weights to the fourth power times a constant) which causes a higher emphasis on heavy axles. By using EALs in the precision calculation, we implicitly include a weighting factor that causes us to treat overweight vehicles with greater importance than low weight vehicles

- the available data allowed easy access to EAL information.

The primary data source used in the analysis was the 1983 LPTM vehicle weight information. Bienniel weight survey data from 1972 through 1982 were also used to check the results obtained using the LTPM information.

The first step in the analysis was to estimate the variation in weights (EALs) between trucks of the same type. This is a simple procedure when actual truck weights are available, as the variation in the population can be estimated directly from the standard deviation of the mean EAL for the sample. As noted earlier, however, the available data was a distribution of axle EALs (for both single axles and tandems), without reference to a particular truck (i.e. the data would have indicated that 4 axles of 1.2 EALs and four of 1.5 EALs were weighed, but did not indicate that those axles correlated to four trucks with total EALS of 2.4, 2.7, 2.7, and 3.0 EALs). The data were available at each of the weigh stations for each of the following truck types:

- 2 axle four tire single units
- 2 axle six tire single units
- 3 axle single units
- 4 or more axle single units
- 3 axle truck or tractor semi-trailer combinations
- 4 axle truck or tractor semi trailers
- 5 or more axle truck or tractor semi-trailers
- 5 axle tractors with two trailers
- 6 or more axle tractors with two trailers

The study team dealt with each of the above categories separately.

For each category, the team estimated one or two "standard" axle configurations (e.g. all five axle tractor trailer combinations were assumed to consist of one single axle and two tandem axles.) The selected configurations were designed to correlate to the number of single and tandem axles and the number of trucks weighed for each type of vehicle.

Secondly, the variation in the mean single and tandem axle weights for each truck type was computed. The variations for the "standard" truck types were then calculated by taking the square root of the sum of the squares of the co-efficients of variation for each of the axles on the truck. For example, the co-efficent of variation of the mean EAL for a 5 axle tractor semi would be calculated as:

$$\text{Variation} = cv(\text{single})^2 + cv(\text{tandem})^2 + cv(\text{tandem})^2$$

While this approach has some significant short-comings (primarily the fact that all trucks do not fall into the "standard" vehicle type categories), it does provide a reasonable estimate of the variation inherent on a truck by truck basis within each of the various vehicle types. Such an estimate is accurate enough to be used to design a sampling plan which will allow for a more un-biased data collection effort. Data collected from a statistically valid plan would then be used to adjust the sample size initially calculated.

The above calculations were done separately for each of the weigh station locations. It was noticed that the cv per truck type was not always the same for the different weigh stations, so an average cv(type) for each truck type was computed as the mean of the cv's from each station for use as the cv(type) in the precision equation presented earlier.

The mean EALs per truck type for all stations were then averaged to estimate the mean EAL for each truck type. The coefficient of variation of that estimate was used as the cv(location) in the precision estimate.

CHAPTER 6. RECOMMENDED PROGRAM

6.1 Introduction

This chapter presents the recommended program structure for the highway traffic data collection activities of the Department. The program is designed to cost effectively meet the needs of the Department's data users, while also meeting the budget constraints of the Department. The reader is referred to Chapter 3 for background on the uses of Department data.

This chapter is structured as eight sections:

- Impact of data needs on the program structure
- Overview of the program structure
- Volume counting
- Vehicle classification counting
- Truck weighing
- Accident data
- Speed data
- Calculated factors.

The first two sections provide a summary of the reasoning behind the program's structure and general information on how the various data collection elements are interrelated within the overall system. The third through eighth sections detail the complete program design. Each section details all traffic counting to be performed under that heading (e.g. Volume Counting includes both short duration and permanent counting locations). The final section discusses the calculation and application of various factors needed to convert raw data into the traffic estimates requested by users.

6.2 Impact of Data Needs on the Collection of Data

If the Department wished to collect all of the data requested by users, it would need to collect volume counts at 0.1 mile intervals on all state highways (requested as an input into the priority array), as well as similar amounts of vehicle classification data, and lesser amounts of vehicle weight data.

As this is not possible due to budget constraints, limits must be placed on what data are collected, while still providing the best possible volume estimate to data users. This means that a limited number of traffic counts, stretched to cover as much pavement as possible and taken over multiple years, must be used to meet all of the above needs. While this is essentially what the Department is currently doing, it is the conclusion of the project team that the current level of data collection is inadequate, with the possible exception of project-oriented, site-specific estimates.

This conclusion is based on:

- the limited amount of non-project related counting currently performed by the Department
- the lack of a statistical basis for the little counting that is done for these purposes.

As a result, it is not currently possible for the Department to know, with any degree of certainty, whether it is correctly allocating its own funds on necessary maintenance, repair and construction work. Appendix C provides additional information on the potential extent of this problem.

6.3 Overview of Program Structure

As indicated in Chapter 3, the Department's traffic data needs can be assigned to three different levels of data collection:

- project specific counts;
- network level site-specific counts;
- system estimates.

The basic program structure chosen to meet these needs consists of the two data collection tiers introduced in Chapter 3:

- statistically valid statewide sampling
- project specific data collection.

The intent of this program structure is to ensure the minimum base of information necessary to supply system estimates, maintain the quality of the most important Department analyses, and at the same time minimize the total cost of the program.

The first element consists of taking counts at a limited number of locations on a routine, preplanned basis to provide the Department with statistically valid estimates of statewide vehicle travel. Direct uses of this statistical sample include estimating:

- statewide VMT
- average percentage of travel by truck versus automobile.
- statewide axle correction factors.

The less obvious need for this data is centered around its use as the best alternative to site-specific data. That is, when site specific information is unavailable for some reason, the average condition for the state for a similar road is the best estimate that can be obtained for that location. Therefore, the better the estimate for the statewide average, the better will be the analyses that use those estimates. Nowhere is the use of these system averages more prevalent than for estimating truck travel for pavement overlay purposes, one of the major tasks of the Department.

The use of statewide averages is necessary for many analyses because of the budget and time limitations placed on those analyses. However, the collection of site specific data usually results in more accurate data for a site than is possible using statewide averages.

The second tier of the data collectgion strategy is designed to provide a vehicle for collecting that project-specific, site-specific data. The recommended strategy is for project engineers to specify to the Data Office what project-specific information they require for each project. They will then fund that data collection out of their project budgets, or accept the best estimates the Data Office can provide given the existing information. Note that "projects" can be any "special" data need which warrants the expenditure of funds to collect data additional to that already collected by The Data Office. Similarly, funds for that "site-specific" data collection can come from any source.

The final ingredient to the program structure is the need to ensure that all traffic information collected by the Department should be:

- stored in a central location
- accessible to the rest of the Department.

It is particularly important that traffic information collected for specific projects be included in the main traffic database since few systemwide data are collected. The project specific counts will thus make up a major portion of the new information available to the Department to update its traffic files.

It is intended that all traffic data collected by either the Data Office or the Districts be input into the TRIPS system, making it available for other Department uses. In this manner, the systemwide data collection will be supplemented by the more extensive counts taken at project locations. The result will be a more up-to-date traffic counting base file, while maintaining:

- the statistical integrity of those data collection elements that warrant it
- providing a mechanism for collecting additional data for specific projects that have sufficient priority and budget to request those extra data.

The supplemental counts taken for projects will supply the additional information necessary for the most important projects and at the same time "flesh out" the general data base to improve the amount and quality of information available for making network-level, site-specific and system estimates.

6.4 Volume Counting

Traffic volume counting consists of two basic types of activities, short duration axle counts and permanent or semi-permanent annual traffic recorders. Both parts are integral to the estimation of AADT c and other traffic volume estimates used in the design of roads, pavements and structures. Short volume counts will be collected as part of both the statistically valid traffic counting effort, and the project specific effort. For the most part, PTRs will only be part of the statistically valid traffic counting effort, although the Department may use them to fulfill specific project needs. PTRs and short counts will be handled separately in the section below.

6.4.1 Short duration counts

A recommendation was made by the Study Steering Committee to limit the volume data collection performed by the Department to those data needs that have immediate financial implications for the Department and those projects which could contribute significantly to the cost of collecting those data. The recommended short duration volume counting element is therefore based on providing the Department with information for the following primary tasks:

- pavement design projects
- other project design needs
- interstate 4R appropriations by the federal government
- the HPMS submittal to FHWA
- priority array calculation.

The data collected to meet these needs will serve as the basis for other volume data needs of the Department and outside users.

6.4.2 HPMS needs

The data collected for the HPMS submittal meets the needs of the Department and Federal government for Interstate 4R appropriations and priority array calculations.

The current FHWA request for HPMS volume data consists of counts on one third of all sample sections each year. Volume counts are requested to be made for 48 hours at one time at each location.

This level of traffic counting represents a yearly traffic counting need for:

- 74 sample sections on interstates (148 traffic counter settings)
- an average of roughly 261 locations (337 traffic counter settings) on other state roads.

The Department does not directly collect information on HPMS sections off the state highway system. If FHWA were to insist on the Department collecting this information as well, the second of these estimates would increase to approximately 700 locations or 1,050 counter settings per year.

To a limited extent, the above count needs will be reduced because some necessary locations will be counted as part of project counts and others have PTR stations located on them. The existing PTR locations cover 37 HPMS sections. It is impossible to estimate the contribution of the project counts, as they differ markedly from year to year.

6.4.3 Project counts

In fiscal year 1985, the Data Office provided counts for projects at roughly 100 separate locations. In FY 1984, this number was 110. These numbers are fairly representative of expected levels of project counting for the near future. Because of the current and future emphasis of the Department on project needs and away from "coverage" counting, this level of data needs for projects may increase as a result of expanding requests for project specific traffic counts.

The potential for increasing numbers of project counts comes as a result of the slow decrease in quality of the basic traffic information database. This reduction in quality of volume estimates should not hurt the selection of project locations significantly, as the criteria for selecting project locations are relatively insensitive to traffic volume. Where it does have an effect is in the confidence design engineers have in using existing traffic estimates for design purposes. As these engineers lose confidence in the quality of existing data, they will tend to request more project specific counting. However, this approach appears to be the most cost effective method for providing project information.

At the present time, counting for the average project includes roughly:

- ten, 72-hour machine axle counts
- one six-hour manual vehicle classification count
- two four-hour manual intersection counts.

The process requires one man-week of field crew effort, including travel time, but not including supervision or data reduction. Additional research is needed before it can be determined whether this is the appropriate level of data collection for most projects.

6.4.4 Manpower needs

As a result of the HPMS and project specific data collection needs, the project team estimates that the Data Office needs slightly more than 3 FTE's to perform the field data collection for the counts described above. This estimate is based on the following findings:

- 100 to 130 projects per year will require project-specific information
- For each project, one man-week of field effort is required to provide the necessary data, for a total of 130 person-weeks
- For HPMS, roughly 500 counter settings not included in the project counts will be necessary.
- Conservatively, these HPMS counts will require 38 person-weeks of field data collection to perform.

This represents a total of 168 man-weeks of effort, or 3.4 FTE (rounded to 3.5). If the number of project counts does not equal 130 or the HPMS data collection takes less time, the extra FTE could be used to further support the general traffic data base, by counting in areas that do not have many HPMS sample sections or many projects or where special needs are apparent for such things as accident analysis. One such case, the collection of at least one or two traffic counts on all state roads

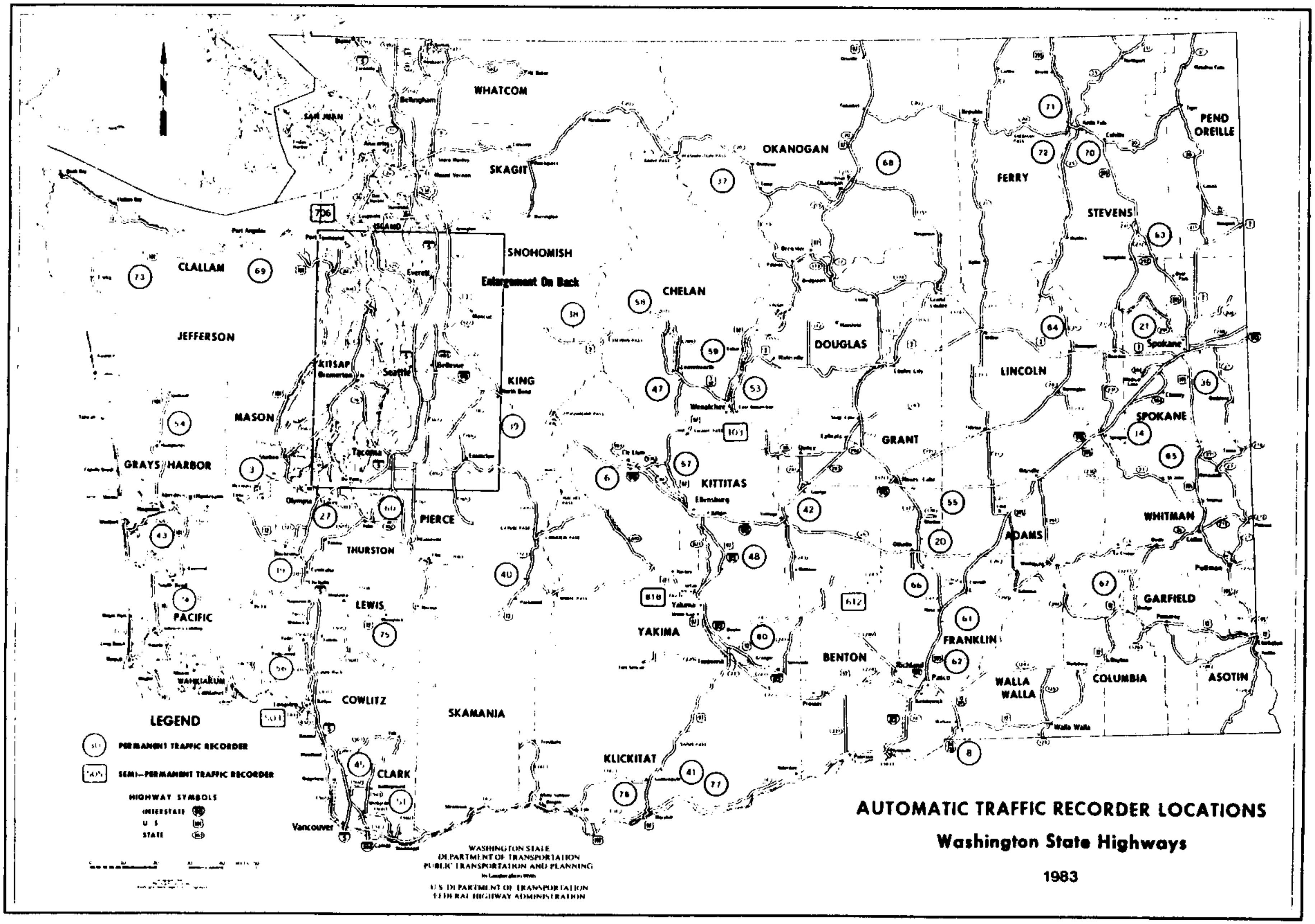


Figure 6.1 Automatic Traffic Recorder Locations Throughout the State

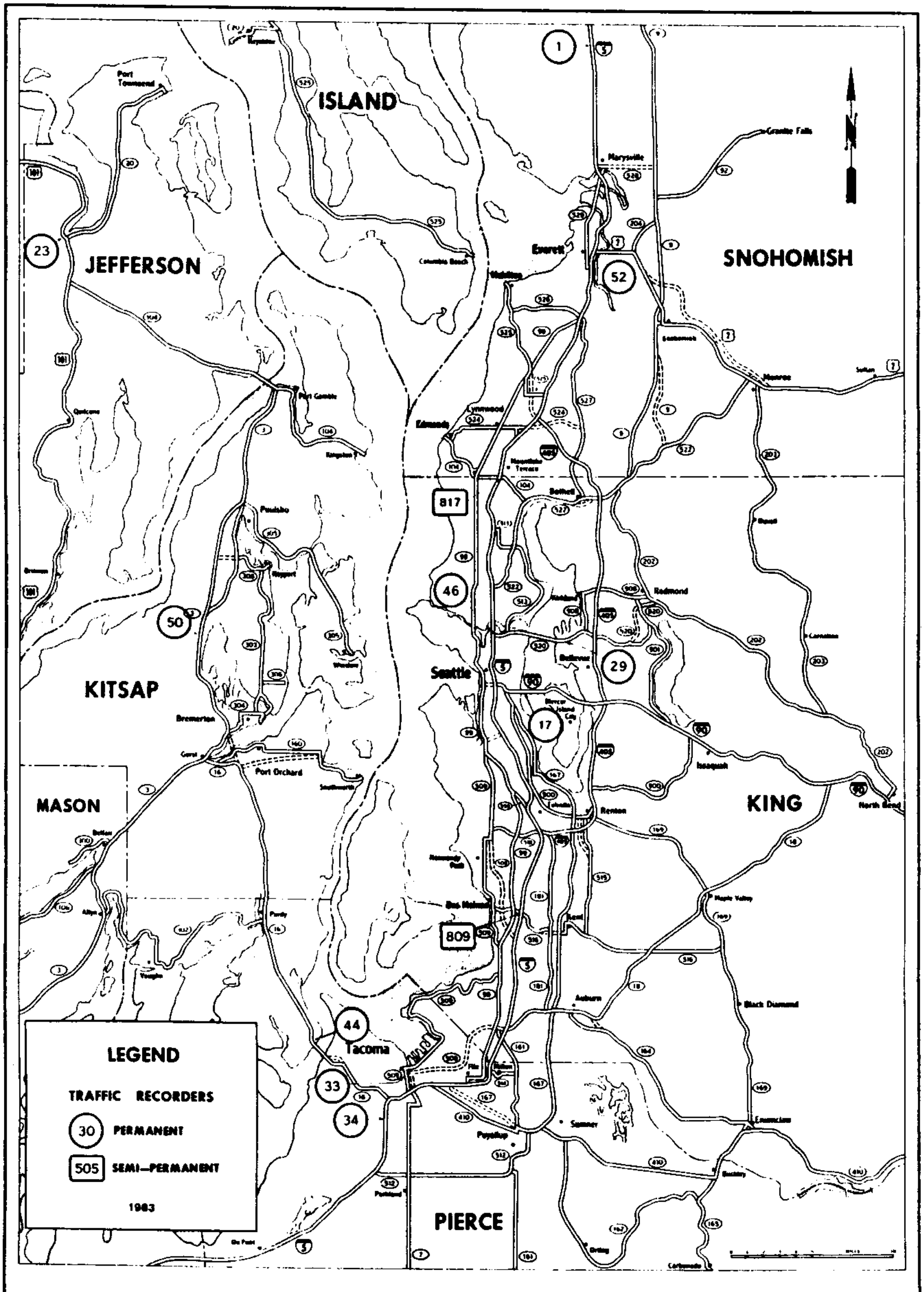


Figure 6.2 Automatic traffic recorder locations around Puget Sound

during the three year counting cycle was previously suggested in Chapter 3.

In addition to these 3.5 FTE, personnel time will be needed for office support, data reduction, and supervision of field crews.

6.4.5 Permanent traffic recorders

The Data Office is currently operating roughly 75 pieces of equipment at 65 PTR locations. These pieces of equipment are distributed as shown in Figures 6.1 and 6.2. As indicated earlier in the report, PTRs serve as data collectors for several purposes:

- AADT at that location
- seasonal factor estimators
- peaking characterisitcs
- statewide travel growth.

Of these uses, their most important use is for estimating seasonal factors.

The factor process currently used by the Department makes extensive use of subjective selection of seasonal factors. The project team does not feel that this is appropriate and recommends that the factor approach developed in Chapter 5 and described in the last section of this chapter be utilized by the Department.

The recommended factor process places PTRs into the following groups for the estimation of seasonal factors:

- rural Interstates
- urban roads
- other rural roads in the Northeast part of the state
- other rural roads in the Southeast part of the state
- other rural roads in the Southwest part of the state
- other rural roads in the Northeast part of the state

- central mountain passes.

Each of the counties in the state is assigned to one of the four "other rural" factor groups. This assignment is detailed in Table 5.1.

To supply the necessary data for estimating seasonal factors, the Department needs betwen 3 and 8 PTRs in each of the 7 factor groups. Table 6.1 shows the distribution of counters as of December 1984.

Based on the analysis in chapter 5, information included in a recent FHWA report [3] and the recommended seven factor groups, the maximum number of PTRs needed for estimating seasonal factors is 56 (i.e. 56 locations, as more than one counting device may be necessary to count volumes at a single location). The Department may wish to maintain more than this to fulfill vehicle classification data needs (see the following section) or to provide project specific information (e.g. monitoring travel on I-5 before, during and after the Vancouver World's Fair).

Based strictly on the need for seasonal factors, the Department could eliminate at least 10 PTR locations. This would result in savings of roughly $300 per month ($3,600 per year). This is a fairly small sum given the amount of data the counters generate, and their potential for providing other useful information to the Department.

6.5 Vehicle Classification Counts

The vehicle classification program element of the Data Office is the biggest weakness of the existing traffic counting program. Like volume counting, vehicle classification information needs to be provided on both a systemwide and a site-specific basis. The existing program element provides a limited amount of project data, and very little systemwide information.

The recommended vehicle classification program is similar to the

Group	1984 PTRs
Rural Interstates	9
Urban Highways	11
NW Rural	9
SW Rural	6
SE Rural	13
NE Rural	4
Central Mountains	7
TOTAL	59

Table 6.1 Number of Existing PTR Locations Per Seasonal Factor Group

volume program. The HPMS is used as the basis for providing a statistically valid estimate of travel by vehicle type, while project specific counting is performed as necessary for individual analyses. The use of permanent vehicle classifying counters (i.e. 365 day per year counts by vehicle type) is also recommended to provide the state with knowledge on the variation of truck travel throughout the year.

6.5.1 Systemwide estimates

The project team recommends that the Department collect a statistically valid sample of vehicle classification counts on six strata:

- rural interstates
- urban Interstates and other freeways and expressways
- rural principal arterials
- urban principal arterials
- rural minor arterials and collectors
- urban minor arterials and collectors.

The recommended levels of precision for each of these strata are shown in Table 6.2. For rural interstates, this level of precision means that the percentage of travel by 5-axle trucks on rural interstates can be estimated within 15 percent with 95 percent confidence. These levels of precision were chosen primarily based on:

- similarity to suggested levels of precision expressed by FHWA in their recent draft counting guide [13]
- the importance of each stratum of highways to the Department
- the cost/benefit of collecting better or worse information for each stratum.

Table 6.2 also shows the number of traffic counts that need to be taken during the three year counting cycle.

Roadway Category	Number of Counts	Achieved Precision*	Level of Confidence
Rural Interstates	104	±15%	90%
Urban Interstates	99	±15%	90%
Rural Principal Arterials	99	±20%	80%
Rural Minor Arterials and Collectors	83	±20%	80%
Urban Principal & Minor Arterials and Collectors	67	±20%	80%
	452		

*In estimating the average percent of travel by 5-axle combination trucks on the stated roadway category.

Table 6.2 Recommended Number of Vehicle Classification Counts and the Level of Precision for the Mean Percentage of Travel by Five Axle Vehicles

These counts would be taken on HPMS volume sample locations. They would preferably be 48-hour, automatic (i.e. machine as opposed to manual) counts. They would also replace the need for volume counting at those locations for the systemwide needs described in the previous section. The stated precision levels assume that these counts are taken randomly throughout the year, on weekdays and weekends.

It is understood that the Department does not currently have the capability to collect vehicle classification information using automatic counters, although the Department is currently acquiring the technology to perform that data collection. It is recommended that until the technology is in place the Department should use 6-hour manual counts, in conjunction with its 48-hour HPMS volume counts, in place of the 48-hour automatic counts. While the longer count duration is preferable, the benefits to be gained by taking vehicle classification counts for 24 or 48 hours in place of six hours, do not exceed the costs of performing that counting manually.

6.5.2 Project counting

The Department currently performs one 6-hour manual classification count and two 4-hour manual intersection counts for most project requests. These three manual counts are the primary reason that machine axle counts are made for 72 hours, in that a shorter count length (i. e. 48 hours) would not allow for all three manual counts. The use of automatic equipment would allow the manual counting requirements to be reduced to the two intersection counts. This will allow the Department to save one day of field data collection from the counting process currently performed. This "saved" day could either be used to reduce the time spent at that project site (and reduce the cost accordingly), or it could be used to collect additional data at that location as determined by future studies on the sensitivity of particular project analyses to data.

As with volume counting, it is vitally important that any vehicle classification counts taken for project purposes, whether they be taken by the Data Office or a District, be entered into the TRIPS system. In this manner, the Department as a whole will benefit from counts taken for specific projects. This information will also be useful if the Department ever decides to implement the designation of heavy usage truck routes (i.e. the designation of routes to a higher standard of pavement design because they are known to carry significant volumes of heavy vehicles).

6.5.3 Permanent counters

One of the areas where the Department has the least amount of information is in the seasonal and daily variation of truck travel. Because of the existing PTR program, the Department can take a short duration volume count on any state road and calculate a reasonable estimate of AADT. The Department cannot do the same with truck travel. It has essentially no information on the seasonal, daily, or day-of-week variation in truck travel.

It is highly recommended that steps be taken to improve the Department's ability to estimate annual truck travel at locations based on short duration counts at those locations. To accomplish this, the Department needs to establish a PTR program for truck travel.

The project team recommends that the existing volume PTRs be upgraded to a status where they can collect vehicle classification information. The counting devices used by the Department now have the capability to collect vehicle length information. In addition, each PTR location needs to have double inductance loops imbedded in the roadway. Most of the Department's PTRs already have these. All that is needed is for the Department to develop or acquire the capability to interrogate the PTR counters, which contain vehicle classification information, using the existing telemetry system.

Once installed and operational, this PTR system will provide the state with information on:

- seasonal variation of travel
- daily variation in truck travel
- differences in truck travel by day of week (particularly weekday versus weekend)
- percentage of truck travel by lane for design purposes
- distribution of truck travel by time of day.

All of this information will lead to improved design information. Once in place, the PTR program will also result in an improvement in the precision levels achieved by the classification counting program outlined in Table 6.2.

As an initial step in this direction, the project team recommends that 20 locations be enabled to collect this information (4 in each of the 5 categories in Table 6.2). These locations are numerous enough to provide improved estimates of seasonal variability and therefore allow a more informed decision concerning the need for more PTR vehicle classification counting locations.

6.5.4 Miscellaneous vehicle classification recommendations.

The project team recommends that the Department update the vehicle classification categories it uses to collect this information. The use of FHWA's 13 category classifications is recommended (see Table 6.3).

Motorcycles (Optional)

Passenger Cars with/without Trailers

2-axle, 4-tire pickups, vans and motorhomes

Buses

2-axle, 6-tire single units

3-axle single unit

4-or-more-axle single unit

4-or-less-axle double unit

5-axle double unit

6-or-more-axle double unit

5-or-less-axle multi-unit

6 axle multi-unit

7-or-more-axle multi-unit

Table 6.3. Recommended FHWA Vehicle Classification Categories

The advantages of this set of vehicle types are:

- it corresponds to the reporting requirements of the HPMS
- it can be collected with acceptable accuracy by automatic counters currently on the market
- it can be easily collapsed into the axle categories used in most design calculations currently performed by the Department.

The Department may wish to delay implementing this recommendation for several months, while The Data Office completes a recently started review of this topic. Some professionals in the Data Office feel that the Department needs greater detail than the FHWA categories yield for large trucks. Data were unavailable to answer this question at the time of this report. The Data office review should provide that information.

6.6 Truck Weighing

The truck weighing program element has a slightly different structure than the volume and vehicle classification elements. At this point, the Department does not collect project- specific truck weights. Insufficient data are available to determine whether such weighing activities would benefit or be cost-effective for various analyses which use truck weight information, particularly pavement design.

As a result, the recommended program structure is for a statistically valid sample of truck weighings to be carried out at HPMS vehicle classification count locations. Further research is warranted to determine the ability, desirability and cost of collectingproject-specific vehicle weights. Information from the currently scheduled testing of the Bridge WIM and piezoelectric cable weighing systems should assist in this analysis.

The recommended truck weighing program is to weigh 200 or more five axle combination vehicles at each of five locations on each of three strata. The three strata are:

- rural interstates
- urban interstates
- rural principal arterials.

Average weights per vehicle type for urban interstates would be used for all urban road designs, while average weights per vehicle type for rural principal arterials would be used for all non-interstate rural highways. The Department may chose to sample from lower functional class roads as well as the above strata. The additional sampling would improve the statistical precision of estimates for those roads, but data is not currently available to calculate that improvement at this time.

The recommended weighing element also differs from the volume and vehicle classification elements in that the sampling framework is not based on the number of days counting should take place, but on the number of trucks that should be weighed at each location. This sampling scheme is currently used by Wisconsin DOT. It was chosen because this is the only method for which data were available to estimate required sample sizes. The recommended weighing program is described in Table 6.4.

This sampling program makes several basic assumptions:

- truck weights by vehicle type do not change over the course of the year (i.e. the average 3S2 truck weighs the same in July as it does in February)
- truck weights do not vary between weekdays and weekends
- truck weights do not change with time of day
- truck weights by vehicle type are not different on high volume roads than on low volume roads (i.e. an average 3S2 on a low

Vehicle Type	Number of Vehicles To Be Weighed at Each Location*	Precision	Confidence Limits
2-axle, 4 tire, su	200	35%	80%
2 axle, 6 tire, su	200	16%	80%
3+ axle, su	200	20%	80%
3-axle, comb.	200	19%	80%
4-axle comb.	200	10%	80%
5+ axle comb.	200	10%	95%
5-axle double	200	11%	95%
6+ axle double	200	14%	95%

Strata: Rural Interstates
Rural Primary Arterials
Urban Interstates

Number of Locations: 5 per strata

*The controlling vehicles should be 5 or 6+ axle doubles on the interstate system, and 5+ axle combinations on the rural primary system. All trucks for all other categories should be weighed. If more than 200 are weighed per location, the precision estimates should be better than those indicated here. If less than 200 are weighed, precision may be worse than indicated here.

**of estimated mean weight per vehicle type.

Table 6.4 Recommended Truck Weighing Program volume rural principal arterial weighs the same as an average 3S2 on a high volume principal arterial)

- the act of weighing does not bias the data being collected (i.e. trucks do not intentionally by-pass the location being weighed).

The most significant impact of this data collection scheme pertains to the amount of field crew time spent at each truck weight location. For high volume roads, the time needed to weigh the appropriate number of trucks will be fairly small, certainly under 24 hours. In the case of interstate highways, one standard shift of the field crew may be sufficient. For low volume roads, the field crew may need several days to collect the desired number of truck weighings.

Because of this uncertainty in manpower scheduling, the Department may want to set time limitations for data collection at any one location. For example, the Department may wish to implement a policy that weighing will take place until either:

- 200 five axle trucks are weighed
- 2 days of weights have been taken.

While this second option would reduce the precision of the data collected from the analysis, it is a logical step to provide limits to the manpower expended for one data item.

A second approach to the problem of manpower scheduling is to have the Department weigh vehicles only at high volume locations. This would reduce the time needed to take the required number of weighings. The only problem with this approach is that it is currently unclear whether truck weights differ between high and low volume roads. If they do, then taking weights on only high volume roads will bias the truck weight estimates towards those roads, and will not represent a true mean value for the state.

Until further dataare available from continuing truck weighing research efforts, the above choice can not be made on a truly informed basis. The project team recommends that until more information is available to revise such a decision, the Department collect truck weights primarily on higher volume roadways, with a very limited number of low volume roads included so that information can be gathered to compare them.

6.7 Accident Data

The project team recommends no changes to the manner in which accident data are collected by the Department. The availability of accident information from the State Patrol makes any other data collection process superfluous. The existing process is also the least costly alternative for the Department.

6.8 Speed Data

The speed data collection effort is mandated by federal regulation. Changes to this program are not recommended.

6.9 Calculated Factors

There are three primary areas where the project team recommends changes to the existing Department process for estimating the various factors applied to raw traffic counts. These areas are:

- seasonal factors
- axle correction factors
- growth factors.

Raw data needed to estimate these factors are already collected as part of the counting strategies described above. The following discussions simply detail how the collected data should be manipulated and used by the Department.

6.10 Seasonal Factors

As a result of the analysis described in Chapter 5 and discussions held with several key engineers in the Transportation Data Office, the project team recommends two changes in theFHWA draft counting guide seasonal factoring approach. [13] The first is the use of linear regression instead of simple averaging of individual monthly PTR factors to calculate seasonal factors. This procedure was presented in Chapter 5. It has a minor effect on the computed group factors when compared to the simple averaging technique, and allows a simple calculation of composite errors in AADT estimates.

The second recommended revision of the FHWA process is that we would permit the use of a single PTR (instead of all factor group PTRs) for estimating a seasonal factor at a specific location when:

- that road section is on the same state highway as the PTR whose factor is to be used
- the PTR is within 30 miles of the road section in question
- no major traffic generator exists between the PTR and the road section in question, where traffic generators include but are not limited to: other State highways, other major roads with an AADT at the point of intersection equal to or greater than the AADT of the State route in question, and any point generator (e.g. a military installation) that more than doubles the existing volume on that road.

This change allows the Department the freedom to use a single PTR factor in place of the group factor where there is a very high probability of knowing:

- that the single PTR factor is more accurate than the group value

- at a later date, what PTR was used and why it was used, so that future analyses can replicate the factoring performed.

The effect of this exception will be most widely felt in the Central Mountain group. This group is composed of very few roads, each with exceptionally high variability in traffic. Almost all sections of the state highways through this region, however, fall under the above exception. This means that each road will essentialy be treated separately. This should result in better seasonal factor estimates than if strict group averages are used. At the same time, the cost should not be significant because there are so few roads in the area, and no new counters are recommended for the factor group.

The project team also believes that the Department's existing seasonal factor approach is too manually oriented. In particular, it leaves too much discretion to the traffic analyst when assigning a seasonal factor. This results in:

- inconsistencies between analysts about what factor to use for a particular raw traffic count
- bias in the AADT estimate as the "judgment" used when selecting a factor tends to force the traffic estimate to match the expected number rather than letting the raw traffic count govern the AADT estimate
- an inability to adjust easily to changing traffic patterns that result from major events (e.g., the Mt. St. Helens eruption of 1980 or the gasoline crises of the 1970's)
- greater difficulty in automating the seasonal factor procedure.

The FHWA approach is considered acceptable, but the team believes that the modifications described above improve on that process given the particular nature of the State of Washington and the Department's traffic counting program.

6.10.1 Axle correction factors

The project team recommends that data collected as part of the statistically valid vehicle classification program be used to estimate axle correction factors for the state. These factors can be estimated by simply assigning an average number of axles to each of the vehicle classification categories collected by the Department. This figure is then multiplied by the fraction of travel associated with that vehicle type (i.e. the percent of travel divided by 100). When this value is computed for each vehicle type and summed together, the result is the inverse of the axle correction factor for the stratum.

Axle correction factors would be applied on the same strata as vehicle classification counts are taken:

- rural interstates
- urban interstates and expressways
- rural principal arterials
- other rural roads
- other urban roads.

For projects, if a vehicle classification count is taken, the Department should use that count to estimate an axle correction factor for that roadway, but only for counts taken at the same time as the vehicle class count. The statewide averages should still be used for axle counts at projects which were on roads that were not included in the vehicle classification count, unless the Department has a strong indication that the statewide average is incorrect for those roads. (e.g. a cement plant is located on one such road, and the truck volumes are obviously higher than the statewide average.)

The recommended vehicle classification program will estimate the statewide average axle correction factor within 0.5 percent with 95 percent confidence for each of the above strata.

6.10.2 Growth factors

Growth factors are a minor part of the factoring process. In almost all cases, the degree of growth experienced by a road over one year is beyond the ability of a short duration traffic count to detect. Growth for an average road section usually lies between plus or minus 6 percent.

The project team does not recommend having the Department expend significant resources attempting to determine road specific growth rates. However, the project team recommends that the Department continue to use its PTRs to estimate growth. One approach to estimating such growth factors was presented in Chapter 5.

The existing PTR program will allow the state to estimate growth in the state within $\pm$ 2 percent. This assumes that the existing PTRs are an unbiased sample of the State's highway system. The estimate is based on the differing growth rates at each of the PTRs and the number of PTRs available to the Department. It should be noted that this precision level relates to the estimation of statewide growth and its application to any one road section will result in error bounds of roughly $\pm$10 percent with 95 percent confidence. Table 5.7 presents growth factors for each of the six seasonal factor groupings analyzed in Chapter 5.

A second approach to growth factor estimation is to use the HPMS volume sample to estimate statewide growth. There are two problems with using the HPMS data to estimate growth. The first is that the state is collecting only about half of the HPMS volume sample directly. The remainder of the counts are supplied by other jurisdictions, and are often of unknown quality. The remaining counts are to be taken only once every three years. This reduces considerably the number of count locations taken every year that can be used to estimate growth.

The second problem is that the HPMS AADT values are simply estimates of AADT, whereas PTR values are actual AADT values. Therefore, the HPMS volume sample has a second source of error not found in the PTR sample, which relates to the factoring procedures described above.

These two factors makes the HPMS volume sample less accurate for estimating statewide growth than the PTRs. However, the HPMS sample does provide a second source for the Department to use when reviewing PTR growth estimates. This will help guard against the problem of bias, because there are not very many PTRs in the state, and it is possible that substantial growth at several PTR locations due to local construction could inordinately affect the growth factor estimation.

CHAPTER 7. IMPLEMENTATION OF RECOMMENDATIONS

7.1 Introduction

This chapter provides assistance to the Department in implementing the recommendations presented in Chapter 5. It includes:

- step-by-step instructions for performing the recommended data manipulations
- instructions on how to phase-in the recommended changes to the existing data collection process
- instructions for determining the precision of various traffic estimates
- an explanation of how to select the recommended samples of vehicle classification and truck weights
- recommendations for work to be performed in future TRIPS design and implementation phases to come
- instructions for using the acquired information for updating the Department's counting samples and precision calculations.
- suggested areas for further research.

This chapter is structured by subject area to be useful as a reference guide for the Department. Because many of the subjects dealt with are interrelated, references to related subject areas within the chapter are included at the beginning of each section to further help the reader.

The chapter is divided into the following eight sections:

- short duration volume counting
- short duration vehicle classification counting
- permanent locations for volume and vehicle classification
- truck weighing

- data manipulation
- TRIPS implementation
- statistical precision estimation
- suggestions for further research.

7.2 Short Duration Volume Counting

This section deals with the implementation of the short count portions of the recommended volume counting effort. It discusses manpower utilization, timing of the counts, and the administration of the program element. Factoring of the counts to obtain AADT estimates is detailed under Data Manipulation in this chapter. The precision of these estimates is discussed in section 7.7.

For the most part, little change needs to be made to the Department's traffic counting procedures to allow the collection of the recommended data. The most significant change is the administrative change necessary to ensure the collection of the appropriate HPMS data.

The Department needs to review the HPMS sample count locations it collects data for, and divide those sections into three, roughly equivalent count groups, for counting over the three year cycle. The Department then needs to institutionalize a yearly review of proposed project count locations and HPMS count needs. This should be done at the time when project counts are being scheduled. The review simply entails the comparison of proposed project count locations and those HPMS locations that are scheduled for counts that year. The HPMS sections not scheduled for project counts will then simply need to be added to the yearly count schedule as most appropriately fits the Department's manpower scheduling.

For those HPMS counts that can not be taken in conjunction with on-going projects, it is suggested that the following counter placement schedule be considered:

- Monday - travel and begin placing counters
- Tuesday - place counters
- Wednesday - place any remaining counters and pick up counters placed on Monday, preferably after they have operated for 48 hours
- Thursday - pick up counters placed Tuesday after they have operated for 48-hours
- Friday - pick up remaining counters and travel.

Time available on Wednesday before picking up counters can be used to check on previous counter placements. Similarly, if all counters can be picked up on Thursday, all or part of Friday can be spent performing office duties, or other necessary tasks.

This schedule allows for a field crew to place counters for two full days, collect 48 hour counts, and still provide time for travel, all within one week. It may not meet all of the Department's needs, but may be successful in some instances in reducing the cost of short count data collection.

No change is made to the seasonal timing of short duration counts. Weekday counts are the most cost effective method for estimating AADT. However, the Department should encourage collecting all data that can be acquired while performing other tasks. The following example may help explain the intent of this. The Department can make use of weekend traffic count information, but the benefits it provides do not usually justify the effort of sending a field crew to specifically collect it. However, if a field crew were to be in an area of the state for two consecutive weeks, it would be a simple (and inexpensive) matter to place counters to operate over the middle weekend of that two week period. The counters could operate unattended, and be picked-up at the start of the second week of data collection. The result would be an essentially "free set" of weekend counts.

Another example of "free" data is to ensure that all traffic data collected by the Department be input into the traffic database, regardless of what entity in the Department collects that information. One prime example is the FLOW freeway surveillance system in District 1. This system operates 365 days per year, but many of the data have not been included in the Annual Traffic Report. This information should be captured and included in the TRIPS database on a regular basis.

7.3 Short Duration Vehicle Classification Counting

This section deals with the selection of vehicle classification sample locations, and the choice of vehicle classes to be collected. The effects of the proposed automated PTR program on estimating annual truck travel will be discussed in the data manipulation section later in this chapter.

7.3.1 Selection

Sample locations have already been established for volume counts as a result of the existing HPMS program. The selection of vehicle classification sample locations from that sample can be performed in several ways. The project team's analysis of available vehicle classification data (primarily the HPMS data collected in 1980 and 1981) indicated that the Department should randomly select a single count day at a given location, from all days in the count year. Counts must be randomlyselected from weekend days as well as the weekdays to account for the differences between truck travel on weekdays and weekends. This is necessary until the PTR program comes into effect, at which time manual weekend counts will no longer be necessary. Once the automated vehicle class PTR program is in operation, the Department can return to collecting only weekday vehicle classification counts, as the PTR data should provide a means of estimating annual conditions at a location directly from an individual classification count, regardless of when that count is taken. This calculation will be quite similar to what is now done with volume counts for the calculation of AADT.

To select the vehicle classification sample, the Department needs to follow these steps:

- create a list of (and sequentially number) HPMS volume segments on state highways for each vehicle class stratum
- randomly select from these lists the appropriate numbers of locations for each stratum, based on Table 6.2 in Chapter 6
- for each location, randomly select a count day (weekday or weekend day) from all days in the year.

(Note that the last step will not be necessary after the Department has its vehicle classification PTR program operating, as the PTR data will allow the Department to seasonally adjust its vehicle classification counts.)

7.4 Truck Weights

To fulfill its obligations to FHWA, the state should continue to collect truck weight information at the LTPM sites. However, it should collect this information using the 200 truck sample size criteria instead of the time-limit criteria currently used. The Department will also need to weigh at a few locations in addition to the LTPM sites. In particular, the Department will need two more rural interstate and four more urban weighing locations. Upon completion of the LTPM contract, it can stop weighing at one rural, non-interstate LTPM site.

For the urban locations, the Department should first review HPMS volume sample locations for suitability for weighing vehicles. The Department should then take a simple random sample of those locations which are considered suitable for weighing. The weighing location should also include a 24 to 48-hour vehicle classification count and a 48 hour volume count in addition to the weight information. This location would then be included as a vehicle classification count for the HPMS submittal. When done simultaneously, these three pieces of information fulfill all of the HPMS submittal needs for three years.

7.5 Data Manipulation

This section deals with the steps involved in estimating and using various calculated factors. This includes the calculation and use of seasonal and axle correction factors, as well as the calculation of AADT and average annual truck travel estimates.

7.5.1 Seasonal factors

The recommended seasonal factor program uses factor groups defined by functional classification and geographic area. Each PTR counter within each group provides daily traffic estimates. The factoring process uses this information to calculate a ratio of average annual traffic to average weekday traffic for each month of the year. To estimate this factor for each group, the procedures described in Section 5.3.2 should be applied, and in particular section 5.3.2.2.

The regression equation yields the seasonal factor for that factor group and month. This factor can then be applied to the mean value of any weekday traffic count to estimate annual average daily traffic.

For example, if a three day vehicle count is performed between Tuesday and Thursday, the Department would average traffic for those count days to get a mean daily traffic volume for the count period. It would then multiply this volume by the seasonal factor to yield an estimate of AADT at that location.

The same process can be followed to calculate Average Saturday (or Friday or Sunday) traffic ratios for each month. These factors would be used to convert a non-weekday traffic count to an estimate of AADT.

7.5.2 Axle correction factors

The calculation of axle correction factors for a given functional class was described in section 5.3.3. The average annual proportion of vehicles in the traffic stream is a required input from the vehicle classification program. Also required is the number of axles for each vehicle type. The procedures described in section 5.3.3 can be used to derive axle correction factors at the system level, as well as for individual classification counts.

7.5.3 PTRs and vehicle classification

The sampling plan for vehicle classification described in section 7.3.1 necessitates taking classification counts throughout the calendar year. This is to allow estimation of the effect of seasonal changes in truck travel. Once the Department has PTRs automatically collecting vehicle classification information, the Department may return to collecting classification counts at their convenience as is done currently with volume data.

Once the PTRs have been operating for one year, the Department will need to calculate ratios of average annual travel to average monthly weekday travel for each truck type. This ratio is similar to the seasonal factor. As with volumes, it is also possible to calculate ratios for weekends. These calculations would be done following the same procedures described above, using vehicle proportions for each of the collected vehicle types in place of total traffic volumes.

One complication to this process will be the need to convert the vehicle length categories recorded by PTRs to the categories defined by number and location of axles that are used by the Department. The easiest and probably best method for doing this conversion is to assign each axle classification to one of the four length classifications shown in Table 7.1. Each of the axle classes in that length group would then be seasonally adjusted in the same manner. The other major alternative would be to perform a fairly large number of manual vehicle classification counts at several of the PTRs in order to determine if the mixture of axle categories within each vehicle length group changes over the year. This could also be done by installing several PTRs capable of sensing axles as well as vehicle lengths.

7.6 TRIPS Implementation

This section outlines how the project team believes TRIPS can best be integrated with the data collection program described in this report. The traffic data to be stored in TRIPS are currently being determined. Besides offering a convenient means for storing and retrieving traffic data, TRIPS offers an excellent opportunity to automate much of the data manipulation currently being performed manually by the Department.

FHWA	Length Category*
Motorcycles	Group 1
Passenger Cars	Group 2
2-axle, 4-tire SUs	Group 2
Buses	Group 3
2-axle, 6-tire SUs	Group 2
3-axle SU	Group 3
4+ - axle SU	Group 3
4-axle Combination	Group 4
5-axle Combination	Group 4
6+ - axle Combination	Group 4
5-axle MU	Group 4
6-axle MU	Group 4
7+ - axle MU	Group 4

*Given Length Categories of:

		Length	<	11'	= Group 1
11'	<	Length	<	25'	= Group 2
25'	<	Length	<	34'	= Group 3
34'	<	Length			= Group 4

Table 7.1 Example Assignment of FHWA Vehicle Classifications to PTR Vehicle Length Categories

TRIPS should store and apply the various factors described in this report, as well as simply store and retrieve input traffic data. Because the calculation and application of factors is to be done on a systematic basis (all factors are applied on the basis of geographic location and the functional class of road), TRIPS should be capable of performing the majority of the manipulations automatically.

It is recommended that the seasonal factors for each factor group and the axle correction factors for each vehicle classification stratum be calculated automatically at the end of each year. These results should be stored in look-up tables on TRIPS. The system can then apply them whenever necessary to raw traffic counts entered into the database. The system should also allow for manual override of the automatic factoring procedure for those locations where point specific axle correction factors, or individual PTR seasonal factors are to be applied in place of the group factors.

It does not matter whether these factors are applied before the data are stored on the system or whether short count volume dataare stored as raw axle counts and TRIPS applies the appropriate factors at the time of use. The important fact is that the system should automatically calculate and apply these factors before outputting data to an end user.

In either case, if both the raw traffic data and the seasonal factors are kept, interested persons may go back and reconstruct how AADT or other traffic estimates were arrived at. In this manner, additional research can be performed into the statistical reliability of the factors, and the effect such factors have on design.

It is further suggested that computer programs be written to provide for the periodic update of these tables. These functions can be performed at least annually (and potentially monthly) based on the data collected from PTRs, vehicle classification and other volume counts. It is even possible for the update process to take place without human intervention, once the appropriate computer programs are written. The Department may wish to have Data Office staff operate the programs, as this will allow additional human review of input data, without the need to meet arbitrarily imposed deadlines that would exist if the computer was to perform a function at a particular time every year.

7.7 Statistical Precision Estimation

The statistical precision of the various traffic estimates and factors can be approximated using the procedures discussed in Chapter 5. To summarize, for:

(i) AADT - use equations (5.5) and (5.4)

(ii) seasonal factors - use equation (5.10) to get the coefficient of variation to insert in equation (5.4)

(iii) axle correction factors - use equation (5.21) to get the coefficient of variation to insert in equation (5.4)

(iv) growth factors - use the equivalent form of equation (5.21) for growth factors, as discussed in section 5.3.4, to get the coefficient of variation to insert in equation (5.4)

(v) AADT by vehicle type - use equations (5.30) and (5.29)

(vi) vehicle classification - use equations (5.25) and (5.24), estimating var (P_c) from equation (5.27) and P_c from equation (5.26)

(vii) truck weight - use equation (5.31) to estimate the precision of the mean EAL estimate for each truck type.

7.8 Suggestions For Further Research

The principal areas for further research into statewide data needs by the Department are in vehicle classification and truck weight information. In summary, the Department needs to establish:

- seasonal trends in truck travel
- whether these trends are constant across the state
- if they are not constant, determine how to stratify the state in order to provide a means of estimating meaningful geographic strata (e.g. a "farm belt", a "logging belt", etc.) for monitoring seasonal fluctuations in truck travel
- if mean truck weights per vehicle type differ by functional classification of roadway
- if mean truck weights per vehicle type differ by time of year

The Department has many analyses that are unable to request vehicle classification information and therefore, must rely on using system (or strata) averages and old classification counts. While the recommended vehicle classification strata will improve the quality of the system estimates, and make them more to more locations, the Department needs to perform some significant research into truck travel in the state. By examining the issues listed above, the Department should be able to determine if there are a group of state roads which exhibit consistently high truck volumes, and others that have very little truck traffic. If these roads can be identified, a revised sampling strategy could be developed which would give even better precision estimates and smaller sample sizes than the functional classification estimates recommended in this report. Until this information is available, however, the functional class strata reported here are the best strata available.

The three truck weight issues listed above all relate to the sparse data that the Department has concerning truck weights. The Department needs to prioritize its selection and acquisition of an unobtrusive truck weighing system. This will allow the Department to collect the information required and, in turn, allow the resolution of such issues as:

- are site-specific truck weights cost-effective for pavement design?
- should the strata used to sample truck weights include more lower functional classification roads?
- are truck weights increasing on a per truck basis, or are just more big trucks using the highways?

Obviously, the Department faces many research needs in addition to those specified above. However, given the important role that such data play in the roadway design process in particular, it is sensible to investigate these data issues and the sensitivity of design and investment decisions to the quality and quantity of data collected.

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APPENDIX A

GLOSSARY OF TERMS

AADT - Annual average daily traffic. The amount of traffic experienced by a road section in a year, divided by 365.

D - Directional split. The percentage of traffic moving in each direction during the design hourly volume.

DEAL - Design equivalent axle load. The number of equivalent axles that a new section of pavement is designed to withstand. A measure of expected loading conditions for a piece of roadway.

DHV - Design hourly volume. The volume used by engineers to size the number of lanes that should be built for a new road. In most cases DHV equals the estimated 30th highest hour of traffic for the design year.

DTN - Design Traffic Number. A measure of Design Equivalent Axle Loads (See DEAL), used by the Asphalt Institute before the latest revision of their design manuals. DTN = DEAL/7300.

EAL - Equivilent axle load, also known as equivilent standard axle load. A measure for tracking the amount of damage done by various weights, by relating that damage to that caused by a single 18 KIP axle.

FHWA - Federal Highway Administration.

Functional Classification - A series of roadway classifications defined by FHWA which categorizes roads by the type of travel that occurs on them.

HPMS - Highway Performance Monitoring System. A statistically valid system used by FHWA as a basis for reporting traffic information.

K - Peak Hour factor. The percentage of daily traffic operating on a road section during the peak period of the day.

PTR - Permanent traffic recorder. Also known as an ATR (Automatic traffic recorder) in some states. A traffic counting device that collects volume information at a location continuously throughout the year.

Priority Array - The result of the procedures used by WSDOT to objectively establish the need for highway system improvements, and then rank those improvements in order of importance.

T - Truck Percentage. The percentage of traffic flow which is trucks.

TRAC - The Washington State Transportation Center.

TRIPS - Transportation Information and Planning Support System. A computerized roadway information system being designed and installed for the Washington State Department of Transportation.

VMT - Vehicle Miles of Travel.

WIM - Weigh-in-Motion. Usually used to describe truck scales that have the capability to weigh trucks which are moving, as opposed to "static" scales which require trucks to stop for weighing purposes.

APPENDIX B

COUNTS IN ADDITION TO HPMS VOLUME LOCATIONS THAT SHOULD BE COUNTED BY THE DEPARTMENT

This appendix presents a list of approximate count locations that the Department should consider counting in addition to those locations included in the HPMS volume sample and those scheduled for project counts. These locations are recommended for two reasons. The first category of locations are on roads that have no HPMS volume sections on them. Counts are recommended so that the Department has some handle on changes to volumes on those roads if no project counts are taken on them during the three year count cycle. These locations should have fairly high priority in being performed at some point in the three year count cycle.

The second category of locations are where significant changes in volume occur that can not be monitored using HPMS volume counts because of their location. HPMS counts are available at other locations on those state highways, but significant volume changes occur between the HPMS section and the road sections in question. These locations should have a much lower count priority in that old count data combined with available HPMS data on those roads can be used to estimate existing traffic levels. The Department may wish to monitor these locations as manpower permits.

<u>Roads With No HPMS Counts</u>

SR 10 Kittitas County
SR 92 Snohomish County
SR 128 Garfield/Asotin Counties
SR 142 Klickitat County
SR 165 Pierce County
SR 207 Chelan County
SR 209 Chelan County

SR 220 Yakima County
SR 411 Cowlitz County
SR 505 Lewis County
SR 506 Lewis County
SR 508 Lewis County
SR 515 King County
SR 901 King County

Roads With Needs For Additional Counts

SR 17 Grant County south of Soap Lake
SR 24 Franklin County, approaching Othello
SR 27 Spokane County south of I-90
SR 28 Grant County between Ephrata and Soap Lake
SR 99 King/Snohomish Counties near county border
SR 103 Pacific County south of Long Beach
SR 106 Mason County south of Belfair
SR 109/115 Grays Harbor, outside of Ocean City
SR 112 Clallam County near Neah Bay
SR 125 Walla Walla County, north of Walla Walla
SR 141 Cowlitz County
SR 162 Pierce County south of Sumner
SR 164 King County southeast of Auburn
SR 167 King County north of Tukwila
SR 195 Whitman County between Pullman and Colfax
SR 231 Lincoln County
SR 305 Kitsap County near Poulsbo
SR 509 King County north of Tacoma
SR 516 King County near Kent
SR 900 King County north of Tukwila

The above count locations are intended only as a suggestions for the Department, and are not to be construed as the only locations where counting is advisable in addition to the HPMS and project counts discussed in the main body of this report.

APPENDIX C

OVERLAY PAVEMENT DEPTH CALCULATION

This appendix details an overlay pavement depth calculation which serves as an example of the effect that data has on the expenditure of Department funds, particularly in the area of pavement overlay design. The procedure used is found in the Asphalt Institute's Overlay Design Manual (MS-17) [14]. It is one of several methods used by the Department for calculating overlay depth.

This example examines the effect of variation of only one of the traffic inputs used in the overlay design calculation (the percentage of five axle trucks in the traffic stream). Note that variation between the actual and estimated values of the other inputs to the design process will also cause errors in the design calculation.

Three designs were performed for this analysis. Each of the designs used the same input assumptions with the exception of the percentage of traffic assumed to be 5 axle trucks. This example looks at the effect of using one standard deviation (estimated from available data) above and below that estimate for design purposes. This represents a range of conditions common on the system.

From an existing Department database, we have estimated that the average percentage of 5-axle trucks on the rural primary arterial system is 7.10 percent of traffic. One standard deviation about this mean is estimated to range from 12.27 to 1.93 percent. These numbers were calculated from data collected as part of the 1982 Highway Performance Monitoring System (HPMS) Vehicle Classification Case Study, for rural primary arterials.

Design Assumptions

The assumptions used in the calculation of both pavement design are shown below:

Design Volume Per Lane	5,000 Vehicles per day
Percent 2 axle Trucks	3.44
Percent 3 axle Trucks	0.71
Percent 4 axle Trucks	0.07
Percent 5 axle Trucks	(Varies See Above)
Percent 6+ axle Trucks	0.18
Equivalent Axle Loads (EAL) per truck	
2 axle trucks	0.11
3 axle trucks	0.47
4 axle trucks	0.66
5 axle trucks	0.98
6+ axle trucks	1.63
Existing Pavement Quality	
Benkelman Beam Deflection Test	
Mean Plus 2 Sigma	0.08 inches

The percentage of trucks within each axle grouping was taken from the HPMS data base for rural primary arterials described earlier. The EAL per truck estimate was taken from a national HPMS data-base, for rural interstates. These estimates are approximate, and may or may not be truly representative of any specific site in Washington State, but are sufficiently accurate for use in this example.

The total equivalent axle load for each truck type for each day is computed as:

Volume * Percent Type of Truck / 100 * EAL/ Truck of that Type

These values are:

	Design 1	Design 2	Design 3
Total EAL 2 axle trucks	18.92	18.92	18.92
Total EAL 3 axle trucks	16.69	16.69	16.69
Total EAL 4 axle trucks	2.31	2.31	2.31
Total EAL 5 axle trucks	601.23	94.57	348.57
Total EAL 6 axle trucks	14.67	14.67	14.67
TOTAL EAL PER DAY	653.82	147.16	401.16

where Design 1 is the mean plus one deviation, Design 2 is the mean minus one deviation, and Design 3 is the mean value of the estimated truck percentage.

With a design life of seven years, the total Design EAL is:

$DEAL_1$ = 7 * Total EAL Per Day * 365 = 1,670,510

$DEAL_2$ = 7 * Total EAL Per Day * 365 = 375,990

$DEAL_3$ = 7 * Total EAL Per Day * 365 = 1,024,954

This may be equated to the Design Traffic Number (DTN) used in the 1977 version of the Overlay Design Manual by the following formula:

DTN = DEAL / 7300

So DTN_1 = 228.8

DTN_2 = 51.5

DTN_3 = 140.4

Using the graph in Exhibit C-1, the overlay depth can be calculated.

Overlay depth 1 = 4.7 inches

Overlay depth 2 = 3.0 inches

Overlay depth 3 = 4.1 inches

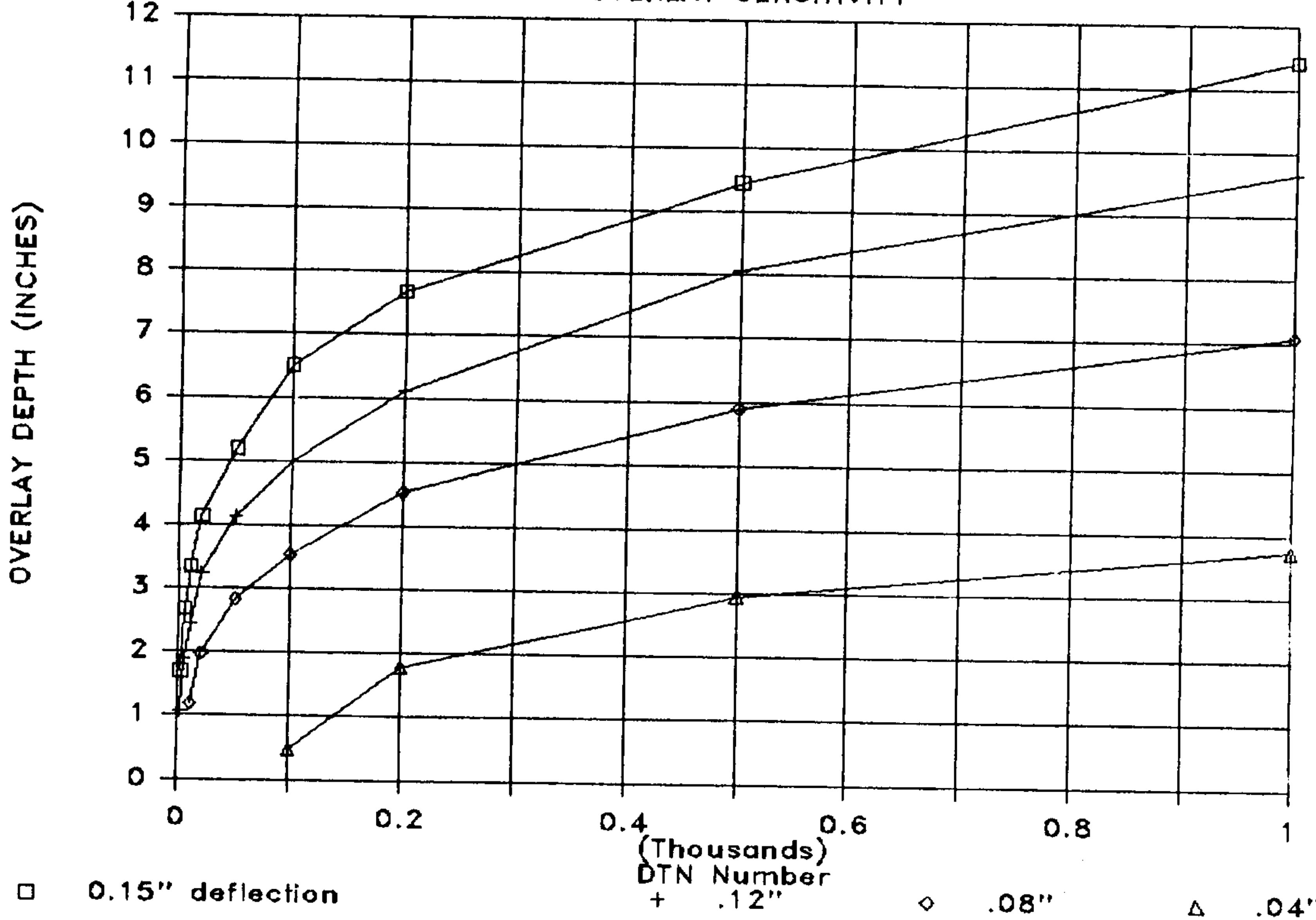
Figure C-1 was taken from the Asphalt Institute's Overlay Design Manual [17].

Results of the Analysis

At roughly $10,000 per inch per lane mile, for the cost of asphalt material, the differences in the various design's material costs for two traffic lanes are large. The high traffic estimate would cost $12,000 per mile more than the design based on the mean, while the low truck estimate would be $22,000 per mile less expensive. Differences of such magnitude will lead to significant misallocation of resources for the Department, given the proposed 1,200 miles of overlay planned for the coming bienium. While the average error is probably not of this magnitude, even an error of only 1/4 inch over these 1,200 miles results in a misallocation of $6,600,000.

Figure C-1

OVERLAY SENSITIVITY



Source: Asphalt Institute's Overlay Design Manual (MS-17), 1977

It must also be realized that both over-designing and under-designing of roads lead to economic losses to the Department. If a road is over-designed, the Department must expend resources for extra pavement that could be better used elsewhere. If it under-designs, the Department might be forced to rehabilitate that section of road earlier than necessary and would suffer even greater costs due to the need for a complete project design and construction as opposed to the current cost of adding additional asphalt to present overlay design.

APPENDIX D

EFFECT OF THE PROPOSED PROGRAM ON ACCIDENT ANALYSES

In most instances, the proposed traffic counting program will improve the data available to the Accident Analysis Section of the Department. Because a high percentage of HPMS sections on the state highway system are included in the volume count sample, a large number of traffic counts on the state highway system will be updated on a regular basis. In addition, by ensuring that all counts taken by the Department for projects or other purposes are adjusted for seasonality and axle corrections and then inserted into TRIPS, the Department will have additional traffic data available to it for most intersections surrounding the major projects it has performed.

Because of these two program elements, the TRIPS database will provide the Accident Analysis Section with traffic counts under three years old for most sections of the state highway system. In addition, it will provide ready access to significant amounts of data on intersection movements on many parts of the highway system.

Because the Accident Analysis Section utilizes traffic volumes for stretches of road 1/100 of a mile long, it is doubtful that the Department will have traffic counts actually located on many of the specific 1/100 mile segments requested by the Accident Analysis Section. For those traffic count locations that fall within HPMS volume count sections, the Analysis Section should use the AADT for those sections of highway. The AADT volume estimate should be reasonable (if not exact) for any location along these highway sections. The only time this will not be the case is if an HPMS section was not properly defined, as each section is intended to be "homogeneous" with respect to traffic volumes.

In actuality, "homogeneous" can mean a variation of roughly 20 to 40 percent on higher volume roads (greater than 20,000 AADT), 40 to 60 percent on medium volume roads (2,500 to 20,000 AADT) and as much as 100 percent on low volume roads (less than 2,500 AADT). On most HPMS sections the fluctuation in volume within the section should be less than this.

For traffic volumes required on highway sections which are not included in the HPMS volume sample, the current method of extrapolating between the two closest available counts provides the best volume estimate. It is impossible to estimate how accurate volumes estimated in this manner are.

A sensitivity analysis performed by the project team showed that variations inherent in the HPMS sample and in the various factoring procedures have only a minor effect on the computation of the accident related portion of the priority array for the Department. However, the expected error bounds may have a more significant effect on individual analyses attempting to examine specific accident situations (e.g., attempting to determine the cause for a large number of rear-end collisions at an intersection).

As a result, in a relatively small number of instances, the Planning Annex may want to collect "special counts" at some locations requested by the Accident Analysis Section, to address the needs of a particular analysis where

- the analysis' outcome will be significantly affected by the volume estimate; and
- the Accident Section has a strong belief that the available volume estimates are not reasonably accurate.

These "special counts" should be very limited in number, and should be used to address previously identified problems. They should not be used to simply "fill out" the available database. While it would be advantageous for the accuracy of the accident analyses to increase the number of traffic counts taken throughout the state highway system, the collection of those counts is not cost effective, given the other requirements of the Department for information obtained using the available data collection budget.