VARIABILITY IN TRAFFIC MONITORING DATA
FINAL SUMMARY REPORT

Tommy Wright*
and
Patricia S. Hu
Center for Transportation Analysis
of
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6073

and

Jennifer Young
and
An Lu
of
University of Tennessee-Knoxville
Knoxville, Tennessee 37831

*Currently with the U. S. Census Bureau

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NOTICE

The contents of this report reflect the views of the authors, who are responsible for the accuracy of the results presented herein. The contents do not necessarily reflect the official policy of the Federal Highway Administration, U. S. Department of Transportation.

The report does not constitute a standard, specification, or regulation.

EXECUTIVE SUMMARY

For highway maintenance and planning purposes, it is desirable to characterize each road segment by its traffic flow [such as the annual average daily traffic (AADT) and the AADT for each vehicle class], by the weight distribution of vehicles that travel on its roads [such as the annual average daily equivalent single axle loadings (ESAL) and the annual average daily weight per vehicle for each vehicle class].

If there were no budget constraints, then each road segment could be continuously monitored every day of the year to determine the values of the aforementioned traffic characteristics. However, in practice, a few road segments are monitored continuously every day of the year to produce annual characteristics of traffic flow. A sample of the remaining road segments are monitored for one or two days each year. These road segments are called the short-term monitored sites. Data collected from the short-term monitored sites are then "adjusted" (using factors based on data collected from the continuously monitored road segments) to produce estimates of annual average daily characteristics. With this general approach, each state strives to provide (or help provide) estimates of annual characteristics for each road segment within its boundaries.

As with almost any data collection effort, the monitoring data suffer from errors from many sources. This report summarizes results of a two year empirical research effort, which was sponsored by the Federal Highway Administration, (i) to study and characterize the *variability* in the traffic data (volume, classification, and weight) from the continuously monitored road segments, and (ii) to study the extent to which this variability is transferred to, and affects the *precision* of the data produced from the road segments which are monitored only one or two days each year. The ultimate hope is not only that states will eventually be able to publish an estimate of a characteristic such as AADT for each road segment, but also that each estimate will be accompanied by a statement of how good the estimate is in terms of the estimated variability or precision which will likely be experienced as a coefficient of variation (i.e., the quotient of a standard deviation and a mean).

This report provides highlights of research reported in five working papers. It should be emphasized that results from this project are based on a few continuously monitored sites from two states — Florida and Washington. Thus, we recommend that data from more sites across a sample of representative states be analyzed in the future to validate the findings from this effort. Significant findings are highlighted below.

The main contributors to the variance in traffic were examined. The larger contributors to traffic count variability are the weekend days rather than the weekdays, the winter months rather than the summer months, and the "all holiday period" days rather than the "non-holiday period" days. These findings confirm the need to annualize data collected from short-term monitored sites, at a minimum, by day-of-week and month-of-the-year factors. These

> 1. Weekend days, winter months and holidays contribute substantially to the variability observed in traffic data. These results confirm the need to annualize short-term monitored data by day-of-the-week and month-of-the-year factors. Without properly adjusting short-term monitored data to reflect these temporal variations, the resulting traffic estimates are biased.

findings also provide guidance should one decide to consider sampling a statistically representative data from the continuously monitoring sites so that data processing effort can be reduced. (See details on page 48).

To study and characterize the variability in the traffic data (volume, classification, and weight) from the continuously monitored road segments, we calculated AADT, AADT by vehicle class, and ESAL and average daily weight per vehicle by vehicle class. Furthermore, we estimated the corresponding coefficients of variation. In general, we found

> 2. The more common the vehicle type, the less variability in the traffic volume. To achieve more reliable AADT estimates, less common vehicle classes should be combined.

that high volume traffic estimates have low associated coefficients of variation, while low volume traffic estimates have high associated coefficients of variation. This is especially illustrated in the classification data. This finding suggests that less common vehicle classes (those account for less than 1% of the daily traffic volume) should be combined in order to achieve reliable AADT estimates. (See details on page 10).

The variability among the weekend daily traffic counts is higher than the variability among weekday daily traffic counts. As commonly known, traffic volume on weekend days is lower than traffic volume on weekdays. Similar results hold for classification data and weigh-in-motion data.

These observed differences between weekend day data and weekday data confirm the need to annualize short-term monitored

> 3. "Day-of-the-week" variance in traffic volume and loading is significant, indicating that adjustment of the short-term monitored data by, at least, weekday and weekend factors is essential.

data by day of week factors, or at least by weekday and weekend factors. Traffic estimates based on **unadjusted/unweighted** data from the short-term monitored sites are biased. (See details on page 22).

> 4. Total traffic volume, the size of the vehicles, and the loads imposed on the roads vary from one month to the next. Without adjusting short-term monitored data to account for this monthly variation, the estimates will be biased.

For the different vehicle classes, the larger coefficients of variation associated with the estimated traffic loadings tend to occur during days in

January and July, while the lower coefficients of variation tend to occur during days in March and April. The level of the coefficients of variation for "day-of-week" is about the same as the level of the coefficients of variation for "month of the year" for both ESAL estimates and weight estimates. These observed monthly variations confirm the need to annualize by month-of-the-year factors, or at least by seasonal factors. Again, without properly adjusting the short-term monitored data to account for this monthly variation, the traffic estimates will be <u>biased</u>. (See details on page 25).

5. There are five different methods for estimating average traffic characteristics -- ranging from simple to complex. Our results show that almost all five methods produce estimates of traffic characteristics that are within 5% of each other. As a result, we recommend the straight forward averaging method because of its simplicity!

Five methods for estimating average characteristics were examined and compared. These methods included the AASHTO method. Because no practical differences were observed among the estimates produced by the five different approaches, we recommended the straight average for simplicity! This method calls for computing the average of the daily traffic estimates. Our results show that almost all five estimates of annual traffic estimates (AADT, AADT by vehicle class, daily ESAL and weight per vehicle) are within 5% of each other. (See details on page 31).

Continuous traffic monitoring is plagued by missing data which seems to mainly be due to equipment failure, construction schedules, and installation dates.

6. The effects of randomly missing data on annual traffic estimates are negligible. However, the more missing data, the more unreliable the estimates. In many cases, we found that the loss of reliability is tolerable

However, data do not appear to be missing in any systematic patterns (i.e., for certain hours of the day, days of the week, nor months of the year.) Rather, data are missing on isolated days as well as on consecutive days. Our simulations indicate that the amount of randomly missing data had negligible effects on the traffic estimates and the associated coefficients of variation for the sites included in this study. However, as the amount of randomly missing data increases, the more unreliable the estimates, even though they are on target (on average). In many cases, the loss of reliability is tolerable. (See details on page 34).

Traffic characteristics were calculated under three scenarios — (1) with all available data, (2) with data associated with all specific holidays removed, and (3) with data associated with all "holiday period" days removed. "Holiday period" days are a specific holiday plus the adjacent days. For example, the "holiday period" days for the July 4 holiday in 1994 include July 1 through 7. Our results show that at most of the sites examined there is less travel during holidays and holiday periods than during non-holidays. However, the differences are negligible — within 2% of each other. Although the effect of holidays and holiday periods appears negligible on the traffic estimates, the effect on CV (i.e., variability) is small, but not negligible. CV's decrease when holidays and holiday periods are removed, indicating that there is more traffic variability during holiday periods. (See details on page 45).

> 7. At most of the sites examined, there is less travel during holidays and holiday periods than during non-holidays. Although the effect of holiday and special days is small on the estimates of total traffic and classification data, but it is not negligible on the corresponding coefficients of variations.

> 8. Traffic differs significantly by direction. Traffic monitoring needs to be conducted in both directions!

The analysis of count and classification data by direction of travel shows that traffic differs significantly by direction. This finding is significant in practice because it confirms the need to monitor traffic volume and classification data in both directions instead of just monitoring in one direction and multiplying the result by two. (The details are presented on page 7).

9. In general, adjustment factors based on data from the continuously monitored sites of similar functional classes work reasonably well in "expanding" 24 hours of traffic volume into an annual estimate. However, the ability of this approach to estimate vehicle classification counts decreases the less common the vehicle. Also, the ability of this approach to estimate traffic loadings deteriorates for vehicle classes with widely varying weights.

W̱e conducted simulation studies to study the extent to which the variability in the traffic data collected from continuously monitored road segments is transferred to, and affects, the precision of the estimates based on data from the short-term monitored sites. In this simulation, we created seasonal (monthly) adjustment factors and day-of-week factors based on data from the continuously monitored sites. Given these factors, we considered that we have only one day's (24 hour period) worth of data from each of the continuous monitored sites. That is, we assumed that the site is a short-term monitored site. Given the factors and the 24 hour period of data, we calculated annual estimates of traffic characteristics (i.e., AADT, and AADT by vehicle class). The precision of an estimate from treating the site as a continuously monitored site (the original estimate) is compared to the precision of an estimate from treating that site as a short-term monitored site (the simulated estimate). The original estimates of traffic characteristics (i.e., AADT, AADT by vehicle class, and daily ESAL per vehicle) are, on average, quite close to the simulated estimates. Based on the maximum ratio, the original AADT estimate and the simulated AADT estimate at a given site are, on average, within 2% of each other. Not surprisingly, the original estimates appear to be more precise, on average, than the simulated estimates. The decrease in the precision typically occurs for vehicle classes that account for less than 1% of daily traffic volume, suggesting that these less common vehicle classes should be combined in order to achieve reliable AADT estimates. In almost all cases, the simulated estimates tend to be higher than the original estimates, possibly suggesting some (slight) positive bias in the simulated estimates. In general, adjustment factors based on data from the continuously monitored sites of similar functional classes work reasonably well in "expanding" 24 hours of traffic data into an annual estimate. (See details on page 52).

> 10. Although they serve different purposes, truck weight estimates (in kips) and ESAL estimates have different corresponding coefficients of variation (CV). ESAL estimates have higher CVs than weight estimates.

Coefficients of variation for truck weight data (in kips) are generally lower and have smaller ranges than the coefficients of variation for ESAL. This pattern repeats itself in the temporal estimates — weekend verse weekdays, winter months verse summer months, etc. In general, daily weight estimates appear to be more reliable than the corresponding daily ESAL estimates. Since these two estimates meet different analytical needs, whether and how one can substitute the other should be investigated in more detail. If not, then research should be undertaken to understand how short-term ESAL can be annualized to produce reliable estimates of annual ESAL.

Recommendations

1. Since continuous monitoring data are plagued by missing data and since our results show that randomly missing data have little effect on traffic estimates and on the estimated coefficients of variation, we recommend that research be supported to determine to what extent sampling can assist continuous traffic monitoring programs. Rather than process the complete continuous monitoring traffic data on a continuous basis, one option is to develop annual traffic estimates based on a statistically representative sample of these data. These estimates can be periodically updated with a more current sample of continuous data. Another option is to sample data collected from Intelligent Transportation System (ITS) developments to characterize traffic patterns.

2. Conduct research to investigate the advantages and disadvantages of combining certain vehicle classes. Four results prompt this recommendation. First, high coefficients of variation associated with AADT tend to occur with vehicle classes that have extremely low mean daily traffic volumes. Second, at almost every one of the eight classification sites, the level of unclassified/other vehicles is quite high relative to what is captured in

other vehicle classes. The large percentage of vehicles being unclassified (Class 14) may signal some concern for the reported counts in the other classes. Third, for vehicle classes with low mean daily traffic volumes, traffic estimates calculated using five estimation approaches are rather different. Fourth, the estimates of traffic characteristics derived from treating the site as a continuously monitored site appear to be more precise, on average, than the simulated estimates from treating the site as a short-term monitored site. This decrease in precision typically occurs for vehicle classes that account for less than 1% of daily traffic volume, suggesting that these less common vehicle classes should be combined in order to achieve reliable AADT estimates.

3. Monitor traffic in both directions. The analysis of count and classification data by direction of travel shows that traffic differs significantly by direction. This finding is significant in practice because it confirms the need to monitor traffic volume and classification data in both directions instead of just monitoring in one direction and multiplying the result by two.

4. Monitor missing data and use graphics and exploring data analysis methods to easily reveal systematic patterns of missing data. Systematic patterns of missing data signal potential equipment problems, thereby providing valuable information for maintenance scheduling. Furthermore, patterns of missing data help guide users against inappropriate analysis and misinterpretation of the data.

5. To better aid the development of highway strategies with accurate and timely traffic characteristics, we propose that traffic data analysis programs in each state include, at a minimum:

   (i)   data editing methods (such as the approaches used by Florida Department of Transportation),
   (ii) tracking of missing data at each continuously monitored site using graphics,
   (iii) development of adjustment factors for AADT estimates from short-term, monitored sites as discussed in [1] and illustrated in [7].
   (iv) computation of total volume averages by day of week and month of year at volume sites,
   (v)   computation of volume and percentages of each vehicle class by day of week and month of year at each classification site,
   (vi) computation of average weight and ESAL per day and month at each WIM

site,

(vii) computation of CVs for publication with AADTs for continuously monitored sites, and

(viii) computation of AADT for continuously monitored sites using simple averages, including in the presence of missing data that do not show a systematic missing pattern.

Also, we recommend that these analyses be conducted on a periodic basis to: verify traffic estimates, identify changes in traffic patterns, and detect and correct equipment malfunction in a timely manner.

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1. INTRODUCTION AND OBJECTIVES

Within each state, traffic data are important for supporting highway needs; furthermore the need exists to better understand and analyze the available data to support improved decision making. Toward this end, each state in the United States has a system of roads and highways which are usually defined as a universe of road segments. A road segment is a definite section of a state road often having the same features (e.g., grade, number of lanes, geometry, etc.). For each road segment in each state, this report assumes that it is desired to know various traffic characteristics including:

Count (Volume) Data -   Annual Average Daily Traffic (AADT)

Classification Count Data -   AADT for Each Vehicle Class

Weigh-In-Motion Data -   Annual Average Daily Equivalent Single Axle Loadings (ESAL) per Vehicle for Each Vehicle Class

-   Annual Average Daily Weight per Vehicle for Each Vehicle Class

These data are absolutely essential for highway maintenance and planning, especially AADT. (Actually, most states currently only use annualized count data, i.e. AADT. Classification and weight data are generally not annualized by the states as will be discussed in this report.) Given no cost constraints, each road segment would be continuously monitored every day of the year to determine values of the four traffic characteristics just noted as well as many others. However, in practice, a few road segments are monitored continuously every day of the year to produce annual characteristics of traffic flow. The remaining road segments are monitored for one or two days each year, and this resulting data are "adjusted" (using factors based on data collected from the continuously monitored road segments) to produce estimates of annual average daily characteristics. With this general approach, each state strives to provide (or help provide) estimates of annual characteristics for each road segment within its boundaries. In 1995, the Federal Highway Administration published its latest edition of the *Traffic Monitoring Guide* [1] to assist states in achieving this end.

Objective of Research Study

As with almost any data collection effort, the monitoring data suffer from errors from many sources. The *objectives* of this two year research effort, which is sponsored by the Federal Highway Administration, are *(i)* to study and characterize the *variability* in the traffic data (volume,

classification, and weight) from the continuously monitored road segments, and *(ii)* to study the extent to which this variability is transferred to, and affects the *precision* of, the data produced from the road segments which are monitored only one or two days each year. The ultimate hope is not only that states will eventually be able to publish an estimate of a characteristic such as AADT for each road segment but also that each estimate will be accompanied by a statement of how good the estimate is in terms of its estimated variability or precision which will likely be expressed as a coefficient of variation (i.e., the quotient of a standard deviation and a mean). While variability is indeed the main objective, other objectives include data analysis of traffic data from continuously monitored sites, data utility to the transportation community, developing data analysis capability, and support highway information needs.

Overall Research Approach

The approach being followed for this research study can be viewed in three major steps.

Step 1: Initial Methodology Development for Data Collected from Continuously Monitored Sites
Using 1994 data from continuously monitored sites in Florida and Washington and elementary statistical methods, it was decided to first develop a methodology for estimating variability in data from a few sites as follows:

(a) Count Data
We used the 1994 traffic **count** data from 21 of Florida's continuously monitored count sites. Details are given in *Variability in Continuously Traffic Monitoring Data-Task II Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Count Data* [2].

(b) Classification Count Data
We used the 1994 traffic **classification count** data from 8 of Florida's continuously monitored classification sites. Details are given in *Variability in Continuous Traffic Monitoring Data-Task V Report: Pilot Methodology Development and Estimates of Variability from Continuous Classification Count Data* [3].

(c) Weigh-In-Motion Data
We used the 1994 traffic **ESAL** and **weight** data from 6 of Washington's continuously monitored weigh-in-motion sites. Details are given in *Variability in Continuous Traffic Monitoring Data-Task VIII Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Weigh-In-Motion Data* [4].

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Step 2: Variability at Short-Term Monitored Sites

We studied how and to what extent variability in data obtained from continuously monitored sites is transferred to annual traffic estimates based on data from short-term monitored sites [7].

Step 3: Guidance for States

Based on results from Steps 1 and 2, we propose, for states to consider, a method for reporting *variability* in traffic estimates for continuously monitored sites and *precision* in traffic estimates for short-term monitored sites.

For details, please refer to the following reports of the Center for Transportation Analysis of the Oak Ridge National Laboratory in Oak Ridge, Tennessee:

Variability in Florida Continuous Traffic Monitoring Data (Working Draft Paper - Task I Report), May 31, 1995,

Variability in Continuous Traffic Monitoring Data Task II Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Count Data, October 1995,

Variability in Continuous Traffic Monitoring Data Task V Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Classification Count Data, January 1996,

Variability in Continuous Traffic Monitoring Data Task VIII Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Weigh-in-Motion Data, April 1996, and

Variability in Continuous Traffic Monitoring Data Tasks IV, VII, and X Report: Precision in Estimates of AADT and AADT by Vehicle Class for Short-Term Traffic Monitoring Sites and Its Relation to Variability in Estimates for Continuously Monitored Sites, November 1996.

2. DESCRIPTION OF SITES USED

Data used to study and characterize the variability in the continuous traffic data come from the sites as described in Table 1. In general, we attempted to select sites for this study which had at least 200 days of 1994 data in both directions of traffic at the site. Note that what may appear to be some inconsistencies in Table 1 actually are not. For example, for Site 9925, we show 308 days of *count* data with an AADT value of 12,661 vehicles. However, for Site 9925, we show 307 days of *classification* count data with an AADT value of 12,909 vehicles. The primary difference in the AADT for Site 9925 between the count and classification count data is not due to the difference in the number of days of data used. Rather, the difference is due to the discrepancy in the total volume of the count data and the total volume of the classification count data (total volume for the classification count data was determined by summing the counts in each of the classes). This type of discrepancy was observed for 10 different dates. This is shown in Table 2.2 of *Variability in Continuous Traffic Monitoring Data-Task V Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Classification Count Data* [3]. Our analysis is based on the data received from Florida, without further editing.

Sites in Table 2 are those used to study the extent to which the *variability* observed in continuous traffic data is transferred to, and affects the *precision* of, the data produced from the roads which are monitored only one or two days each year. More sites were included to study the precision since at least two sites within each major road type (e.g., urban interstates, urban others, rural interstates, and rural others) are needed to calculate corresponding adjustment factors.

Table 1.
Sites Used to Study the *Variability* in Continuous Traffic Data

	State	Data Type	Site	Functional Class	Number of Days of Available Data	Approximate 1994 AADT
1.	Florida	Count	119	Rural Principal Arterial Interstate [01]	212	30,180
2.	Florida	Count	223	Rural Principal Arterial Other [02]	231	4,474
3.	Florida	Count	65	Rural Principal Arterial Other [02]	322	7,382
4.	Florida	Count	9925	Rural Principal Arterial Other [02]	308	12,661
5.	Florida	Count	104	Rural Principal Arterial Other [02]	347	22,098
6.	Florida	Count	118	Rural Principal Arterial Other [02]	345	22,262
7.	Florida	Count	170	Rural Minor Arterial [06]	353	5,284
8.	Florida	Count	136	Rural Major Collector [07]	263	6,336
9.	Florida	Count	133	Urban Principal Arterial Interstate [11]	283	28,026
10.	Florida	Count	179	Urban Principal Arterial Interstate [11]	210	54,599
11.	Florida	Count	130	Urban Principal Arterial Interstate [11]	341	110,865
12.	Florida	Count	196	Urban Principal Arterial Interstate [11]	252	154,304
13.	Florida	Count	204	Urban Principal Arterial Other Freeway/ Expressway [12]	212	28,294
14.	Florida	Count	114	Urban Principal Arterial Other [14]	267	14,436
15.	Florida	Count	177	Urban Principal Arterial Other [14]	333	33,290
16.	Florida	Count	102	Urban Principal Arterial Other [14]	278	40,753
17.	Florida	Count	154	Urban Principal Arterial Other [14]	220	44,030
18.	Florida	Count	113	Urban Principal Arterial Other [14]	326	45,825
19.	Florida	Count	197	Urban Principal Arterial Other [14]	212	47,270
20.	Florida	Count	246	Urban Minor Arterial [16]	278	7,681
21.	Florida	Count	175	Urban Minor Arterial [16]	342	39,920
1.	Florida	Classification	9925	Rural Principal Arterial Other [02]	307	12,909
2.	Florida	Classification	170	Rural Minor Arterial [06]	353	5,284
3.	Florida	Classification	114	Urban Principal Arterial Other [14]	266	14,447
4.	Florida	Classification	177	Urban Principal Arterial Other [14]	284	33,540
5.	Florida	Classification	113	Urban Principal Arterial Other [14]	323	45,867
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7.	Florida	Classification	246	Urban Minor Arterial [16]	277	7,686
8.	Florida	Classification	175	Urban Minor Arterial [16]	342	39,920
1.	Washington	Weigh-In-Motion	P10	Rural Principal Arterial Interstate [01]	282	1653*
2.	Washington	Weigh-In-Motion	P05	Rural Principal Arterial Other [02]	346	377*
3.	Washington	Weigh-In-Motion	P17	Rural Minor Arterial [06]	364	425*
4.	Washington	Weigh-In-Motion	P29	Urban Principal Arterial Interstate [11]	365	4,180*
5.	Washington	Weigh-In-Motion	P19	Urban Principal Arterial Other Freeway/ Expressway [12]	365	2314*
6.	Washington	Weigh-In-Motion	P07	Urban Principal Arterial Other [14]	334	281*

*Estimate of AADT excludes vehicle classes 1 and 2.

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1.	Florida	Count	223	Rural Principal Arterial Other [02]	231	4,474
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8.	Florida	Classification	175	Urban Minor Arterial [16]	342	39,920
1.	Washington	Weigh-In-Motion	P05	Rural Principal Arterial Other [02]	346	377*
2.	Washington	Weigh-In-Motion	P17	Rural Minor Arterial [06]	364	425*
3.	Washington	Weigh-In-Motion	P03	Rural Minor Arterial [06]	331	773*
4.	Washington	Weigh-In-Motion	P29	Urban Principal Arterial Interstate [11]	365	4,180*
5.	Washington	Weigh-In-Motion	P3N	Urban Principal Arterial Interstate [11]	364	3266*
6.	Washington	Weigh-In-Motion	P5S	Urban Principal Arterial Interstate [11]	288	3101*
7.	Washington	Weigh-In-Motion	P19	Urban Principal Arterial Other Freeway/ Expressway [12]	365	2314*
8.	Washington	Weigh-In-Motion	P20	Urban Principal Arterial Other Freeway/ Expressway [12]	362	3173*
9.	Washington	Weigh-In-Motion	P07	Urban Principal Arterial Other [14]	334	281*

*Estimate of AADT excludes vehicle classes 1 and 2.

3. SELECTED PRELIMINARY RESULTS ON THE VARIABILITY IN CONTINUOUS TRAFFIC MONITORING DATA

The reader is reminded that every result or remark in this study is based on a few selected continuously monitored sites from Florida and Washington states.

3.1 Differences in Direction of Travel

For each of Florida's 21 count sites and each "day of the week," we hypothesize that there was a difference between the mean daily traffic volume in direction 1 and the mean traffic volume in direction 2. Similarly, for each of Florida's 8 classification sites, for each "day of the week," and for each vehicle class, we hypothesize that there was a difference between the mean daily traffic volume for a specific vehicle type in direction 1 and the mean daily traffic volume for the same specific type in direction 2. To answer these questions, we used a *paired t test* for each site and each day of the week. The complete results are given in Table 3 for the 21 count sites and results for the 8 classification sites are given in Table 4.

Table 3.

**Results of Paired *t* Tests Comparing the Average Counts in
Both Directions by Site and Day of the Week**

Site	Day of the Week						
	Sun	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**
119	*					*	
223	*	*	*	*	*	*	*
65	*	*	*	*	*	*	
9925	*					*	*
104		*	*	*	*	*	*
118	*						
170	*	*	*	*	*	*	
136	*	*	*	*	*	*	*
133	*	*		*	*	*	*
179	*				*		*
130	*	*	*	*	*	*	*
196	*	*	*	*	*	*	
204	*	*	*	*	*	*	*
114	*	*	*		*		*
177	*	*	*	*	*	*	*
102	*	*	*	*	*	*	*
154	*	*	*	*	*	*	*
113	*	*	*	*	*	*	*
197	*	*	*	*	*	*	*
246	*	*	*	*	*	*	*
175	*		*	*	*	*	*

Note: The * means that the averages were found to be statistically different at á=.05 level of significance.
A blank means that the averages were not found to be statistically different at á=.05 level of significance.

Table 4.

Summary Results on Differences in Directional Classification Data by Vehicle Class

Vehicle Class		Statistically Different at á=.05 (Paired *t* Test)
(1)	Motorcycles	Yes
(2)	Passenger Cars	Yes
(3)	Other Two-Axle, Four-Tire, Single-Unit	Yes
(4)	Buses	Yes
(5)	Two-Axle, Six-Tire, Single-Unit Trucks	Yes
(6)	Three-Axle, Single-Unit Trucks	Yes
(7)	Four-or-More Axle, Single-Unit Trucks	Yes
(8)	Four-or-Less Axle, Single-Trailer Trucks	Yes
(9)	Five-Axle, Single-Trailer Trucks	Yes
(10)	Six-or-More Axle, Single-Trailer Trucks	Yes
(11)	Five-or-Less Axle, Multi-Trailers Trucks	No*
(12)	Six-Axle, Multi-Trailers Trucks	No*
(13)	Seven-or-More Axle, Multi-Trailers Trucks	Yes
(14)	Unclassified/Other	Yes

* Though not statistically different, the mean daily number of vehicles counted in these classes at each of the sites tended to be less that "1 vehicle"!

SUMMARY REMARKS
Differences in Direction of Travel

The analysis of count and classification data by direction of travel shows that traffic differs significantly by direction. This finding is significant in practice because it confirms the need to monitor traffic volume and classification data in both directions instead of just monitoring in one direction and multiplying the result by two. This analysis was not performed on WIM data because there are no data for separate directions.

3.2   Annual Traffic Estimates and Associated Coefficients of Variation

For each of Florida's 21 count sites and using the days of available 1994 data, we computed AADT by taking the average of the daily count values. We also computed the coefficient of variation by

$$coefficient\ of\ variation\ =\ \frac{standard\ deviation\ of\ the\ daily\ count\ values}{AADT}\ X\ \ 100\%$$

Results are in Table 5.

For each of Florida's 8 classification count sites and using the days of available 1994 data, we computed the 1994 mean daily count by vehicle class and associated coefficients of variation (Table 6). For each of Washington's 6 weigh-in-motion sites and using the days of available 1994 data, we computed, by vehicle class, the 1994 mean daily ESAL per vehicle, the 1994 mean daily weight per vehicle and associated coefficients of variation (Tables 7 and 8, respectively). The equation used to derive ESAL values by the Washington State Department of Transportation is taken from the AASHTO Guide for Design of Pavement Structures, 1986. It is a function of the following factors: number of axles on vehicle, load on axles in 1000's of kilograms, terminal serviceability, and whether the road surface is either rigid or flexible pavement. For flexible payments, a structural number (ranging from 1–6) is needed. To compute an ESAL value applying to rigid pavements, a slab thickness (ranging from 6 to 12 inches) is needed.

Table 5.
1994 Estimated AADT and Associated Coefficients of Variation (CV)

Site	Estimated AADT	CV(%)	Site	Estimated AADT	CV(%)	Site	Estimated AADT	CV(%)
119	30,180	21.2	136	6,336	18.6	177	33,290	16.6
223	4,474	16.5	133	28,026	15.4	102	40,753	14.4
65	7,382	11.1	179	54,599	13.7	154	44,030	11.6
9925	12,661	15.0	130	110,865	8.9	113	45,825	14.0
104	22,098	8.0	196	154,304	12.2	197	47,270	16.1
118	22,262	12.6	204	28,294	11.7	246	7,681	10.4
170	5,284	12.3	114	14,436	13.6	175	39,920	22.4

Table 6.
1994 Estimated Mean Daily Count (AADT*) by Vehicle Class
and Associated Coefficients of Variation
(Based on 8 Florida Classification Sites)

Vehicle Class	Classification Site ID							
	9925	170	114	177	113	197	246	175
Motorcycle (1)	12 (249%)	7 (129%)	37 (179%)	79 (125%)	23 (52%)	350 (181%)	4 (79%)	38 (101%)
Passenger car (2)	10,538 (21%)	4,080 (11%)	12,390 (12%)	28,661 (15%)	39,755 (13%)	41,385 (15%)	5,816 (11%)	34,830 (22%)
2-axle 4-tire SU (3)	1,737 (25%)	749 (21%)	1,533 (24%)	3,189 (29%)	4,753 (23%)	3,853 (31%)	1,354 (26%)	2,897 (40%)
Bus (4)	8 (53%)	3 (82%)	4 (172%)	22 (46%)	6 (93%)	46 (151%)	36 (98%)	42 (71%)
2-axle 6-tire SU (5)	176 (49%)	9 (59%)	27 (72%)	53 (56%)	59 (58%)	90 (59%)	54 (55%)	61 (53%)
3-axle SU (6)	59 (51%)	69 (51%)	108 (59%)	93 (65%)	162 (47%)	203 (43%)	40 (59%)	135 (95%)
4$^+$-axle SU (7)	8 (125%)	11(109%)	5 (172%)	18 (65%)	26 (121%)	11 (102%)	3 (181%)	18 (151%)
4-axle S. Trailer (8)	71 (52%)	72 (30%)	159 (23%)	331 (36%)	363 (34%)	375 (38%)	122 (32%)	299 (51%)
5-axle S. Trailer (9)	96 (44%)	45 (45%)	49 (49%)	215 (55%)	79 (45%)	159 (47%)	113 (48%)	231 (30%)
6$^+$-axle S. Trailer (10)	2 (96%)	4 (76%)	6 (72%)	10 (67%)	4 (83%)	4 (76%)	1 (122%)	5 (156%)
5-axle M. Trailer (11)	1 (140%)	0 (747%)	0 (456%)	4(86%)	1 (149%)	13 (57%)	0 (306%)	1 (127%)
6-axle M. Trailer (12)	0 (600%)	0 (1327%)	0 (938%)	1 (93%)	0 (268%)	2 (94%)	0(581%)	1 (140%)
7$^+$-axle M. Trailer (13)	2 (109%)	12 (95%)	0 (272%)	199 (119%)	6 (120%)	0 (310%)	0 (214%)	125 (175%)
Unclassified (14)	200 (64%)	224 (78%)	129 (49%)	664 (54%)	642 (21%)	782 (55%)	143 (37%)	1,241 (126%)

SU = Single Unit

* Numbers in parenthesis are the associated coefficients of variation (CV)

Table 7.

1994 Estimated Average Daily *ESAL** per Vehicle, AADT and Associated Coefficients of Variation by Vehicle Class

(6 Washington Weigh-in-Motion Sites)

Vehicle Class		Weigh-in-Motion Site ID					
		P10	**P05**	**P17**	**P29**	**P19**	**P07**
2-axle 4-tire SU (3)	ESAL	0.01 (39.0%)	0.01 (139.1%)	0.01 (211.8%)	0.12 (341.8%)	0.01 (54.4%)	0.00 (0.0%)
	AADT	**32.3**	**14.8**	**4.7**	**30.7**	**19.8**	**0.0**
Bus (4)	ESAL	0.45 (36.0%)	0.59 (156.0%)	0.12 (344.8%)	0.69 (47.3%)	0.78 (41.8%)	0.46 (113.2%)
	AADT	**22.5**	**1.4**	**0.3**	**26.2**	**20.8**	**1.6**
2-axle 6-tire SU (5)	ESAL	0.08 (36.1%)	0.13 (76.4%)	0.13 (139.8%)	0.12 (73.1%)	0.10 (45.7%)	0.32 (72.2%)
	AADT	**307.8**	**114.1**	**46.0**	**1197.8**	**1085.7**	**29.9**
3-axle SU (6)	ESAL	0.25 (44.1%)	0.53 (103.3%)	0.28 (88.3%)	0.45 (45.9%)	0.60 (32.1%)	0.39 (52.4%)
	AADT	**30.9**	**16.2**	**10.4**	**268.0**	**243.4**	**36.3**
4$^+$-axle SU (7)	ESAL	0.22 (285.3%)	0.17 (294.3%)	0.08 (397.0%)	1.02 (86.5%)	1.19 (52.1%)	0.42 (220.5%)
	AADT	**0.8**	**0.4**	**0.4**	**14.6**	**25.0**	**0.3**
4-axle S. Trailer (8)	ESAL	0.27 (32.9%)	0.94 (84.1%)	0.95 (92.7%)	0.57 (50.3%)	0.36 (46.2%)	0.87 (67.5%)
	AADT	**83.4**	**27.3**	**12.2**	**317.1**	**120.4**	**8.8**
5-axle S. Trailer (9)	ESAL	0.97 (30.2%)	1.34 (38.9%)	1.64 (25.2%)	1.42 (27.1%)	0.97 (34.1%)	1.41 (26.3%)
	AADT	**811.7**	**111.1**	**185.2**	**1485.0**	**398.0**	**108.6**
6$^+$-axle S. Trailer (10)	ESAL	0.84 (34.5%)	1.22 (75.1%)	0.91 (50.8%)	1.09 (33.9%)	0.85 (37.0%)	1.06 (44.6%)
	AADT	**49.3**	**13.2**	**30.3**	**146.2**	**163.1**	**28.5**
5-axle M. Trailer (11)	ESAL	1.23 (35.3%)	1.35 (75.3%)	1.95 (33.1%)	1.53 (37.7%)	0.39 (111.1%)	0.77 (178.3%)
	AADT	**53.0**	**6.0**	**15.8**	**70.9**	**5.4**	**1.6**
6-axle M. Trailer (12)	ESAL	0.79 (38.3%)	1.19 (57.3%)	1.77 (43.9%)	1.53 (32.7%)	1.76 (42.5%)	1.83 (68.9%)
	AADT	**65.5**	**20.5**	**30.0**	**113.6**	**15.1**	**7.0**
7$^+$-axle M. Trailer (13)	ESAL	1.16 (33.0%)	1.68 (52.9%)	1.34 (29.2%)	1.56 (30.4%)	1.63 (27.3%)	1.62 (25.0%)
	AADT	**135.9**	**31.6**	**85.4**	**414.2**	**180.1**	**51.8**
Unclassified (14)	ESAL	0.37 (289.3%)	0.72 (97.3%)	0.47 (237.6%)	0.54 (109.0%)	0.43 (75.7%)	1.27 (130.3%)
	AADT	**60.0**	**20.5**	**4.3**	**95.4**	**37.0**	**6.2**

SU = Single Unit

Some numbers rounded to zero.

* Numbers in parenthesis are the associated coefficients of variation (CV)

Table 8.

1994 Estimated Average Daily *Weight per Vehicle (Kips), AADT and Associated Coefficients of Variation by Vehicle Class
(6 Washington Weigh-in-Motion Sites)**

Vehicle Class		Weigh-in-Motion Site ID					
		P10	**P05**	**P17**	**P29**	**P19**	**P07**
2-axle 4-tire Single Unit	Weight	11.4 (10.2%)	8.4 (24.4%)	10.0 (30.4%)	14.1 (83.5%)	10.9 (10.3%)	0.0 (0.0%)
	AADT	**32.3**	**14.8**	**4.7**	**30.7**	**19.8**	**0.0**
Bus (4)	Weight	30.7 (8.7%)	19.3 (81.0%)	6.3 (200.6%)	29.9 (32.2%)	30.3 (16.8%)	16.7 (94.0%)
	AADT	**22.5**	**1.4**	**0.3**	**26.2**	**20.8**	**1.6**
2-axle 6-tire Single Unit	Weight	10.6 (10.7%)	9.2 (17.8%)	9.6 (20.7%)	10.6 (29.8%)	10.4 (13.8%)	16.7 (16.0%)
	AADT	**307.8**	**114.1**	**46.0**	**1197.8**	**1085.7**	**29.9**
3-axle Single Unit (6)	Weight	23.4 (11.0%)	25.4 (25.4%)	23.1 (28.7%)	28.1 (22.9%)	30.7 (10.4%)	27.9 (19.5%)
	AADT	**30.9**	**16.2**	**10.4**	**268.0**	**243.4**	**36.3**
4$^+$-axle Single Unit (7)	Weight	12.4 (156.7%)	8.0 (209.0%)	4.5 (306.5%)	36.6 (61.3%)	45.8 (38.0%)	13.2 (188.7%)
	AADT	**0.8**	**0.4**	**0.4**	**14.6**	**25.0**	**0.3**
4-axle S. Trailer (8)	Weight	24.8 (11.8%)	30.2 (26.7%)	32.7 (33.5%)	28.1 (26.3%)	25.0 (19.1%)	35.0 (31.3%)
	AADT	**83.4**	**27.3**	**12.2**	**317.1**	**120.4**	**8.8**
5-axle S. Trailer (9)	Weight	54.9 (8.5%)	51.1 (10.7%)	59.3 (8.1%)	59.8 (8.7%)	51.3 (9.4%)	58.0 (7.4%)
	AADT	**811.7**	**111.1**	**185.2**	**1485.0**	**398.0**	**108.6**
6$^+$-axle S. Trailer (10)	Weight	59.0 (10.8%)	55.1 (22.5%)	50.6 (18.7%)	61.0 (14.7%)	55.3 (12.6%)	60.1 (19.9%)
	AADT	**49.3**	**13.2**	**30.3**	**146.2**	**163.1**	**28.5**
5-axle M. Trailer (11)	Weight	51.8 (11.2%)	46.4 (22.7%)	57.4 (12.9%)	52.0 (24.0%)	29.0 (46.8%)	31.3 (81.6%)
	AADT	**53.0**	**6.0**	**15.8**	**70.9**	**5.4**	**1.6**
6-axle M. Trailer (12)	Weight	55.2 (10.4%)	54.5 (17.1%)	61.8 (14.6%)	65.8 (13.8%)	67.0 (21.1%)	63.4 (31.2%)
	AADT	**65.5**	**20.5**	**30.0**	**113.6**	**15.1**	**7.0**
7$^+$-axle M. Trailer (13)	Weight	76.1 (9.7%)	71.8 (15.3%)	75.0 (9.3%)	78.0 (15.1%)	84.5 (9.5%)	78.9 (10.1%)
	AADT	**135.9**	**31.6**	**85.4**	**414.2**	**180.1**	**51.8**
Unclassified (14)	Weight	19.0 (31.2%)	23.8 (42.4%)	20.1 (61.6%)	14.9 (58.1%)	16.5 (36.4%)	27.2 (39.1%)
	AADT	**60.0**	**20.5**	**4.3**	**95.4**	**37.0**	**6.2**

* Numbers in parenthesis are the associated coefficients of variation (CV)

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SUMMARY REMARKS
Annual Traffic Estimates and Associated Coefficients of Variation

The coefficients of variation associated with the overall AADT for the 21 Florida sites range from 8% to 22% (Table 5).

In general and not surprisingly, the coefficients of variation by vehicle class tended to be larger than the coefficients of variation for all the classes combined. The range of the coefficients of variation associated with AADT is the smallest for passenger cars, from 11% to 22%; and the highest for six-axle multi-trailer trucks, from 93% to 1,327% (Table 6). For each classification site, higher mean daily traffic counts for a vehicle class tended to have the lower coefficients of variation. As expected, Table 6 shows that the variability of passenger cars (Classes 2 and 3) is much less than that of other categories. This reinforces the need to take longer classification counts than volume counts and hence supports one of the basic recommendations from the *TMG*. Also the data show that Classes 1, 4, 7, 10, 11, 12, and 13 have such few vehicles as to question the need to bother with these categories in the Florida sites examined. This should also be raised as a potential question for any categories with small counts at any site in any state.

Coefficients of variation for the weight per vehicle estimates are generally lower and have shorter ranges than the coefficients of variation for the ESAL per vehicle estimates (Tables 7 and 8).

3.3 Coefficients of Variation (CV) by "Day of Week"

3.3.1 Coefficients of Variation (CV) for AADT by "Day of Week"

The range of the coefficients of variation for AADT by "day of week" for each of Florida's 21 sites are given in Table 9. For example, the lowest Sunday CV for AADT among the 21 sites was 4% and the highest Sunday CV among 21 sites was 18%. We observe similar ranges of CV for each day of the week.

Table 9.
CV Ranges Over Days of Week for AADT Over Florida's 21 Count Sites

	Days of Week						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Combined Vehicles	4-18%	4-18%	2-18%	2-17%	2-18%	3-20%	4-21%

3.3.2 Coefficients of Variation (CV) for AADT by Vehicle Class by "Day of Week"

The ranges of the coefficients of variation over the seven days of the week is the lowest for passenger cars (Class 2) and the next lowest for is other two-axle four-tire single-unit vehicles (Class 3). By far, the highest ranges exist for vehicle classes 11 (five-or-less axles, multi-trailer trucks), 12 (six-axle, multi-trailer trucks), and 13 (seven-or-more axles, multi-trailer trucks), but the absolute mean daily traffic volumes in each of these classes is quite low.

For each vehicle class at each site, we ranked mean *daily traffic volume* over the day of the week from the lowest (=1) to the highest (=7). For each vehicle class and for each day, we summed the ranks over the 8 classification sites. Then, we ranked the sums from 1 to 7 and reported the results for each vehicle class (Table 10). For example, the highest mean daily traffic volume for "three-axle, single-unit trucks" occur on Wednesday while the lowest mean daily traffic volume for this vehicle class occur on Sunday (Table 10). For this same vehicle class, the days with highest mean daily traffic volume occur Wednesday, Thursday, and Friday; while the days with lowest mean daily traffic volume tend to be Sunday, Saturday, Monday, and Tuesday. Note that the ranking for "three-axle, single-unit trucks" does not differ much from the ranking for all vehicles combined.

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In a way analogous to that described above, Table 11 gives ranks by vehicle class of *coefficients of variation* over the days of the week based on the 8 classification sites. For the 8 classification sites that the highest coefficients of variation for "three-axle, single-unit trucks" occur on Sunday (the day with the lowest mean daily traffic volume), while the lowest coefficient of variation for this vehicle class occur on Tuesday.

For each vehicle class collectively over the 8 classification sites, relatively high days of mean daily traffic volume are on Mondays, Tuesdays, Wednesdays, Thursdays, and Fridays; and relatively low days of traffic volume are on Saturdays and Sundays. However, the reverse seems true for associated coefficients of variation. For each class collectively over the 8 classification sites, relatively low coefficients of variation are on Mondays, Tuesdays, Wednesdays, Thursdays, and Fridays; and relatively high coefficients of variation on are Saturdays and Sundays (see Figure 1 for Site 9925 data). Lines associated with an individual vehicle class are labeled by a number that represents the specific vehicle class. For example, the line labeled AADTV1 represents the average daily AADT of Vehicle Class 1, which is motorcycle, and the line labeled AADT5 represents the average daily AADT of Vehicle Class 5, which is 2-axle 6-tire single unit truck (Table 10). Also, note that the scale is different in each plot. One finding illustrated in Figure 1 is that the higher the daily traffic volume the lower the coefficient of variation. For example, the coefficients of variation associated with the AADTs of 4-axle single unit trucks at Florida Site 9925 reach as high as 250%, largely due to the infrequency of this type of vehicle - less than 50 such vehicles on a typical day.

Table 10.
Ranks of the Mean Daily Traffic Volumes
By Vehicle Class Over the Days of the Week Based on the 8 Classification Sites
(1=lowest; 7=highest)

Vehicle Class	Day of Week						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
(1) Motorcycles	2	6	5	3	3	7	1
(2) Passenger Cars	1	3	4	5	6	7	2
(3) Other 2 Axle, 4 Tire, S Unit	1	3	4	5	6	7	2
(4) Buses	1	3	5	4	6	7	2
(5) 2 Axle, 6 Tire, S Unit	1	3	7	5	6	4	2
(6) 3 Axle, S Unit	1	3	4	7	6	5	2
(7) 4+ Axle, S Unit	1	5	7	6	4	3	2
(8) 4- Axle, S Trailer	1	3	6	4	5	7	2
(9) 5 Axle, S Trailer	1	3	6	7	5	4	2
(10) 6+ Axle, S Trailer	1	5	7	4	6	3	2
(11) 5- Axle, M Trailers	1	3	4	7	5	5	2
(12) 6 Axle, M Trailers	2	3	4	6	5	6	1
(13) 7+ Axle, M Trailers	1	5	4	7	3	6	2
(14) Unclassified/Others	1	3	4	6	5	7	2
COMBINED VEHICLES*	1	3	4	5	6	7	2

*Combined Vehicles Ranking is based on Table 4.2 of [2].

Table 11.
Ranks of the Coefficients of Variation for Traffic Volumes
By Vehicle Class Over the Days of the Week Based on the 8 Classification Sites
(1=lowest; 7=highest)

Vehicle Class	Day of Week						
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
(1) Motorcycles	7	1	2	5	4	2	6
(2) Passenger Cars	5	7	2	4	3	1	5
(3) Other 2 Axle, 4 Tire, S Unit	6	7	1	2	4	3	5
(4) Buses	7	4	4	3	1	2	6
(5) 2 Axle, 6 Tire, S Unit	7	5	2	1	3	4	6
(6) 3 Axle, S Unit	7	5	1	2	4	3	6
(7) 4+ Axle, S Unit	7	2	1	5	3	4	6
(8) 4- Axle, S Trailer	7	5	1	2	4	2	6
(9) 5 Axle, S Trailer	5	5	2	3	4	1	7
(10) 6+ Axle, S Trailer	7	4	1	2	3	5	6
(11) 5- Axle, M Trailers	7	5	2	3	1	3	6
(12) 6 Axle, M Trailers	5	2	3	3	1	6	7
(13) 7+ Axle, M Trailers	7	2	5	3	4	1	6
(14) Unclassified/Others	7	6	2	4	3	1	5
COMBINED VEHICLES*	6	7	1	4	3	2	5

*Combined Vehicles Ranking is based on Table 4.2 of [2].
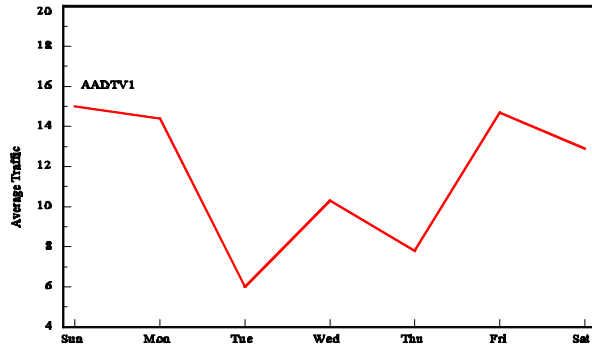
Figure 1.1. Average 1994 Daily Motorcycle Traffic - Site 9925
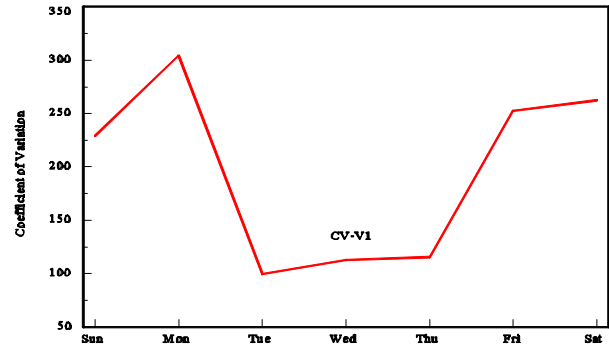
Figure 1.1a. Coefficient of Variation for Motorcycles - Site 9925
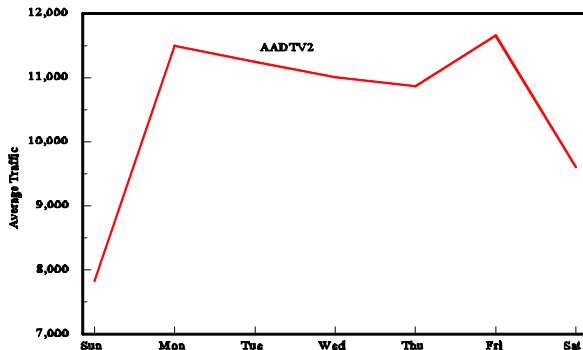
Figure 1.2. Average 1994 Daily Passenger Cars traffic - Site 9925
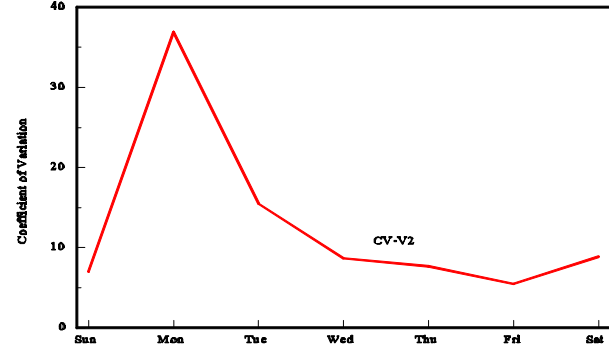
Figure 1.2a. Coefficient of Variation for Passenger Cars - Site 9925

Figure 1.3. Average 1994 Daily Passenger Vehicle 2 Traffic - Site 9925
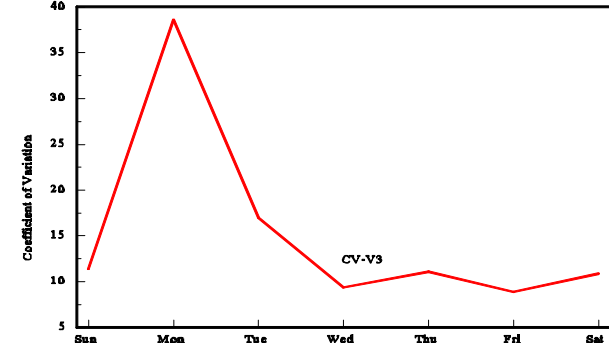
Figure 1.3a. Coefficient of Variation for Passenger Vehicles 2 - Site 9925
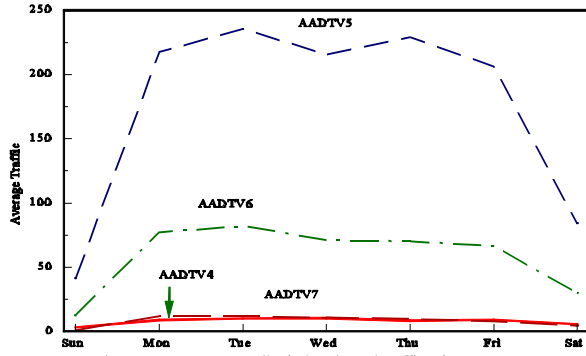
Figure 1.4. Average 1994 Daily Single Unit Truck Traffic - Site 9925
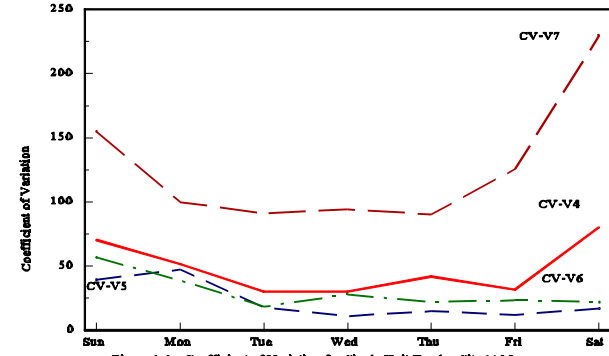
Figure 1.4a. Coefficient of Variation for Single Unit Trucks- Site 9925

Fig. 1. Vehicle Class Mean Daily Traffic Counts and Coefficients of Variation by Day of Week for Florida Classification Site 9925
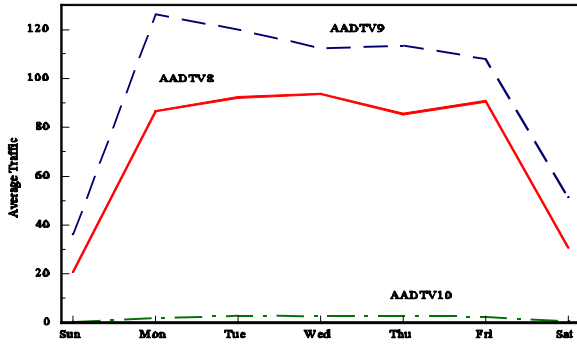
Figure 1.5. Average 1994 Daily Single Trailer Truck Traffic - Site 9925
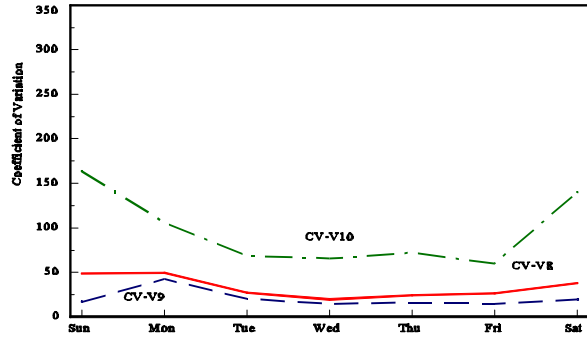
Figure 1.5a. Coefficient of Variation for Single Trailer Trucks - Site 9925
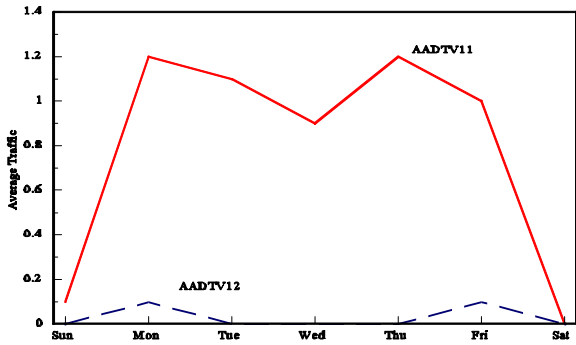
Figure 1.6. Average 1994 Daily Twin Trailer Truck Traffic - Site 9925
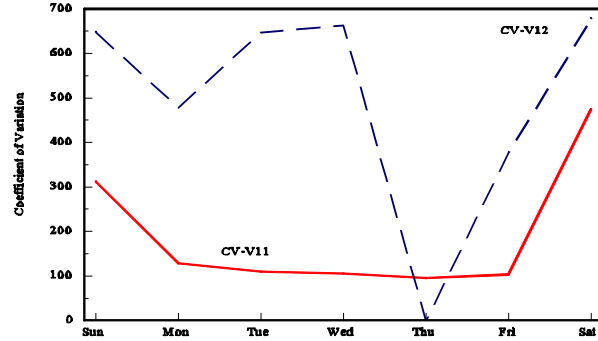
Figure 1.6a. Coefficient of Variation for Twin Trailer Trucks - Site 9925
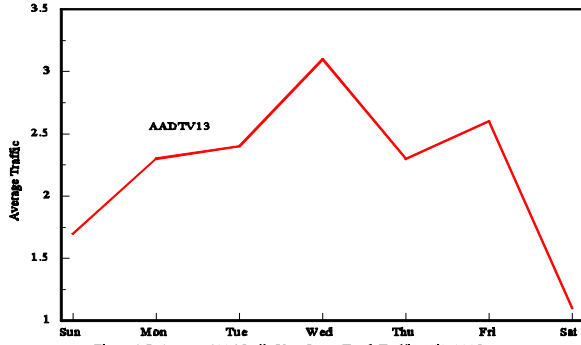
Figure 1.7. Average 1994 Daily Very Large Truck Traffic - Site 9925
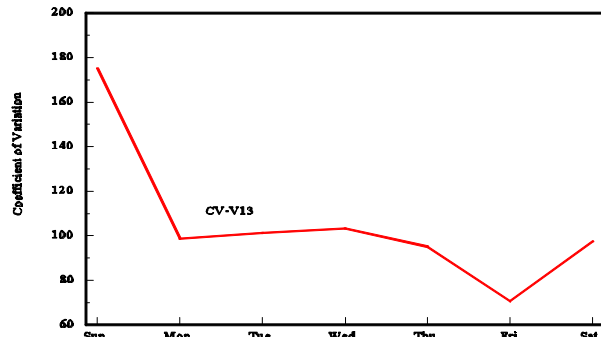
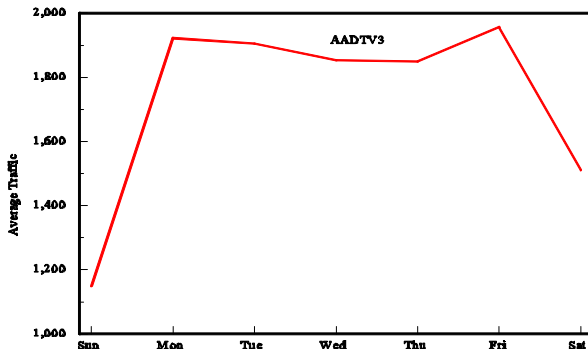Figure 1.7a. Coefficient of Variation for Very Large Trucks - Site 9925
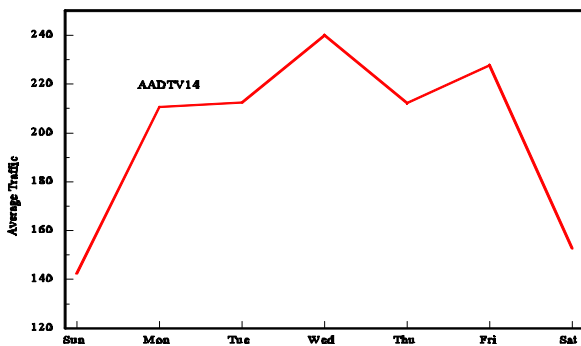
Figure 1.8. Average 1994 Daily Unknown Vehicle Traffic - Site 9925
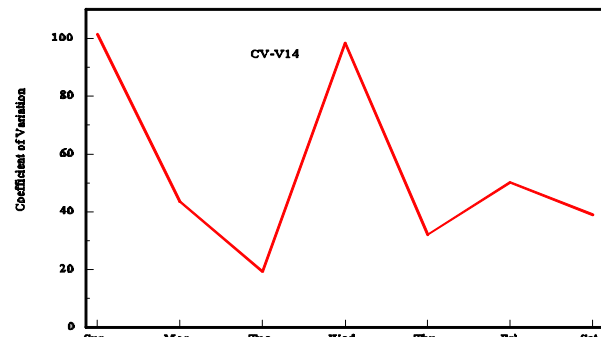
Figure 1.8a. Coefficient of Variation for Unknown Vehicles - Site 9925

Fig. 1. (continued)

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3.3.3 Coefficients of Variation (CV) for Daily ESAL per Vehicle Ranges Over "Days of Week"

The lowest and shortest ranges of the "day of week" coefficients of variation for daily ESAL per vehicle that range over the seven days of the week are for 5-axle single trailers (Vehicle Class 9) (Table 12). Relatively low and short ranges are also observed for Classes 10 (6-or-more axle, single trailers), 12 (6-axle, multi trailers), and 13 (2-or-more axle, multi trailers). The highest and longest ranges appear to exist for 4-or-more axles, single-unit trucks (Classes 7) and for unclassified vehicles (Class 14).

Table 12.
CV Ranges over Days of Week for "ESAL" for
Each Vehicle Class at Each of the 6 Washington Weigh-In-Motion Sites

Vehicle Class	Weigh-In-Motion Sites					
	P10	**P05**	**P17**	**P29**	**P19**	**P07**
(3) Other 2 Axle, 4 Tire, S Unit	30-53	61-235	69-253	268-555	43-67	
(4) Buses	32-42	118-168	208-393	37-60	27-57	78-224
(5) 2 Axle, 6 Tire, S Unit	26-35	54-137	84-260	23-196	23-40	31-157
(6) 3 Axle, S Unit	34-57	62-194	45-163	27-63	22-49	33-85
(7) 4^+ Axle, S Unit	181-343	213-707	325-714	55-190	29-237	156-672
(8) 4^- Axle, S Trailer	23-45	55-110	58-151	22-116	24-64	35-120
(9) 5 Axle, S Trailer	28-32	34-43	21-28	24-28	28-43	22-27
(10) 6^+ Axle, S Trailer	29-40	58-95	41-70	29-38	29-61	25-87
(11) 5^- Axle, M Trailers	28-38	45-97	27-42	26-50	82-209	118-287
(12) 6 Axle, M Trailers	34-46	44-75	32-60	29-39	29-71	41-129
(13) 7^+ Axle, M Trailers	31-34	45-55	22-36	26-40	24-31	20-34
(14) Unclassified Vehicles	79-346	65-187	142-341	91-137	44-150	69-242

3.3.4 Coefficients of Variation (CV) for Daily Weight per Vehicle Ranges Over "Days of Week"

The lowest and shortest ranges of the "day of week" coefficients of variation for daily weight estimates exist for Vehicle Class 9, 5-axle, single trailers (Table 13). By far, the highest and longest ranges appear to exist for four-or-more axles, single unit trucks (Class 7).

Table 13.
CV Ranges over Days of Week for "Weight" for Each Vehicle Class
at Each of the 6 Weigh-In-Motion Sites from Washington

Vehicle Class	Weigh-In-Motion Sites					
	P10	P05	P17	P29	P19	P07
(3) Other 2 Axle, 4 Tire, S Unit	8-12	18-31	27-36	57-91	8-18	
(4) Buses	8-9	51-113	151-233	21-47	7-29	59-163
(5) 2 Axle, 6 Tire, S Unit	8-11	14-21	14-26	7-70	7-10	9-25
(6) 3 Axle, S Unit	8-14	13-37	11-51	8-34	6-12	7-43
(7) 4$^+$ Axle, S Unit	120-202	158-527	247-714	37-122	8-175	129-452
(8) 4$^-$ Axle, S Trailer	7-16	15-28	20-55	6-50	6-15	14-49
(9) 5 Axle, S Trailer	7-9	9-12	6-9	6-13	8-11	7-8
(10) 6$^+$ Axle, S Trailer	9-13	15-36	15-27	9-17	10-19	8-39
(11) 5$^-$ Axle, M Trailers	6-18	16-32	9-20	11-39	34-82	52-225
(12) 6 Axle, M Trailers	9-13	14-22	10-24	8-22	10-45	12-58
(13) 7$^+$ Axle, M Trailers	9-10	10-22	7-10	7-29	8-11	6-16
(14) Unclassified Vehicles	21-36	32-63	38-70	34-74	22-36	17-60

SUMMARY REMARKS
Annual Traffic Estimates and Coefficients of Variation by "Day of Week"

In general, high coefficients of variation tend to occur with vehicle classes that have extremely low mean daily traffic volumes (Figure 2).

For "day of week", high average daily traffic counts appear to have low coefficients of variation. The lowest variability in daily counts seems to occur on Tuesdays, Wednesdays, Thursdays, and Fridays. As a result, the variability among the *weekend* daily traffic counts seems to be higher than the variability among the *weekday* daily traffic counts.

Similarly, the larger coefficients of variation for different vehicle classes tend to occur on Sundays, Mondays, and Saturdays; while the lower coefficients of variation tend to occur on Tuesday through Friday. The lowest CV ranges associated with AADT exist for passenger cars and the highest range exist for multi-trailer trucks. There are statistically significant (á = 0.05) differences between means (and standard deviations) for *weekend* days and *weekdays* at each classification site for each vehicle class.

The "day of week" coefficients of variation for weight are generally lower and have shorter ranges than those for ESAL. The low coefficients of variation for ESAL and weight are for Class 9 (5-axle single-trailer truck) which is generally the class with the highest daily proportion of vehicles. For both ESAL and weight estimates, there are statistically significant differences between mean values for *weekdays* and *weekend* days at each weigh-in-motion site for each vehicle class.

For more details on the statistical differences (á = .05) between means (and standard deviations) for weekdays and weekend days that were observed for the following data, see the indicated reports:

count data	:	Chapter 5 of Task II Report,
classification data	:	Chapter 6 of Task V Report, or
ESAL data/weight data	:	Chapter 6 of Task VIII Report.

These observed differences between weekend day data and weekday data confirm the need that annualization by day of week factors, or at least by weekday and weekend factors, is a necessity.
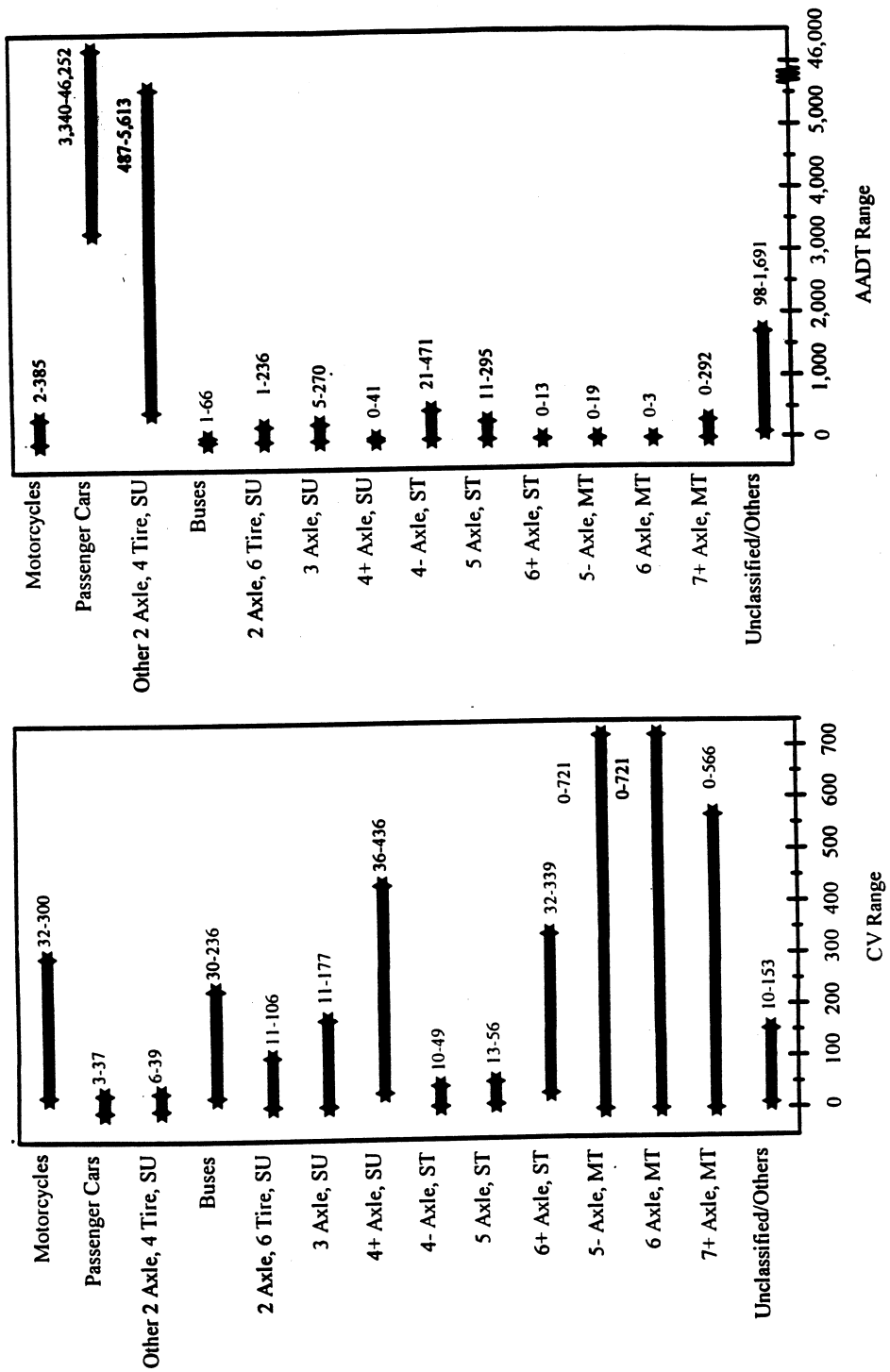
Fig. 2. Ranges of "Day of Week" AADT and Associated CV by Vehicle Class
(based on 8 Florida Classification Sites)

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3.4   Coefficients of Variation (CV) by "Month of Year"

3.4.1   Coefficients of Variation (CV) for AADT by "Month of Year"

We observe similar ranges of CV for each month of the year (Table 14) and slightly higher CV's for the month of the year than for the day of the week.

Table 14.
CV Ranges Over Months of Year
for AADT over Florida's 21 Count Sites (%)

	Month of Year											
All	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Vehicles	6-25	6-23	6-20	7-24	5-26	5-19	6-25	5-21	2-24	7-22	9-25	8-27

3.4.2 Coefficients of Variation (CV) for AADT by Vehicle Class by "Month of Year"

The lowest and shortest ranges of the "month-of-the- year" coefficients of variation are for passenger cars (Class 2) and the next lowest ranges are for other 2-axle, 4-tire, single-unit trucks (Class 3). Also as in Table 15, the highest and longest ranges are for multi-trailer trucks (Classes 11, 12, and 13), mainly because of the low mean daily traffic volumes of these vehicles.

3.4.3   **Coefficients of Variation (CV) for Daily ESAL per Vehicle by Vehicle Class by "Month of Year"**

For the 6 weigh-in-motion sites, the lowest and shortest ranges of the "month-of-the-year" coefficients of variation for daily ESAL per vehicle exist for 5-axle, single-trailer trucks (Class 9) and 7-or-more axles, multi-trailer trucks (Class 13) (Table 16). As in Table 12 for "day-of- week" for ESAL, we observe the highest and longest ranges for 4-or-more axle, single-unit trucks and unclassified trucks.

Table 15.
CV Ranges Over Months of Year for Each Vehicle Class
at Each of the 8 Classification Sites from Florida

Vehicle Class	Classification Sites							
	9925	170	114	177	113	197	246	175
(1) Motorcycles	53-287	33-108	0-64	43-113	26-95	44-77	42-95	38-108
(2) Passenger Cars	10-48	9-13	0-16	12-16	10-16	1-17	7-12	19-26
(3) Other 2 Axle, 4 Tire, S Unit	15-55	16-30	0-30	25-43	19-26	4-34	17-33	27-36
(4) Buses	35-65	61-109	0-163	26-61	49-140	5-84	40-71	25-53
(5) 2 Axle, 6 Tire, S Unit	38-75	49-62	0-79	49-76	45-67	5-65	38-69	45-59
(6) 3 Axle, S Unit	39-75	26-71	0-63	40-94	35-51	20-50	54-63	48-113
(7) 4+ Axle, S Unit	51-194	58-184	0-208	48-75	65-127	67-105	112-200	67-175
(8) 4- Axle, S Trailer	35-83	18-33	0-36	30-46	27-36	11-45	21-42	33-52
(9) 5 Axle, S Trailer	29-70	36-47	0-52	44-74	39-49	5-56	44-53	21-30
(10) 6+ Axle, S Trailer	66-103	58-127	0-78	54-83	64-122	48-87	97-134	70-145
(11) 5- Axle, M Trailers	58-288	0-556	0-539	41-150	111-280	35-67	0-548	78-177
(12) 6 Axle, M Trailers	0-557	0-548	0-305	63-164	0-424	63-131	0-548	79-195
(13) 7+ Axle, M Trailers	60-156	48-374	0-409	36-176	65-154	0-331	135-421	99-328
(14) Unclassified/Others	23-123	21-38	0-43	28-62	17-23	4-36	20-38	42-181

Table 16.
CV Ranges over Months of Year for "ESAL" for Each Vehicle Class
at Each of the 6 Weigh-In-Motion Sites from Washington

Vehicle Class	Weigh-In-Motion Sites					
	P10	P05	P17	P29	P19	P07
(3) Other 2 Axle, 4 Tire, S Unit	15-61	40-288	41-315	31-469	31-66	
(4) Buses	12-32	108-179	178-557	21-67	22-49	50-254
(5) 2 Axle, 6 Tire, S Unit	22-37	40-98	43-156	29-174	33-49	32-115
(6) 3 Axle, S Unit	27-47	56-119	48-98	17-51	18-32	35-94
(7) 4$^+$ Axle, S Unit	158-394	169-548	178-548	60-144	28-63	138-453
(8) 4$^-$ Axle, S Trailer	18-30	45-78	55-100	27-69	29-53	46-83
(9) 5 Axle, S Trailer	8-24	16-54	11-34	7-29	12-32	13-32
(10) 6$^+$ Axle, S Trailer	16-32	42-90	19-61	11-35	19-33	24-71
(11) 5$^-$ Axle, M Trailers	15-38	41-128	17-42	19-47	80-199	95-277
(12) 6 Axle, M Trailers	11-41	28-66	20-55	11-35	26-52	48-86
(13) 7$^+$ Axle, M Trailers	8-24	21-62	16-45	7-29	8-33	15-30
(14) Unclassified Vehicles	32-338	51-114	82-303	47-131	55-80	76-175

3.4.4 Coefficients of Variation (CV) for Average Daily Weight per Vehicle by Vehicle Class by "Month of Year"

For the 6 weigh-in-motion sites, ranges over "month-of-the-year" coefficients of variation for weight are shown in Table 17. We continue to observe that the lowest and shortest ranges appear to occur for 5-axle, single-trailer trucks (Class 9) and that the highest and longest ranges appear to exist for 4-or-more axles, single-trailer trucks (Class 7).

Table 17.
CV Ranges over Months of Year for "Weight" for Each Vehicle Class
at Each of the 6 Weigh-In-Motion Sites from Washington

Vehicle Class	Weigh-In-Motion Sites					
	P10	P05	P17	P29	P19	P07
(3) Other 2 Axle, 4 Tire, S Unit	4-11	11-46	11-52	20-99	6-21	
(4) Buses	3-8	66-116	144-557	5-59	6-35	36-237
(5) 2 Axle, 6 Tire, S Unit	5-11	9-21	9-28	6-80	10-15	8-28
(6) 3 Axle, S Unit	6-12	15-34	15-42	6-42	6-11	9-36
(7) 4$^+$ Axle, S Unit	116-247	140-504	144-548	36-109	20-47	126-385
(8) 4$^-$ Axle, S Trailer	6-12	17-31	21-40	15-49	12-22	21-43
(9) 5 Axle, S Trailer	3-7	5-23	5-12	2-17	4-8	4-8
(10) 6$^+$ Axle, S Trailer	5-10	15-31	7-24	3-29	6-14	7-32
(11) 5$^-$ Axle, M Trailers	5-21	13-35	7-22	10-41	35-78	58-107
(12) 6 Axle, M Trailers	3-10	7-24	5-24	3-23	11-41	25-37
(13) 7$^+$ Axle, M Trailers	3-7	7-23	5-15	3-22	3-10	4-20
(14) Unclassified Vehicles	9-46	16-42	33-86	12-81	25-45	24-58

3.5 Daily Vehicle Mix

Averaging over the 8 classification sites, we obtain the following rankings for the average daily traffic percent mix for 1994 at each classification site (Table 18). (All percents are rounded). Figure 3 presents a graphical example of the count distribution of all vehicle types combined and the class empirical distribution for four vehicle types. Figure 3 shows that the distribution of daily traffic can differ greatly among the vehicle types at a site. For example for Site 9925, the distribution of daily motorcycle traffic (Class 1) is much less variable from day to day than the distribution of daily bus traffic (Class 4).

The occurrence of a multi-trailer vehicle on any day is rare. At almost every one of the 8 classification sites, the level of unclassified/other vehicles is quite high relative to what is captured in other vehicle classes. The large percentage of vehicles being unclassified (Class 14) may signal some cause for concern for the reported counts in the other vehicle classes. It may also signal the need to consider decreasing the number of classes until technology can be improved to distinguish better between similar types of vehicles. This decrease in the number of classes may also lead to a significant decrease in the level of unclassified. One such grouping is proposed in Table 19.

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Table 18.
1994 Daily Vehicle Mix Based on Florida's 8 Classification Sites

	Percent	Vehicle Class	
Highest Ranked Class	83.39	(2)	Passenger Cars
	11.39	(3)	Other 2 Axle, 4 Tire, S Unit Vehicles
	2.09	(14)	Unclassified/Others
	0.99	(8)	4- Axle, S Trailer Trucks
	0.64	(9)	5 Axle, S Trailer Trucks
	0.55	(6)	3 Axle, S Unit Trucks
	0.38	(5)	2 Axle, 6 Tire, S Unit Trucks
	0.21	(1)	Motorcycles
	0.15	(13)	7$^+$ Axle, M Trailers Trucks
	0.11	(4)	Buses
	0.06	(7)	4$^+$ Axle, S Unit Trucks
	0.03	(10)	6$^+$ Axle, S Trailer Trucks
	0.01	(11)	5- Axle, M Trailers Trucks
Lowest Ranked Class	0.00	(12)	6 Axle, M Trailers Trucks
Total	100.00%		

Table 19.
Potential Grouping Scheme of Vehicles

Potential Group Class	Vehicle Classes
G1 Passenger Vehicles -1	2 Passenger Cars
	3 Other 2 Axle, 4 Tire, Single Unit
G2 Single-Unit Trucks	4 Buses
	5 2 Axle, 6 Tire, Single Unit
	6 3 Axle, Single Unit
	7 4$^+$ Axle, Single Unit
G3 Single-Trailer Trucks	8 4$^-$ Axle, Single Trailer
	9 5 Axle, Single Trailer
	10 6$^+$ Axle, Single Trailer
G4 Multi-Trailer Trucks	11 5$^-$ Axle, Multi-Trailer
	12 6 Axle, Multi-Trailer
G5 Unknown Vehicle	14 Unclassified/Other (includes Vehicle Classes 1 and 13)
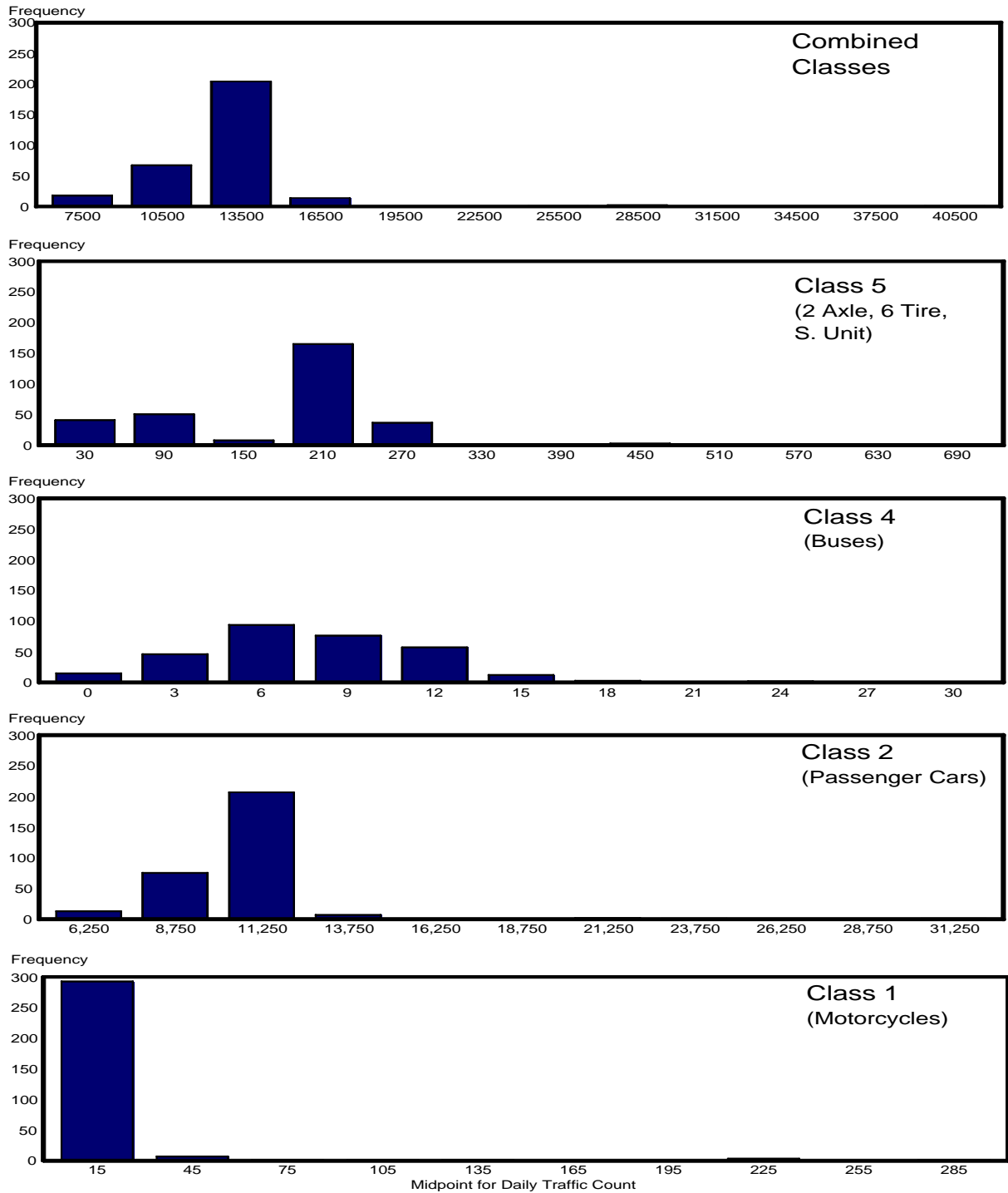
Fig. 3. Example of Combined and Class Empirical Distributions of
1994 Daily Traffic Counts for Classification Site 9925

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3.6. Examination of Five Different Methods for Computing Annual Traffic Estimates

3.6.1 Five Methods for Computing Annual Traffic Estimates

For a given road segment or a site on a given road segment, the aim of **annual average daily traffic (AADT)** is to characterize "...typical daily traffic (count) on (the) road segment for all days of the week, Sunday through Saturday, over the period of one year." [5] Depending on the amount and quality of available data, it appears that there are several methods to compute a quantity to pursue this aim. We compared the following five different methods of computing "typical" daily traffic volume, volume by vehicle class, and average daily ESAL and weight per vehicle:

Method 1:   Average of All Days (Standard Method).
Method 2:   Average of "Monthly" Averages.
Method 3:   Average of "Day of Week" Averages.
Method 4:   Average of "Monthly" and "Day of Week" Averages (AASHTO Method).
Method 5:   Weighted Average of Average of Monthly "Weekday" and "Weekend Day" Averages.

It is assumed that Methods 2 through 5 are proposed to compensate for various patterns of missing data. Detailed steps for each method are described in [2], [3] and [4]. A tool called the maximum ratio is used to determine how close these five estimates are to each other, and how close this set of five estimates is to the true unknown value of the parameter (in our case, AADT, daily ESAL or weight per vehicle) [6].

For illustration purpose, 1994 AADTs for 21 Florida count sites that are estimated using the aforementioned five methods are given in Table 20.

Table 20.

A Comparison AADT Computed Estimates by the Five Different Methods

Func Class[**]	Site	No. of Days	No. of Weekdays	No. of Weekend Days	Number of							No. of Mos	AADT - Methods					How Close Are Methods[*]
					Sun	Mon	Tue	Wed	Thu	Fri	Sat		1	2	3	4	5	
01	119	212	153	59	28	31	30	31	33	28	31	10	30,180	29,592	30,282	29,587	29,613	2.35%
02	223	231	160	71	36	30	35	32	29	34	35	12	4,474	4,427	4,479	4,492	4,439	1.47%
02	65	322	227	95	47	44	46	48	45	44	48	12	7,382	7,375	7,383	7,385	7,373	0.16%
02	9925	308	219	89	43	42	42	44	46	45	46	12	12,661	12,670	12,654	12,653	12,672	0.15%
02	104	347	248	99	48	50	50	50	47	51	51	12	22,098	22,122	22,084	22,118	22,139	0.25%
02	118	345	246	99	48	48	48	50	50	50	51	12	22,262	22,269	22,238	22,234	22,281	0.21%
06	170	353	253	100	48	49	50	52	51	51	52	12	5,284	5,284	5,275	5,277	5,283	0.17%
07	136	263	185	78	40	39	40	37	32	37	38	11	6,336	6,294	6,372	6,329	6,314	1.24%
11	133	283	201	82	41	43	40	41	38	39	41	10	28,026	28,058	28,062	28,097	28,085	0.25%
11	179	210	144	66	33	30	29	29	32	24	33	12	54,599	54,259	54,801	54,432	54,154	1.19%
11	130	341	244	97	48	49	49	46	52	48	49	12	110,865	110,819	110,846	110,677	110,781	0.17%
11	196	252	177	75	37	38	34	38	33	34	38	10	154,304	154,480	154,764	154,899	155,022	0.47%
12	204	212	151	61	30	32	32	31	27	29	31	9	28,294	28,047	28,354	28,131	28,046	1.10%
14	114	267	192	75	38	40	40	37	39	36	37	12	14,436	14,695	14,437	14,581	14,578	1.80%
14	177	333	235	98	48	48	46	47	45	49	50	12	33,290	33,428	33,341	33,486	33,524	0.70%
14	102	278	200	78	39	40	41	42	40	37	39	10	40,753	40,737	40,775	40,768	40,708	0.17%
14	154	220	154	66	33	31	31	32	26	34	33	11	44,030	43,851	44,143	43,923	44,265	0.95%
14	113	326	229	97	47	47	46	47	41	48	50	12	45,825	45,793	45,900	45,874	45,943	0.33%
14	197	212	151	61	32	29	30	31	32	29	29	9	47,270	47,716	47,374	47,412	47,325	0.94%
16	246	278	197	81	39	40	40	41	36	40	42	10	7,681	7,706	7,686	7,710	7,713	0.41%
16	175	342	244	98	48	49	47	48	50	50	50	12	39,920	39,922	39,905	39,891	39,945	0.14%

* How close are the methods? The 5 estimates are within X% of each other.

** For functional class definition, see Table 1.

3.6.2 Preliminary Comments Based on the Empirical Comparison

For each of the 21 Florida count sites, all of the 5 estimates of AADT are within 2.5% or less of each other. Actually, for 15 out of the 21 sites, the 5 estimates of AADT are within less than 1% of each other. For example with Site 170, the percent closeness (maximum ratio) of the 5 estimates is computed by

$$Percent\ Closeness\ =\ Maximum\ Ratio$$

$$=\ \frac{Max\ Estimate - Min\ Estimate}{Min\ Estimate} \times 100\%$$

$$=\ \frac{5{,}284 - 5{,}275}{5{,}275} \times 100\%$$

$$\approx\ 0.17\%.$$

For practical purposes, it can be argued that this preliminary result shows no real differences among the estimates produced by the five different methods for the count sites which all suffer from various patterns of missing data.

For most vehicle classes at each site, all of the 5 estimates of AADT are within 5% or less of each other. These AADT estimates by classes (i.e., classification data) are not as close as the estimates for all vehicle classes combined (i.e., count data). In cases where the 5 estimates of AADT are not within 5% of each other, we observe that the estimates from Methods 1 and 3 are lower than the estimates from Methods 2, 4, and 5. A closer look at these cases reveals that there is: *(i)* a difference in "monthly" daily means, *(ii)* not a very great difference in "day of week" daily means, and *(iii)* a difference in amount of data from month to month, but not a very great difference in data from one day of the week to the next. Indeed, in many of these cases where the 5 estimates of AADT are not within 5% of each other, the vehicle traffic volume is near zero or the difference among the estimates is less than "1" vehicle.

For vehicle classes with low mean daily traffic volumes, a few cases gave 5 estimates which were not very close to each other. On the other hand, for vehicle classes with high mean daily traffic volumes, the 5 methods produced estimates which were very close to each other. These results may be additional motivation for combining some vehicle classes, especially among classes with low mean daily traffic volumes.

Similar to results with count data and classification data, the 5 different estimation methods appear to have little effect on the daily means of ESAL and weight for each vehicle class [4].

SUMMARY REMARKS
Five Different Estimation Methods

Almost all of the 5 estimates of annual estimates (AADT, AADT by vehicle class, daily ESAL and weight per vehicle) are within at most 5% of each other. Because no practical differences were observed among the estimates produced by the five different approaches (including the AASHTO Method), we recommend Method One for simplicity! Method One calls for computing the average of the daily traffic estimates.

3.7 Missing Data

Continuous traffic monitoring is plagued by missing *(i)* count data, *(ii)* classification count data, and *(iii)* weigh-in-motion data. Data are missing for several reasons including *(i)* equipment failure, *(ii)* construction, *(iii)* removal of data during the editing process, and (iv) the time of equipment installation. Tables 21, 22, and 23 show graphics which show the level of missing 1994 days of data at the sites for the different types of data.

For the sites considered, relatively few days of weigh-in-motion data are missing. A close examination of the three tables (graphics) would reveal that missing data for a given site are roughly uniformly distributed over the days of the week, but not roughly uniformly distributed over the months of the year. For example, by looking at the 8 classification sites, we show the number of days in 1994 where data are missing by days of week (Table 24) and by month of year (Table 25).

Table 21.
Graphic of Missing Days for the 21 Selected Sites from Florida's District 5
(Block Means Missing Day)

Days in the Year

35
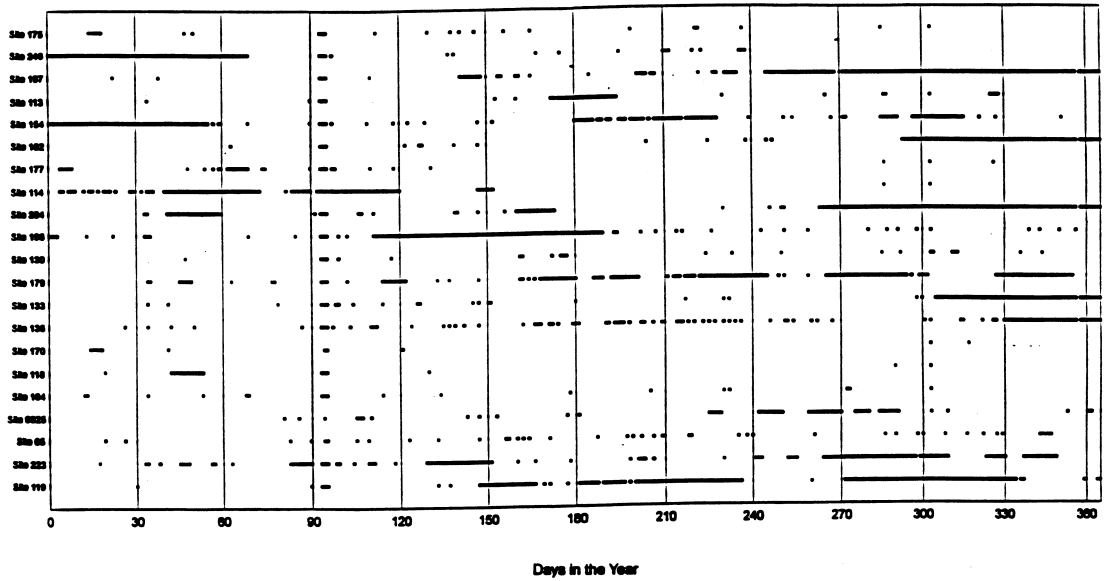
Table 22.
Graphic of Missing Days for the 8 Selected Classification Sites from Florida's District 5
(Block Means Missing Day)
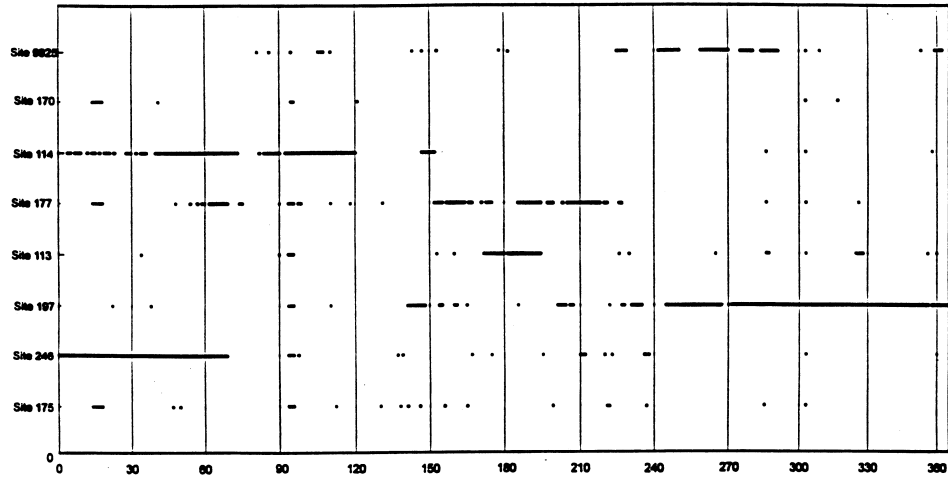
Table 23.
Graphic of Missing Days for the 6 Selected WIM Sites from Washington
(Block Means Missing Day)

Days in the Year

36
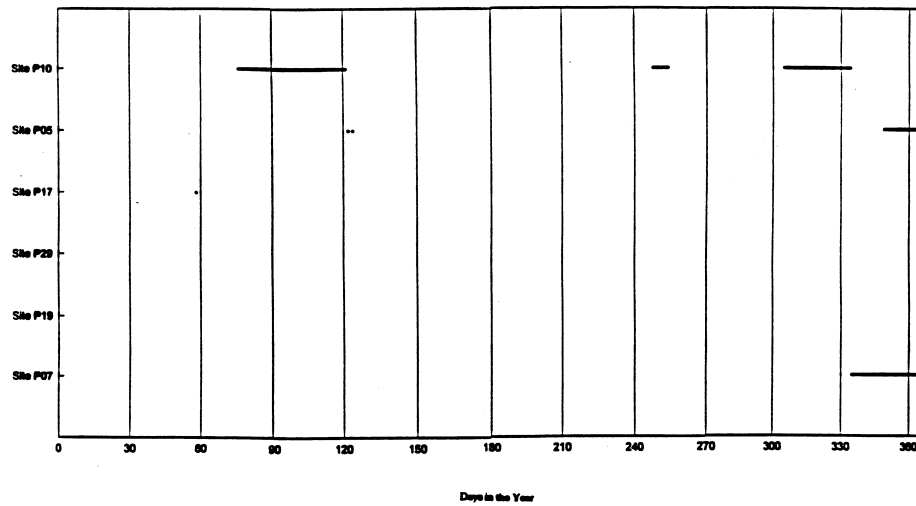
Table 24.

1994 Missing Days of Classification Data by Days of Week

Site	Sun	Mon	Tue	Wed	Thu	Fri	Sat
9925	10	10	10	8	6	7	7
170	4	3	2	0	1	1	1
114	14	12	12	15	13	16	17
177	10	14	11	13	14	10	9
113	6	6	6	5	12	4	3
197	20	23	22	21	20	23	24
246	13	13	12	11	16	12	11
175	4	3	5	4	2	2	3

Table 25.

1994 Missing Days of Classification Data by Months of Year

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
9925	0	0	2	5	2	3	0	7	19	15	1	4
170	5	1	0	2	1	0	0	1	0	1	1	0
114	15	24	22	29	5	1	0	0	0	2	0	1
177	5	4	11	7	1	18	22	10	0	2	1	0
113	0	1	1	3	0	12	13	2	1	3	4	2
197	1	1	0	4	8	5	7	8	27	31	30	31
246	31	28	10	4	2	2	4	5	0	1	0	1
175	5	2	0	4	4	2	1	3	0	2	0	0

It is clear from Tables 21, 22, and 23 that the missing days of traffic monitoring data occur in *single isolated days* as well as in *consecutive days*.

3.8 Simulations with Randomly Missing Data

The effect of missing data on annual traffic estimates (i.e., AADT, AADT by vehicle class, average daily ESAL, and weight per vehicle) was investigated. On all study sites, we randomly set data to be missing. Three levels of missing data were simulated:

(*i*)   5% of days of data missing at random,
(*ii*)   20% of days of data missing at random, and
(*iii*) 50% of days of data missing at random.

The simulation follows the following steps. For a specific Florida site, let N be its number of days of available "edited" count data. Let $d_1 = .05N$, and round to the nearest integer. Next, randomly select and remove d_1 days of count data from the given site. For the $N - d_1$ remaining days of count data, compute the average daily traffic and the associated coefficient of variation. Replace the d_1 days and repeat the above steps 999 additional times. Thus, for the given site, we have 1,000 different values of average daily traffic and 1,000 different coefficients of variation. Compute the average of the 1,000 values of average daily traffic and denote it by $SADT_1$ for "simulated average daily traffic" without 5% of days of count data. This process was repeated for each of the 21 Florida count sites.

We repeated this procedure under the scenarios that 20% or 50% of days of count data were missing. The simulated average daily traffic without 20% of days of count data is denoted by $SADT_2$, and the simulated average daily traffic without 50% of days of count data is denoted by $SADT_3$. The results of this simulation of count data are described in Table 26.

If data for 5% or 20% of the days are missing at random, the simulated AADTs (denoted by $SADT_1$ and $SADT_2$, respectively) are essentially the same as the original AADT for each site. Though the simulated average value of AADT when data for 50% of the days are missing (denoted by $SADT_3$) is also close to the original AADT, it does not tend to be as close as $SADT_1$ and $SADT_2$. Note also from the values in parentheses in columns 5, 6 and 7 of Table 26 that the simulated standard errors increase from $SADT_1$ to $SADT_2$ to $SADT_3$.

Under random sampling, sampling theory states that the expected values of $SADT_1$, $SADT_2$ and $SADT_3$ will all be AADT and that the standard errors will increase from $SADT_1$ to $SADT_2$ to $SADT_3$. That is, the more (randomly) missing data, the more unreliable the estimate, even though the estimate is on target (on average).

For these 21 sites, one might argue that even with 50% of the count data missing at random, the reliability of the estimate is quite high. And, the loss in AADT reliability due to missing data might very well be tolerable. Results based on sites examined suggest that randomly missing data do not significantly bias the estimation of average traffic and loading patterns. More research is needed, which is beyond the scope of this research study.

In summary, these preliminary simulations suggest that randomly missing days of count data have little effect on the average value of the coefficient of variation with AADT, based on the non-missing days of count data. Similarly, randomly missing days of classification count data (or weigh-in-motion data) appear to have little effect on the mean traffic volume estimate (or weigh-in-motion estimates) and associated CV estimate for each vehicle class.

Table 26.

Simulation Results for $AADT_1$ with Randomly Missing Days of Count Data*

Func Class***	Site	N	Original AADT	Amount of Randomly Missing Data			How Close are $SADT_i$ and AADT? The 2 estimates are within X% of each other.		
				5%	20%	50%			
				$SADT_1$*****	$SADT_2$*****	$SADT_3$*****	$SADT_1$	$SADT_2$	$SADT_3$
01	119	212	30,180	30,185 (101)	30,179 (215)	30,207 (445)	0.02%	0.00%	0.09%
02	223	231	4,474	4,474 (12)	4,475 (24)	4,475 (46)	0.01%	0.02%	0.02%
02	65	322	7,382	7,381 (11)	7,383 (22)	7,385 (45)	0.01%	0.01%	0.04%
02	9925	308	12,661	12,661 (25)	12,661 (55)	12,657 (109)	0.00%	0.00%	0.03%
02	104	347	22,098	22,099 (21)	22,101 (48)	22,091 (95)	0.00%	0.02%	0.03%
02	118	345	22,262	22,264 (34)	22,263 (75)	22,256 (156)	0.01%	0.00%	0.03%
06	170	353	5,284	5,283 (8)	5,285 (17)	5,285 (36)	0.01%	0.03%	0.01%
07	136	263	6,336	6,336 (17)	6,336 (37)	6,336 (71)	0.01%	0.00%	0.00%
11	133	283	28,026	28,028 (58)	28,031 (128)	28,016 (261)	0.01%	0.02%	0.04%
11	179	210	54,599	54,599 (121)	54,592 (264)	54,603 (523)	0.00%	0.01%	0.01%
11	130	341	110,865	110,863 (124)	110,861 (254)	110,847 (529)	0.00%	0.00%	0.02%

*   Simulated results are rounded. Some percents rounded to zero.

**   For functional class definition, see Table 1.

***   The numbers in parenthesis are the standard deviations of the 1,000 simulated values $SADT_i$ for each site.

| Func Class[*] | Site | N | Original AADT | Amount of Randomly Missing Data | | | How Close are SADT$_i$ and AADT? The 2 estimates are within X% of each other. | | |
| | | | | 5% | 20% | 50% | | | |
				SADT$_1$[**]	SADT$_2$[***]	SADT$_3$[***]	SADT$_1$	SADT$_2$	SADT$_3$
11	196	252	154,304	154,308 (265)	154,318 (590)	154,339 (1,175)	0.00%	0.01%	0.02%
12	204	212	28,294	28,293 (54)	28,287 (113)	28,301 (228)	0.01%	0.03%	0.02%
14	114	267	14,436	14,436 (28)	14,436 (58)	14,429 (126)	0.00%	0.01%	0.05%
14	177	333	33,290	33,292 (69)	33,282 (155)	33,303 (314)	0.01%	0.02%	0.04%
14	102	278	40,753	40,756 (83)	40,753 (170)	40,755 (343)	0.01%	0.00%	0.00%
14	154	220	44,030	44,031 (77)	44,030 (176)	44,035 (338)	0.00%	0.00%	0.01%
14	113	326	45,825	45,826 (82)	45,829 (173)	45,820 (369)	0.00%	0.01%	0.01%
14	197	212	47,270	47,272 (120)	47,278 (263)	47,270 (527)	0.01%	0.02%	0.00%
16	246	278	7,681	7,681 (11)	7,682 (23)	7,682 (49)	0.00%	0.01%	0.01%
16	175	342	39,920	39,917 (113)	39,917 (238)	39,927 (485)	0.01%	0.01%	0.02%

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* Simulated results are rounded. Some percents rounded to zero.

** For functional class definition, see Table 1.

*** The numbers in parenthesis are the standard deviations of the 1,000 simulated values SADT$_i$ for each site.

The simulated average values of coefficient of variation (SCV_1, SCV_2 and SCV_3 in Table 27) are all essentially the same as CV. As with AADT, if we look at the associated simulated standard errors in parenthesis, we see that SCV_1 is more reliable than SCV_2 which is more reliable than SCV_3.

In addition to having single days of data missing in isolation, missing data also tend to be missing for 2 or more consecutive days. This seems reasonable if the main reason for missing data is equipment failure and if the time to discover and repair the failure is allowed. The effect of the following different variations of missing consecutive days on AADT and CV was investigated.

   (*i*)   One randomly missing week.
  (*ii*)   Two randomly missing weeks.
 (*iii*)   One randomly missing period of two consecutive weeks.
  (*iv*)   Two randomly missing periods of two consecutive weeks.
   (*v*)   One randomly missing month.
  (*vi*)   Two randomly missing months.
 (*vii*)   One randomly missing period of two consecutive months.

These missing data patterns emulate, to some extent, data patterns that were observed in Tables 21 through 23.

All seven different patterns of randomly consecutive missing days of count data have simulated average values $SADT_i$ (i=I,...,VII) that are all essentially the same as AADT for each site and are all quite close to each other for each site. The simulated standard errors increase from $SADT_I$ to $SADT_{VII}$.

There appear to be no patterns of systematically missing data at each of the selected sites (See Tables 21 through 23). It is difficult to say that the missing days of data are missing at random. However, the message of this analysis is that if we have randomly missing days, even high levels of randomly missing days, reliable results for AADT (or AADT by vehicle class, average daily ESAL and weight per vehicle) can be obtained. This is based on theoretical results in probability sampling theory. Even if we have randomly consecutive missing days (clusters), reliable results for AADT can still be obtained which are also based on theoretical results. These findings also suggest the possibility of estimating typical traffic and loading patterns based on a statistical sample of the continuous data, rather than based on the entirety of the available continuous data. One advantage of sampling continuous data is to reduce the data processing burden. Sampling strategies (based on "days" or "clusters of days") can be developed that reliably provide the details of the sought after "100% data from continuously monitored sites."

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SUMMARY REMARKS
Effects of Missing Data on Annual Traffic Estimates

Continuous traffic monitoring is plagued by missing data which seems to mainly be due to equipment failure, construction schedules, and installation dates. Data do not appear to be missing for certain hours of the day, days of the week, nor months of the year. Data are missing on isolated days as well as on consecutive days. For 6 weigh-in-motion sites, entire months of weigh-in-motion data at a site can be missing due to construction or new installation. We observed no systematic pattern of missing data. Continuous traffic monitoring which results in 365 days of complete data currently seems to be uncommon.

Missing data seem to have a negligible effect on estimated traffic characteristics (i.e., AADT, AADT by vehicle class, daily ESAL or daily weight per vehicle). However, the reliability of the estimated traffic characteristics (i.e., AADT, AADT by vehicle class, daily ESAL or weight per vehicle) decreases (on average) as the amount of randomly missing data increase (5% $\rightarrow$ 20% $\rightarrow$ 50%). That is, as the amount of randomly missing data increases, the more unreliable the estimates, even though they are on target (on average). In many cases, the loss of reliability is tolerable. Similarly, the amount of missing data had negligible effect on the estimated coefficients of variation for the sites considered.

It is important to track missing data at each monitoring site. Graphics such as shown in Tables 21, 22, or 23 can easily reveal systematic patterns of missing data. Systematic patterns of missing data typically signal potential equipment problems. By tracking missing data on a periodic basis, these problems can be corrected in a timely fashion.

Table 27.
Simulation Results for CV with Randomly Missing Days of Count Data*

Func Class	Vol Group	Site	N	CV	Amount of Randomly Missing Data			How Close are SCV_i and CV? The 2 estimates are within X% of each other.**		
					5%	20%	50%			
					SCV_1***	SCV_2***	SCV_3***	SCV_1	SCV_2	SCV_3
01	04	119	212	21.2	21.2	21.2	21.2	0.05%	0.05%	0.33%
					(0.3)	(0.6)	(1.3)			
02	01	223	231	16.5	16.5	16.5	16.4	0.18%	0.06%	0.79%
					(0.4)	(0.8)	(1.6)			
02	02	65	322	11.0	11.1	11.1	11.0	0.04%	0.04%	0.15%
					(0.1)	(0.2)	(0.4)			
02	03	9925	308	15.0	15.0	15.0	15.0	0.06%	0.06%	0.26%
					(0.2)	(0.4)	(0.7)			
02	05	104	347	8.0	8.0	8.0	8.0	0.08%	0.08%	0.08%
					(0.1)	(0.2)	(0.4)			
02	05	118	345	12.6	12.6	12.6	12.6	0.06%	0.06%	0.29%
					(0.2)	(0.4)	(0.7)			
06	03	170	353	12.3	12.3	12.3	12.3	0.07%	0.18%	0.10%
					(0.1)	(0.3)	(0.5)			
07	03	136	263	18.6	18.6	18.6	18.6	0.03%	0.07%	0.07%
					(0.2)	(0.4)	(0.8)			
11	02	133	283	15.4	15.4	15.4	15.3	0.06%	0.00%	0.46%
					(0.2)	(0.5)	(1.0)			
11	03	179	210	13.7	13.7	13.8	13.7	0.01%	0.14%	0.30%
					(0.2)	(0.4)	(0.7)			
11	05	130	341	8.9	8.9	8.9	8.9	0.04%	0.07%	0.15%
					(0.1)	(0.2)	(0.3)			
11	07	196	252	12.2	12.2	12.2	12.2	0.01%	0.01%	0.01%
					(0.1)	(0.3)	(0.6)			
12	02	204	212	11.7	11.7	11.8	11.7	0.03%	0.06%	0.11%
					(0.2)	(0.3)	(0.7)			
14	04	114	267	13.6	13.6	13.6	13.7	0.01%	0.01%	0.30%
					(0.2)	(0.3)	(0.7)			
14	07	177	333	16.6	16.6	16.6	16.6	0.06%	0.06%	0.18%
					(0.2)	(0.4)	(0.7)			
14	08	102	278	14.4	14.4	14.4	14.4	0.02%	0.05%	0.30%
					(0.2)	(0.4)	(0.8)			
14	08	154	220	11.6	11.6	11.6	11.6	0.03%	0.03%	0.03%
					(0.1)	(0.3)	(0.6)			
14	09	113	326	14.0	14.0	14.0	14.0	0.04%	0.04%	0.11%
					(0.2)	(0.4)	(0.7)			
14	09	197	212	16.1	16.1	16.1	16.1	0.01%	0.08%	0.01%
					(0.2)	(0.5)	(1.0)			
16	03	246	278	10.4	10.4	10.4	10.4	0.06%	0.04%	0.04%
					(0.1)	(0.2)	(0.5)			
16	08	175	342	22.4	22.4	22.4	22.4	0.01%	0.01%	0.08%
					(0.2)	(0.5)	(1.0)			

* The numbers in parenthesis are the standard deviations of the 1,000 simulated values SCV_i for each site.

** See Appendix C for more details.

*** Simulated results are rounded. Some percents rounded to zero.

3.9   Effect of Holidays and Special Days

The table below lists holidays and "holiday periods" in 1994, defined with the assistance of the Florida DOT. For each of the 21 selected sites, Table 28 presents the AADT and CV calculated under the following conditions:

Condition 1: All days of data used
Condition 2: Data with all specific holidays removed
Condition 3: Data with all "holiday period" days removed

where

Holiday	Specific Date	"Holiday Period"
New Year's Day	January 1, 1994	January 1, 2, 3, 4, 1994
Martin Luther King B-Day	January 17, 1994	January 14, 15, 16, 17, 18, 1994
Memorial Day	May 30, 1994	May 27, 28, 29, 30, 31, 1994
Independence Day	July 4, 1994	July 1, 2, 3, 4, 5, 6, 7, 1994
Labor Day	September 5, 1994	September 2, 3, 4, 5, 6, 1994
Veterans Day	November 11, 1994	November 10, 11, 12, 1994
Thanksgiving	November 24, 1994	November 21, 22, 23, 24, 25, 26, 27, 28, 1994
Christmas	December 25, 1994	December 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 1994

From Table 28, the AADT *increases* at 18 of the 21 sites from Condition 1 (all available days) to Condition 2 (all days except specific holidays). Also, the AADT *increases* at 15 of the 21 sites from Condition 1 (all available days) to Condition 3 (all days except those in holiday periods). However, in both cases, the increases (and decreases) are relatively small amounts. The closeness of the AADT values under the three different conditions is reflected in Table 28.

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Based on these preliminary results, and assuming a minimum number of days of available edited data, the effect of holidays and holiday periods on overall AADT is negligible. Similarly, the effect of holiday and holiday period traffic seems negligible on overall daily traffic counts, ESAL, and weight estimates for each vehicle class.

From Table 28, the (rounded) CV *decreases* at 16 of the 21 sites from Condition 1 (all available days) to Condition 2 (all days except specific holidays). Also the (rounded) CV *decreases* at 20 of the 21 sites from Condition 1 (all available days) to Condition 3 (all days except those in holiday periods). However, in both cases these decreases are small. Moreover, these decreases in CV are not surprising when one considers that the daily traffic on these holiday period days is less than on the rest of the days.

Although the effect of holidays and holiday periods on overall AADT appears negligible, the effect on CV, i.e., variability, is small but not negligible. Similar results were observed for the classification data [3] and for the weigh-in-motion data [4].

SUMMARY REMARKS
Effect of Holiday and Special Days on Annual Traffic Characteristics

Although the effect of holidays and holiday periods appears negligible on overall AADT, daily traffic counts by vehicle class, daily ESAL and weight estimates for each vehicle class, the effect on CV (i.e., variability) is small but not negligible.

It is very interesting to note that removal of holidays and holiday periods tended to yield increased AADT at most of the sites examined. This suggests that the traffic is lower during the holidays than during non-holidays and seems to refute the common belief that holiday periods have more traffic. Examination of this point is recommended for more sites in more states. The observation that CV's decrease when holidays and holiday periods are removed indicates that there is likely more traffic variability during holiday periods.

Table 28.
Effect of Holidays and Special Days on AADT and CV (%)

Func'l Class**	Site	AADT Condition 1	AADT Condition 2	AADT Condition 3	How Close Are The AADT's?*	CV Condition 1	CV Condition 2	CV Condition 3	How Close Are The CV's?*
01	119	30,180	30,111	29,681	1.68%	21.2	21.3	20.5	3.71%
02	223	4,474	4,486	4,447	0.88%	16.5	16.5	15.7	5.16%
02	65	7,382	7,370	7,330	0.70%	11.1	11.0	11.0	0.45%
02	9925	12,661	12,741	12,785	0.98%	15.0	14.2	13.9	7.63%
02	104	22,098	22,145	22,229	0.59%	8.0	7.8	7.8	3.09%
02	118	22,262	22,322	22,110	0.96%	12.6	12.5	10.9	15.96%
06	170	5,284	5,303	5,308	0.46%	12.3	11.9	11.7	5.04%
07	136	6,336	6,376	6,434	1.55%	18.6	18.0	17.5	6.23%
11	133	28,026	28,008	27,968	0.21%	15.4	15.5	15.1	2.45%
11	179	54,599	54,753	54,866	0.49%	13.7	13.7	13.8	0.95%
11	130	110,865	110,998	110,777	0.20%	8.9	8.9	8.8	1.36%
11	196	154,304	154,805	155,392	0.71%	12.2	11.8	11.4	6.84%
12	204	28,294	28,414	28,542	0.88%	11.7	11.5	11.3	3.89%
14	114	14,436	14,519	14,533	0.68%	13.6	12.8	12.6	8.10%
14	177	33,290	33,502	33,534	0.73%	16.6	15.9	15.7	5.86%
14	102	40,753	40,993	41,177	1.04%	14.4	13.8	13.5	6.89%
14	154	44,030	44,251	44,372	0.78%	11.6	11.0	10.3	12.33%
14	113	45,825	46,035	46,165	0.74%	14.0	13.3	13.1	6.64%
14	197	47,270	47,449	47,742	1.00%	16.1	15.6	15.2	5.86%
16	246	7,681	7,712	7,745	0.83%	10.4	10.0	9.8	5.82%
16	175	39,920	40,255	40,537	1.54%	22.4	21.4	20.9	7.32%

*   How close are the 3 estimates? The 3 estimates are within X% of each other.
** For functional class definition, see Table 1.

3.10 Empirical Analysis of Variance of Continuous Traffic Monitoring Data

We also investigate the main contributors to the variance in traffic in terms of the "day of week," "month of year," and "holiday periods" vs. "non-holiday periods." Contributions to the variability for each day of the week were ranked as 1= the smallest daily contribution to variability and 7 = the largest daily contribution to variability. Table 29 is an overall ranking of the days of the week in terms of their contributions to traffic count variability, averaged over all 21 Florida count sites. Table 30 is an overall ranking of the months of the year, in terms of their contributions to traffic count variability.

Similarly, Table 31 presents an overall ranking of the days of the week in terms of their contributions to traffic classification variability. The contributions to traffic classification variability differ among vehicle classes. For example, for motorcycles (Vehicle Class 1), buses (4), and single units (7), the larger daily contributor to variability tends to be weekdays rather than weekend days. For passenger cars (2), other 2-axle 4-tire single-unit vehicles (3), single units (5 and 6), and single-trailer trucks (8 and 9), the larger daily contributors to variability tend to be weekend days rather than weekdays. For multi-trailers trucks (11, 12, and 13), the larger daily contributor to variability tends to be weekdays rather than weekend days for Week Type 1 (Monday through Friday) and for Week Type 2 (Monday through Thursday), except for vehicle class 12 (6-axle, multi-trailer trucks).

Similarly, Table 32 presents an overall ranking of the months of the year in terms of their contributions to traffic *classification* variability. Again, the "month-of-year" contributions to the variability in traffic classification data differ among vehicle classes. For vehicle classes 1, 4, 7, 11, 12, 13, and 14, the larger daily contributor to the variability in traffic *classification* data tends to be "non-holiday period days" rather than the "all holiday period days." The reverse is true for vehicle classes 2, 3, 5, 6, 8, 9, and 10.

Table 29.

Overall Ranking for Contributions to Variability of Traffic *Count* Data by Days of Week

(based on 21 Florida count sites)

1 (smallest contributor to variability)	Tuesday
2	Monday
3	Wednesday
4	Thursday
5	Saturday
6	Friday
7 (largest contributor to variability)	Sunday

Table 30.

Overall Ranking for Contributions to Variability of Traffic *Count* Data

by Months of Year

(based on 21 Florida count sites)

1 (smallest contributor to variability)	June
2	August
3	May
4	October
5	February
6	April
7	July
8	September
9	March
10	November
11	January
12 (largest contributor to variability)	December

Table 31.

Overall Ranking for Contributions to Variability of Traffic *Classification* Data by Days of Week

(based on 8 Florida Classification Sites)

	Day of Week						
Vehicle Class	Sun	Mon	Tue	Wed	Thu	Fri	Sat
(1) Motorcycles	2	3	4	7	5	6	1
(2) Passenger Cars	7	4	1	2	3	6	5
(3) Other 2 Axle, 4 Tire, S Unit	7	3	1	2	4	5	5
(4) Buses	2	4	6	3	7	4	1
(5) 2 Axle, 6 Tire, S Unit	7	3	4	2	5	1	6
(6) 3 Axle, S Unit	7	3	1	4	5	2	6
(7) 4+ Axle, S Unit	2	4	5	7	6	3	1
(8) 4- Axle, S Trailer	7	3	1	2	4	5	6
(9) 5 Axle, S Trailer	7	5	2	3	4	1	6
(10) 6 Axle, S Trailer	6	6	4	2	5	2	1
(11) 5- Axle, M Trailers	2	3	4	6	5	7	1
(12) 6 Axle, M Trailers	4	2	2	6	5	7	1
(13) 7+ Axle, M Trailers	3	5	5	7	2	4	1
(14) Unclassified/Other	4	4	2	6	3	7	1
COMBINED*	7	4	1	2	3	6	5

* From Result 22 of [2] using only the 8 classification sites.

Table 32.

Overall Ranking for Contributions to

Variability of Traffic *Classification* Data by Months of Year

(Based on 8 Florida Classification Sites)

Vehicle Class	Month of Year											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(1) Motorcycles	7	7	12	11	4	5	2	1	3	10	5	7
(2) Passenger Cars	12	5	6	2	4	3	8	1	9	6	11	10
(3) Other 2 Axle, 4 Tire, S Unit	11	9	12	6	3	2	7	1	4	9	7	4
(4) Buses	11	7	12	10	5	1	2	3	4	8	6	9
(5) 2 Axle, 6 Tire, S Unit	11	5	8	2	8	4	3	1	5	10	12	7
(6) 3 Axle, S Unit	8	11	5	4	12	2	10	1	6	9	7	3
(7) 4+ Axle, S Unit	10	12	8	1	5	4	7	3	2	6	9	10
(8) 4- Axle, S Trailer	11	6	8	4	7	1	2	2	5	12	10	8
(9) 5 Axle, S Trailer	6	5	11	4	12	3	8	1	2	10	7	8
(10) 6 Axle, S Trailer	5	4	6	3	10	12	11	8	1	1	8	7
(11) 5- Axle, M Trailers	1	2	10	6	3	9	8	7	12	11	5	4
(12) 6 Axle, M Trailers	10	8	4	12	9	4	3	6	2	1	11	7
(13) 7+ Axle, M Trailers	6	4	7	1	2	9	7	2	4	12	11	10
(14) Unclassified/Other	7	11	6	3	2	4	5	1	8	12	8	8
COMBINED*	12	6	10	3	5	1	9	2	7	4	7	11

*From Result 23 of Task II Report using only the 6 classification sites (9925, 170, 114, 177, 113, and 175) that had classification data for all twelve months of 1994.

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4. PRECISION OF SHORT-TERM TRAFFIC MONITORING DATA

       We conducted simulation studies to study the extent to which the variability in the continuous traffic data is transferred to, and affects the precision of, short-term monitoring data. In these studies, we created seasonal (monthly) factors and day-of-week factors from the continuous monitoring sites. Given these factors, we considered that we have only one day's (24 hour period) worth of data from each of the continuous monitoring sites. That is, we assumed that the site is a short-term monitored site. Given the factors and the 24 hour period of data, we calculated annual estimates of traffic characteristics (i.e., AADT, AADT by vehicle class, daily ESAL and weight per vehicle). Our interest is in the **precision** of these estimates. To get an appropriate indication of this precision, we calculated an annual estimate based on each day of available data for each site. Thus, for a given continuously monitored site and with N days of data, we have N different annual estimates, each obtained by treating the site as a short-term monitored site. We also have the original estimate obtained by treating the site as a continuously monitored site. For each site, we compute the average of the squared deviations, where a deviation is the difference in the original annual estimate as a continuously monitored site and an annual estimate obtained as though the site were a short-term monitored site. If these deviations are small, then we may surmise that the results

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obtained from the short-term monitored sites are as good as those from the continuously monitored sites. Conversely, as these deviations increase we may be more concerned about the precision of estimates obtained from short-term monitored sites. The original measures of precision given in Table 33 are obtained by dividing the CVs in Table 5 by the

$$\sqrt{number\ of\ days}\ .$$

By doing this, we are treating the original observations as a random sample, AADT as a sample mean, and "original" estimated precision as the estimated standard error of the sample mean.

Monthly (seasonal) factors and day-of-week factors were calculated based on procedures recommended by the *Traffic Monitoring Guide* [1], and are described in [7]. Empirical results for count data are in Table 33. In general, empirical results should be accepted with caution. The empirical results reported herein are no exception, especially because we view data from a small number of sites and only from two states.

In Table 33, the first AADT estimate is the original estimate, by treating the site as a continuously monitored site. The other two AADT estimates are averages of the estimates computed by treating the site as a short-term monitored site. Based on the maximum ratio [6], we observed that all estimates at a given site are, on average, within 2% of each other.

When each site is treated as a short-term monitored site and an estimate for AADT is calculated, these simulated estimates tend to be higher, on average, than the original estimates in almost all cases. This may suggest some (slight) positive bias in the simulated estimates. That is, adjustments of short-term monitored data by day-of-the-week and month-of-the-year factors appear to over-estimate the typical traffic and loading patterns. Further research should be undertaken based on data from more sites to assess whether and why estimates from short-term monitored sites tend to be positively biased.

Not surprisingly, the original estimates (continuous monitoring) appear to be more precise, on average, than the simulated estimates (short-term monitored). This apparent decrease in the precision of the simulated estimates is, in part, very likely due to possible bias.

Table 33.
Precision of Original and Simulated AADTs
(Based on 20 Florida Count Sites)

Grp	Site	Number of Days	Original Estimates Estimated AADT	Estimated Precision	Simulated Estimates (Factors used contain information from site being estimated.) Estimated AADT	Square Root of MSE	Estimated Precision	Simulated Estimates (Factors used do not contain information from site being estimated.) Estimated AADT	Square Root of MSE	Estimated Precision	Maximum Ratio (The 3 Estimates are within X% of each other.)
2	65	322	7382	0.61%	7,502	1,037	13.8%	7,522	1,181	15.7%	1.90%
2	104	347	22098	0.43%	22,375	1,770	7.9%	22,419	1,979	8.8%	1.45%
2	118	345	22262	0.68%	22,490	2,108	9.4%	22,531	2,266	10.1%	1.21%
2	136	263	6336	1.15%	6,363	783	12.3%	6,367	890	14.0%	0.49%
2	170	353	5284	0.65%	5,311	354	6.7%	5,316	390	7.3%	0.61%
2	223	231	4474	1.09%	4,528	615	13.6%	4,537	673	14.8%	1.41%
2	9925	308	12661	0.85%	12,671	1,142	9.0%	12,673	1,250	9.9%	0.09%
3	130	341	110865	0.48%	111,625	6,635	5.9%	111,963	7,724	6.9%	0.99%
3	133	283	28026	0.92%	27,949	3,085	11.0%	27,897	3,579	12.8%	0.46%
3	179	210	54599	0.95%	54,870	4,569	8.3%	54,940	5,357	9.8%	0.62%
3	196	252	154304	0.77%	155,952	14,598	9.4%	156,704	19,127	12.2%	1.56%
4	102	278	40753	0.86%	40,807	2,478	6.1%	40,822	2,617	6.4%	0.17%
4	113	326	45825	0.78%	45,960	2,474	5.4%	45,980	2,599	5.7%	0.34%
4	114	267	14436	0.83%	14,605	1,009	6.9%	14,642	1,085	7.4%	1.43%
4	154	220	44030	0.78%	44,123	2,992	6.8%	44,124	3,297	7.5%	0.21%
4	175	342	39920	1.21%	39,438	5,066	12.8%	39,364	5,585	14.2%	1.41%
4	177	333	33290	0.91%	33,358	2,329	7.0%	33,394	2,480	7.4%	0.31%
4	197	212	47270	1.11%	47,020	2,882	6.1%	46,992	3,082	6.6%	0.59%
4	204	212	28294	0.80%	28,646	3,229	11.3%	28,674	3,590	12.5%	1.34%
4	246	278	7681	0.62%	7,750	577	7.4%	7,757	638	8.2%	0.99%

Grp: 1 = Rural interstate   2 = Rural others   3 = Urban Interstate   4 = Urban others

For classification data, we made use of 1994 classification count data for eight of Florida's continuously monitored classification sites as well as nine of Washington's continuously monitored weigh-in-motion sites. Data from Florida's classification sites include all vehicles counted at a site while data from Washington's WIM sites are limited to vehicle classes 3 through 14. Results from [7] are given in Tables 34 and 35.

Empirical results for classification data show that for a particular vehicle class, the original estimate of AADT, treating the sites as continuously monitored sites, is quite close to, but usually smaller than, the simulated estimate of AADT, treating the sites as short-term monitored sites. As expected, the estimates of AADT based on treating the sites as continuously monitored sites are more precise than the estimates of AADT based on treating the sites as short-term monitored sites.

Similar results are found in ESAL estimates. Results from [7] are given in Table 36. To avoid the problem of small sample size, we grouped trucks into the following vehicle classes:

Grouped Vehicle Class	Original Vehicle Class
G1 Passenger Vehicles	(3) Other 2 Axle, 4 Tire, Single Unit
G2 Single-Unit Trucks	(4) Buses
	(5) 2 Axle, 6 Tire, Single Unit
	(6) 3 Axle, Single Unit
	(7) 4^+ Axle, Single Unit
G3 Single-Trailer Trucks	(8) 4^- Axle, Single Trailer
	(9) 5 Axle, Single Trailer
	(10) 6^+ Axle, Single Trailer
G4 Multi-Trailer Trucks	(11) 5^- Axle, Multi-Trailer
	(12) 6 Axle, Multi-Trailer
G5 Very Large Trucks	(13) 7^+ Axle, Multi-Trailer
G6 Unknown Vehicle	(14) Unclassified/Other Vehicle

In reality, ESAL or weight estimates that are calculated based on 24- or 48-hours of data are reported **unadjusted**. That is, short-term WIM data are not adjusted by day-of-the-week and month-of-the-year factors. Since our results show that traffic loading varies substantially by day of the week and by month of the year, we adjust the short-term WIM data in a way similar to that of short-term traffic count data. When a site is treated as a short-term monitored site and daily ESAL estimate per vehicle is simulated, the simulated estimates are almost always higher than the original estimates (about 93% of the time). This suggests that there may be some slight positive bias present in the simulated ESAL estimates. The precision of the estimates is also much better, on average, for the original ESAL estimates than for the simulated estimates (about 96% of the time).

Annualizing short-term WIM data by day-of-the-week and month-of-the-year factors produces reasonable estimates for three truck groups — single-trailer trucks, multi-trailer trucks, and 7-axle multi-trailer trucks. However, this approach produces ESAL and daily weight estimates for the remaining truck groups that have unacceptably low precision (Table 36). This finding might be attributable to the large variability observed in the daily ESALs for these groups. Data from three Washington WIM sites were used to illustrate how variability in daily loadings can influence the reliability of simulated estimates (Table 37). Data from more sites across a sample of representative states should

be analyzed to confirm these findings. Furthermore, research is needed to quantify the impact of reporting **unadjusted** short-term WIM data. Finally, if this impact is consequential, then a procedure should be developed to adjust short-term WIM data to more accurately reflect temporal variations.

**Table 34. Precision of Original and Simulated AADTs
by Vehicle Classes for 8 Florida Classification Sites**

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
2	9925	307	(1) Motorcycles	12	14.2%	34	108.37	222.7%
			(2) Passenger Cars	10,538	1.2%	10,504	1,926.38	18.3%
			(3) Other 2 Axle, 4 Tire, S Unit	1,737	1.4%	1,722	377.56	21.9%
			(4) Buses	8	3.0%	10	6.80	71.0%
			(5) 2 Axle, 6 Tire, S Unit	176	2.8%	190	81.53	43.0%
			(6) 3 Axle, S Unit	59	2.9%	64	31.32	48.7%
			(7) 4$^+$ Axle, S Unit	8	7.2%	14	22.97	159.6%
			(8) 4$^-$ Axle, S Trailer	71	3.0%	69	38.55	55.8%
			(9) 5 Axle, S Trailer	95	2.5%	98	34.15	35.0%
			(10) 6$^+$ Axle, S Trailer	2	5.5%	2	2.00	97.9%
			(11) 5$^-$ Axle, M Trailers	1	8.0%	--	--	--
			(12) 6 Axle, M Trailers	--	--	--	--	--
			(13) 7$^+$ Axle, M Trailers	2	6.2%	3	7.02	212.4%
			(14) Unclassified/Other	200	3.6%	313	290.78	92.8%
2	170	353	(1) Motorcycles	7	6.9%	17	28.14	167.6%
			(2) Passenger Cars	4,080	0.6%	4,116	399.52	9.7%
			(3) Other 2 Axle, 4 Tire, S Unit	749	1.1%	754	104.94	13.9%
			(4) Buses	3	4.4%	3	2.40	84.9%
			(5) 2 Axle, 6 Tire, S Unit	9	3.2%	9	4.40	50.4%
			(6) 3 Axle, S Unit	69	2.7%	85	84.65	99.2%
			(7) 4$^+$ Axle, S Unit	11	5.8%	14	18.58	135.5%
			(8) 4$^-$ Axle, S Trailer	72	1.6%	97	69.28	71.4%
			(9) 5 Axle, S Trailer	45	2.4%	45	15.47	34.4%
			(10) 6$^+$ Axle, S Trailer	4	4.0%	4	2.79	74.6%
			(11) 5$^-$ Axle, M Trailers	--	--	--	--	--
			(12) 6 Axle, M Trailers	--	--	--	--	--
			(13) 7$^+$ Axle, M Trailers	12	5.1%	13	15.24	114.8%
			(14) Unclassified/Other	224	4.1%	264	245.07	92.9%

--means estimate of AADT(*i*) was at or near zero

Table 34. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
4	113	323	(1) Motorcycles	23	2.9%	101	127.38	126.1%
			(2) Passenger Cars	39,755	0.7%	39,917	2,382.29	6.0%
			(3) Other 2 Axle, 4 Tire, S Unit	4,743	1.3%	4,855	610.48	12.6%
			(4) Buses	6	5.2%	18	22.13	119.9%
			(5) 2 Axle, 6 Tire, S Unit	59	3.2%	67	27.26	40.6%
			(6) 3 Axle, S Unit	162	2.6%	215	134.58	62.5%
			(7) 4^+ Axle, S Unit	25	6.7%	34	34.48	102.6%
			(8) 4^- Axle, S Trailer	363	1.9%	384	89.45	23.3%
			(9) 5 Axle, S Trailer	79	2.5%	81	17.79	21.9%
			(10) 6^+ Axle, S Trailer	4	4.6%	5	4.25	85.5%
			(11) 5^- Axle, M Trailers	1	8.3%	1	1.24	167.3%
			(12) 6 Axle, M Trailers	--	--	--	--	--
			(13) 7^+ Axle, M Trailers	6	6.7%	16	34.84	212.8%
			(14) Unclassified/Other	642	1.2%	739	220.49	29.9%
4	114	266	(1) Motorcycles	37	11.0%	196	579.05	294.9%
			(2) Passenger Cars	12,390	0.7%	12,604	940.57	7.5%
			(3) Other 2 Axle, 4 Tire, S Unit	1,533	1.5%	1,619	208.61	12.9%
			(4) Buses	4	10.6%	15	47.92	314.1%
			(5) 2 Axle, 6 Tire, S Unit	27	4.4%	26	13.25	51.6%
			(6) 3 Axle, S Unit	108	3.6%	113	54.19	48.1%
			(7) 4^+ Axle, S Unit	5	10.6%	6	9.88	164.0%
			(8) 4^- Axle, S Trailer	158	1.4%	185	84.59	45.7%
			(9) 5 Axle, S Trailer	49	3.0%	49	13.15	26.6%
			(10) 6^+ Axle, S Trailer	6	4.4%	6	4.23	68.4%
			(11) 5^- Axle, M Trailers	--	--	--	--	--
			(12) 6 Axle, M Trailers	--	--	--	--	--
			(13) 7^+ Axle, M Trailers	--	--	--	--	--
			(14) Unclassified/Other	129	3.0%	149	100.87	67.7%

--means estimate of AADT(i) was at or near zero

Table 34. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
4	175	342	(1) Motorcycles	38	5.5%	195	403.99	207.7%
			(2) Passenger Cars	34,830	1.2%	34,389	5,246.37	15.3%
			(3) Other 2 Axle, 4 Tire, S Unit	2,897	2.2%	2,822	783.93	27.8%
			(4) Buses	42	3.9%	132	169.32	128.4%
			(5) 2 Axle, 6 Tire, S Unit	60	2.9%	70	35.17	50.5%
			(6) 3 Axle, S Unit	135	5.1%	158	232.08	146.8%
			(7) 4^+ Axle, S Unit	18	8.2%	28	79.77	282.1%
			(8) 4^- Axle, S Trailer	299	2.8%	296	115.07	38.9%
			(9) 5 Axle, S Trailer	231	1.6%	289	158.02	54.6%
			(10) 6^+ Axle, S Trailer	5	8.5%	5	12.69	234.4%
			(11) 5^- Axle, M Trailers	1	6.9%	1	2.09	153.6%
			(12) 6 Axle, M Trailers	1	7.6%	1	0.90	145.9%
			(13) 7^+ Axle, M Trailers	125	9.5%	209	508.79	243.9%
			(14) Unclassified/Other	1,241	6.8%	1,276	1,566.74	122.8%
4	177	284	(1) Motorcycles	79	7.4%	384	716.38	186.6%
			(2) Passenger Cars	28,661	0.9%	28,716	1,926.80	6.7%
			(3) Other 2 Axle, 4 Tire, S Unit	3,189	1.7%	3,234	585.82	18.1%
			(4) Buses	21	2.8%	70	69.11	98.3%
			(5) 2 Axle, 6 Tire, S Unit	53	3.3%	68	40.89	59.8%
			(6) 3 Axle, S Unit	93	3.8%	126	120.51	95.8%
			(7) 4^+ Axle, S Unit	18	3.8%	35	38.51	108.8%
			(8) 4^- Axle, S Trailer	331	2.1%	353	79.67	22.6%
			(9) 5 Axle, S Trailer	215	3.3%	220	85.54	38.9%
			(10) 6^+ Axle, S Trailer	10	4.0%	11	6.28	58.8%
			(11) 5^- Axle, M Trailers	4	5.1%	2	2.91	125.6%
			(12) 6 Axle, M Trailers	1	5.5%	1	1.36	110.1%
			(13) 7^+ Axle, M Trailers	199	7.1%	729	1,841.07	252.5%
			(14) Unclassified/Other	664	3.2%	742	411.72	55.5%

--means estimate of AADT(i) was at or near zero

Table 34. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
4	197	212	(1) Motorcycles	350	12.4%	554	1,030.41	186.1%
			(2) Passenger Cars	41,385	1.0%	41,517	2,288.99	5.5%
			(3) Other 2 Axle, 4 Tire, S Unit	3,853	2.2%	3,723	537.17	14.4%
			(4) Buses	46	10.3%	58	97.81	167.8%
			(5) 2 Axle, 6 Tire, S Unit	90	4.1%	96	48.60	50.9%
			(6) 3 Axle, S Unit	203	3.0%	230	76.79	33.5%
			(7) 4$^+$ Axle, S Unit	11	7.0%	13	16.00	122.4%
			(8) 4$^-$ Axle, S Trailer	375	2.6%	366	69.85	19.1%
			(9) 5 Axle, S Trailer	159	3.2%	160	29.84	18.7%
			(10) 6$^+$ Axle, S Trailer	4	5.2%	5	3.30	72.1%
			(11) 5$^-$ Axle, M Trailers	13	3.9%	30	26.85	89.6%
			(12) 6 Axle, M Trailers	2	6.4%	2	1.55	93.6%
			(13) 7$^+$ Axle, M Trailers	--	21.3%	1	2.42	440.5%
			(14) Unclassified/Other	782	3.8%	834	518.46	62.2%
4	246	277	(1) Motorcycles	4	4.7%	12	17.25	138.9%
			(2) Passenger Cars	5,816	0.6%	5,904	783.75	13.3%
			(3) Other 2 Axle, 4 Tire, S Unit	1,354	1.5%	1,468	458.13	31.2%
			(4) Buses	36	5.9%	71	92.47	129.4%
			(5) 2 Axle, 6 Tire, S Unit	53	3.3%	97	153.02	157.9%
			(6) 3 Axle, S Unit	40	3.6%	44	16.81	38.3%
			(7) 4$^+$ Axle, S Unit	3	10.9%	4	7.50	194.6%
			(8) 4$^-$ Axle, S Trailer	122	1.9%	133	39.61	29.8%
			(9) 5 Axle, S Trailer	113	2.9%	114	27.59	24.3%
			(10) 6$^+$ Axle, S Trailer	1	7.3%	2	2.85	173.6%
			(11) 5$^-$ Axle, M Trailers	--	--	--	--	--
			(12) 6 Axle, M Trailers	--	--	--	--	--
			(13) 7$^+$ Axle, M Trailers	--	--	1	2.96	351.0%
			(14) Unclassified/Other	143	2.2%	165	71.59	43.4%

--means estimate of AADT(*i*) was at or near zero

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
2	P03	331	(3) Other 2 Axle, 4 Tire, S Unit	14	2.8%	17	9.09	54.0%
			(4) Buses	8	1.7%	12	9.94	83.0%
			(5) 2 Axle, 6 Tire, S Unit	233	1.8%	239	53.66	22.0%
			(6) 3 Axle, S Unit	55	3.8%	56	31.15	56.0%
			(7) 4^+ Axle, S Unit	17	11.8%	27	57.73	214.0%
			(8) 4^- Axle, S Trailer	46	3.3%	47	18.39	39.0%
			(9) 5 Axle, S Trailer	257	2.4%	259	68.68	27.0%
			(10) 6^+ Axle, S Trailer	21	4.6%	21	12.42	59.0%
			(11) 5^- Axle, M Trailers	16	2.5%	18	9.13	49.0%
			(12) 6 Axle, M Trailers	23	2.5%	28	12.03	42.0%
			(13) 7^+ Axle, M Trailers	51	3.1%	53	18.20	34.0%
			(14) Unclassified/Other	30	2.9%	35	23.13	67.0%
2	P05	346	(3) Other 2 Axle, 4 Tire, S Unit	15	3.1%	15	7.66	52.0%
			(4) Buses	1	5.8%	2	2.81	161.0%
			(5) 2 Axle, 6 Tire, S Unit	114	1.5%	118	28.91	25.0%
			(6) 3 Axle, S Unit	16	3.4%	21	15.42	75.0%
			(7) 4^+ Axle, S Unit	--	--	1	3.63	265.0%
			(8) 4^- Axle, S Trailer	27	2.6%	29	10.97	38.0%
			(9) 5 Axle, S Trailer	111	2.3%	112	26.05	23.0%
			(10) 6^+ Axle, S Trailer	13	2.9%	16	10.73	68.0%
			(11) 5^- Axle, M Trailers	6	2.6%	7	3.36	51.0%
			(12) 6 Axle, M Trailers	21	1.9%	26	14.89	57.0%
			(13) 7^+ Axle, M Trailers	32	2.9%	33	14.58	45.0%
			(14) Unclassified/Other	21	2.5%	22	10.02	46.0%

--means estimate of AADT(i) was at or near zero.

Table 35. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
2	P17	334	(3) Other 2 Axle, 4 Tire, S Unit	5	3.5%	5	3.71	70.0%
			(4) Buses	--	--	--	--	--
			(5) 2 Axle, 6 Tire, S Unit	46	2.0%	47	14.46	31.0%
			(6) 3 Axle, S Unit	10	4.2%	13	11.49	90.0%
			(7) 4$^+$ Axle, S Unit	--	--	2	18.33	881.0%
			(8) 4$^-$ Axle, S Trailer	12	3.2%	13	7.58	56.0%
			(9) 5 Axle, S Trailer	185	2.1%	205	82.13	40.0%
			(10) 6$^+$ Axle, S Trailer	30	3.3%	36	21.58	60.0%
			(11) 5$^-$ Axle, M Trailers	16	2.4%	17	8.40	49.0%
			(12) 6 Axle, M Trailers	30	4.8%	30	26.53	88.0%
			(13) 7$^+$ Axle, M Trailers	85	2.7%	95	40.91	43.0%
			(14) Unclassified/Other	4	3.4%	5	2.74	60.0%
3	P29	364	(3) Other 2 Axle, 4 Tire, S Unit	31	4.2%	35	30.21	87.0%
			(4) Buses	26	3.9%	29	25.16	86.0%
			(5) 2 Axle, 6 Tire, S Unit	1,198	1.8%	1,216	327.42	27.0%
			(6) 3 Axle, S Unit	268	2.9%	263	123.31	47.0%
			(7) 4$^+$ Axle, S Unit	15	7.0%	27	82.58	302.0%
			(8) 4$^-$ Axle, S Trailer	317	3.0%	346	228.94	66.0%
			(9) 5 Axle, S Trailer	1,485	2.2%	1,513	365.31	24.0%
			(10) 6$^+$ Axle, S Trailer	146	3.4%	152	88.84	58.0%
			(11) 5$^-$ Axle, M Trailers	71	4.2%	82	75.39	92.0%
			(12) 6 Axle, M Trailers	114	2.9%	127	94.64	75.0%
			(13) 7$^+$ Axle, M Trailers	414	3.1%	420	233.78	56.0%
			(14) Unclassified/Other	95	4.0%	102	82.92	81.0%

--means estimate of AADT(i) was at or near zero.

Table 35. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
3	P3N	365	(3) Other 2 Axle, 4 Tire, S Unit	16	2.8%	17	8.76	50.0%
			(4) Buses	85	1.9%	93	43.58	47.0%
			(5) 2 Axle, 6 Tire, S Unit	1,270	1.5%	1,295	287.35	22.0%
			(6) 3 Axle, S Unit	145	2.4%	155	49.62	32.0%
			(7) 4$^+$ Axle, S Unit	40	6.0%	118	947.93	802.0%
			(8) 4$^-$ Axle, S Trailer	220	2.5%	219	83.79	38.0%
			(9) 5 Axle, S Trailer	932	2.1%	921	194.88	21.0%
			(10) 6$^+$ Axle, S Trailer	141	2.7%	138	44.36	32.0%
			(11) 5$^-$ Axle, M Trailers	55	2.6%	56	24.77	45.0%
			(12) 6 Axle, M Trailers	48	2.5%	47	15.76	33.0%
			(13) 7$^+$ Axle, M Trailers	184	2.0%	217	105.11	48.0%
			(14) Unclassified/Other	129	3.0%	140	79.74	57.0%
3	P5S	362	(3) Other 2 Axle, 4 Tire, S Unit	9	2.6%	12	9.24	80.0%
			(4) Buses	40	1.5%	47	18.06	38.0%
			(5) 2 Axle, 6 Tire, S Unit	903	1.5%	929	162.83	18.0%
			(6) 3 Axle, S Unit	162	3.7%	181	124.18	69.0%
			(7) 4$^+$ Axle, S Unit	12	5.7%	24	49.16	201.0%
			(8) 4$^-$ Axle, S Trailer	189	2.0%	234	104.78	45.0%
			(9) 5 Axle, S Trailer	1,115	2.1%	1,161	237.66	20.0%
			(10) 6$^+$ Axle, S Trailer	137	2.4%	159	55.04	35.0%
			(11) 5$^-$ Axle, M Trailers	120	1.9%	142	60.60	43.0%
			(12) 6 Axle, M Trailers	114	2.0%	125	37.29	30.0%
			(13) 7$^+$ Axle, M Trailers	189	2.8%	197	58.30	30.0%
			(14) Unclassified/Other	113	1.9%	128	60.39	47.0%

--means estimate of AADT(*i*) was at or near zero.

Table 35. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
4	P07	365	(3) Other 2 Axle, 4 Tire, S Unit	--	--	--	--	--
			(4) Buses	2	6.6%	2	2.38	140.0%
			(5) 2 Axle, 6 Tire, S Unit	30	2.6%	29	11.63	40.0%
			(6) 3 Axle, S Unit	36	3.5%	33	16.03	48.0%
			(7) 4$^+$ Axle, S Unit	--	--	1	2.83	495.0%
			(8) 4$^-$ Axle, S Trailer	9	3.3%	9	5.14	58.0%
			(9) 5 Axle, S Trailer	109	2.8%	117	47.72	41.0%
			(10) 6$^+$ Axle, S Trailer	28	3.3%	31	16.38	53.0%
			(11) 5$^-$ Axle, M Trailers	2	6.0%	2	1.84	115.0%
			(12) 6 Axle, M Trailers	7	3.8%	8	6.23	79.0%
			(13) 7$^+$ Axle, M Trailers	52	3.1%	53	21.05	40.0%
			(14) Unclassified/Other	6	4.0%	6	4.19	73.0%
4	P19	365	(3) Other 2 Axle, 4 Tire, S Unit	20	2.3%	23	12.18	53.0%
			(4) Buses	21	2.6%	38	39.80	104.0%
			(5) 2 Axle, 6 Tire, S Unit	1,086	1.7%	1,150	306.98	27.0%
			(6) 3 Axle, S Unit	243	2.9%	260	79.93	31.0%
			(7) 4$^+$ Axle, S Unit	25	4.3%	42	112.64	266.0%
			(8) 4$^-$ Axle, S Trailer	120	2.5%	127	35.64	28.0%
			(9) 5 Axle, S Trailer	398	3.0%	373	137.82	37.0%
			(10) 6$^+$ Axle, S Trailer	163	3.4%	167	84.16	50.0%
			(11) 5$^-$ Axle, M Trailers	5	4.1%	6	5.37	84.0%
			(12) 6 Axle, M Trailers	15	3.6%	14	8.45	58.0%
			(13) 7$^+$ Axle, M Trailers	180	3.1%	191	124.57	65.0%
			(14) Unclassified/Other	37	2.0%	47	25.35	54.0%

--means estimate of AADT(i) was at or near zero.

Table 35. (continued)

Group	Site	Number of Days	Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated AADT(i)	Estimated Precision	Estimated AADT(i)	Square Root of MSE	Estimated Precision
4	P20	288	(3) Other 2 Axle, 4 Tire, S Unit	52	3.1%	51	21.00	41.0%
			(4) Buses	18	3.3%	32	29.98	93.0%
			(5) 2 Axle, 6 Tire, S Unit	1,231	1.5%	1,368	445.23	33.0%
			(6) 3 Axle, S Unit	244	3.3%	281	119.54	43.0%
			(7) 4$^+$ Axle, S Unit	15	6.4%	44	307.22	696.0%
			(8) 4$^-$ Axle, S Trailer	123	2.7%	145	75.79	52.0%
			(9) 5 Axle, S Trailer	832	2.7%	1,036	556.23	54.0%
			(10) 6$^+$ Axle, S Trailer	207	4.3%	233	126.28	54.0%
			(11) 5$^-$ Axle, M Trailers	16	2.5%	25	19.75	78.0%
			(12) 6 Axle, M Trailers	71	2.5%	101	69.98	69.0%
			(13) 7$^+$ Axle, M Trailers	258	3.6%	288	136.32	47.0%
			(14) Unclassified/Other	104	2.2%	132	73.02	55.0%

--means estimate of AADT(i) was at or near zero.

Table 36. Precision of Original and Simulated ESALs by Grouped Vehicle Classes
For Washington's Weigh-In-Motion Sites

Group	Site	Number of Days	Grouped Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated ESAL(Gi)	Estimated Precision	Estimated ESAL(Gi)	Square Root of MSE	Estimated Precision
2	P03	331	G1 Passenger Vehicles	0.00776	5.5%	0.01042	0.0153	146.4%
			G2 Single-Unit Trucks	1.11291	3.2%	1.57475	2.1940	139.3%
			G3 Single-Trailer Trucks	2.46255	2.0%	2.54536	0.7711	30.3%
			G4 Multi-Trailer Trucks	2.19869	2.0%	2.34148	0.9338	39.9%
			G5 Very Large Trucks	1.12415	2.0%	1.21982	0.4579	37.5%
			G6 Unknown Vehicles	0.54097	4.2%	0.82244	0.8950	108.8%
2	P05	346	G1 Passenger Vehicles	0.00711	7.5%	0.00857	0.0102	118.5%
			G2 Single-Unit Trucks	1.42218	4.9%	3.37957	20.7556	614.1%
			G3 Single-Trailer Trucks	3.49431	2.7%	3.57936	1.3996	39.1%
			G4 Multi-Trailer Trucks	2.54665	2.8%	2.60830	1.3257	50.8%
			G5 Very Large Trucks	1.68011	2.8%	1.74882	0.8893	50.9%
			G6 Unknown Vehicles	0.71534	5.2%	1.08816	1.1556	106.2%
2	P17	334	G1 Passenger Vehicles	0.00846	11.6%	0.01137	0.0427	375.3%
			G2 Single-Unit Trucks	0.61247	5.8%	0.69815	0.8596	123.1%
			G3 Single-Trailer Trucks	3.49826	2.0%	3.66065	1.2035	32.9%
			G4 Multi-Trailer Trucks	3.72136	1.7%	3.89418	1.4247	36.6%
			G5 Very Large Trucks	1.33664	1.6%	1.46540	0.5242	35.8%
			G6 Unknown Vehicles	0.47389	13.0%	0.59070	1.3783	233.3%
3	P29	364	G1 Passenger Vehicles	0.11783	17.9%	0.12667	0.4572	360.9%
			G2 Single-Unit Trucks	2.28722	2.5%	2.36025	1.2103	51.3%
			G3 Single-Trailer Trucks	3.07931	1.3%	3.05715	0.6445	21.1%
			G4 Multi-Trailer Trucks	3.06553	1.5%	3.05917	0.7299	23.9%
			G5 Very Large Trucks	1.55673	1.6%	1.58010	0.4615	29.2%
			G6 Unknown Vehicles	0.54108	5.7%	1.00086	2.1043	210.2%
3	P3N	365	G1 Passenger Vehicles	0.01584	5.8%	0.08419	0.1224	145.4%
			G2 Single-Unit Trucks	1.98667	2.0%	2.05632	0.6258	30.4%
			G3 Single-Trailer Trucks	2.56789	1.3%	2.56358	0.4854	18.9%
			G4 Multi-Trailer Trucks	2.21641	1.7%	2.22774	0.6612	29.7%
			G5 Very Large Trucks	1.54463	1.5%	1.58012	0.4017	25.4%
			G6 Unknown Vehicles	0.94208	6.3%	1.26129	1.9036	150.9%

Table 36. (continued)

Group	Site	Number of Days	Grouped Vehicle Class	Original Estimates		Simulated Estimates (Factors do not contain information from site being estimated.)		
				Estimated ESAL(Gi)	Estimated Precision	Estimated ESAL(Gi)	Square Root of MSE	Estimated Precision
3	P5S	362	G1 Passenger Vehicles	0.01347	4.0%	0.06994	0.0949	135.7%
			G2 Single-Unit Trucks	2.90065	1.9%	3.18204	1.3810	43.4%
			G3 Single-Trailer Trucks	3.59569	0.6%	3.87116	1.0939	28.3%
			G4 Multi-Trailer Trucks	4.16916	0.8%	4.48423	1.2702	28.3%
			G5 Very Large Trucks	2.11898	1.3%	2.31569	0.8945	38.6%
			G6 Unknown Vehicles	0.97310	4.7%	1.54597	2.0733	134.1%
4	P07	365	G1 Passenger Vehicles	---	---	---	---	---
			G2 Single-Unit Trucks	1.58737	4.0%	1.64574	1.2088	73.4%
			G3 Single-Trailer Trucks	3.34056	1.7%	3.51789	1.1436	32.5%
			G4 Multi-Trailer Trucks	2.60388	4.2%	2.77120	2.3220	83.8%
			G5 Very Large Trucks	1.61962	1.3%	1.70562	0.4533	26.6%
			G6 Unknown Vehicles	1.27191	6.8%	1.94420	6.1319	315.4%
4	P19	365	G1 Passenger Vehicles	0.01110	2.8%	0.01146	0.0058	50.7%
			G2 Single-Unit Trucks	2.68042	2.0%	2.82533	1.0342	36.6%
			G3 Single-Trailer Trucks	2.17607	1.6%	2.15623	0.4653	21.6%
			G4 Multi-Trailer Trucks	2.15544	2.3%	2.51769	1.8746	74.5%
			G5 Very Large Trucks	1.62796	1.4%	1.60996	0.3114	19.3%
			G6 Unknown Vehicles	0.43418	4.0%	0.47889	0.3083	64.4%
4	P20	288	G1 Passenger Vehicles	0.00987	2.8%	0.01029	0.0043	42.1%
			G2 Single-Unit Trucks	2.53717	2.3%	2.78393	1.2998	46.7%
			G3 Single-Trailer Trucks	2.79177	1.3%	2.86504	0.6115	21.3%
			G4 Multi-Trailer Trucks	2.47074	1.9%	2.98795	1.9049	63.8%
			G5 Very Large Trucks	1.85853	1.4%	1.86646	0.3259	17.5%
			G6 Unknown Vehicles	0.35285	5.4%	0.63348	1.6695	263.6%

Table 37. Range of Coefficients of Variation (CV) and
Estimated Precision of the Original and the Simulated ESAL Estimates
For 3 Washington's Weigh-In-Motion Sites

Site	Grouped Vehicle Class	Range of CVs for Daily ESAL per Vehicle (%)	Estimated Precision	
			Original ESAL Estimate (Gi)	Simulated ESAL Estimate (Gi)
P05	G1 Passenger Vehicles	139.1%	7.5%	118.5%
	G2 Single-Unit Trucks	76.4-294.3%	4.9%	614.1%
	G3 Single-Trailer Trucks	38.9-75.1%	2.7%	39.1%
	G4 Multi-Trailer Trucks	57.3-75.3%	2.8%	50.8%
	G5 Very Large Trucks	52.9%	2.8%	50.9%
	G6 Unknown Vehicles	97.3%	5.2%	106.2%
P17	G1 Passenger Vehicles	211.8%	11.6%	375.3%
	G2 Single-Unit Trucks	88.3-397.0%	5.8%	123.1%
	G3 Single-Trailer Trucks	25.2-92.7%	2.0%	32.9%
	G4 Multi-Trailer Trucks	33.1-43.9%	1.7%	36.6%
	G5 Very Large Trucks	29.2%	1.6%	35.8%
	G6 Unknown Vehicles	237.6%	13.0%	233.3%
P29	G1 Passenger Vehicles	341.8%	17.9%	360.9%
	G2 Single-Unit Trucks	45.9-86.5%	2.5%	51.3%
	G3 Single-Trailer Trucks	27.1-50.3%	1.3%	21.1%
	G4 Multi-Trailer Trucks	32.7-37.7%	1.5%	23.9%
	G5 Very Large Trucks	30.4%	1.6%	29.2%
	G6 Unknown Vehicles	109.0%	5.7%	210.2%

SUMMARY REMARKS
Precision of Short-term Monitored Data

The original estimates of traffic characteristics (i.e., AADT, AADT by vehicle class, and daily ESAL per vehicle) by treating the sites as a continuously monitored sites are, on average, quite close to the simulated estimates treating the sites as short-term monitored sites. Based on the maximum ratio, the original AADT estimate and simulated AADT estimates at a given site are, on average, within 2% of each other.

The simulated estimates tend to be higher than the original estimates in almost all cases. This may suggest some (slight) positive bias in the simulated estimates.

Not surprisingly, the original estimates (continuous monitoring) appear to be more precise, on average, than the simulated estimates (short-term monitoring). This apparent decrease in the precision of the simulated estimates is, in part, very likely due to possible bias.

Similar empirical results are observed for classification data. The decrease in the precision of the simulated estimates typically occurs for vehicle classes that account for less than 1% of the daily traffic volume, suggesting that these less common vehicle classes be combined to achieve reliable AADT estimates.

The approach that is used to adjust short-term traffic count data produces acceptable ESAL estimates for short-term monitoring WIM sites only if the daily loading does not substantially vary. For vehicle classes in which the daily loading varies widely, a new approach needs to be developed to more accurately reflect the temporal variations.

In general, the methodology that uses factors from continuously monitored sites seems to work extremely well for producing estimates of total traffic volume for short-term monitored sites. However, its ability to produce estimates of vehicle classification counts for short-term monitored sites decreases for less common vehicle types, those accounting for less than 1% of daily traffic volume. One option to overcome this problem is to combine these less common vehicle classes. Applying this factoring method to short-term WIM data is inappropriate. A new procedure needs to be developed.

5. RECOMMENDATIONS FOR FUTURE TRAFFIC DATA COLLECTION PROGRAM

Based on findings from this study, recommendations for future traffic data collection efforts can be summarized into five major points:

❶ **Support research to determine to what extent sampling can efficiently assist continuous traffic monitoring to characterize traffic patterns.**

Continuous monitoring data are plagued by missing data. In fact, a continuous traffic monitoring program that would provide 365 days of complete data seems to be extremely rare. We conducted simulation studies to assess the impact of randomly missing data—on traffic estimates. Preliminary results suggest that: (1) randomly missing data have little effect on *traffic estimates*, and (2) the loss in reliability in AADT estimates, due to missing data, may very well be tolerable, even though the reliability decreases as missing data increase. Similarly, the amount of missing data had negligible effect on the estimated *coefficients of variation* for the sites considered.

Our analysis of randomly missing days shows that reliable results can be obtained for AADT (AADT by vehicle class, average daily ESAL and weight per vehicle), even with high levels of randomly missing data. This finding is based on theoretical results in probability sampling theory. Even if we have randomly consecutive missing days (clusters), reliable results for AADT can still be obtained, a conclusion that is also based on probability sampling theory.

These findings suggest that rather than processing the <u>entire</u> continuous traffic data on a <u>continuous</u> basis, it might be feasible to sample this continuous data stream and, perhaps, to update traffic estimates on a <u>periodic</u> basis. Sampling strategies (based on "days" or "clusters of days") can be developed to provide estimates, essentially as accurate and reliable as one would obtain from "100% data from continuously monitored sites."

The contributions to the variability in traffic data vary by the day of the week, weekends versus weekdays, the month of the year, and holiday periods versus non-holiday periods. In fact, the greater contributors to traffic *count* variability are the weekend days rather than the weekdays, the winter months rather than the summer months, and the "all holiday period" days rather than the "non-holiday period" days.

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Daily contributors to the variability in daily traffic *classification* data differ among vehicle classes. These results provide preliminary guidance for one to consider a larger role of sampling in traffic monitoring programs. It suggests that one should sample more where there is greater variability.

❷ **Conduct research to investigate the advantages and disadvantages of combining certain vehicle classes.**

Four results prompt this recommendation. First, high coefficients of variation (i.e. variability) associated with AADT tend to occur with vehicle classes that have extremely low mean daily traffic volumes (Figure 2). To lower these high coefficients of variation, one can consider reducing the number of vehicle classes by combining less common vehicle classes. This reduction may also lead to *better quality* classification data in cases where one class is difficult to be distinguished from another when using current monitoring classification equipment.

Second, the occurrence of a multi-trailer vehicle on any day is rare. At almost every one of the eight classification sites, the level of unclassified/other vehicles is quite high relative to what is captured in other vehicle classes. The large percentage of vehicles being unclassified (Class 14) may signal some concern for the reported counts in the other classes. It may also signal the need to consider decreasing the number of classes until technology can be improved to distinguish among similar types of vehicles with greater certainty. This decrease in the number of vehicle classes may also lead to a significant decrease in the level of unclassified vehicles. One such grouping is proposed in Table 19.

Third, for vehicle classes with low mean daily traffic volumes, traffic estimates calculated using five different approaches, ranging from simple to complex, are rather different. On the other hand, for vehicle classes with high mean daily traffic volumes, the five approaches produced estimates no more than 5 percent difference from each other. These results may be additional motivation for combining some vehicle classes, especially among classes with low mean daily traffic columns.

Fourth, the estimates of traffic characteristics based on continuously monitoring data appear to be more precise, on average, than the simulated estimates in which the site is treated as a short-term monitored site. This decrease in precision typically occurs for vehicle classes that account for less than 1% of daily traffic volume, suggesting that

these less common vehicle classes should be combined in order to achieve reliable AADT estimates.

We are aware that this recommendation for research is based on data from only a few sites in only two states.

❸ **Monitor traffic in both directions.**

The analysis of count and classification data by direction of travel shows that traffic differs significantly by direction. This finding is significant in practice because it confirms the need to monitor traffic volume and classification data in both directions instead of just monitoring in one direction and multiplying the result by two. (We are aware that most states already know this, and it is recognized in all relevant prior documents on traffic monitoring.)

This analysis was not performed on WIM data because there are no directional WIM data.

❹ **Monitor missing data.**

Monitor missing data and use graphics and exploring data analysis methods to easily reveal systematic patterns of missing data. Systematic patterns of missing data signal potential equipment problems, thereby providing valuable information for maintenance scheduling. Furthermore, patterns of missing data help guide users to avoid inappropriate analysis and misinterpretation of the data.

❺ **Continue data analysis program of traffic monitoring data.**

For sure, any data analysis of traffic monitoring data should be in support of clearly stated objectives. We have provided a variety of elementary analyses using data from Florida and Washington states. Details are found in [2], [3], [4], [7], [16]. To better aid the development of highway strategies with more accurate and timely traffic characteristics, we propose that the traffic data analysis programs in each state include, at a minimum::

   (i)   data editing methods (such as the approaches used by Florida Department of Transportation, [11] and [16],

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(ii)   tracking of missing data at each continuously monitored site using graphics,

(iii)   development of adjustment factors for AADT estimates from short-term, monitored sites as discussed in [1] and illustrated in [7].

(iv)   computation of total volume averages by day of week and month of year at volume sites,

(v)   computation of volume and percentages of each vehicle class by day of week and month of year at each classification site,

(vi)   computation of average weight and ESAL per day and month at each WIM site,

(vii)   computation of CVs for publication with AADTs for continuously monitored sites, and

(viii)   computation of AADT for continuously monitored sites using simple averages, including in the presence of missing data that do not show a systematic missing pattern.

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