FHWA/IN/JTRP-2000/23

Final Report

DETERMINATION OF PRACTICAL ESALS PER TRUCK VALUES ON INDIANA ROADS

Sedat Gulen
John Nagle
John Weaver
Victor Gallivan

December 2000

Final Report

FHWA/IN/JTRP-2000/23

DETERMINATION OF PRACTICAL ESALS PER TRUCK VALUES ON INDIANA ROADS

by

Sedat Gulen
Pavement Research and Statistical Engineer
Division of Research
Indiana Department of Transportation

John Nagle
Safety/Congestion Management Engineer
Program Development Division
Indiana Department of Transportation

John Weaver
Chief
Program Development Division
Indiana Department of Transportation

Victor Lee Gallivan
Pavement/Materials Engineer
Federal Highway Administration
Indiana Division

Joint Transportation Research Program
Project No. C-36-54EEE
File No. 3-3-57
SPR-2331

INDOT Division of Research
West Lafayette, Indiana
December 2000

TECHNICAL REPORT STANDARD TITLE AGE

1. Report No. FHWA/IN/JTRP-2000/23	**2. Government Accession No.**	**3. Recipient's Catalog No**
4. Title and Subtitle Determination of Practical ESALs Per Truck Values on Indiana Roads		**5. Report Date** December 2000 **6. Performing Organization Code**
7. Author(s) Sedat Gulen, John Nagle, John Weaver and Victor Lee Gallivan		**8. Performing Organization Report No.** FHWA/IN/JTRP-2000/23
9. Performing Organization Name and Address Joint Transportation Research Program Indiana Department of Transportation Research Division P.O. Box 2279 West Lafayette, IN 47906		**10. Work Unit No.** **11. Contract or Grant No.** SPR-2331
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North senate Building Indianapolis, In 46204		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**

15. Supplementary Notes
Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration

16. Abstract
The Indiana Department of Transportation (INDOT) has been using ESAL (Equivalent Single Axle Load) values for pavement design. The current ESAL values were obtained in the late 1970. However, truck deregulation and higher allowable maximum loads have increased the 1970's values. Updated ESAL values are needed for better road designs.

The 1998 and 1999 traffic data from the all Weight-in-Motion (WIM) stations were obtained and used to compute updated ESAL values for multiple unit trucks (Class 9/F-9) and single unit trucks (Class 5, 6 and 7). Statistical analyses indicated that average ESAL values for 1998 and 1999 are statistically the same, but the average ESAL values for interstates roads and non-interstates roads are not all statistically the same. Some WIM stations were deleted for definite calibration problems. Due to other calibration deficiencies, the data was refined before final ESAL computations. Then the following ESAL values were computed and recommended to be used for future INDOT road designs:

For Multiple Unit Trucks (Class 9):

a) 1.3 ESAL/Truck for flexible pavements
b) 2.0 ESAL/Truck for rigid pavements

For Single Unit Trucks (Class 5, 6 & 7):

a) 0.6 ESAL/Truck for flexible pavements
b) 0.9 ESAL/Truck for rigid pavements

17. Key Words ESAL, Equivalent Single Axle Loads, Pavement Design, WIM	**18. Distribution Statement** N0 Restrictions. This document is available to the public through National Technical Information Center, Springfield, VA 22161

19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 28	**22. Price**

INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

TRB Subject Code: 24-01 Pavement Management Systems *December 2000*
Publication No.FHWA/IN/JTRP-2000/23, SPR-2331 *Final Report*

Practical Pavement Performance Prediction Models for Indiana Roads

Introduction

The Indiana Department of Transportation (INDOT) uses equivalent single axle load (ESAL) values as part of the information needed for pavement design. The current ESAL values were last estimated in the late 1970s. However, truck deregulation and higher allowable maximum loads have led to increases in truck weights and axle-loads on Indiana roads. This study investigated updating the ESAL values in order to validate current pavement design process.

There are currently thirty-six WIM Stations, twenty-six of them on Interstate Roads and the remaining are on the other INDOT roads. The 1998 and 1999 traffic data from the all Weigh-in-Motion (WIM) stations were obtained and an average ESAL value per lane per day was computed for multiple unit trucks (Class 9/F-9) and single unit trucks (Class 5, 6 and 7) as a group. Some WIM stations were deleted because of calibration problems. Due to other calibration deficiencies, the data was further refined before final ESAL computations were made.

Findings

The following conclusions and recommendations were based on this research study using 1998 and 1999 traffic data:

1. The updated ESAL values computed for Single Unit and Multiple Unit Trucks, are higher than those used currently.

2. The average ESAL values on Interstates roads are statistically higher than on Non-Interstates roads.

3. Even though the average ESAL values for Interstates and Non-Interstates roads are not statistically the same, for all practical purposes the following overall ESAL values per truck are recommended to be used for future road pavement mix designs in Indiana are:

<u>For Multiple Unit Trucks (class 9):</u>
1.3 for flexible pavements
2.0 for rigid pavements

<u>For Single Unit Trucks (Class 5, Class 6 and Class 7):</u>
0.6 for flexible pavements
0.9 for rigid pavements

4. The distribution of the ESALs and gross weights of trucks was found to be approximately normally distributed.

5. The accuracy of the ESAL values is dependent upon the accuracy of the WIM stations. It is recommended that the calibrations of the WIM stations use class 9 trucks.

Implementation

The research results were presented to the pavement design committee and they have already implemented the new ESAL estimates into their design of pavements.

This research has led to more valid pavement designs for today's traffic of heavier and increased numbers of commercial vehicles.

Contact

For more information:

John Weaver/John Nagle
Principal Investigators
Indiana Department of Transportation
Roadway Management Division.
State Office Building Room: N808
100 N. Senate Avenue.
Indianapolis, IN 46204
Phone: 317-232-5884
Fax: (317) 232-5478

Sedat Gulen
Principal Investigator
Indiana Department of Transportation
Research Division
1205 Montgomery Road
P.O.Box 2279
West Lafayette, IN 47906
Phone: (765) 463-1521
Fax: (765) 497-1665

Indiana Department of Transportation
Division of Research
1205 Montgomery Street
P.O. Box 2279
West Lafayette, IN 47906
Phone: (765) 463-1521
Fax: (765) 497-1665

Purdue University
Joint Transportation Research Program
School of Civil Engineering
West Lafayette, IN 47907-1284
Phone: (765) 494-9310
Fax: (765) 496-1105

ACKNOWLEDGMENTS

This report was prepared by Sedat Gulen, John Nagle, John Weaver for the Indiana Department of Transportation and Lee Gallivan for the Federal Highway Administration, Indiana Division. The authors wish to thank Mr. Gordon Hooker, Research Division, who reduced the raw data and prepared various plots for this research. The authors would also thank to Geraldine Lampley, Program Development Division, who supplied the original raw data.

I. INTRODUCTION:

Indiana Department of Transportation (INDOT) has been increasingly using the average ESAL (Equivalent Single Axle Load) per truck for pavement design. The current ESAL values per multiple-unit truck and single-unit truck were prepared and validated in the late 1970's, Table 1, Chapter 52, INDOT Design Manual[1]. Truck deregulation and higher allowable maximum loads have affected these 1970's values. For this reason more realistic and reasonable ESAL estimates are now required on the title sheets of plans for design of pavements in Indiana and the results of this study will also improve ESAL/Truck factors for estimating design ESALs.

INDOT has thirty six weigh-in-motion (WIM) sites total. Thirty-two WIM sites were constructed in 1992-93 in conjunction with the Long Term Pavement Performance (LTPP) efforts. An additional site was constructed to monitor a research project in 1993 and three sites were installed for monitoring of pavement warranty projects. The sites used International Road Dynamics® Inc. bending plates, on site data collector and software. Many of the bending plates and load cells have now been replaced by piezo weight sensors. Each location is calibrated once a year by maintenance agreement and after a major repair to the site. Sites were calibrated using a class 7 vehicle of a known weight of 22.7 Mg (50,000 lbs.).

II. OBJECTIVE:

The objective of this research study is to update the average ESAL estimate values for multiple unit trucks (F-9) and single unit trucks (F-5, F-6 and F-7), Table 2, for use in pavement design procedures.

III. DATA COLLECTION

The data were obtained from all installed WIM stations. There are currently thirty six WIM stations, twenty six of them on Interstate Roads and the remaining are on the other INDOT roads as shown on Table 3 and Table 4. In order to represent the most recent ESAL values, the 1998 and 1999 data collected by the WIM stations were compiled.

The average daily ESAL data for the single unit trucks and multiple unit trucks were calculated using AASHTO formulas and compiled from the WIM axle distributions. Due to calibration problems and breakdown of some WIM stations the ESAL data were refined by deleting data from the following categories.

a. If Class 9 truck (F-9) Gross Vehicle Weight (GVW) is equal to zero
b. If ESAL for F-9 is less than or equal 0.04
c. If GVW for Class 9 truck is less than 13.5 Mg (30,000 lbs.)
d. If GVW for Class 9 truck is greater than 56.6 Mg (125,000 lbs.)
e. If Class 7 truck GVW is equal to zero or greater than 30.8 Mg (68,000 lbs.)
f. If Class 6 truck GVW is equal to zero or greater than 23.6 Mg (52,000 lbs.)
g. If Class 5 truck GVW is equal to zero or greater than 17.2 Mg (38,000 lbs.)

VI. DATA ANALYSES

Looking at the distribution of classes of trucks it was observed that the five-axle semi (class 9) trucks typically made up 80% of the volumes of all trucks and over 85% of all calculated ESALs. Therefore Class 9's were used for the data analysis to simplify the calculations. An average ESAL per truck was also determined for Class 5, 6 and 7's as a group since the pavement design calculations asked for one. The distribution of daily average ESAL values and daily average gross vehicle weights were checked and found to be approximately normally distributed for each WIM station and the variances were also found to be homogeneous, Figures 1-6. The ESAL values used in the statistical analyses were computed for flexible pavement with terminal PSI=2.5 and Structural Number=5. The Analysis of Variances (ANOVA)[2] and other statistical techniques were utilized to analyze the ESAL data by using the SAS[3] Institute Statistical Package Version 8.00.

ANOVA indicated that:

1. The average ESAL values, for class 9 trucks, of individual WIM stations are all not statistically the same.
2. The effect of the year on average ESAL values is not statistically significant.
3. The average ESAL values of the WIM stations on Interstates Roads are statistically higher than on Non-Interstates Roads, Table 5 and Table 6.

Since average ESAL values are statistically different for individual WIM stations on Interstates and Non-Interstates roads, various average ESAL values for Class 9, Class 5, Class 6 and Class 7 trucks were computed. Tables 7 and 8 show average ESAL values of Class 5, 6, 7, and 9 trucks. Tables 7 and 8 also show standard deviation, number of lane days (observations), average (AVG) total number of trucks, total traffic, and percent of Class 9 trucks by years and WIM Stations.

Table 7 and 8 shows, for example, for WIM site 4110, in 1998, the average ESAL per class 9 trucks is 2.0. The average GVW was 28.3 Mg (62,199 lbs.) with 353 lane days of observations.

Table 9 shows overall average ESAL values, number of lane days and standard deviations for Class 5, 6 and 7 trucks on all roads combined. The weighted ESAL value for Single Unit Trucks was then computed from Table 9 and found to be 0.6 ESAL/Truck.

Table 10 shows overall average ESAL values, number of lane days, GVW in pounds, total truck count, total traffic count and percent of Class 9 Trucks. The weighted average ESAL Class 9 Trucks was then computed as 1.3 ESAL/Truck.

Updated ESAL values for Single Unit and Multiple Unit Trucks are then computed and listed in Table 11. Table 11 also shows the effect of varying the terminal PSI from the department standard value of 2.5 to 2.0 PSI. This demonstrates the nominal effect of varying the terminal serviceability on the ESAL calculation.

VII. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were based on this research study using 1998 and 1999 traffic data:

1. The updated ESAL values computed for Single Unit and Multiple Unit Trucks, Table 6, are higher than those used currently.

2. The average ESAL values on Interstate roads are statistically higher than on Non-Interstate roads.

3. Even though the average ESAL values for Interstates and Non-Interstates roads are not statistically the same, for all practical purposes the following overall ESAL values per truck are recommended to be used for future road pavement mix designs in Indiana.

   For Multiple Unit Trucks (class 9):
   - **1.3** ESAL/Truck for flexible pavements
   - **2.0** ESAL/Truck for rigid pavements

   For Single Unit Trucks (Class 5, Class 6 and Class 7):
   - **0.6** ESAL/Truck for flexible pavements
   - **0.9** ESAL/Truck for rigid pavements

4. The distribution of the ESAL and the GVW of trucks was found to be approximately normally distributed.

5. The accuracy of the ESAL values is dependent upon the accuracy of the WIM stations. It is recommended that the calibrations of the WIM stations use class 9 trucks.

REFERENCES

1. INDOT, Chapter 52, Pavement Design Manual.
2. Anderson V. L. and McLean R. A., *Design of Experiments Realistic Approaches*, Mercel Decker Inc., New York N. Y.
3. SAS Publications on Statistics and Linear Models, SAS Institute Inc., Cary. NC.

LIST OF TABLES

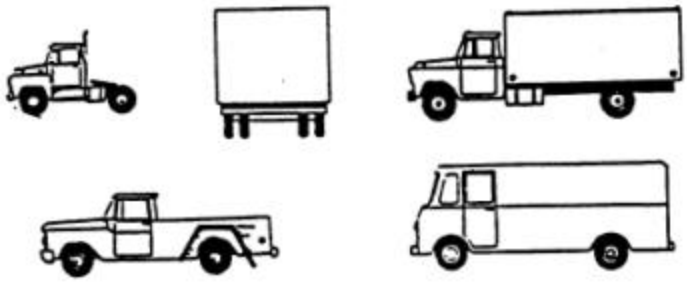
LIST OF FIGURES

Table 1. The current ESAL Values for INDOT

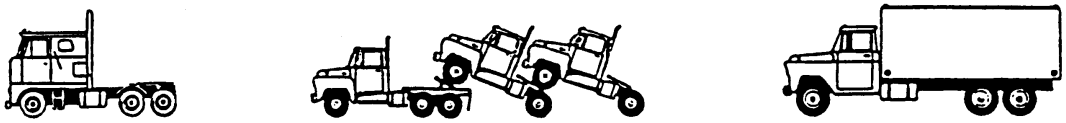
Pavement Type	Single Unit Trucks	Multiple Unit Trucks
Flexible	0.316	0.860
Rigid	0.230	1.115

Table 2. Class 5 (F-5), Class 6 (F-6) , Class 7 (F-7) and Class 9 (F-9) Trucks.

Classification #5 Two-Axle, Six-Tire Single Unit Truck (SU): All vehicles on a single frame including camping and recreational vehicles, motor homes, large step vans, etc. having *2 Axles and Dual Rear Tires.*

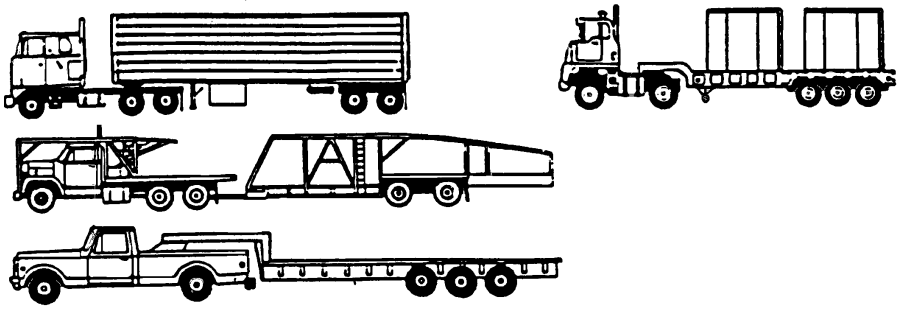


Classification #6 Three-Axle Single Unit Truck (SU): All vehicles on a single frame having three axles.



Classification #7 Four or More Axle Single Unit Truck (SU): All vehicles on a single frame having four or more axles.

Classification #9 Five-Axle Single Trailer Truck (Combo): All vehicles consisting of two units, of which the pulling unit is a tractor or single unit truck.



Note: Figures were taken from *"Operation Tips Trafi COMP® III"*, Model 241 operating manual, as modified by INDOT.

Table 3.

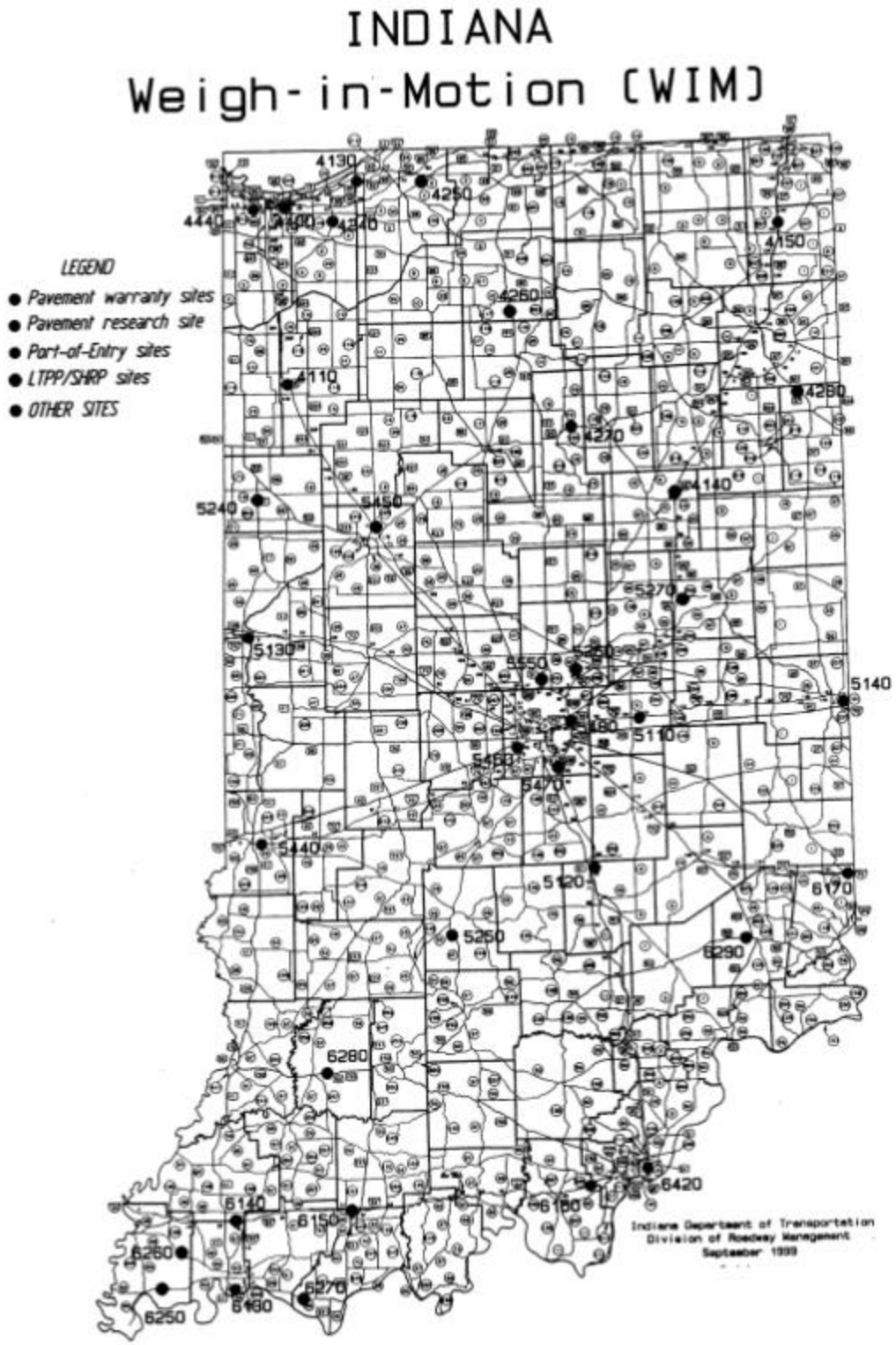

INDIANA
Weigh-in-Motion (WIM)
LEGEND
Pavement warranty sites
Pavement research site
Port-of-Entry sites
LTPP/SHRP sites
OTHER SITES
4130
4250
4440
4340
4150
4260
4110
4280
4270
4140
5240
5450
5270
5130
5550
5140
5110
5470
5440
5120
6170
5250
6290
6280
6420
6150
6260
6270
6190
6250
Indiana Department of Transportation
Division of Roadway Management
September 1999

Table 4. Listing of WIM Stations

WIM STATION	LOCATION
4110	On 1-65 3.6 miles N. of SR 114
4130	On 1-94 3.4 miles E. of US 421
4140	On 1-69 4.1 miles N. of SR 18
4150	On 1-69 3.5 miles N. of US 6
4240	On SR 49 1.5 miles S. of US 6
4250	On SR 2 2.8 miles W. of US 20
4260	On US 31 4.0 miles N. of SR 110
4270	On US 24 6.4 miles E. of SR 19
4280	On US 27 6.2 miles S. of SR 469
4440	On 1-80/94 0.9 mile E. of SR 912
5110	On 1-70 4.28 mile E. of SR 9
5120	On 1-65 1.0 mile S. of SR 252
5130	On 1-74 0.6 mile E. of SR 63
5140	On 1-70 0.5 mile W. of US 40
5240	On US 41 1.7 miles S. of SR 18
5250	On SR 37 2.8 miles S. of SR 45 S
5260	On SR 37 0.9 mile N. of SR 238
5270	On SR 332 0.4 mile E. of I-69
5440	On 1-70 0.7 mile E. of US 41
5450	On 1-65 1.3 miles N. of SR 25
5460	On 1-465 0.7 mile N. of I-70W
5470	On 1-65 0.6 mile S. of Southport Rd
5480	On 1-465 1.0 mile S. of US 36E
5550	On US 31 0.5 mile N. of 116 St.
6130	On 1-164 2.25 mile E. of US 41
6140	On 1-64 1.5 miles W. of SR 57
6150	On 1-64 1.1 miles E. of SR 161
6160	On 1-64 1.0 mile W. of SR 62/64
6170	On 1-74 0.8 mile E. of US 52
6250	On SR 62 5.1 miles E. of SR 69
6260	On SR 66 0.9 mile W. of SR 65
6270	On SR 66 6.1 miles E. of SR 61
6280	On US 50 11.1 mile W. of US 231
6290	On US 50 0.85 mile W. of US 421
6420	On I-65 0.9 miles S. 0f I-265

Table 5. Duncan's Multiple Range Test for ESAL9

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	31504
Error Mean Square	2.425866
Harmonic Mean of Cell Sizes	12356.52

Number of Means	2
Critical Range	0.03884

Duncan Grouping	Mean	N	Roads
A	**1.37490**	**23070**	**INTERSTATES**
B	**1.23984**	**8438**	**NON-INTERSTATES**

Means with the same letter under “Duncan Grouping” are not significantly different.
Means with the different letter under “Duncan Grouping” are significantly different.

NOTE: Cell sizes are not equal.

Where:

N = Number of Observations (lane-days)

Mean = Average ESAL/Truck value

Table 6. Average ESAL Values of Interstates (INT) and Non-Interstates (NINT) Roads

ROADS	YEAR	AVG. ESAL5	AVG. ESAL6	AVG. ESAL7	AVG. ESAL9	S9	N9	AVWGHT9	TOTAL_F9	T_ADT	PRCT_F9
INT	98	0.14	0.41	1.73	1.18	1.28	11339	54246	17799644	119347130	15
INT	99	0.19	0.70	1.84	1.54	2.08	12143	55808	18453701	142830973	13
NINT	98	0.19	0.63	2.63	1.26	0.75	4176	53744	1127922	18034400	6
NINT	99	0.18	0.60	2.23	1.22	0.87	4262	52497	901638	18522540	5

Where: AVG. = Average
ESAL5= ESAL for Class 5 truck
ESAL6= ESAL for Class 6 truck
ESAL7= ESAL for Class 7 truck
ESAL9= ESAL for Class 9 truck
S9 = Standard Deviation of ESAL for Class 9 Trucks
N9 = Number of Days (Observations) for Class 9 Trucks
AVWGHT9 = Average GVW Weight in lbs. for Class 9 Trucks
TOTAL_F9= Total numbers of Class 9 Trucks
T_ADT = Total traffic
PRCT_F9 = Percent of Class 9 Trucks = (TOTAL_F9/T_ADT)*100

Note: Mg = 1000 Kg = 2.2075 Kips = 2207.5 lbs.
lbs. = 1/2207.5 Mg

Table 7. Average ESAL values of WIM Stations by years

SITE	YEAR	AVG. ESAL5	AVG. ESAL6	AVG. ESAL7	AVG. ESAL9	S9	N9	AVWGHT9	TOTAL_F9	T_ADT	PRCT_F9
4110	98	0.24	0.59	2.14	2.00	1.98	353	62199	1041126	3500713	30
4110	99	0.28	0.55	2.03	1.36	1.36	357	57219	972011	3648949	27
4130	98	0.08	0.37	0.99	0.95	0.48	157	55008	192267	1181379	16
4130	99	0.07	0.74	1.08	1.54	2.28	1539	57090	1681399	12264426	14
4140	98	0.43	0.56	1.19	3.17	1.83	128	66444	262257	1086691	24
4140	99	0.08	0.16	0.72	0.35	0.19	236	37793	556860	2287585	24
4150	98	0.06	0.36	1.96	0.88	0.24	1227	53999	1041762	8102358	13
4150	99	0.07	0.30	1.46	0.68	0.71	1021	47851	918608	6699807	14
4250	98	0.15	0.52	2.01	0.81	0.45	335	49447	29244	1298348	2
4250	99	0.16	0.61	3.28	0.82	0.25	418	51429	46544	1586597	3
4260	98	0.14	0.26	1.69	0.78	0.57	350	46725	209000	1820541	11
4260	99	0.19	0.21	1.06	1.46	0.86	318	49261	105517	1733455	6
4270	98	0.10	0.45	2.04	1.04	0.63	578	55051	200041	2094049	10
4270	99	0.06	0.24	1.37	0.60	0.18	706	48275	248067	2536184	10
4440	98	0.08	0.13	0.77	0.79	0.74	367	46074	1179152	7427882	16
4440	99	0.11	0.37	1.36	0.94	0.72	35	49885	40331	2041203	2
5110	98	0.10	0.36	1.31	1.36	1.02	1366	57369	2880747	10676272	27
5110	99	0.19	0.51	1.37	1.42	1.12	736	58806	1331715	6327112	21
5120	98	0.09	0.28	1.68	0.75	0.29	1001	51559	1131723	8505395	13
5120	99	0.10	0.29	1.19	0.94	1.40	984	51432	1809567	10334443	18
5130	98	0.07	0.36	0.65	0.95	0.89	479	49275	391844	3072107	13
5130	99	0.04	0.30	0.67	0.68	1.03	378	46426	524354	2306624	23
5140	98	0.15	0.37	1.37	1.05	1.00	676	51522	1247071	8340708	15
5140	99	0.20	0.55	1.25	1.57	0.70	633	60667	1930699	7200285	27
5240	98	0.29	0.50	2.04	1.30	0.32	312	59802	150421	572047	26
5240	99	0.62	0.54	3.13	1.44	0.49	92	59988	36031	144630	25
5250	98	0.16	0.69	2.36	0.96	0.23	320	51154	94530	2025888	5
5250	99	0.16	0.35	1.18	0.54	0.23	346	42111	80757	2200297	4
5260	98	0.34	1.51	4.36	1.89	0.60	341	59124	76156	2515952	3
5260	99	0.25	1.90	4.28	1.72	0.68	347	57610	74401	2496548	3
5270	98	0.05	0.35	2.14	0.60	0.21	287	47781	16709	1405305	1
5270	99	0.06	0.49	2.69	0.88	0.51	396	50998	26104	2080380	1
5440	98	0.12	0.26	0.80	0.76	0.43	595	50980	1536115	6694978	23
5440	99	0.08	0.64	1.79	1.14	0.85	408	53513	1094240	4931142	22
5450	98	0.09	0.33	1.69	1.08	0.96	710	51704	1952674	8966121	22
5450	99	0.08	0.27	1.28	0.92	0.74	648	51154	2300703	8415835	27
5460	98	0.15	0.35	1.95	1.17	0.72	1051	56422	1383317	18412506	8
5460	99	0.18	0.41	1.61	1.09	1.30	947	55748	1209219	17075652	7
5480	98	0.17	2.75	7.02	5.07	4.48	247	77352	361266	6558648	6
5480	99	0.55	2.81	5.33	5.21	3.96	994	76829	1158894	27129442	4
5550	98	0.14	0.47	1.64	0.93	0.18	15	53294	3885	149346	3
5550	99	0.16	0.41	1.05	0.93	1.22	218	51835	75486	2296784	3

Table 8. Average ESAL values of WIM Stations by years (continuation of Table 7)

SITE	YEAR	AVG. ESAL5	AVG. ESAL6	AVG. ESAL7	AVG. ESAL9	S9	N9	AVWGHT9	TOTAL_F9	T_ADT	PRCT_F9
6130	98	0.14	0.48	2.09	1.64	0.59	601	61317	233576	5200627	4
6130	99	0.17	0.52	2.09	1.58	0.78	795	59086	345773	7083884	5
6140	98	0.16	0.30	1.65	0.83	0.55	611	50800	679859	3308499	21
6140	99	0.36	0.85	2.10	1.83	1.47	697	58535	513293	4249281	12
6160	98	0.27	0.41	1.91	1.05	1.10	1248	50147	1675023	12085551	14
6160	99	0.12	0.28	2.12	1.13	0.64	657	49831	955205	6497096	15
6170	98	0.12	0.30	1.27	0.92	0.25	391	55701	410355	3924431	10
6170	99	0.12	0.35	0.73	0.91	0.63	533	49849	393757	5418197	7
6250	98	0.19	1.14	5.05	1.72	0.58	287	49331	88784	1689862	5
6250	99	0.39	1.37	3.63	1.91	0.62	111	50712	35193	635687	6
6260	98	0.20	0.61	2.16	1.78	0.87	286	59767	6260	996914	1
6260	99	0.16	0.34	1.04	1.11	0.65	338	53773	9541	1183752	1
6270	98	0.22	0.39	2.11	1.22	0.26	278	56961	60137	1322232	5
6270	99	0.20	0.68	2.05	2.16	0.58	345	65195	65919	1569923	4
6280	98	0.13	0.35	2.25	0.89	0.47	172	41387	66384	825392	8
6280	99	0.08	0.22	1.42	0.85	0.42	171	45232	43138	834161	5
6290	98	0.26	0.66	3.14	1.77	0.96	623	58162	130212	1439950	9
6290	99	0.27	0.72	2.79	1.81	1.25	668	56756	130397	1513296	9
6420	98	0.13	0.33	1.37	0.82	0.46	92	51918	195352	1859706	11
6420	99	0.09	0.33	1.08	0.76	0.95	282	49935	639337	5873408	11

Where: Site = WIM Station Number

AVG. = Average

ESAL5= ESAL for Class 5 truck

ESAL6= ESAL for Class 6 truck

ESAL7= ESAL for Class 7 truck

ESAL9= ESAL for Class 9 truck

S9 = Standard Deviation of ESAL for Class 9 Trucks

N9 = Number of Lane Days (Observations) for Class 9 Trucks

AVWGHT9 = Average GVW in lbs. for Class 9 Trucks

TOTAL_F9= Total numbers of Class 9 Trucks

T_ADT = Total traffic

PRCT_F9 = Percent of Class 9 Trucks = (TOTAL_F9/T_ADT)*100

Note: Mg = 1000 Kg = 2.2075 Kips = 2207.5 lbs.

lbs. = 1/2207.5 Mg

Table 9. Overall Average ESAL Values for Class 5, 6 and 7 Trucks by years

YEAR	AVG. ESAL5	S5	N5	AVG. ESAL6	S6	N6	AVG. ESAL7	S7	N7
98	0.15	0.41	9318	0.36	0.41	9329	1.3	0.91	9243
99	0.16	0.29	10702	0.44	0.54	10864	1.2	0.99	10792

$$Weighted\,ESAL = \frac{0.15 * 9318 + 0.36 * 9329 + 1.3 * 9243 + 0.16 * 10702 + 0.44 * 10864 + 1.2 * 10792}{9318 + 10702 + 9329 + 10864 + 9243 + 10792} = 0.6$$

Where: S5 = Standard Deviation of ESAL for Class 5 trucks

N5 = Number of Lane Days (observations) for Class 5 trucks

S5 = Standard Deviation of ESAL for Class 6 trucks

N6 = Number of Lane Days (observations) for Class 6 trucks

S7 = Standard Deviation of ESAL for Class 7 trucks

N7 = Number of Lane Days (observations) for Class 7 trucks

Table 10. Overall average ESAL values for Class 9 Trucks by Years

YEAR	AVG. ESAL9	S9	N9	AVWGHT9	TOTAL_F9	T_ADT	PRCT_F9
1998	1.21	1.16	15117	54318	17748097	129632516	14
1999	1.44	1.81	16319	54904	19312729	158554862	12

$$Weighted\ ESAL = \frac{1.21*15117 + 1.44*16319}{15117 + 16319} = 1.32$$

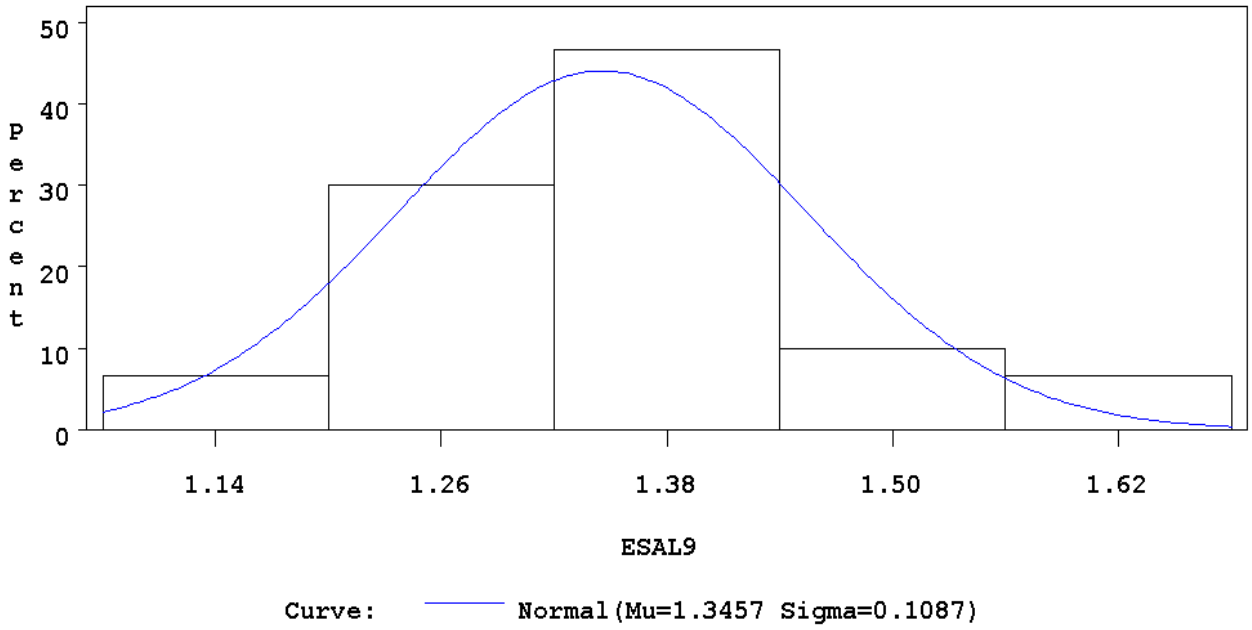
Note: The terms in the column heads are defined before.

Table 11. Updated ESAL Values

PAVEMENT TYPE	SN	TERMINAL PSI	DEPTH in	SINGLE UNIT CLASS 5-7	MULTIPLE UNIT CLASS 9
Flexible	5	2.5	-	0.6	1.3
Flexible	5	2.0	-	0.98*0.8= 0.59	1.3*0.98= 1.27
Rigid	-	2.5	10	0.6*1.57 = 0.9	1.3*1.57= 2.0
Rigid	-	2.0	10	0.98*1.2 = 0.89	0.98*2.0= 1.96

Where: SN= Structural Number
PSI= Pavement Serviceability Index

Figure 1. WIM Station 4110, on I-65, September 1999, North Bound Travel lane



Where:

ESAL9= ESAL for Class 9 (F-9) truck

Mu = Mean ESAL/Truck

Sigma = Standard Deviation

Figure 2. WIM Station 4250, on SR-2, May 1999, South Bound travel Lane

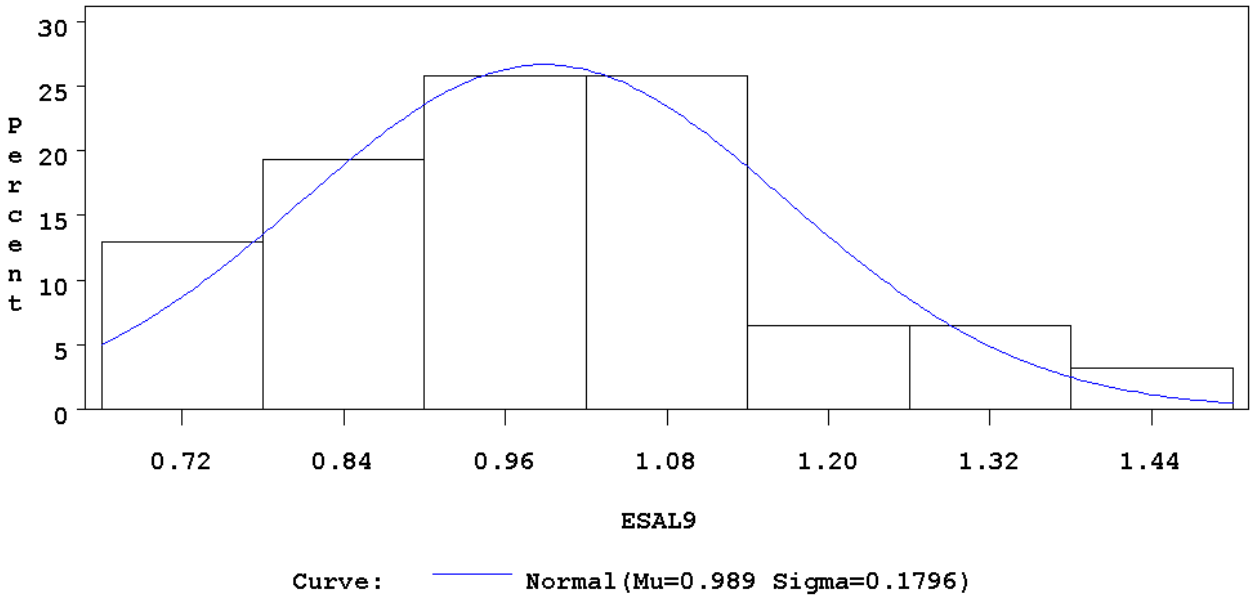


Figure 3. WIM station 5110, on I-70, May 1999, East Bound Travel Lane

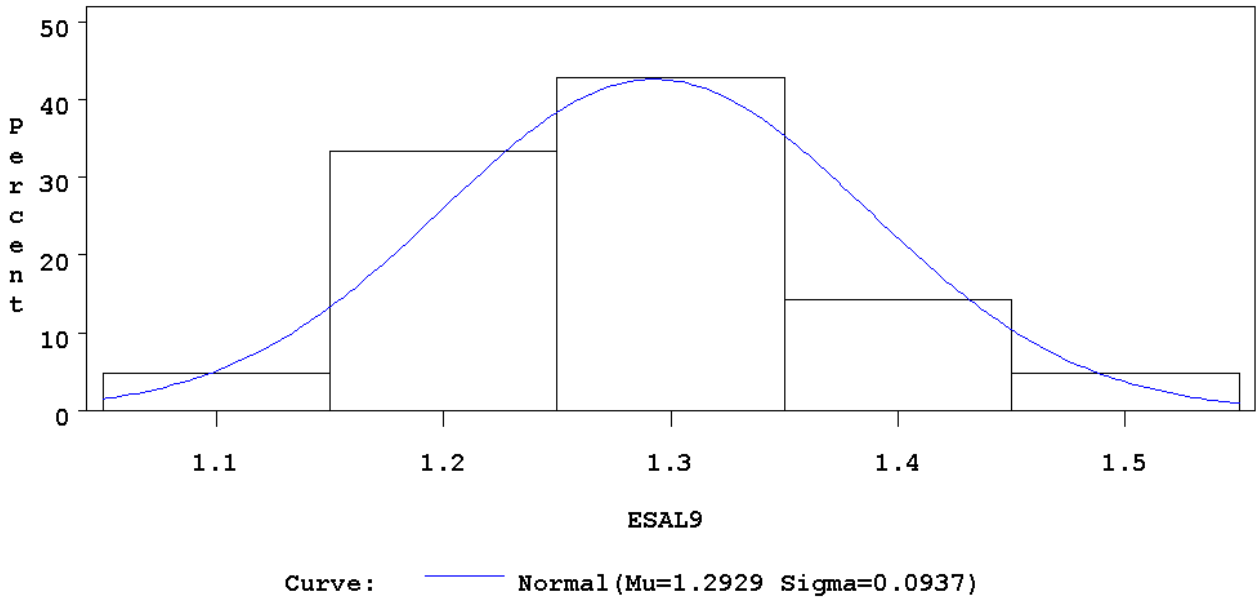
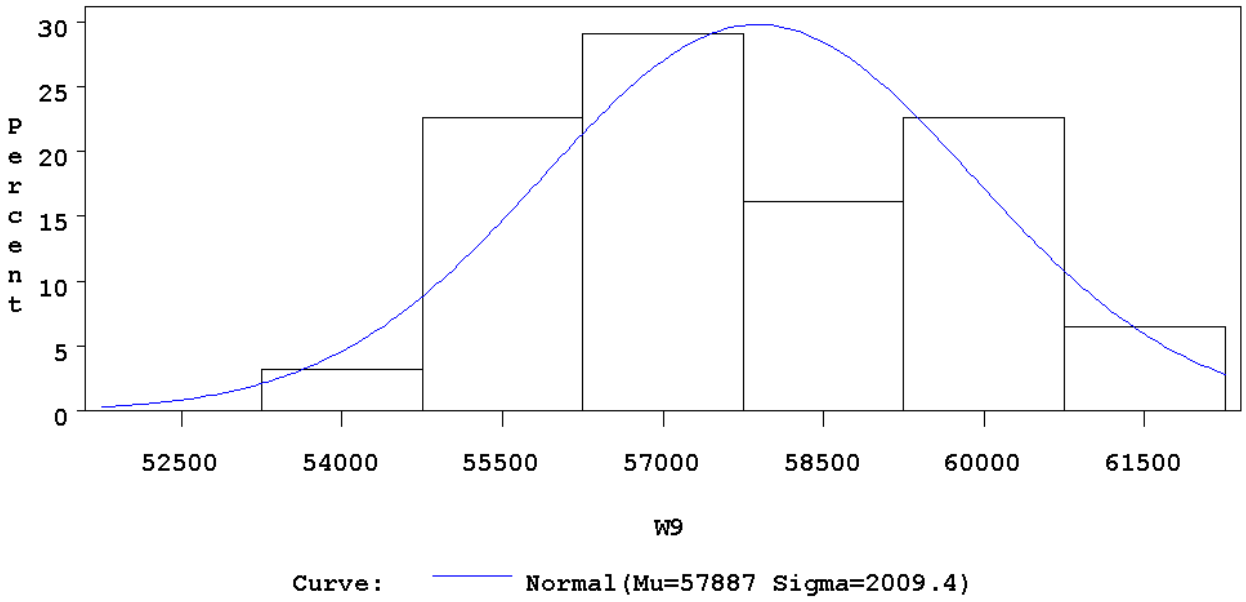


Figure 4. WIM station 4110, on I-65, May 1999, South Bound Travel Lane



Where: W9 = Average daily GVW weight of Class 9 truck in lbs.

Mu = Average monthly GVW weight of Class 9 truck in lbs.

Note: ***Mg = 1000 Kg = 2.2075 Kips = 2207.5 lbs.***

lbs. = 1/2207.5 Mg

Figure 5. WIM station 4250, on SR-2, June 1999, South Bound Travel Lane

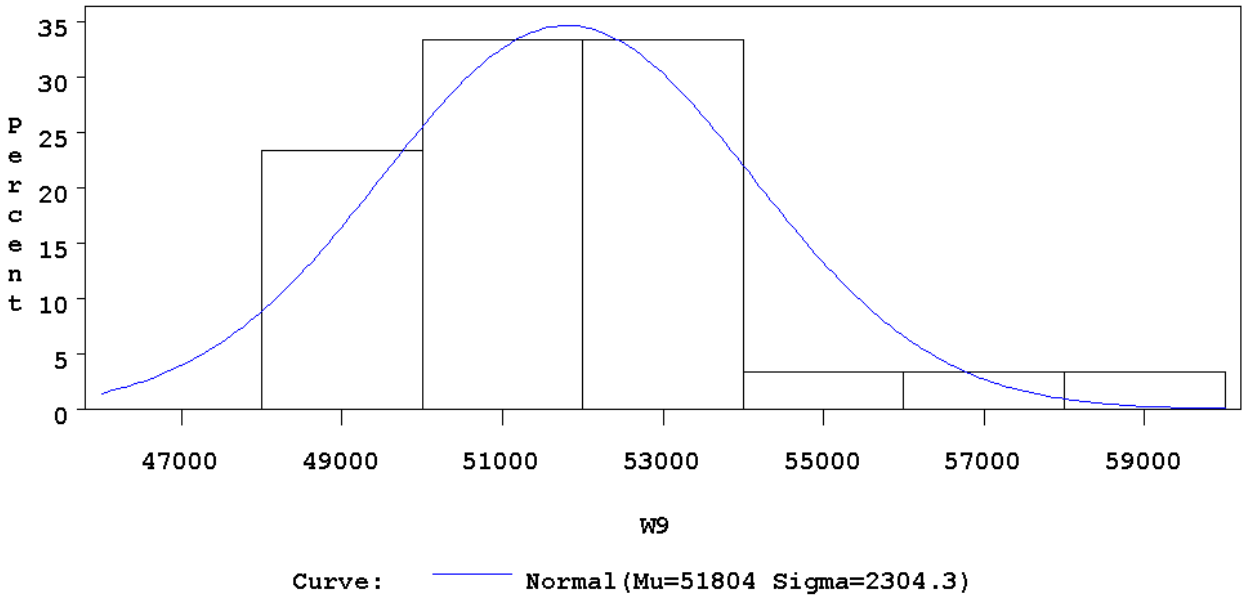


Figure 6. WIM station 5110, on I-70, October 1999, East Bound Travel Lane