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VARIABILITY IN CONTINUOUS TRAFFIC MONITORING DATA
(A Preliminary Report)

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ABSTRACT

Each state in the United States can be viewed as a universe of road segments. For each road segment in each state, it is desired to know various traffic characteristics based on count data, classification count data, and weigh-in-motion data.

These data are absolutely essential for highway design, maintenance, safety, and planning. Given no cost constraints, each road segment would be continuously monitored every day of the year. However, in practice, a few (sample of) 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 characteristics. With this general approach, each state strives to provide (or help provide) estimates of annual characteristics for each road segment within its jurisdiction. In 1985, the Federal Highway Administration (FHWA) published the *Traffic Monitoring Guide* to assist states in achieving this end.

As with almost any data collection effort, the monitoring data suffers from errors from many sources. In this paper, we report some empirical findings in a research project sponsored by the FHWA. This research project studied the **variability** in the traffic data from the continuously monitored road segments from state(s) and, 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 that states will eventually be able to not only publish an estimate of a characteristic such as AADT for each road segment, but also that each estimate will be accompanied by a statement expressing how good the estimate is in terms of its estimated variability or precision, which will likely be expressed as a coefficient of variation.

VARIABILITY IN CONTINUOUS TRAFFIC MONITORING DATA

(A Preliminary Report)

1. INTRODUCTION

Each state in the United States can be viewed as a universe of road segments. A state road segment is a definite section of a state road. For each road segment in each state, it is desired to know various traffic characteristics including:

Count 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. 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* to assist states in achieving this end.

Objective of Research Study

As with almost any data collection effort, the monitoring data suffers from errors from many sources. The *objective* of this two year research effort, which is sponsored by the Federal Highway Administration, is (i) to study and characterize the *variability* in the traffic data 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 four 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* (October 1995), unpublished report of Oak Ridge National Laboratory's Center for Transportation Analysis.

(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* (January 1996), unpublished report of Oak Ridge National Laboratory's Center for Transportation Analysis.

(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* (April 1996), unpublished report of Oak Ridge National Laboratory's Center for Transportation Analysis.

Step 2: Extension of Initial Methodology for Continuously Monitored Sites

Methods developed for the few sites under Step 1 are applied to a larger collection of continuously monitored sites from Florida and Washington. Estimates of variability associated with continuously monitored sites would be computed.

Step 3: Variability at Short-Term Monitored Sites

We will study how and to what extent variability in data obtained from continuously monitored sites is transferred to estimates based on data from short-term monitored sites.

Step 4: Guidance for States

Based on results from Steps 1, 2, and 3, we will write a report which provides guidance to states for report *variability* in estimates for continuously monitored sites and *precision* in estimates for short-term monitored sites.

2. DESCRIPTION OF SITES USED IN PILOT STUDY

Data used in the pilot study discussed in this paper come from the sites as described in Table 1. 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 also show only 307 days of classification count data. Using only 307 days of data, we get an AADT value of 12,909 vehicles. Thus the difference in reported AADT for site 9925 is because a different number of days of data are used. In general, we attempted to select sites for the pilot study which had at least 200 days of 1994 data in both directions of traffic at the site.

3. SELECTED PRELIMINARY RESULTS FROM THE PILOT STUDY

The reader is reminded that every result or remark in this paper is *preliminary* and based only on a few selected continuously monitored sites from Florida and Washington. We have yet to analyze data from all sites in these two states. Even after analyses of data from these two states, generalization to all states should be done with great care, if at all.

3.1 Differences in Direction of Travel

3.1.1 Investigation of Differences in Count Data by Traffic Direction

For each of Florida's 21 count sites and each "day of the week," we want to know if there was a difference between the mean daily traffic volume in direction 1 and the mean traffic volume in direction 2. To answer this question, we used a *paired t test* for each site and each day of the week as follows. Our discussion focuses on Site 119 and Sunday as the "day of the week."

Step 1. For site 119 and for all Sundays in 1994, we paired all daily traffic counts in one direction with the daily traffic counts in another direction.

Table 1

Continuously Monitored Sites Used in Pilot Study

	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
6.	Florida	Classification	197	Urban Principal Arterial Other [14]	212	47,270
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.

Step 2. In one direction for the 28 Sundays of available data, we computed an average value of 14,878 vehicles per Sunday. For the other direction, we computed an average value of 16,581 vehicles per Sunday.

Step 3. Using a *paired t test,* the Sunday average for the two directions at Site 119 were found to be statistically different at the .05 level of significance.

The complete results are given in Table 2 for the 21 count sites from which we observe that the majority of the average daily traffic counts by direction at a site for each day of the week are statistically different at level .05.

The analysis of count data by direction of travel shows that traffic differs significantly by direction. The preliminary finding confirms the known fact that in order to adequately quantify traffic at the specific location, both directions of travel need to be monitored. Monitoring in only one direction and multiplying by two might be inadequate.

3.1.2 Investigation of Differences in Classification Count Data by Traffic Direction

For each of Florida's 8 classification sites, each "day of the week," and each vehicle class, we wanted to know if 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. A summary of the results over the 7 days of the week at the 8 sites for the vehicle classes is given in Table 3. Thus by vehicle type, we also see significant differences in traffic volume by direction of travel.

Table 2
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 the averages were found to be statistically different at α=.05 level of significance.
A blank means the averages were not found to be statistically different at α=.05 level of significance.

Table 3
General Test Results by Vehicle Class

Vehicle Class		Statistically Different at α=.05 (Paired *t* Test)
(1)	Motorcycles	Yes
(2)	Passenger Cars	Yes
(3)	Other 2 Axle, 4 Tire Single Unit Vehicles	Yes
(4)	Buses	Yes
(5)	2 Axle, 6 Tire, Single Unit S Trucks	Yes
(6)	3 Axle, Single Unit Trucks	Yes
(7)	4 or More Axle, Single Unit Trucks	Yes
(8)	4 or Less Axle, Single Unit Trucks	Yes
(9)	5 Axle, Single Trailer Trucks	Yes
(10)	6 or More Axle, Single Trailer Trucks	Yes
(11)	5 or Less Axle, Multi-Trailers Trucks	No*
(12)	6 Axle, Multi-Trailers Trucks	No*
(13)	7 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"!

3.2 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 4, 5, and 6 show graphics which show the level of missing 1994 days of data at the sites for the different types of data.

Table 4
Graphic of Missing Days for the 21 Selected Sites from Florida's District 5
(Block Means Missing Day)

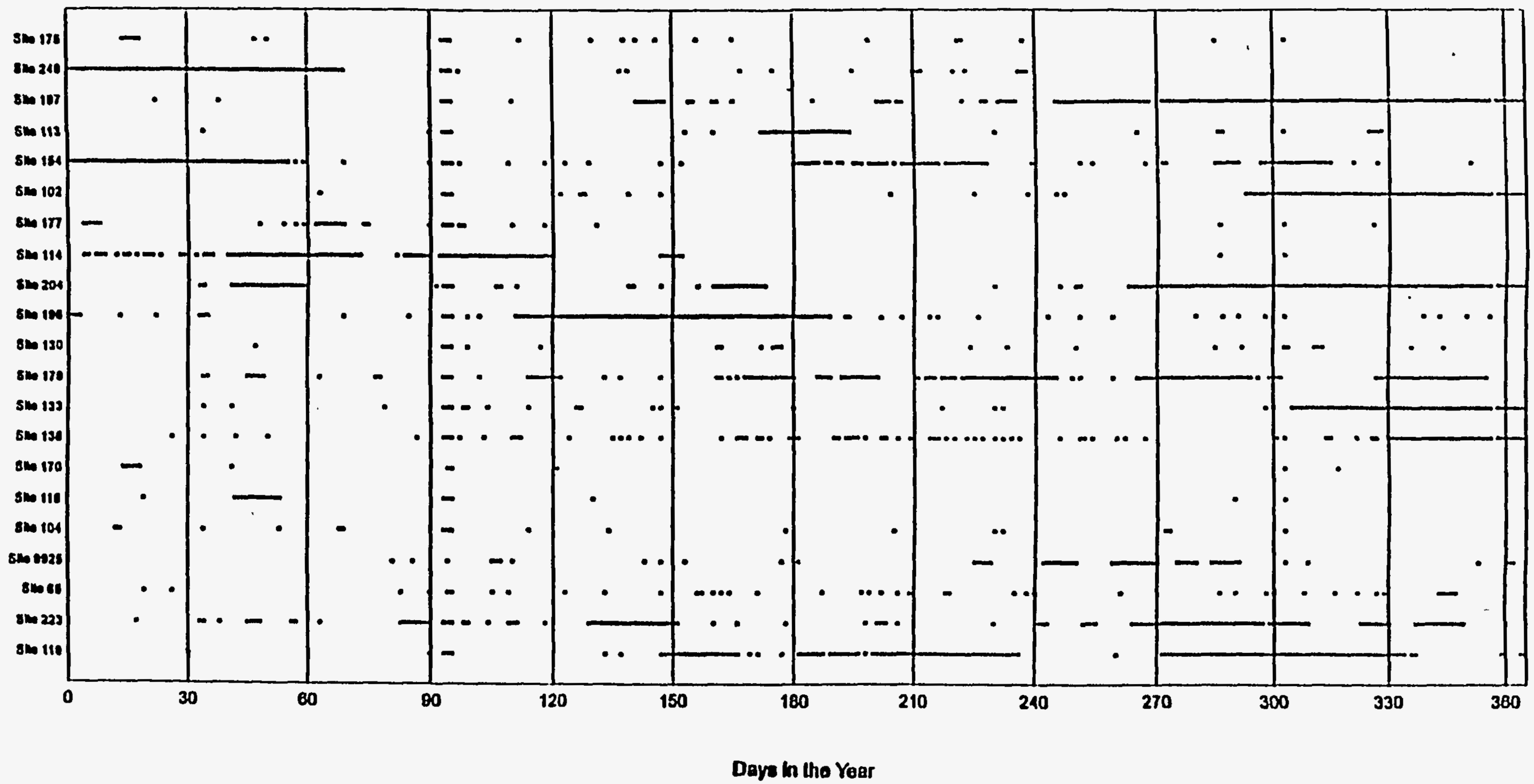


Table 5
Graphic of Missing Days for the 8 Selected Classification Sites from Florida's District 5
(Block Means Missing Day)

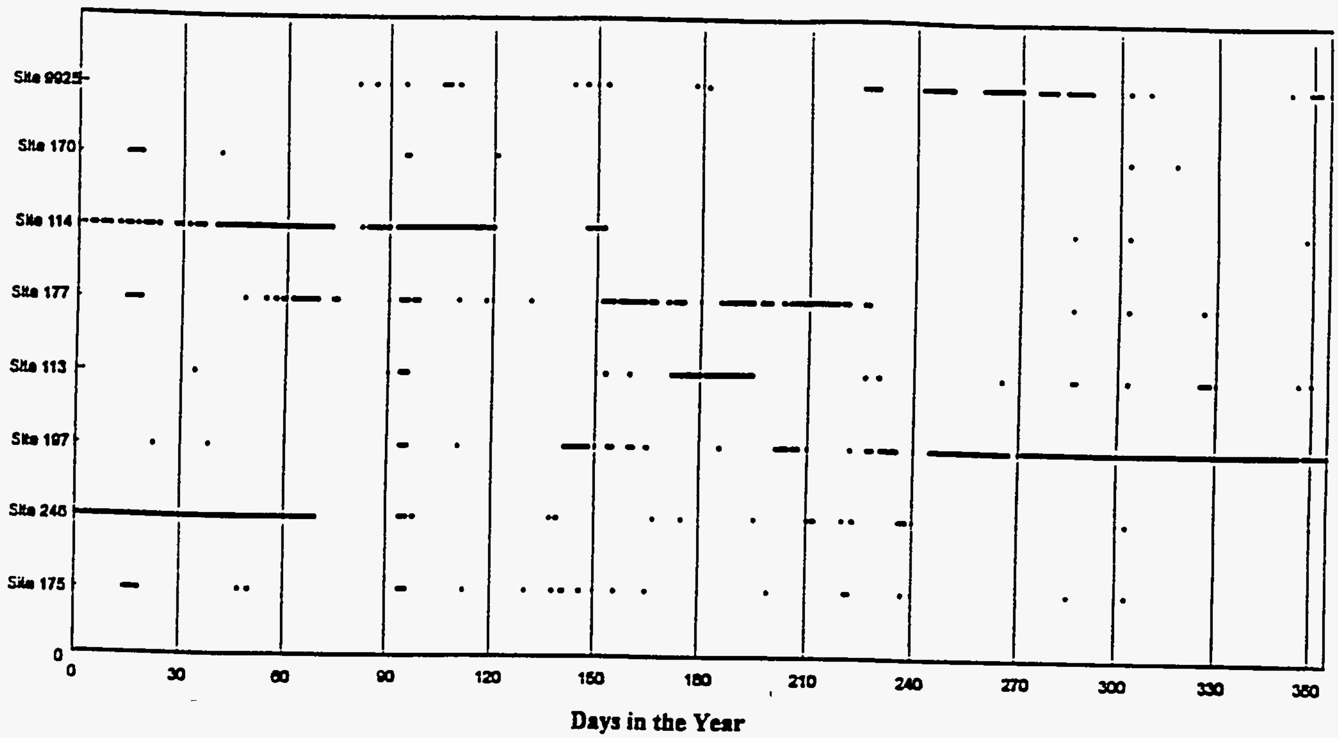
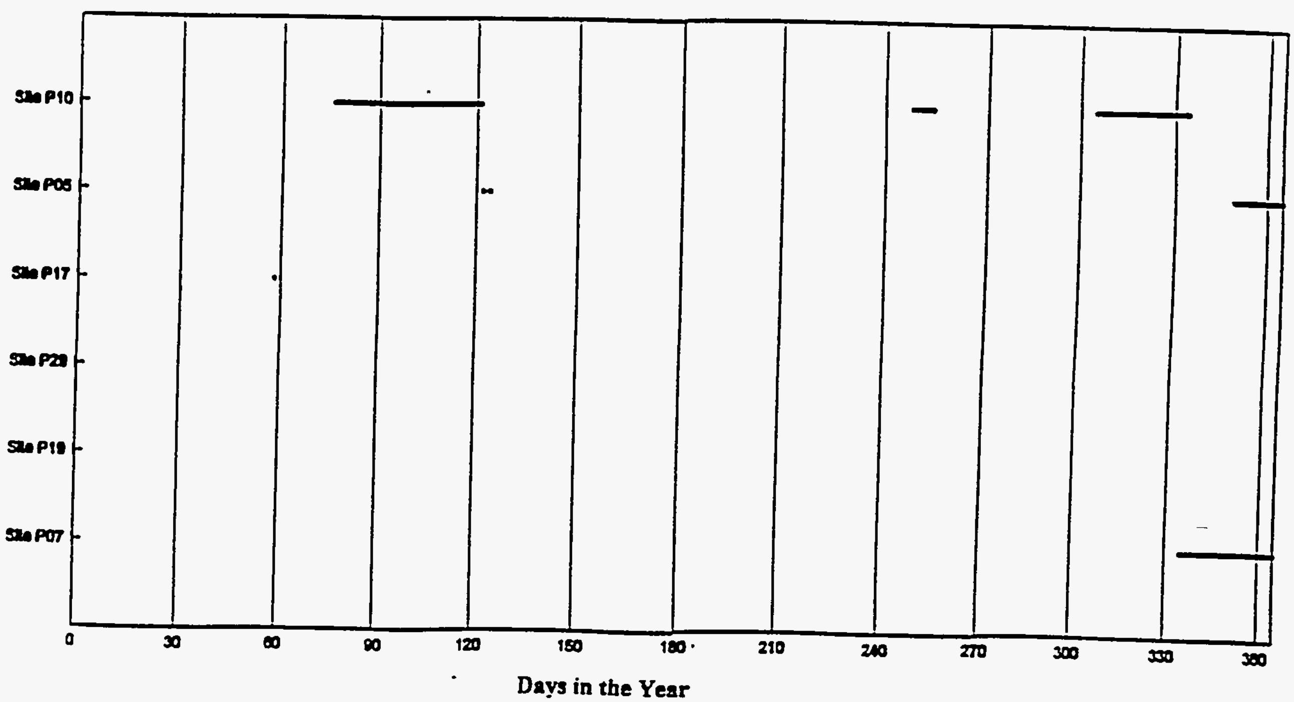


Table 6
Graphic of Missing Days for the 6 Selected WIM Sites from Washington
(Block Means Missing Day)



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 1994 missing days by days of week and by month of year.

Table 7
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 8
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 4, 5, and 6 that the missing days of traffic monitoring data occur in *single isolated days* as well as in *consecutive days*.

3.3 Annual Estimates and Associated Coefficients of Variation

3.3.1 AADT 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

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

The results are given in Table 9.

Table 9
1994 Estimated AADT and Associated Coefficients of Variation (CV)

Site	Estimated AADT	CV(%)	Site	Estimated AADT	CV(%)	Site	Estimate 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

3.3.2 AADT by Vehicle Class and Associated Coefficients of Variation

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. Results are in Table 10.

Table 10
1994 Estimated Mean Daily Count (AADT) by Vehicle Class and Associated Coefficients of Variation (CV)

Vehicle Class		Classification Site							
		9925	170	114	177	113	197	246	175
(1)	Mean Daily Count	12	7	37	79	23	350	4	38
	CV	249%	129%	179%	125%	52%	181%	79%	101%
(2)	Mean Daily Count	10,538	4,080	12,390	28,661	39,755	41,385	5,816	34,830
	CV	21%	11%	12%	15%	13%	15%	11%	22%
(3)	Mean Daily Count	1,737	749	1,533	3,189	4,753	3,853	1,354	2,897
	CV	25%	21%	24%	29%	23%	31%	26%	40%
(4)	Mean Daily Count	8	3	4	22	6	46	36	42
	CV	53%	82%	172%	46%	93%	151%	98%	71%
(5)	Mean Daily Count	176	9	27	53	59	90	54	61
	CV	49%	59%	72%	56%	58%	59%	55%	53%
(6)	Mean Daily Count	59	69	108	93	162	203	40	135
	CV	51%	51%	59%	65%	47%	43%	59%	95%
(7)	Mean Daily Count	8	11	5	18	26	11	3	18
	CV	125%	109%	172%	65%	121%	102%	181%	151%
(8)	Mean Daily Count	71	72	159	331	363	375	122	299
	CV	52%	30%	23%	36%	34%	38%	32%	51%
(9)	Mean Daily Count	96	45	49	215	79	159	113	231
	CV	44%	45%	49%	55%	45%	47%	48%	30%
(10)	Mean Daily Count	2	4	6	10	4	4	1	5
	CV	96%	76%	72%	67%	83%	76%	122%	156%
(11)	Mean Daily Count	1	0	0	4	1	13	0	1
	CV	140%	747%	456%	86%	149%	57%	306%	127%
(12)	Mean Daily Count	0	0	0	1	0	2	0	1
	CV	600%	1,327%	938%	93%	268%	94%	581%	140%
(13)	Mean Daily Count	2	12	0	199	6	0	0	125
	CV	109%	95%	272%	119%	120%	310%	214%	175%
(14)	Mean Daily Count	200	224	129	664	642	782	143	1,241
	CV	64%	78%	49%	54%	21%	55%	37%	126%

3.3.3 Average ESAL per Vehicle by Vehicle Class, Average Weight per Vehicle by Vehicle Class and Associated Coefficients of Variation

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 and report them respectively in Tables 11 and 12.

Table 11
1994 Estimated Average Daily ESAL per Vehicle by Vehicle Class and Associated Coefficients of Variation (CV)

Vehicle Class		Weigh-in-Motion Sites					
		P10	P05	P17	P29	P19	P07
(3)	Mean Daily ESAL per Vehicle	0.01	0.01	0.01	0.12	0.01	0.00
	CV	39.0	139.1	211.8	341.8	54.4	0.0
(4)	Mean Daily ESAL per Vehicle	0.45	0.59	0.12	0.69	0.78	0.46
	CV	36.0	156.0	344.8	47.3	41.8	113.2
(5)	Mean Daily ESAL per Vehicle	0.08	0.13	0.13	0.12	0.10	0.32
	CV	36.1	76.4	139.8	73.1	45.7	72.2
(6)	Mean Daily ESAL per Vehicle	0.25	0.53	0.28	0.45	0.60	0.39
	CV	44.1	103.3	88.3	45.9	32.1	52.4
(7)	Mean Daily ESAL per Vehicle	0.22	0.17	0.08	1.02	1.19	0.42
	CV	285.3	294.3	397.0	86.5	52.1	220.5
(8)	Mean Daily ESAL per Vehicle	0.27	0.94	0.95	0.57	0.36	0.87
	CV	32.9	84.1	92.7	50.3	46.2	67.5
(9)	Mean Daily ESAL per Vehicle	0.97	1.34	1.64	1.42	0.97	1.41
	CV	30.2	38.9	25.2	27.1	34.1	26.3
(10)	Mean Daily ESAL per Vehicle	0.84	1.22	0.91	1.09	0.85	1.06
	CV	34.5	75.1	50.8	33.9	37.0	44.6
(11)	Mean Daily ESAL per Vehicle	1.23	1.35	1.95	1.53	0.39	0.77
	CV	35.3	75.3	33.1	37.7	111.1	178.3
(12)	Mean Daily ESAL per Vehicle	0.79	1.19	1.77	1.53	1.76	1.83
	CV	38.3	57.3	43.9	32.7	42.5	68.9
(13)	Mean Daily ESAL per Vehicle	1.16	1.68	1.34	1.56	1.63	1.62
	CV	33.0	52.9	29.2	30.4	27.3	25.0
(14)	Mean Daily ESAL per Vehicle	0.37	0.72	0.47	0.54	0.43	1.27
	CV	289.3	97.3	237.6	109.0	75.7	130.3

Some numbers rounded to zero.

Table 12
1994 Estimated Average Daily Weight per Vehicle by Vehicle Class and Associated Coefficients of Variation (CV) (Kips)

Vehicle Class		Weigh-in-Motion Sites					
		P10	P05	P17	P29	P19	P07
(3)	Mean Daily Weight per Vehicle	11.4	8.4	10.0	14.1	10.9	0.0
	CV	10.2	24.4	30.4	83.5	10.3	0.0
(4)	Mean Daily Weight per Vehicle	30.7	19.3	6.3	29.9	30.3	16.7
	CV	8.7	81.0	200.6	32.2	16.8	94.0
(5)	Mean Daily Weight per Vehicle	10.6	9.2	9.6	10.6	10.4	16.7
	CV	10.7	17.8	20.7	29.8	13.8	16.0
(6)	Mean Daily Weight per Vehicle	23.4	25.4	23.1	28.1	30.7	27.9
	CV	11.0	25.4	28.7	22.9	10.4	19.5
(7)	Mean Daily Weight per Vehicle	12.4	8.0	4.5	36.6	45.8	13.2
	CV	156.7	209.0	306.5	61.3	38.0	188.7
(8)	Mean Daily Weight per Vehicle	24.8	30.2	32.7	28.1	25.0	35.0
	CV	11.8	26.7	33.5	26.3	19.1	31.3
(9)	Mean Daily Weight per Vehicle	54.9	51.1	59.3	59.8	51.3	58.0
	CV	8.5	10.7	8.1	8.7	9.4	7.4
(10)	Mean Daily Weight per Vehicle	59.0	55.1	50.6	61.0	55.3	60.1
	CV	10.8	22.5	18.7	14.7	12.6	19.9
(11)	Mean Daily Weight per Vehicle	51.8	46.4	57.4	52.0	29.0	31.3
	CV	11.2	22.7	12.9	24.0	46.8	81.6
(12)	Mean Daily Weight per Vehicle	55.2	54.5	61.8	65.8	67.0	63.4
	CV	10.4	17.1	14.6	13.8	21.1	31.2
(13)	Mean Daily Weight per Vehicle	76.1	71.8	75.0	78.0	84.5	78.9
	CV	9.7	15.3	9.3	15.1	9.5	10.1
(14)	Mean Daily Weight per Vehicle	19.0	23.8	20.1	14.9	16.5	27.2
	CV	31.2	42.4	61.6	58.1	36.4	39.1

3.3.4 Remarks

From Table 9, the coefficients of variation associated with AADT for the 21 sites range from 10% to 20%.

From Table 10, the coefficients of variation associated with AADT by vehicle class for the 8 sites range from 11% to 22% for vehicles in Vehicle Class 2 to a range from 93% to 1,327% for vehicles in Vehicle Class 12. For each classification site, higher mean daily traffic counts for a vehicle class tended to have the lower coefficients of variation.

From Tables 11 and 12, we tended to see lower coefficients of variation for the weight per vehicle estimates than for the ESAL per vehicle estimates.

In general and not surprising, the coefficients of variation by vehicle class tended to be larger than the coefficients of variation for the classes combined (Table 9).

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

3.4.1 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 13. Thus for example, for Sunday and for AADT, the lowest CV among the 21 sites was 4% and the highest CV among 21 sites was 18%. We observe similar ranges of CV for each day of the week.

Table 13
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

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

For the 8 classification sites, we see "day of week" coefficients of variation that range over the seven days of the week as shown in Table 14. The lowest ranges exist for "Passenger Cars" (Class 2). The next lowest range exists for "Other Two-Axle, Four Tire, Single Unit Vehicles" (Class 3). By far, the highest ranges exist for vehicle classes 11, 12, and 13, but the absolute mean daily traffic volumes in each of these classes is quite low.

Table 14
CV Ranges Over Days of Week for Each Vehicle Class at Each of the 8 Classification Sites

Vehicle Class	Classification Sites							
	9925	170	114	177	113	197	246	175
(1) Motorcycles	100-300	112-155	121-193	100-134	32-89	161-206	51-102	75-108
(2) Passenger Cars	6-37	5-8	5-8	5-10	4-9	3-8	7-10	7-14
(3) Other 2 Axle, 4 Tire, S Unit	9-39	11-15	9-16	11-26	6-13	8-15	19-25	23-30
(4) Buses	30-80	55-108	62-236	34-50	73-106	134-161	86-111	35-68
(5) 2 Axle, 6 Tire, S Unit	11-47	29-94	35-65	22-49	23-56	18-98	28-106	16-81
(6) 3 Axle, S Unit	19-57	38-71	23-115	24-138	28-44	11-27	24-60	61-177
(7) 4+ Axle, S Unit	91-230	86-137	121-346	36-101	93-111	54-174	113-436	129-297
(8) 4- Axle, S Trailer	20-49	25-38	11-38	12-30	17-27	10-24	15-32	29-47
(9) 5 Axle, S Trailer	15-43	23-36	14-35	28-56	13-30	13-26	14-37	19-23
(10) 6+ Axle, S Trailer	66-164	54-115	32-200	36-100	57-158	46-133	94-232	119-339
(11) 5- Axle, M Trailers	96-474	0-721	0-633	69-121	91-349	16-566	0-648	86-485
(12) 6 Axle, M Trailers	0-678	0-721	0-632	72-121	209-495	56-316	0-640	93-314
(13) 7+ Axle, M Trailers	71-175	75-164	0-351	61-161	94-171	182-566	143-351	144-219
(14) Unclassified/Others	19-101	71-81	29-88	23-69	10-14	46-55	31-37	101-153

It is clear that some vehicle classes, the coefficients of variation are quite high (e.g., CV=721 for day of week for Vehicle Class 12 at Site 170 for 1994). These high coefficients of variation tend to occur with vehicle classes that have extremely low mean daily traffic volumes. To lower these high coefficients of variation, one might consider reducing the number of vehicle classes. This reduction may also lead to *better quality* classification data where one class is difficult to be distinguished from another using current monitoring classification equipment.

3.4.3 Coefficients of Variation (CV) for ESAL per Vehicle by Vehicle Class Ranges Over "Days of Week"

For the 6 weigh-in-motion sites, we see "day of week" coefficients of variation for ESAL that range over the seven days of the week as shown in Table 15. The lowest and shortest ranges appear to exist for "5 Axle, S Trailer" (Class 9). We also observe relatively low and short ranges for Classes 10, 12, and 13. The highest and longest ranges appear to exist for Vehicle Classes 7 and 14.

Table 15
CV Ranges over Days of Week 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	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

3.4.4 Coefficients of Variation (CV) for Weight per Vehicle by Vehicle Class Ranges Over "Days of Week"

For the 6 weigh-in-motion sites, we see "day of week" coefficients of variation for weight that range over the seven days of the week as shown in Table 16. The lowest and shortest ranges appear to exist for "5 Axle, S Trailer" (Class 9). By far, the highest and longest ranges appear to exist for Vehicle Class 7.

Table 16
CV Ranges over Days of Week for "Weight" for Each Vehicle Class at Each of the 6 Weigh-In-Motion Sites from Washington

	Weigh-In-Motion Sites					
Vehicle Class	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

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

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

We observe similar ranges of CV for each month of the year. Comparing Tables 13 and 17, we observe slightly higher CV's for the month of the year than for the day of the week.

Table 17
CV Ranges Over Months of Year for AADT over Florida's 21 Count Sites

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

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

For the 8 classification sites, we see "month of year" coefficients of variation that range over the twelve months of the year as shown in Table 18. As in Table 14, the lowest and shortest ranges are for "Passenger Cars" (Class 2) and the next lowest ranges are for Class 3 "Other Two-Axle, Four Tire, Single Unit Vehicles." Also as in Table 14, the highest and longest ranges are for Vehicle Classes 11, 12, and 13, mainly because of the low mean daily traffic volumes.

Table 18
CV Ranges Over Months of Year for Each Vehicle Class at Each of the 8 Classification Sites

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

3.5.3 Coefficients of Variation (CV) for ESAL per Vehicle by Vehicle Class by "Month of Year"

For the 6 weigh-in-motion sites, we see "month of year" coefficients of variation for ESAL that range over the twelve months of the year as shown in Table 19. The lowest and shortest ranges appear to exist for "5 Axle, S Trailer" (Class 9) and "7+ Axle, M Trailers," (Class 13). As in Table 15 for "days of week" for ESAL, we observe the highest and longest ranges for Vehicle Classes 7 and 14.

Table 19
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

3.5.4 Coefficients of Variation (CV) for Weight per Vehicle by Vehicle Class by "Month of Year"

For the 6 weigh-in-motion sites, we see ranges over "month of year" in coefficients of variation for weight that range over the twelve months of the year as shown in Table 20. We continue to see that the lowest and shortest ranges appear to occur for "5 Axle, S Trailer" (Class 9) and that the highest and longest ranges appear to exist for vehicles in Class 7.

Table 20
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

3.6 Daily Vehicle Mix

Averaging over the 8 classification sites, we obtain the following ranking for the average daily traffic percent mix for 1994 at each classification site (Table 21). (All percents are rounded).

At almost every one of the 8 classification sites, the level of unclassified/other vehicles is quite high relative to what is captured in Classes 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13. The large percentage of vehicles being unclassified (Class 14) may signal some cause for 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 better between similar type vehicles. This decrease in the number of classes may also lead to a significant decrease in the level of unclassifieds. One such grouping is given in Table 22.

Table 21
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 22
Potential Grouping Scheme of Vehicles

Potential Group Class	Vehicle Classes
G1 Motorcycles	1 Motorcycles
G2 Passenger Vehicles -1	2 Passenger Cars
G3 Passenger Vehicles - 2	3 Other 2 Axle, 4 Tire, Single Unit
G4 Single Unit Trucks	4 Buses
	5 2 Axle, 6 Tire, Single Unit
	6 3 Axle, Single Unit
	7 4 or More Axle, Single Unit
G5 Single Trailer Trucks	8 4 or Less Axle, Single Trailer
	9 5 Axle, Single Trailer
	10 6 or More Axle, Single Trailer
G6 Twin Trailer Trucks	11 5 or Less Axle, Multi-Trailer
	12 6 Axle, Multi-Trailer
G7 Very Large Trucks	13 7 or More Axle, Multi-Trailers
G8 Unknown Vehicle	14 Unclassified/Other Vehicles

Averaging over the 6 weigh-in-motion sites, we obtain the following ranking for the average daily traffic percent mix for 1994 at each Washington weigh-in-motion site. We also note a relatively high level of unclassified vehicles among these sites (Table 23).

Table 23
1994 Daily Vehicle Mix Based on Washington's 6 Weigh-In-Motion Sites

	Percent	Vehicle Class	
Highest Ranked Class	35.6	(9)	5 Axle, S Trailer
	24.3	(5)	2 Axle, 6 Tire, S Unit
	12.2	(13)	7+ Axle, M Trailers
	6.4	(6)	3 Axle, S Trailer
	5.7	(10)	6+ Axle, S Trailer
	5.2	(8)	4-Axle, S Trailer
	3.7	(12)	6 Axle, M Trailers
	2.7	(14)	Unclassified Vehicles
	1.8	(11)	5 Axle, M Trailers
	1.4	(3)	Other 2 Axle, 4 Tire, S Unit
	0.7	(4)	Buses
Lowest Ranked Class	0.3	(7)	4+ Axle, S Unit
Total	100.00		

3.7. Examination of Different Methods for Computing AADT

3.7.1 Five Methods for Computing AADT

For a given road segment or 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." [Reference: *AASHTO Guidelines for Traffic Data Programs (1992)*, American Association of State Highway and Transportation Officials, Washington, DC, p. 108.] Depending on the amount and quality of available data, it appears that there are several methods to compute a quantity to pursue this aim as discussed in Sections 3.7.2–3.7.6.

3.7.2 Method 1: Average of All Days (Standard Method)

If x_i is the total daily traffic count on a given road segment for the i^{th} day, where i=1, 2, ..., N, define AADT to be

$$AADT_1 = \frac{\sum_{i=1}^{N} x_i}{N} .$$

Ideally, N=365 (or 366). In practice, N, which is the number of days with available "edited" counts during a year, is often less than 365 (or 366). If N=365 (or 366), all would likely use $AADT_1$.

3.7.3 Method 2: Average of "Monthly" Averages

If certain months of the year (e.g. winter months) have more days with missing data than other months of the year (e.g. summer months), then the definition in Method 1 tends to give a number $AADT_1$ which is influenced more than it should be by the summer months and influenced less than it should be by the winter months. This seems undesirable, and in an attempt to overcome or guard against this and to give equal influence to the months of the year, $AADT_2$ is proposed.

Step 1. For month i, let

$\bar{x}_i$ be the average of the total daily traffic counts.

Note that $\bar{x}_i$ is based on the number of days of available counts for month i.

Step 2. Then AADT can be taken as

$$AADT_2 = \frac{\sum_{i=1}^{M} \bar{x}_i}{M}$$

where M is the number of months with sufficient data to compute a value $\bar{x}_i$. Ideally M=12. However, in practice, M is often less than 12 as revealed by Table 2.1 for the sites in Florida's District 5.

3.7.4 Method 3: Average of "Day of Week" Averages

If certain days of the week (say Tuesdays and Wednesdays) tend to have missing days of data while other days of the week tend to not have missing days of data, the definition in Method 1 tends to give a number $AADT_1$ which is overly influenced by counts from days other than Tuesdays and Wednesdays. This seems undesirable because the traffic volume is clearly different among the different days of the week, particularly between weekdays and weekend days. In an attempt to overcome this and to give equal influence to the days of the week, $AADT_3$ is proposed.

Step 1. For the i^{th} day of the week, let

$\bar{Y}_i$ be the average of the total daily traffic counts for all of the i^{th} days of the week during the year for which there are available "edited" counts.

Step 2. Then AADT can be taken as

$$AADT_3 = \frac{\sum_{i=1}^{W} \bar{Y}_i}{W}$$

where W is the number of days of the week with sufficient data to compute a value $\bar{Y}_i$. Ideally W=7.

Method 4 is a combination of Methods 2 and 3 and it attempts to simultaneously equalize the effect of the months of the year and days of the week on AADT.

3.7.5 Method 4: Average of "Monthly" and "Day of Week" Averages (AASHTO Method)

Step 1. For the i[th] day of the week in month j, let

$\bar{x}_{ij}$ be the average of the total daily traffic counts.

Then we have

$$\text{for Sunday,} \quad \bar{x}_{1.} = \frac{\bar{x}_{11} + \bar{x}_{12} + \cdots + \bar{x}_{1,M_1}}{M_1} \; ;$$

$$\text{for Monday,} \quad \bar{x}_{2.} = \frac{\bar{x}_{21} + \bar{x}_{22} + \cdots + \bar{x}_{2,M_2}}{M_2};$$

$$\vdots$$

$$\text{for Saturday,} \quad \bar{x}_{7.} = \frac{\bar{x}_{71} + \bar{x}_{72} + \cdots + \bar{x}_{7,M_7}}{M_7},$$

where M_i is the number of months with an average for day of week i for i=1, ..., 7. Ideally each M_i=12.

Step 2. Then AADT can be taken as

$$AADT_4 = \frac{\bar{x}_{1.} + \bar{x}_{2.} + \bar{x}_{3.} + \bar{x}_{4.} + \bar{x}_{5.} + \bar{x}_{6.} + \bar{x}_{7.}}{7}.$$

Method 4 is recommended by AASHTO. (*AASHTO Guidelines for Traffic Data Programs*, p. 52)

3.7.6 Method 5: Weighted Average of Average of Monthly "Weekday" and "Weekend Day" Averages

To ensure appropriate contributions to annual average daily traffic of weekdays and weekend days, Method 5 is considered.

Step 1. For *weekdays* in month j, let

$\bar{Y}_{wj}$ be the average of the total daily traffic count.

Then for weekdays,

$$AADT_{weekday} = \frac{\bar{Y}_{w1} + \bar{Y}_{w2} + \ldots + \bar{Y}_{w,M_w}}{M_w}$$

where M_w is the number of months with a *weekday* average. Ideally M_w=12.

Step 2. For *weekend days* in month j, let

$\bar{x}_{ej}$ be the average of the total daily traffic count.

Then for weekend days,

$$AADT_{weekend} = \frac{\bar{x}_{e1} + \bar{x}_{e2} + \ldots + \bar{x}_{e,M_e}}{M_e}$$

where M_e is the number of months with a *weekend* average. Ideally M_e=12.

Step 3. Then AADT can be taken as

$$AADT_5 = \frac{5}{7} AADT_{weekday} + \frac{2}{7} AADT_{weekend}$$

Note under Method 5 that we are taking the weekend days to be Saturday and Sunday.

For the 21 Florida selected sites, and using the available 1994 data, the AADT for the different methods are given in Table 24.

3.7.7 Preliminary Comments Based on the Empirical Comparison

From the last column of Table 24, note that for each site, 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

Table 24
A Comparison of the Computed AADTs for the Five Different Methods

Func Class**	Site	No. of Days	No. of Weekdays	No. of Weekend Days	Number of Sun	Mon	Tue	Wed	Thu	Fri	Sat	No. of Mos	AADT - Methods 1	2	3	4	5	How Close Are Methods*
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. See Section 3.7.7 for more details.
** For functional class definition, see Table 1.

$$
\begin{aligned}
\textit{Percent Closeness} &= \textit{Maximum Ratio} \\
&= \frac{\textit{Max Estimate} - \textit{Min Estimate}}{\textit{Min Estimate}} \times 100\% \\
&= \frac{5{,}284 - 5{,}275}{5{,}275} \times 100\% \\
&\approx 0.17\%.
\end{aligned}
$$

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 sites which all suffer from various patterns of missing data.

It seems reasonable to conclude, based on preliminary evidence, that the 5 estimates are essentially the same for each of the sites. However, to conclude that the 5 estimates for a given site are at or near the "true" AADT (based on measurement error free data from 365 or 366 days) would be incorrect. In fact, we may *never* know whether or not we have the true AADT for any given site.

If no practical difference in the estimates continues to hold for the additional sites to be analyzed in later Tasks, we recommend use of Method One for simplicity!

By using the same five methods, similar results were observed for the classification data (Task V Report, Chapter 7) and for the weigh-in-motion (Task VIII Report, Chapter 7).

3.8 Effect of Holidays and Special Days

3.8.1 Effect of Holidays and Special Days on AADT and CV

The table below gives 1994 holidays and "holiday period" as defined by the Florida DOT. For each of the 21 selected sites, Table 25 presents computations of $AADT_1$ and CV under these 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	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

3.8.2 Preliminary Comments

From Table 25, 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 3 different conditions is reflected in the sixth and seventh columns with percents.

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.

From Table 25, 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 gives smaller values than for the rest of the days.

While the effect of holiday 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 (Task V Report) and for the weigh-in-motion data (Task VIII).

Table 25
Effect of Holidays and Special Days on AADT and CV (%)

Func 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.

3.9 Simulations with Randomly Missing Count Data

3.9.1 Simulations with Randomly Missing Days: Effect on AADT

In this section, we investigate the effect on AADT when individual days of data are missing at random. Throughout all simulations in this section, AADT is the mean of the available data. We do this for three levels of missing data:

(*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.

3.9.1.1 Five Percent of Days of Count Data Missing at Random

For a specific one of Florida's 21 selected sites, 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 1000 different values of average daily traffic and 1000 different coefficients of variation. Compute the average of the 1000 values of average daily traffic and denote this 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 selected sites.

3.9.1.2 Twenty Percent of Days of Count Data Missing at Random

For each of Florida's 21 selected sites, repeat the steps of Section 3.9.1.1 except here, the remaining days are $N - d_2$ where $d_2 = .2N$ and $SADT_2$ is the "simulated average daily traffic" without 20% of days of count data.

3.9.1.3 Fifty Percent of Days of Count Data Missing at Random

For each of Florida's 21 selected sites, repeat the steps of Section 3.9.1.1 except here, the remaining days are $N - d_3 = .5N$ and $SADT_3$ is the "simulated average daily traffic" without 50% of days of count data.

The results of the simulations are described in Table 26.

3.9.1.4 Preliminary Comments

From columns 5, 6 and 7 of Table 26, if 5% or 20% of the days' data are missing at random, the simulated average values of $SADT_1$ and $SADT_2$ are essentially the same as $AADT_1$ for each site. Though the simulated average value $SADT_3$ (column 7 of Table 26) is also close to $AADT_1$, 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 that the simulated standard errors increase from $SADT_1$ to $SADT_2$ to $SADT_3$.

Under random sampling, sampling theory tells us that the expected values of $SADT_1$, $SADT_2$ and $SADT_3$ will all be $AADT_1$ 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 result even though it is on target (on the average).

For these 21 preliminary sites, one might argue that even with 50% of the count data missing at random, the reliability of the estimate is quite high. In fact, if equipment failure due to use is the chief cause for missing data, then a more efficient approach for collecting traffic data might be to abandon continuous monitoring. Rather than attempt to employ the equipment at a single site for each and every day of the year, it might be better to employ the equipment only on randomly selected days, hence decreasing its use while extending its life. Preliminary results suggest that the loss in AADT reliability due to missing data might very well be tolerable. More research is needed, which is beyond the scope of this research study. The use of sampling with continuously monitored sites should likely permit more resources for the short term monitoring sites.

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.

4. CONCLUDING COMMENT

The empirical results and comments in this paper are all based on observations for a small set of continuously monitored sites from Florida and Washington using 1994 data. More details and other empirical results are given in the reports for Tasks II, V, and VIII. The validity of most of these empirical results will likely be increased only as additional data are analyzed from other sites, including sites from other states.

Table 26
Simulation Results for $AADT_1$ with Randomly Missing Days of Count Data**

Func Class***	Site	N	$AADT_1$	Amount of Randomly Missing Data: 5%	20%	50%	How Close are $SADT_i$ and $AADT_1$? The 2 estimates are within X% of each other.		
				$SADT_1$*	$SADT_2$*	$SADT_3$*	$SADT_1$	$SADT_2$	$SADT_3$
01	119	212	30,180	30,185	30,179	30,207	0.02%	0.00%	0.09%
				(101)	(215)	(445)			
02	223	231	4,474	4,474	4,475	4,475	0.01%	0.02%	0.02%
				(12)	(24)	(46)			
02	65	322	7,382	7,381	7,383	7,385	0.01%	0.01%	0.04%
				(11)	(22)	(45)			
02	9925	308	12,661	12,661	12,661	12,657	0.00%	0.00%	0.03%
				(25)	(55)	(109)			
02	104	347	22,098	22,099	22,101	22,091	0.00%	0.02%	0.03%
				(21)	(48)	(95)			
02	118	345	22,262	22,264	22,263	22,256	0.01%	0.00%	0.03%
				(34)	(75)	(156)			
06	170	353	5,284	5,283	5,285	5,285	0.01%	0.03%	0.01%
				(8)	(17)	(36)			
07	136	263	6,336	6,336	6,336	6,336	0.01%	0.00%	0.00%
				(17)	(37)	(71)			
11	133	283	28,026	28,028	28,031	28,016	0.01%	0.02%	0.04%
				(58)	(128)	(261)			
11	179	210	54,599	54,599	54,592	54,603	0.00%	0.01%	0.01%
				(121)	(264)	(523)			
11	130	341	110,865	110,863	110,861	110,847	0.00%	0.00%	0.02%
				(124)	(254)	(529)			

* The numbers in parenthesis are the standard deviations of the 1,000 simulated values $SADT_i$ for each site.
** Simulated results are rounded. Some percents rounded to zero.
*** For functional class definition, see Table 1.

Table 26 (continued)
Simulation Results for $AADT_1$ with Randomly Missing Days of Count Data**

Func Class***	Site	N	$AADT_1$	Amount of Randomly Missing Data: 5% $SADT_1$*	20% $SADT_2$*	50% $SADT_3$*	How Close are $SADT_i$ and $AADT_1$? The 2 estimates are within X% of each other. $SADT_1$	$SADT_2$	$SADT_3$
11	196	252	154,304	154,308	154,318	154,339	0.00%	0.01%	0.02%
				(265)	(590)	(1,175)			
12	204	212	28,294	28,293	28,287	28,301	0.01%	0.03%	0.02%
				(54)	(113)	(228)			
14	114	267	14,436	14,436	14,436	14,429	0.00%	0.01%	0.05%
				(28)	(58)	(126)			
14	177	333	33,290	33,292	33,282	33,303	0.01%	0.02%	0.04%
				(69)	(155)	(314)			
14	102	278	40,753	40,756	40,753	40,755	0.01%	0.00%	0.00%
				(83)	(170)	(343)			
14	154	220	44,030	44,031	44,030	44,035	0.00%	0.00%	0.01%
				(77)	(176)	(338)			
14	113	326	45,825	45,826	45,829	45,820	0.00%	0.01%	0.01%
				(82)	(173)	(369)			
14	197	212	47,270	47,272	47,278	47,270	0.01%	0.02%	0.00%
				(120)	(263)	(527)			
16	246	278	7,681	7,681	7,682	7,682	0.00%	0.01%	0.01%
				(11)	(23)	(49)			
16	175	342	39,920	39,917	39,917	39,927	0.01%	0.01%	0.02%
				(113)	(238)	(485)			

* The numbers in parenthesis are the standard deviations of the 1,000 simulated values $SADT_i$ for each site.
** Simulated results are rounded. Some percents rounded to zero.
*** For functional class definition, see Table 1.

5. REFERENCES

1. *AASHTO Guidelines for Traffic Data Programs (1992)*, American Association of State Highway and Transportation Officials, Washington, D.C.

2. *Traffic Monitoring Guide, U. S. DOT*, (Oct. 1992), Federal Highway Administration, Washington, D.C.

3. Tsao, H. and Wright, T. (1983). "On the Maximum Ratio: A Tool for Assisting Inaccuracy Assessment," *The American Statistician, 37* 339-342.

4. *Variability in Continuous Traffic Monitoring Data Task II Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Count Data,* (Oct. 1995), unpublished report of the Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831.

5. *Variability in Continuous Traffic Monitoring Data Task V Report: Pilot Methodology Development and Estimates of Variability from Continuous Traffic Classification Count Data*, (January 1996), unpublished report of the Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831.

6. *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), unpublished report of the Center for Transportation Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831.