Selected Results from the First Three Years of the Oregon Automatic Monitoring Demonstration Project

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Until the 1980s, the majority of highway traffic data was obtained manually. However, with the evolution of microcomputers, cost-effective automatic data-collection equipment has been implemented. A comprehensive system is made up of weigh-in-motion, automatic vehicle classification, and automatic vehicle identification. Weigh-in-motion determines axle and vehicle weight at full speed on the highway, automatic vehicle classification classifies the traffic into groups (19 in Oregon) by identification of axle spacings, and automatic vehicle identification acts as an "electronic license plate," which can be used with weigh-in-motion and automatic vehicle classification to characterize individual vehicles. These new technologies enable continuous and relatively accurate monitoring of traffic, and therefore lead to improved planning, pavement design, and other activities that use the data. Oregon State Highway Division is a leader in demonstrating automatic vehicle monitoring, which was initiated in the state in 1983. Data are collected in unprecedented amounts at five sites on Interstate 5 (I-5). Oregon State University has developed prototype BASIC software to process the weekly data from the busiest site in tabular or graphical form, designed to enable data to be distributed in the various units in the highway division. Selected results are included in this paper, and other data are presented that show comparison of weights obtained with weigh-in-motion and with static scales. The advantages of having automatic vehicle monitoring data are demonstrated. In particular, the continuous monitoring of the traffic stream completely defines daily, weekly, and seasonal traffic patterns, and clearly indicates growth.

For many years highway vehicle data have been collected for different purposes. Data concerning truck and car volumes are used in transportation planning. Truck gross and axle weight data are needed for weight enforcement and pavement design. Obtaining these data is not a simple task. Vehicle counting was originally done using simple manual counters that required substantial manpower. With the advent of pneumatic tube counters, vehicle counting became much easier and less expensive; however, this method had many limitations for vehicle classification. Truck-weight information has traditionally been obtained from weigh stations where trucks must be stopped and weighed statically. Because these methods of traffic and weight data acquisition were lengthy and costly, statistical data were usually based on short-term sample data. Data obtained in this manner are not reliable because bias is introduced into sample data by the manual data collection methods and the lack of continuously open weigh stations.

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In recent years a new approach has revolutionized vehicle data acquisition technology. In-motion weighing of vehicles at normal highway traffic speeds has become possible at reasonable cost. Induction loops can be used for counting and as part of a classification system (that also needs axle sensors), and automatic identification of vehicles has become a reality. The integration of weight-in-motion (WIM), automatic vehicle classification (AVC), and automatic vehicle identification (AVI) systems in one site provides continuous and accurate data that can be used for a variety of purposes, which include

1. Size, weight, and speed enforcement;
2. Transportation planning;
3. Pavement design and management;
4. Truck fleet management; and
5. Vehicle taxation.

It is significant to note that low-cost WIM and AVC devices have been identified as vital to the Long-Term Pavement Performance (LTPP) element of the Strategic Highway Research Program (SHRP) *(1)*, for which traffic data for hundreds of sites will be required.

In the future an integrated system of many sites in a network will provide a much more powerful means of providing enough information for hazardous material monitoring and crime detection.

Oregon State Highway Division (OSHD) initiated a program in 1983 to evaluate WIM, AVC, and AVI. OSHD currently has five sites in which AVC and AVI are operational and two in which WIM, AVC, and AVI are operational. In addition, OSHD has a portable WIM device that requires installation at suitable bridges. Details of the entire Oregon automatic vehicle monitoring (AVM) program have been described previously by Krukar and Henion *(2)*.

PURPOSE AND SCOPE

The purpose of this paper is to present some results from Oregon's WIM/AVC/AVI demonstration project.

Included in the paper are data applying mainly to Oregon's Jefferson site, but data from the other sites are also included. The Jefferson site on I-5 northbound was chosen for the initial development of data-reduction procedures because it is the only high-speed WIM/AVC/AVI installation and is operated continuously. This site obtains data for both northbound lanes. Data were first collected at this site in April 1984, and presented in this paper will be data collected since that time. The early development of software for post-processing of the data collected at the Jefferson site has been described by Mohseni *(3)*. Bell and Mohensi *(4)* have described subsequent work. The development of software is an ongoing effort, reflecting the continuing development of AVM technology and its applications.

RESULTS FROM THE JEFFERSON SITE

The WIM system at this site is an International Road Dynamics (IRD) Automatic Highway Scale. The AVC system is made up of two loops connected to a DEC LS1-11/2 computer at the roadside. A microwave AVI system can identify those trucks that have installed an electronic license plate (ELP) voluntarily. At present, about 200 trucks are fitted with ELPs.

The tables output form from the Jefferson system is converted to numeric data files that are then used to produce weekly plots and tables. Numeric files are also used to create cumulative files that contain data for several weeks and are used to produce cumulative plots and tables. Vehicle classifications used in the Oregon weigh-in-motion study are shown in Figure 1. These classifications are based on vehicle axle arrangement and length.

Data Collection

The following primary (raw) data are collected by the WIM/AVC/AVI system on the passage of each vehicle:

1. Time and day of pass by roadside unit,
2. Vehicle license plate by AVI system,
3. Vehicle length by AVC system,
4. Axle spacing and number of axles by AVC system, and
5. Weight of individual axle (by WIM).

These data are then processed by the roadside computer to produce the secondary "cooked" data listed as follows:

1. Vehicle axle arrangement,
2. Vehicle classification based on axle arrangements,
3. Axle and gross vehicle weight, and
4. AASHTO rigid and flexible Equivalent Single Axle Load (ESAL).

The roadside computer outputs the data in two forms: tables and view. The view data consist of primary and secondary data for each vehicle and can be accessed at the time of passage. These data are not stored in the roadside computer because of

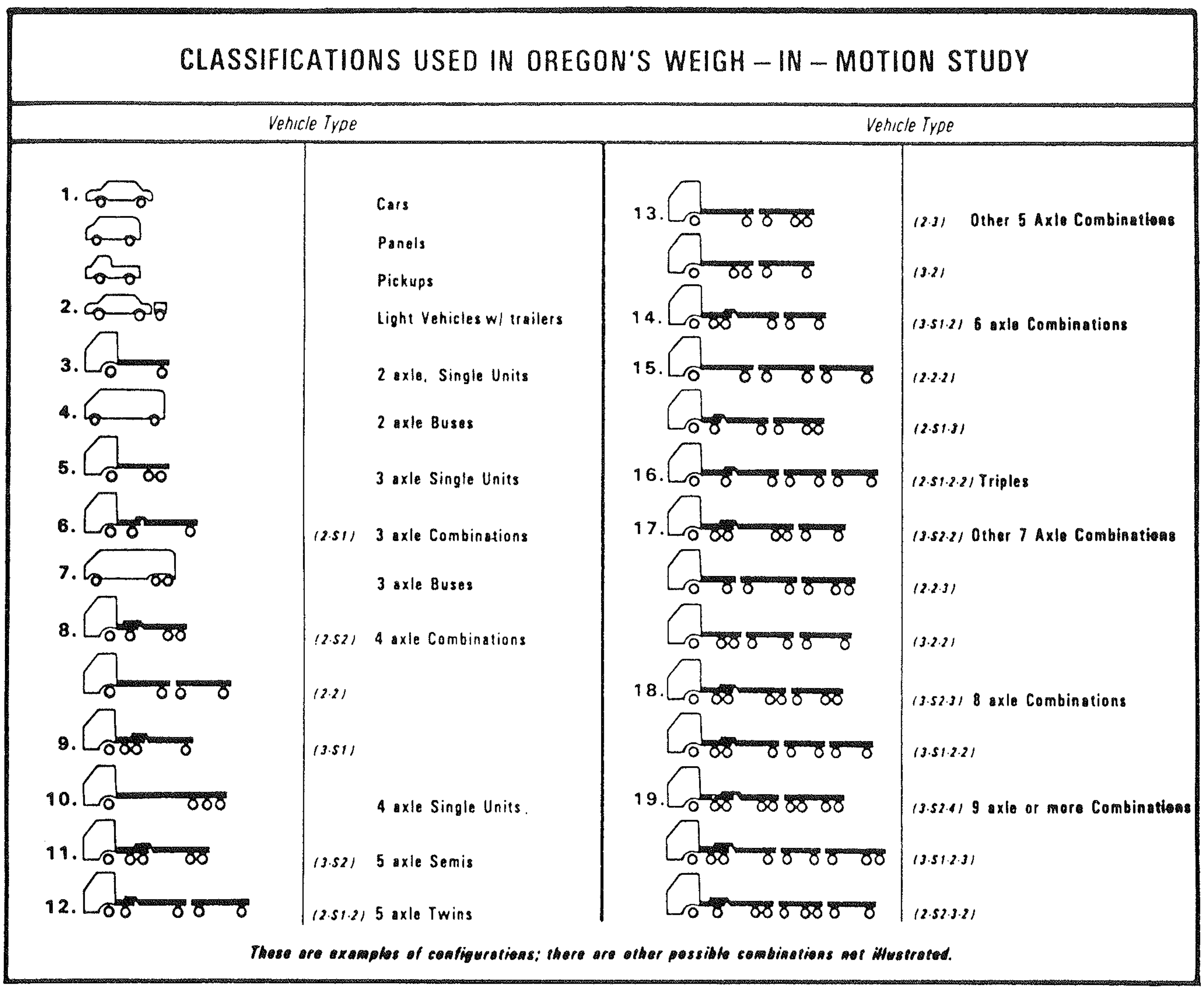

FIGURE 1 Classifications used in Oregon's weigh-in-motion study.

the large memory size needed. Rather, the raw and cooked data are processed into 11 tables in the form of a report, referred to as the tables output form. The following are the titles of the tables:

1. Most Recent Vehicles With Transponders (ELPs),
2. Weight Distribution and Average 18-k ESAL by Vehicle Type,
3. Numbers of Truck Axles by Weight,
4. Vehicles with the Highest Flexible 18-k ESAL,
5. Average Vehicle Length in Feet by Type,
6. Number of Vehicles and 18-k ESAL by Day of the Week (Lane 1),
7. Number of Vehicles and 18-k ESAL by Day of the Week (Lane 2),
8. Cars and Single Unit Truck Volume by Hour and Day of the Week,
9. Five-Axle Semis and Other Truck Volume by Hour and Day of the Week,
10. Traffic Volume by Speed Range, and
11. Five-Axle Semis (Type 11) Flexible 18-k ESAL.

Note that the first five tables are cumulative tables and provide data for a desired period of time (usually 1 week), which is controlled by OSHD from a remote computer. The rest of the tables are daily tables and contain data for each day of the week beginning on Mondays at 00.00 hr. Tables 1 and 2 are examples of the third and fourth tables listed in the table titles. Both of these provide detailed axle load data.

Data Communication and Storage

The tabular weekly reports (tables) that are collected at the Jefferson site are transferred to the OSHD Economic Services unit in Salem via modem. Other users can also access the data. To transfer the reports, the computer operator in Salem calls the on-site computer every Monday morning and downloads the reports onto an IBM-AT hard disk. Any communications software can be used to download the reports.

Reports have been obtained by Oregon State University from ODOT since April 7, 1984, and stored on an IBM-XT hard disk. In order to have continuous data, the report from an adjacent week was used whenever the report for a week was not available or was incomplete (about 10 percent of all weeks). Presented in this paper are data obtained through September 1986 (130 weeks).

Procedure for Reducing Data

The view and tabular output are originally in report form (i.e., output file form). Thus, the first task is to convert the tables into

TABLE 1 NUMBERS OF TRUCK AXLES BY WEIGHT

Front Axles Weight (kips)	#	Single Axles Weight (kips)	#	Tandem Axles Weight (kips)	#	Tridem Axles Weight (kips)	#
< 4	1947	< 4	1766	< 8	707	< 8	9
4-5	628	4-5	1179	8-10	713	8-10	2
5-6	303	5-6	1164	10-12	918	10-12	10
6-7	354	6-7	1053	12-14	1093	12-14	4
7-8	691	7-8	967	14-16	756	14-16	2
8-9	2223	8-9	846	16-18	700	16-18	3
9-10	3240	9-10	754	18-20	702	18-20	2
10-11	3105	10-11	624	20-22	651	20-22	1
11-12	1960	11-12	585	22-24	686	22-24	3
12-13	513	12-13	637	24-26	669	24-26	1
13-14	55	13-14	594	26-28	670	26-28	2
14-15	9	14-15	563	28-30	811	28-30	2
15-16	5	15-16	638	30-32	1383	30-32	2
16-17	3	16-17	667	32-34	2292	32-34	1
17-18	2	17-18	723	34-36	2896	34-36	1
18-19	0	18-19	752	36-38	1706	36-38	4
19-20	0	19-20	618	38-40	451	38-40	1
20-21	0	20-21	482	40-42	71	40-42	2
21-22	1	21-22	325	42-44	10	42-44	0
22-23	0	22-23	141	44-46	7	44-46	1
23-24	0	23-24	65	46-48	2	46-48	1
24+up	0	24+up	25	48-50	3	48-50	1
				50+up	3	50-52	0
						52-54	1
						54-56	0
						56-58	0
						58-60	0
						60-62	0
						62-64	0
						64-66	0
						66-68	0
						68-70	0
						70-72	0
						72-74	0
						74+up	0

	Front	Single	Tandem	Tridem
Overweight Axles:	n/a	1038	5149	n/a
Total Axles:	15039	15168	17900	56
Average Weight:	8.7	10.8	25.9	20.8
Percent Overloads[a]	n/a	6.0	28.3	n/a

Note: Oregon State Highway Division, Interstate 5, Jefferson Site, from Monday, June 24, 1985, at 8:10 a.m. to Monday, July 1, 1985, at 8:06 a.m.

[a]These estimates are based on WIM data, not static weights.

TABLE 2 VEHICLES WITH HIGHEST FLEXIBLE 18-K ESAL

#	Type	Lane	Day	Time	Axle (or Axle Group) Weights 1st	2nd	3rd	4th	5th	6th	Axle Configuration	Gross Weight	Speed	18-K ESAL Rigid	Flexible
1	12	1	Tue Jun 25	13:01	8.7	25.4	22.7	23.1	21.6		11111	101.5	56	12.11	10.99
2	16	1	Sun Jun 30	02:24	9.4	22.4	20.5	21.3	16.3	22.5	1111111	129.1	56	10.44	9.87
3	16	1	Mon Jun 24	15:42	8.1	22.2	23.5	20.4	21.1	15.5	1111111	126.5	48	10.39	9.77
4	12	1	Thu Jun 27	10:59	9.1	22.1	24.6	18.7	23.8		11111	98.3	57	10.66	9.76
5	12	1	Mon Jun 24	15:29	10.0	21.2	24.3	19.5	24.1		11111	99.1	54	10.52	9.66
6	11	1	Thu Jun 27	20:48	8.9	47.2	52.0				122	108.1	55	17.43	9.39
7	12	1	Tue Jun 25	15:23	9.7	21.9	21.3	20.7	24.8		11111	98.4	60	10.17	9.37
8	12	1	Mon Jun 24	08:55	9.3	22.6	21.1	23.1	22.3		11111	98.4	56	10.10	9.34
9	16	1	Sat Jun 29	02:56	9.9	22.1	23.5	18.0	18.8	15.2	1111111	127.0	57	9.73	9.23
10	15	1	Mon Jun 24	08:10	11.5	42.6	54.7	4.6			1221	113.4	62	16.74	9.07
11	12	1	Wed Jun 26	15:17	9.5	20.5	21.6	19.1	25.6		11111	96.3	59	9.74	8.96
12	12	1	Thu Jun 27	19:50	8.8	19.6	23.2	20.2	24.0		11111	95.8	54	9.46	8.76
13	12	1	Wed Jun 26	19:41	8.6	22.3	23.7	18.0	22.3		11111	94.9	59	9.24	8.57
14	16	1	Wed Jun 26	15:02	8.3	19.6	18.1	19.7	21.9	20.6	1111111	124.9	48	8.85	8.52
15	12	1	Fri Jun 28	13:04	9.7	20.8	23.0	18.7	23.6		11111	95.8	58	9.16	8.50
16	11	1	Wed Jun 26	21:47	8.5	45.9	50.2				122	104.6	36	15.57	8.42
17	19	1	Tue Jun 25	14:44	11.3	20.8	43.1	44.8	40.0		12222	160.0	55	15.10	8.38
18	12	1	Sat Jun 29	17:38	9.4	22.5	21.6	21.4	20.8		11111	95.7	58	8.83	8.27
19	14	1	Wed Jun 26	20:28	8.9	26.8	24.9	19.1	23.9		12111	103.6	63	9.34	8.25
20	12	1	Fri Jun 28	11:09	9.2	21.2	23.3	17.9	22.8		11111	94.4	59	8.82	8.21
21	12	1	Thu Jun 27	08:13	10.5	23.6	22.7	19.8	19.0		11111	95.6	58	8.76	8.17
22	13	1	Mon Jun 24	10:49	11.1	45.4	22.5	22.1			1211	101.1	55	11.34	8.15
23	14	1	Mon Jun 24	12:10	9.2	30.3	20.4	23.8	23.4		12111	107.1	62	9.29	8.12
24	12	1	Mon Jun 24	15:29	8.7	21.8	23.1	18.7	21.8		11111	94.1	55	8.67	8.10
25	12	1	Mon Jul 1	06:27	9.2	25.3	19.3	18.5	20.4		11111	92.7	63	8.51	7.89
26	12	1	Mon Jun 24	16:57	9.4	20.5	23.1	17.9	22.6		11111	93.5	58	8.35	7.81
27	12	1	Tue Jun 25	15:23	9.3	21.9	22.4	18.5	21.4		11111	93.5	60	8.16	7.67
28	12	1	Wed Jun 26	15:17	9.5	19.9	22.8	18.1	22.9		11111	93.2	57	8.18	7.67
29	12	1	Mon Jun 24	22:40	8.8	23.0	18.6	19.3	22.8		11111	92.5	57	8.19	7.66
30	17	1	Fri Jun 28	16:19	11.5	32.9	23.2	23.0	15.1	16.4	121111	122.1	57	8.80	7.62
31	17	2	Tue Jun 25	15:51	12.3	32.5	19.0	22.1	19.7	20.2	121111	125.8	59	8.61	7.62
32	12	1	Fri Jun 28	15:46	8.9	21.2	21.8	21.2	20.3		11111	93.4	58	8.07	7.60
33	15	1	Thu Jun 27	03:26	8.3	26.8	38.0	34.6			1122	107.7	55	10.47	7.53
34	16	1	Sun Jun 30	02:14	9.4	20.6	19.6	17.4	17.1	20.6	1111111	122.2	56	7.72	7.52
35	16	1	Wed Jun 26	22:47	9.0	23.4	21.1	19.1	19.6	9.0	1111111	108.9	58	7.95	7.49
36	19	2	Mon Jun 24	14:54	9.8	17.6	38.8	42.1	43.7		12222	152.0	52	13.45	7.47
37	14	1	Wed Jun 26	11:51	8.4	28.7	20.7	22.0	23.8		12111	103.6	57	8.43	7.47
38	12	1	Fri Jun 28	14:14	9.0	23.9	21.8	18.3	18.8		11111	91.8	55	7.94	7.44
39	12	1	Thu Jun 27	20:50	8.8	21.1	22.5	17.3	22.0		11111	91.7	57	7.84	7.37
40	12	1	Thu Jun 27	14:20	9.9	22.4	19.2	19.8	21.9		11111	93.2	58	7.78	7.35

Note: Oregon State Highway Division, Interstate 5, Jefferson Site from Monday, June 24, 1985, at 8:10 a.m. to Monday, July 1, 1985, at 8:06 a.m. ESAL = equivalent standard axle load.

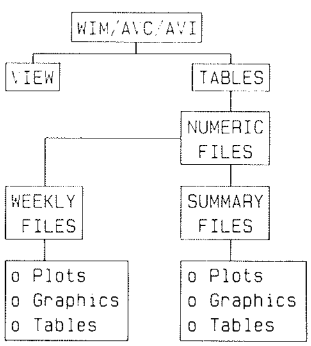

FIGURE 2 Data processing and presentation.

numeric form so that data (numbers) can be read individually as a data file. This is done by the CHEWALL BASIC program, which enables the user to create the numeric files for a number of weeks. For each table in each week one numeric file is created. WIM Tables 1 and 4 are not converted to numeric files because the data in these tables are only useful in the report form. Thus, nine numeric files are created for each week of the year. These numeric files are the source of data for weekly and cumulative summary tables and plots. Shown in Figure 2 is a flowchart depicting the data-reduction process.

Weekly Summary Tables and Plots

The data in the 11 tables are reduced and summarized in 3 summary tables and in 19 plots for each week. This is done by the WKMENU computer program written in IBM BASIC. Three summary tables summarize the weekly data for different applications. The user can select the desired plot for plotting and summary tables for printing. Selected plots for 1 week are shown in Figures 3 through 10. Table 3 shows summary table information for vehicle volumes and ESALs.

Cumulative Plots and Tables

The data in the numeric files are used to produce cumulative summary files. This is done by using the TABMENU computer program, which reads data from the previously created numeric files for a specified number of weeks and prints the data into a cumulative summary file. Thus, a summary file contains data for several weeks. There are 21 choices of summary files, as follows:

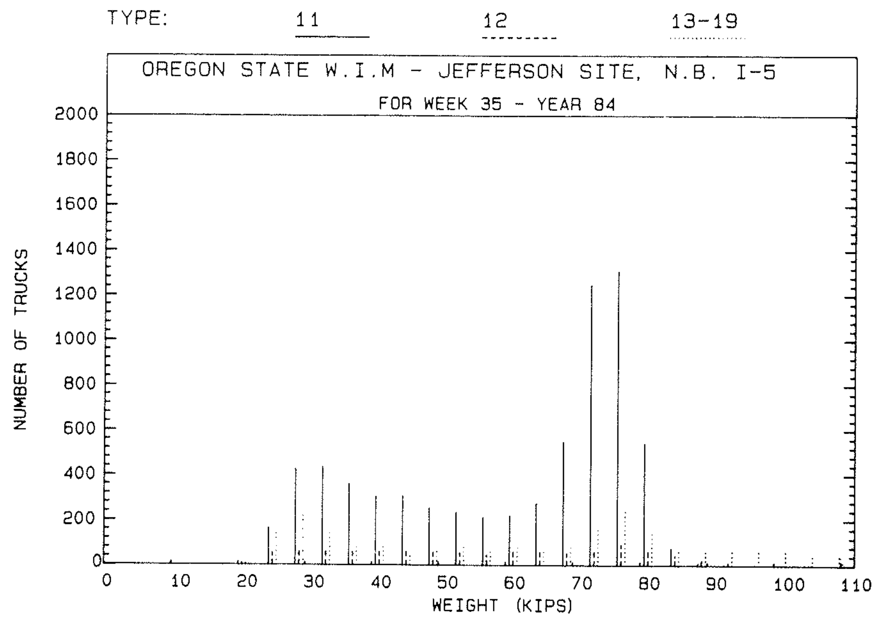

FIGURE 3 Weight distribution by vehicle type.

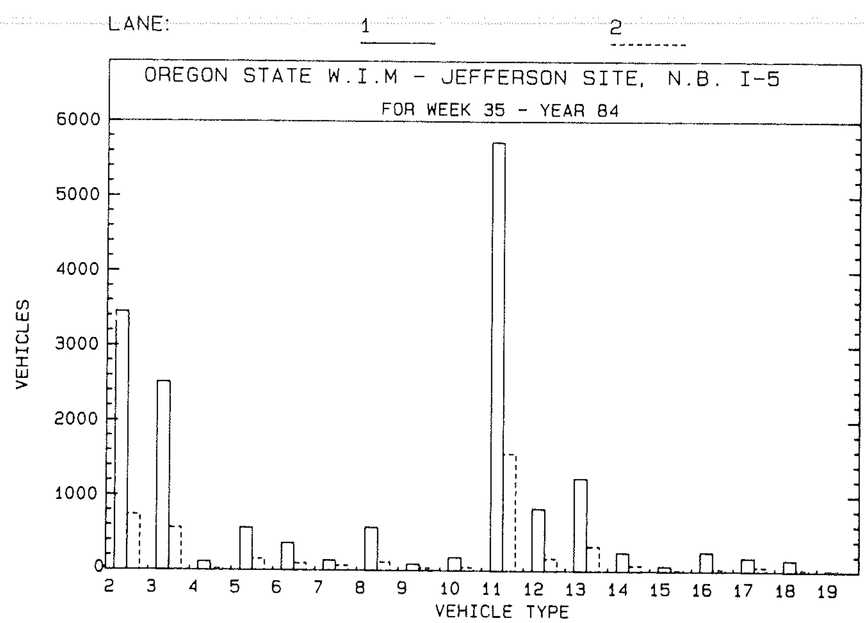

FIGURE 4 Average weekly volume by type and lane.

1. Average Weight of Light Trucks (Both Lanes),
2. Average Weight of Heavy Trucks (Both Lanes),
3. Average ESAL for Light Trucks (Both Lanes),
4. Average ESAL for Heavy Trucks (Both Lanes),
5. Weekly Axle Volume by Type (Both Lanes),
6. Average Axle Weight by Type (Both Lanes),
7. 5 Axle Semis Front Axle Weight—Lane 1,
8. 5 Axle Semis Front Axle Weight—Lane 2,
9. Truck and Vehicle Weekly Volume (Both Lanes),
10. Weekly Truck Volume by Type (Both Lanes—Types 3–19),
11. Weekly Truck Volume by Type (Both Lanes—Types 12–19),
12. Percent Trucks in Vehicles by Lane,
13. Percent Vehicles not Weighed by Lane,
14. Percent Truck Types in Trucks (Both Lanes),
15. Percent Vehicles in Lane 2,
16. Weekly ESAL by Lane (Both Lanes),
17. Weekly ESAL by Truck Class (Both Lanes—Types 3–19),
18. Weekly ESAL by Truck Class (Both Lanes—Types 12–19),
19. Percent Weekly ESAL by Truck Class (Both Lanes),
20. Percent ESAL in Lane 2 by Type, and
21. Average Weekday Speed (Both Lanes).

Note that all ESALs are for flexible pavement and those parts of the title in parentheses are omitted on the plots and tables.

Summary files should be checked for errors and aberrations because inconsistencies in WIM operation and modem

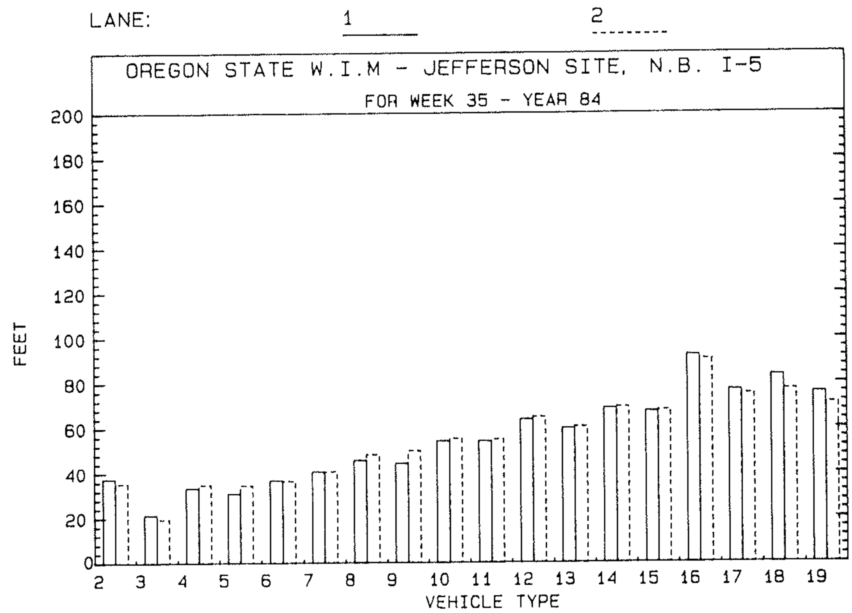

FIGURE 5 Average weekly length by type and lane.

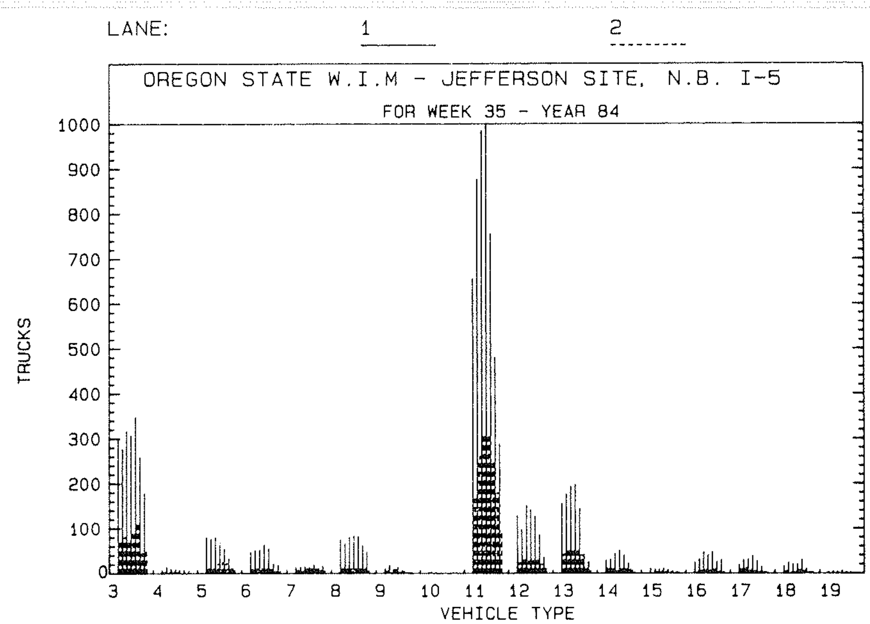

FIGURE 6 Daily truck volume by type.

communication may mean that values may not be representative of the data for some of the weeks. This can be done by an editor's program such as SPFPC, or by suitable word processing software.

Once summary files are corrected, they can be printed by TABMENU or plotted by using the PLOTMENU computer program. Menu options are used for both programs. To plot the summary files, an HP 7475A series plotter is used. An option is to show the plot graphically on the computer screen and then to copy the graphic to a printer. Figures 11 through 22 show selected summary plots. Figure 12 is plotted from an extended version of the example summary file (for average ESALs of heavy trucks), shown in Table 4. Illustrated in this table is an example of the result of incomplete data; week 51 data were incomplete, and were replaced with week 52 data, which show low ESALs because of the holiday season.

Limitations of the Tables and Plots

Owing to deliberate or accidental misses, about 20 percent of vehicles are not weighed by the system, with an average of about 14 percent within that 20 percent being unclassified. Deliberate misses are attributed to about 5 percent of vehicles, and the remaining misses are due to lane changes at the site. The majority of the data in the weekly reports represents either classified (about 86 percent) or weighed (about 80 percent) vehicles. In fact, only two of the tables in the weekly reports

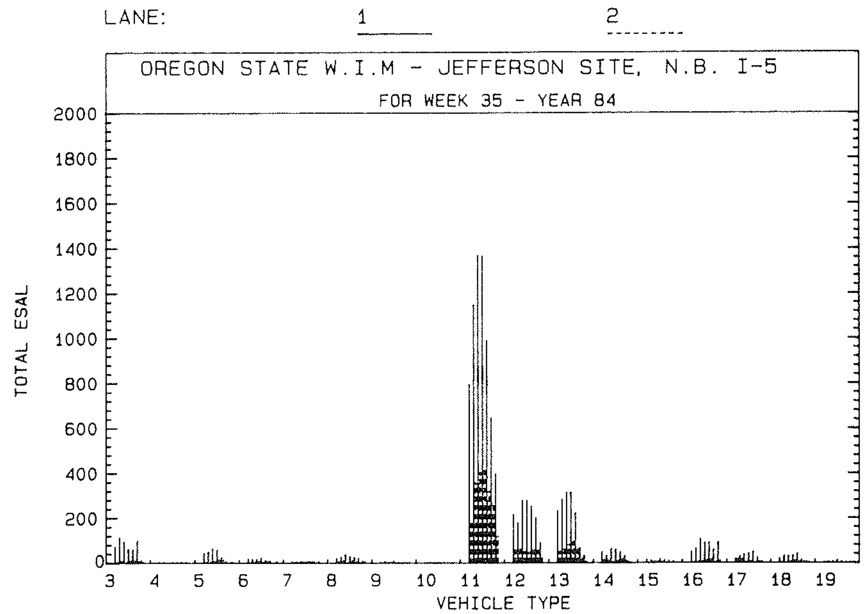

FIGURE 7 Daily total truck ESAL by type.

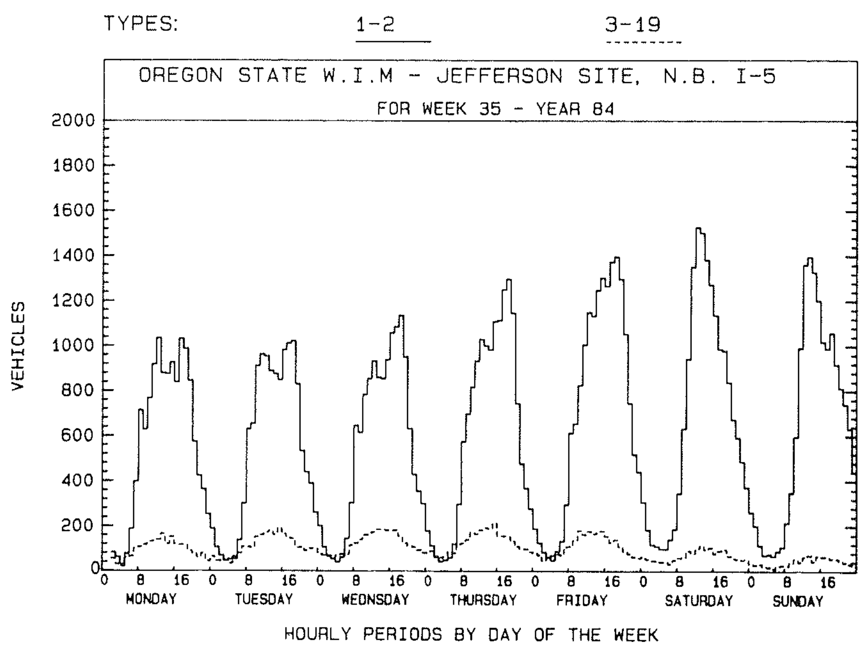

FIGURE 8 Hourly vehicle volume by class and day of week.

indicate the total vehicles not weighed each day, and clearly there can be no data indicating the classification of those vehicles not weighed or not classified.

For this reason, all of the plots that can be developed represent only a portion of the total traffic. No attempt has been made as yet to adjust the data, as accurate adjustment factors cannot be developed except when considering the total traffic. However, the weekly summary tables (e.g., Table 3) do present adjusted data, assuming that all unclassified and unweighed vehicles are evenly distributed among the 19 vehicle classifications. The cumulative summary tables contain no such adjustment at the present time.

COMPARISON OF TRUCK WEIGHTS OBTAINED AT DIFFERENT SITES

The Jefferson WIM site is located approximately 30 mi south of the Woodburn weigh station, also on I-5, where a WIM sorter system is in use. The sorter system is used to expedite passage of legally loaded vehicles through the station, but causes those vehicles close to or in excess of the statutory limits to be directed to static scales for traditional weighing. There are approximately 200 Oregon trucks voluntarily fitted with electronic tags for automatic identification at Jefferson,

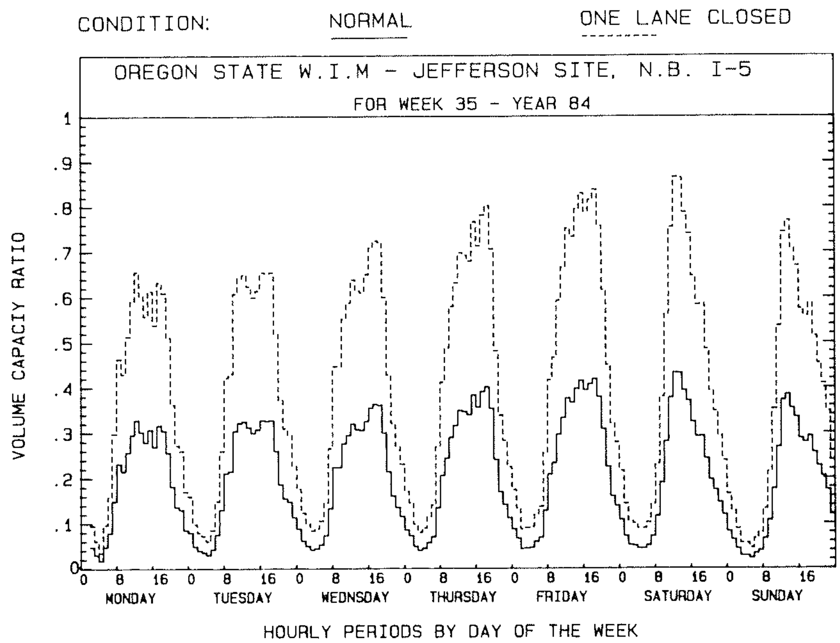

FIGURE 9 Hourly volume capacity ratio.

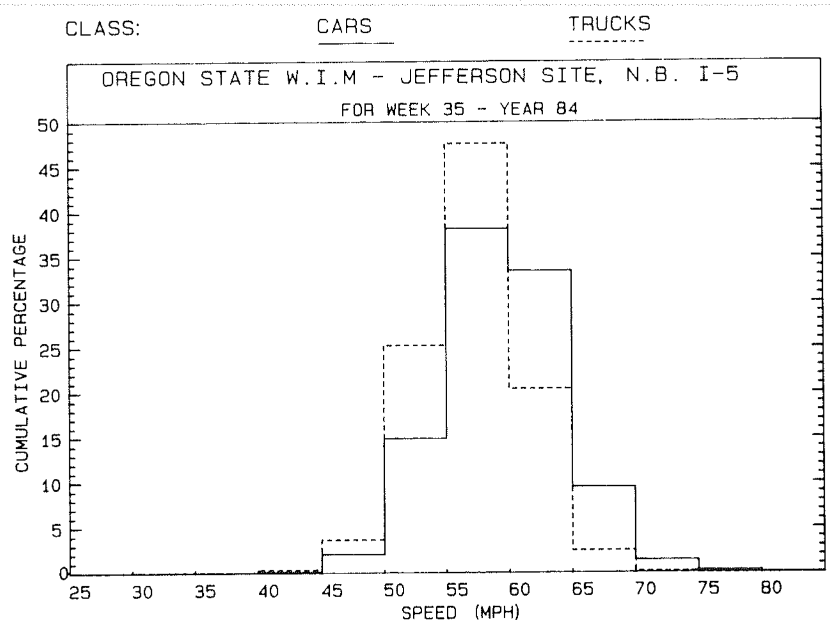

FIGURE 10 Average weekday speed distribution.

Woodburn, and four other locations on I-5. This allows detailed comparison of their axle and gross loads, as they will be weighed at both WIM sites and on the static scales (if requested as part of a short study) provided they travel through the I-5 corridor.

Table 5 shows data from a recent study in which Jefferson WIM data were compared with Woodburn static data for Type 11 trucks. This study considered all trucks rather than just those with tags, and was accomplished by matching Public Utility Commission (PUC) plate numbers at each location. The data show that the mean gross loads measured at Jefferson in Lane 1 are 5 percent higher than the static loads. This difference is used elsewhere in this paper in estimating overloading. However, it should be noted that the differences vary with axle type, gross weight, and lane.

DISCUSSION OF DATA COLLECTED

Some significant aspects of the data are highlighted in the following paragraphs.

Weekly Data

Vehicle Length

It can clearly be seen in Figure 5 that Type 16 trucks are the largest trucks using I-5, averaging about 90 ft long. This is as expected, because Type 16 is a 2-S1-2-2 triple-trailer vehicle (see Figure 1). The 2-S2-2-2 triple trailer included in Type 18 could be longer, but is less frequent than the 3-S2-3 truck, and therefore is not reflected in the average length of Type 18.

TABLE 3 ADJUSTED WEEKLY TRUCK DISTRIBUTION BY TYPE

Type	Description	No. of Vehicles	Percent Vehicles	Average ESAL	Total ESAL
1	Cars	109477	82.2	0.00	0.00
2	Cars+Trailers	4792	3.6	0.00	0.00
3&4	Rigid 2-Axle	3590	2.7	0.12	430.75
5&7	Rigid 3-Axle	816	0.6	0.42	342.74
10	Rigid 4-Axle	0	0.0	0.00	0.00
6	3-Axle Semi	515	0.4	0.31	159.53
8&9	4-Axle Semi	1059	0.8	0.33	349.63
11	5-Axle Semi	8560	6.4	1.62	13867.69
12	5-Axle Twin	1188	0.9	2.45	2910.91
13-19	Other	3244	2.4	1.80	5839.22
3-19	Total (Trucks)	18972	14.2	1.26	23900.45
1-19	Total (All)	133241	100.00	0.18	23900.45

Note: From Monday, June 24, 1985, at 8:10 a.m. to Monday, July 1, 1985, at 8:06 a.m. ESAL = equivalent standard axle load.

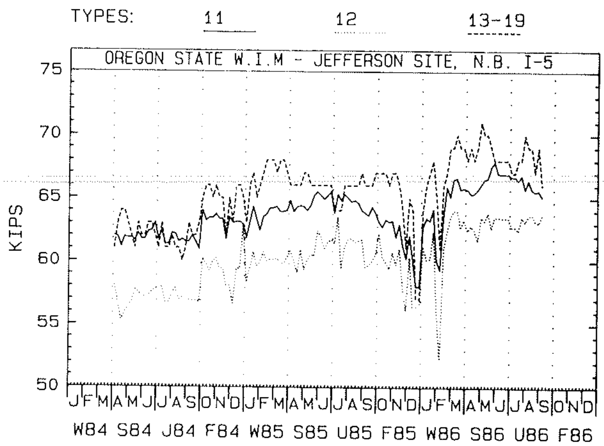

FIGURE 11 Average weight of heavy trucks.

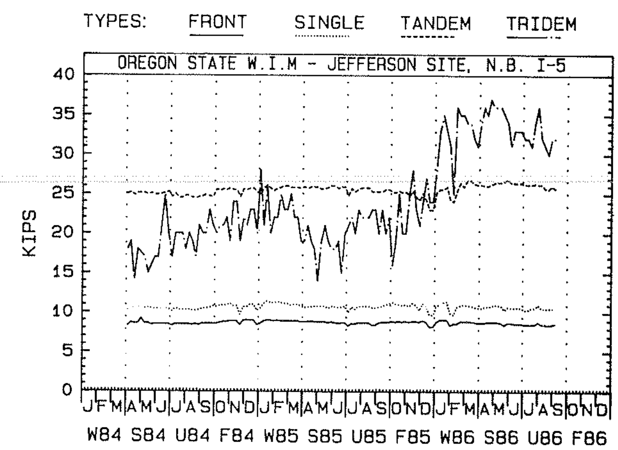

FIGURE 13 Average axle weight by type.

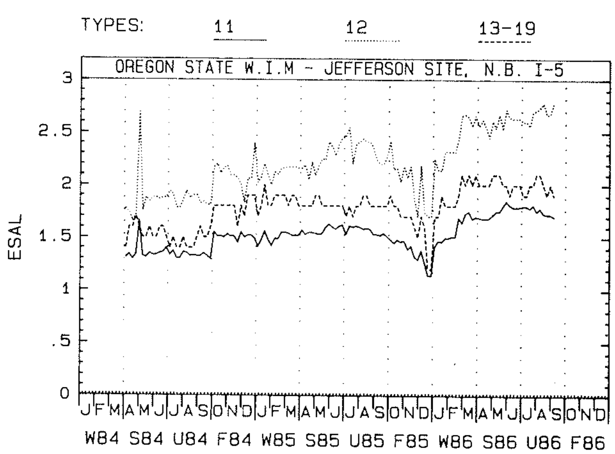

FIGURE 12 Average ESAL for heavy trucks.

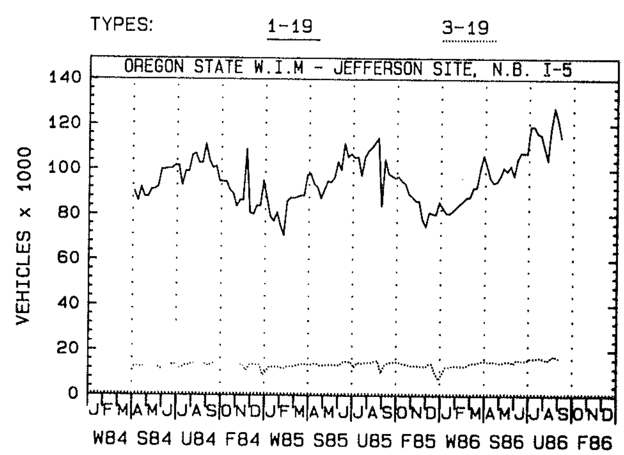

FIGURE 14 Truck and vehicle weekly volume.

Volume of Vehicles by Lane Each Day

It is shown in Figure 4 that, excluding cars, the Type 11 truck (3-S2) is the most frequently occurring vehicle. About half of the truck traffic is this type of vehicle. It can also be noted (see Figure 6) that the peak day for truck traffic is either Wednesday or Thursday.

Hourly Volumes of Cars and Trucks

It can be seen in Figure 8 that, for the week shown, there is no pronounced morning peak hour, but that the afternoon peak for Types 1 and 2 (cars and other light vehicles) is 5:00 to 6:00 p.m., Monday to Friday. The weekend peaks are at about midday. It is also shown in Figure 8 that for the week covered, which was followed by the Labor Day holiday, the heaviest flow occurs on a Saturday. During spring and summer the

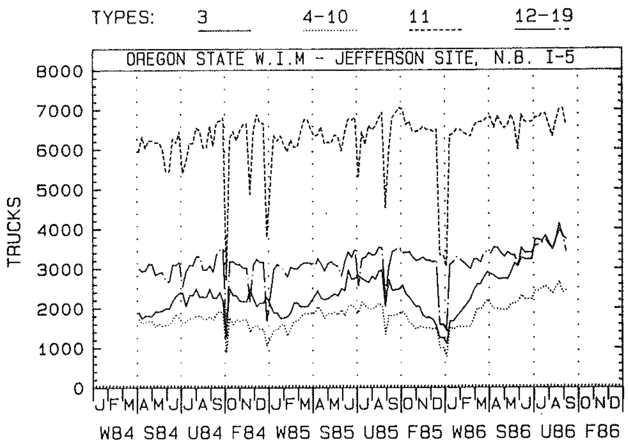

FIGURE 15 Weekly truck volume by type (Types 3; 4–10; 11; 12–19).

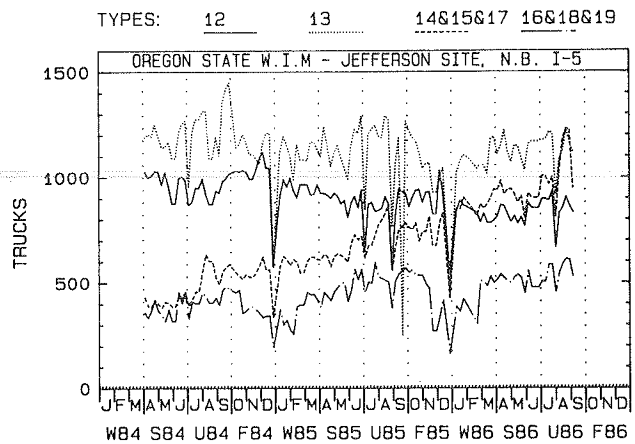

FIGURE 16 Weekly truck volume by type (Types 12; 13; 14, 15, and 17; 16, 18, and 19).

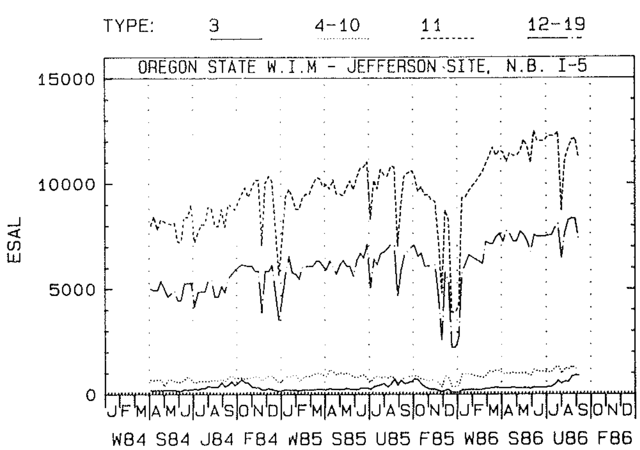

FIGURE 17 Weekly ESAL by truck class (Types 3; 4–10; 11; 12–19).

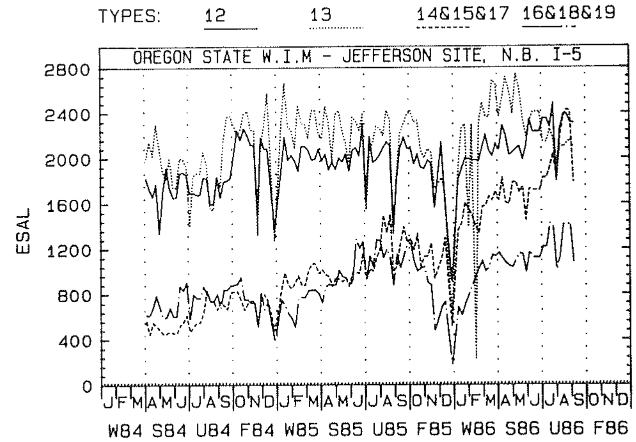

FIGURE 18 Weekly ESAL by truck class (Types 12; 13; 14, 15, and 17; 16, 18, and 19).

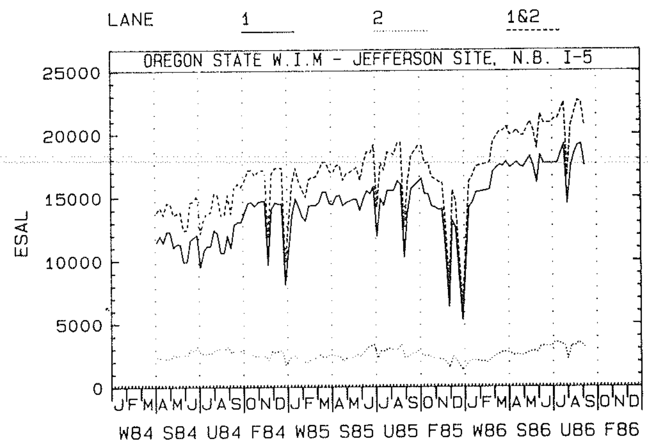

FIGURE 19 Total ESAL by lane.

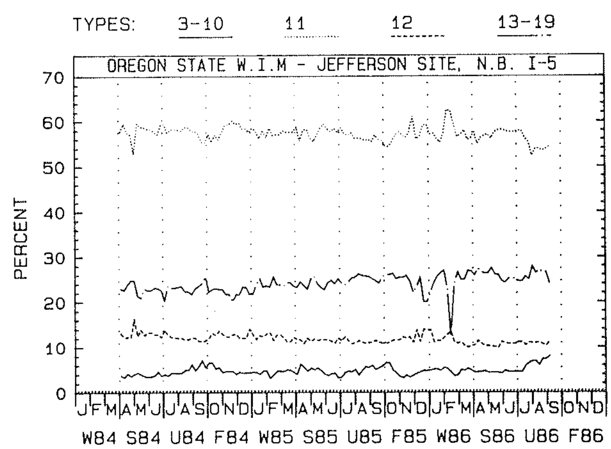

FIGURE 20 Percent weekly ESAL by truck class.

heaviest flows for Types 1 and 2 are consistently observed on Friday, Saturday, and Sunday. During winter and fall, Friday tends to be the busiest day.

Volume Capacity Ratio

Shown in Figure 9 is the demand on the freeway at Jefferson. This is based on the assumption that a single lane has a capacity of 2,000 vehicles/hr under normal operating conditions. With the flow conditions prevailing at Jefferson, there are no 1-hr periods when 0.45 capacity is exceeded for the example shown, assuming one lane closed results in a peak of 0.88 capacity during the Saturday peak hour. To date, there have been no occasions when these values have exceeded 0.50 or 1.00, respectively.

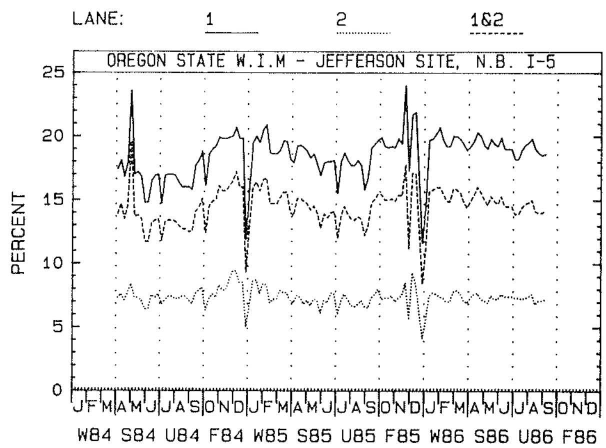

FIGURE 21 Percent trucks in vehicles by lane.

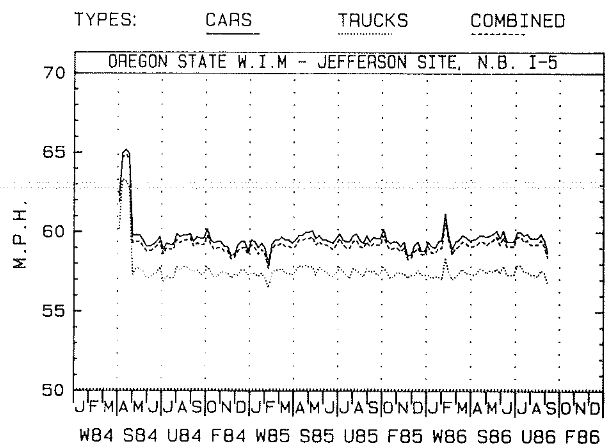

FIGURE 22 Average weekday speed.

TABLE 4 EXAMPLE SUMMARY FILE: AVERAGE ESAL FOR HEAVY TRUCKS

Week	Year,	Types:	11	12	13-19
1	85		1.49	2.40	1.90
2	85		1.41	2.02	1.70
3	85		1.48	2.08	1.80
4	85		1.56	2.20	2.00
5	85		1.48	2.09	1.80
6	85		1.42	2.00	1.80
7	85		1.49	2.12	1.90
8	85		1.49	2.10	1.90
9	85		1.55	2.16	1.90
10	85		1.55	2.16	1.90
11	85		1.54	2.17	1.80
12	85		1.52	2.17	1.90
13	85		1.52	2.17	1.90
14	85		1.52	2.16	1.80
15	85		1.57	2.16	1.80
16	85		1.53	2.19	1.80
17	85		1.55	2.05	1.80
18	85		1.55	2.22	1.80
19	85		1.54	2.09	1.90
20	85		1.53	2.18	1.90
21	85		1.60	2.24	1.80
22	85		1.63	2.41	1.80
23	85		1.60	2.36	1.80
24	85		1.58	2.28	1.80
25	85		1.61	2.39	1.80
26	85		1.62	2.45	1.80
27	85		1.53	2.46	1.70
28	85		1.61	2.55	1.80
29	85		1.60	2.20	1.70
30	85		1.61	2.39	1.80
31	85		1.60	2.41	1.80
32	85		1.58	2.44	1.90
33	85		1.59	2.41	1.90
34	85		1.58	2.41	1.80
35	85		1.53	2.35	1.80
36	85		1.53	2.24	1.80
37	85		1.52	2.20	1.80
38	85		1.54	2.20	1.80
39	85		1.51	2.27	1.80
40	85		1.48	2.42	1.90
41	85		1.45	2.15	1.80
42	85		1.48	2.16	1.80
43	85		1.46	2.03	1.70
44	85		1.47	2.18	1.70
45	85		1.39	2.07	1.70
46	85		1.42	2.19	1.70
47	85		1.32	1.87	1.60
48	85		1.29	1.70	1.50
49	85		1.38	2.19	1.70
50	85		1.26	1.74	1.60
51	85		1.14	1.70	1.20
52	85		1.14	1.70	1.20

Note: ESAL = equivalent standard axle load.

Speed

Speed trends are shown in Figure 10. About 80 percent of the traffic is traveling faster than 55 mph and 20 percent faster than 60 mph. Trucks and cars are traveling at about the same speed, but truck speeds are more uniform. Because most of the traffic is traveling at about the same speed, the operating characteristic at this site is very safe.

Truck Weights and ESALs

It is clearly shown in Figure 7 that the Type 11 truck provides by far the most significant contribution to weekly ESAL for the week shown. Other trucks with 5 or more axles, particularly Types 12 and 13, provide a significant contribution. More recent data show a decline in the percentage contribution of Types 11, 12, and 13, and an increase in that due to Types 14 through 19. This will be discussed further in the section on summary data.

Estimation of Overloading

Table 1 shows that, for the week shown, about 6 percent of measured single axle loads and 28 percent of measured tandem axle loads are above the federal limits of 20,000 lb and 34,000 lb, respectively. As shown in Table 5, for Type 11 trucks the WIM weights for Lane 1 are about 5 percent higher than static weights. Using this difference as a conservative factor to apply to each lane and all axles, estimates of overloaded axles should be reduced by about 50 percent, resulting in about 3 percent and 15 percent respectively for single and tandem axles. Clearly, great care should be taken in calibrating WIM scales and in interpreting data if accurate estimates of overloading are required.

Table 2 gives a clear indication of the types of vehicle providing the heaviest loads and most pavement damage (highest ESALs). This table shows the 40 heaviest vehicles each week (loads should be reduced by about 5 percent to reflect static weights). With the exception of two vehicles, all the trucks are double- or triple-trailer types with predominantly single axles, and with a few exceptions all loads are within 10 percent of the statutory axle load limits. It should be noted that many of the vehicles shown will be operating under permit. The table shows that ESAL values range from about 7 to almost 11 per truck [flexible pavement, structural number (SN) = 5], and the total ESAL from these trucks alone is about 350, or 2 percent of the total ESAL for the week shown.

Adjustments to Data

Shown in Table 3 are adjusted vehicle volumes and ESALs for 1 week. The adjustment is achieved by using data from the weekly tables, which enables the number of vehicles that are

TABLE 5 PERCENT COMPARISON OF DYNAMIC WEIGHTS VERSUS STATIC WEIGHT

				Weight Comparisons - %		
Lane	Sample Size	Heavy Vehicles		Arithmetic Mean	Mean Deviation	Standard Deviation
1	1671	All Trucks	GVW	+5.0	3.7	7.2
			Front Axle	+0.6	4.3	6.2
			Drive Axles	+6.4	5.1	10.3
			Trailer Axles	+5.6	5.4	9.5
	93	Trucks GVW >	70,000 lbs	+5.6	2.5	3.6
			Front Axle	0.0	4.4	6.1
2	422	All Trucks	GVW	-1.6	1.7	4.1
			Front Axle	-6.0	5.2	7.6
			Drive Axles	-1.6	3.8	4.5
			Trailer Axles	-0.4	5.4	7.4
	23	Trucks GVW >	70,000 lbs	-0.5	3.4	4.7
			Front Axle	-7.1	5.9	8.9

Note: Jefferson high-speed weigh-in-motion (WIM) versus Woodburn Static Scale 3S-2 heavy vehicles (five-axle semis, Type 11), October 7, 8, 9, 11, and 15, 1985. 1 = range of heavy vehicle gross vehicle weights (GVWs) at Jefferson WIM from sample size 29,300 lb low to 88,200 lb high. 2 = range of heavy vehicle GVWs at Jefferson WIM from sample size 27,600 lb low to 89,700 lb high.

either not classified or not weighed to be identified. This number is then distributed proportionally among all vehicles. To date this is the only attempt at adjustment that has been made. However, such adjustments will be applied to all plotted data in the future because of the significant differences that result.

Summary Data

Data Variations

All the plots show that there are few consecutive weeks when the observed data in any category are constant. Some of the peaks and valleys observed are due to slight differences in the time at which the data were dumped. Some of them are caused by changes in calibration of the system. The majority of the variations are a reflection of variable traffic characteristics. However, there are a number of trends that are clearly demonstrated.

Growth Trends

An increase in weight for all heavy trucks (Types 11 through 19) is shown in Figure 11. This increase in weight of heavy trucks (also indicated by an increase in average ESAL in Figure 12) was partially due to a calibration change in early October of 1984. However, an increase in the weekly ESAL can be seen in Figures 17 through 19, which is due to more than the calibration increase. The actual increase in weekly ESALs is about 1,000 ESAL/yr (about 7 percent).

The volume of longer combination vehicles (Types 12 through 19) is increasing (see Figure 15); it is shown in Figure 16 that this is caused by an increase in Types 14, 15, and 17, which are predominantly doubles. Shown in Figures 17 and 18 are accompanying increases in ESALs, in particular from Types 14, 15, and 17. This trend is encouraging because the contribution of five-axle twins (Type 12) is decreasing, as verified in Figure 20, which also shows a decrease in ESAL contribution from Type 11 (3S-2). The five-axle twin truck is potentially the most damaging vehicle when fully loaded to the legal limit, because it has the minimum number of axles feasible, which are all single axles.

Seasonal Trends

It is shown in Figures 15 and 16 that there is a trend of higher truck traffic in summer and autumn. However, this is small compared with the total traffic stream data (Figure 14), which shows clearly that traffic is heaviest in August and lightest in January and February. The range for 1984–1986 is from about 80,000 vehicles/week to about 115,000/week (both lanes).

Truck Characteristics

The percentage of trucks in Lane 1 varies from about 15 to 21 percent (see Figure 21), and in Lane 2 from about 12 to 17 percent. There are about 14,000 trucks/week (in both lanes), on the average (see Figure 15), with a total ESAL of about 20,000 (see Figure 19). Type 11 trucks provide about 60 percent of the weekly ESAL (see Figure 20), but a little under 50 percent of the total truck volume (see Figure 15). As shown in Table 4 and Figure 12, the average ESAL values for Type 11 trucks are about 1.5 and for Type 12 trucks about 2.1. These values are high as a result of the WIM weights being about 5 percent higher than static weights, and if the weights were reduced by this amount, average values of about 1.2 and 1.7 would result for Type 11 and Type 12 trucks, respectively. These estimates are conservative because WIM weights were less than 5 percent high in Lane 2 (see Table 5).

The average weight of tridem axles has increased dramatically since the fall of 1985, as shown in Figure 13. Although the total number of tridem axles is very small (see Table 1), their frequency is increasing, and this is a trend to be observed carefully in the future.

Speed

It is shown in Figure 22 that after one initial calibration change, the average traffic speed has remained fairly constant—at about 59 mph. Cars are consistently faster than trucks by about 2 mph.

Summary

The data collected from a continuously operational fixed site such as the Jefferson site provides valuable information. However, the considerable data collected must be processed before they are usable. Once processed the data could be used to establish statistical sampling plans for future sites. For instance, it is possible to establish exact patterns for traffic flow by hour, day of the week, and week of the year. Thus, data collected for short periods from similar sites could be extrapolated with reasonable confidence. Such techniques could be used for simple traffic counts or for portable WIM sites.

CONCLUSIONS

The following conclusions are drawn from the study:

1. AVC systems provide accurate and continuous data about vehicle volume, classification, speed, and weight. These data need to be adjusted to account for differences in WIM weights and static weights and for those vehicles that are not classified or not weighed;
2. Procedures for processing the data from the Jefferson traffic-monitoring site have been presented. These present the data in easy-to-read plots and tables that show distinct trends in the data. Because adjustments have not yet been made to the plots, only general trends and average values are emphasized at this time;
3. A major trend observed is the seasonal variation in traffic volume, which shows that the weekly volume of cars and other light vehicles traveling in summer is about 25 percent more than in winter. Similarly, it has been found that traffic speeds are uniform, with average truck speeds about 2 mph less than car speeds;
4. Data obtained from the Jefferson WIM site can be conveniently used for establishing pavement design parameters and various other traffic parameters for a variety of design and planning activities;
5. An example of significant pavement design data is the definition of ESAL for each truck type. For example, the average ESAL for Type 11 (3S-2) trucks is about 1.5, and that for Type 12 (2-S1-2) about 2.1. These values would adjust to about 1.2 and 1.7, respectively, if the difference between WIM and static weights is considered; and
6. There is a trend of increasing volume of longer-combination vehicles (Types 12 through 19). Within this group, the volume of Types 14, 15, and 17 is increasing and the volume of five-axle twins (Type 12) decreasing. This should slow the rate of increase in ESALs, because the vehicle types that are increasing have more axles than those that are decreasing.

FUTURE DEVELOPMENTS

Data from a fixed WIM, such as those at the Jefferson site, are of limited usefulness as they can only be extrapolated to similar Interstate sites. Nevertheless, they provide insight into traffic behavior, insight that was impossible to obtain before reliable WIM data became available. OSHD is in the process of developing a long-range plan for making use of WIM and associated vehicle-monitoring technology. The plan will address the recommendations of the Federal Highway Administration, as published in the 1985 *Traffic Monitoring Guide (5)*. This will require use of at least two portable WIM devices to be used continuously at selected sites on a statewide basis. These would be used in conjunction with the bridge WIM.

Developments in AVI are anticipated, indicating that they may be used on a widespread basis in the near future. A new port of entry will become operational on I-5 southbound at Woodburn during 1986. This will have the capability of allowing trucks with AVI devices to bypass the static scales and PUC station provided that they meet both weight and PUC requirements. It is anticipated that WIM/AVC/AVI technology will play a vital role in highway research in the near future and that both public and private sectors will benefit.

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