ANALYSIS OF TRAFFIC LOADINGS ON INTERSTATE HIGHWAYS IN ILLINOIS

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Development and Field Testing of an Illinois Pavement Feedback System

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16. Abstract 
An analysis of heavy traffic loadings on the Illinois Interstate Highway system was conducted. Volumes and weights of single and multiple unit trucks were determined and converted to cumulated 18-Kip equivalent single axle loads (ESAL) for every construction section over the period 1956 to 1986.

Results show that the Interstate highway pavements have been subjected to far greater traffic loadings than which they were designed. Annual 18-Kip ESAL's (one direction outer traffic lane), which averaged about 300,000 in the late 1950's and early 1960's have grown to 1,200,000 in 1986. The growth rate of cumulative 18-Kip ESAL's for the average pavement section has been over 8 percent compounded annually over the past 20 years and shows no sign of slowing down.

The traffic data have been input into the Illinois Pavement Feedback Database for use by agency personnel. It is recommended that improved estimating procedures be developed for 18-Kip ESAL's to be used for future pavement design and rehabilitation purposes.

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DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.
List of Reports


Research Report 517-4, "Analysis of the Traffic Loadings on Interstate Highways in Illinois," by Michael I. Darter, Ricardo A. Salsilli, Mark E. Dwiggins, Thomas Fitch and Alan Lundberg, describes the compilation of annual traffic volumes and classifications and the estimation of equivalent single axle loads (ESAL's) for each pavement section and shows the dramatic growth of ESALs over the past 30 years, FHWA-IL-UI-222, 1989.
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ANALYSIS OF TRAFFIC LOADINGS ON INTERSTATE HIGHWAYS IN ILLINOIS

INTRODUCTION

The Illinois Interstate Highway system is the third largest in the nation (1940 miles) and includes four transcontinental routes. In Illinois in 1987, more than 52 percent of all goods shipped by highway moved on the Interstate Highway system, and 64 percent of all truck travel (in vehicles miles) was on the Interstates. The majority of manufactured goods are transported on the Interstate system (3). The following statistics illustrate the truck loading problem. Annual truck vehicle miles traveled on Interstates increased 35 percent from 2 billion in 1982 to 2.7 billion in 1987. A change in federal law in 1983 raised the size limit and the maximum allowable weight for trucks from 73,280 pounds to 80,000 pounds. The combination of heavier and greater volumes of heavy trucks greatly increase the damage to the Interstate pavements (3).

An analysis of heavy traffic loadings on the Illinois Interstate system has been conducted. The objective of this study is to provide factual information on past trends of loadings that will be helpful for many design and planning purposes. The annual traffic volumes and classifications for every pavement section on the Interstate highway system was compiled. This data were then reduced to 18-Kip Equivalent Single Axle Loads (ESAL) that can be used as traffic loading values for various pavement analyses and to aid in pavement design and rehabilitation. The data have been input into the Illinois Pavement Feedback Data System (IPFS) for use by IDOT personnel.

A knowledge of traffic loading data are crucial to understanding past pavement performance, predicting future condition and in programming and designing future pavement rehabilitations. Traffic data have been collected by Illinois Department of Transportation (IDOT) Districts at various points along highways since the 1930's. These data are published in the form of traffic maps approximately once every four years by the IDOT Office of Planning and Programming. ADT, heavy commercial traffic, and multiple unit traffic volumes are published on separate maps.

Traffic data were compiled for this study in two phases. The downstate data (Districts 2-9) were compiled by the IDOT Bureau of Design with the assistance of the districts. The data for Cook County and the surrounding four counties comprising District One were compiled by the University of Illinois using information supplied by District One.
DEFINITION OF TERMS

The following definitions are utilized in this document.

ADT
Average annual daily traffic (number of vehicles) for a 24 hour period in both directions. The sum of Multiple Units, Single Units, and Passenger Cars.

Heavy Commercial Traffic
Six-tire and three-axle single unit trucks and buses and all multiple unit trucks. Prior to 1980 light pickup trucks and vans were included in this category on the traffic maps.

Single Units (SU)
Six-tire and three-axle single unit trucks and buses. Calculated by subtracting Multiple Unit volumes from Heavy Commercial volumes. Prior to 1980 light pickup trucks and vans were included in this category.

Multiple Units (MU)
Tractor-semi-trailer combinations, large truck and trailer combinations and two-trailer combinations.

Passenger Cars
Passenger cars. Calculated by subtracting Heavy Commercial volumes from ADT. Since 1980 this category included all four-tire trucks and vans.

18-Kip Equivalent Single-Axle Loads (ESAL)
The equivalent number of 18-kip single-axle load applications to cause the same loss of serviceability as a given number of mixed (regular) traffic load applications. The total number of ESAL’s (in millions) expected over the pavement design period is defined as the IDOT traffic factor (TF).

DOWNSTATE TRAFFIC DATA

Data Collection

The Policies and Procedures Section of the IDOT Bureau of Design compiled traffic volume and classification data for the Interstate highways from IDOT traffic maps and entered the data into a computerized file. Traffic data values were assigned to pavement sections having uniform construction as defined by the IDOT Pavement Review Team. Where a major traffic change occurred within a section, the section was split into two or more sections of uniform traffic. The data were obtained from the date of the section’s opening to traffic through the end of year 1986.
Data Verification

The districts verified the data compiled by the Policies and Procedures Section. As part of the verification process, the districts supplied additional traffic data to fill in any long gaps between data points on the traffic maps.

DISTRICT ONE TRAFFIC DATA

Data Collection

District One presented a more difficult problem. The traffic data were collected from the traffic maps. Unfortunately, there were not enough data along District 1 Interstate highways to accurately assign traffic values to individual pavement sections along the entire length of each route. Also the Heavy Commercial data are widely scattered. The Chicago Area Transportation Study (CATS) supplied additional ADT data. The University of Illinois estimated District One traffic data as part of the Illinois Pavement Feedback System research project.

Procedure for Estimating Traffic Data

The Interstate and selected supplemental freeways were divided into sections at interchanges between which there was at least one data point (ADT, SU, or MU) on any of the quadrennial traffic maps. Traffic volumes for each of the classifications were estimated for each section by the following procedure.

Multiple Units

First, plots of MU volume versus milepost were prepared for each major segment along a route for each year data were available as shown in Figure 1 for I-55 for 1976. Separate plots were prepared for each year a traffic count was available. A smooth curve was then drawn connecting the data points along the route as shown in Figure 1. The curve was used to estimate missing MU data values.

Then, MU data values for missing years from the time of construction through 1986 were estimated for each section using the data set compiled in the previous step. Data values for missing years were estimated using regression to best fit a growth curve through the existing data:

\[ \text{MU} = \text{MU}_0 (1 + g)^{Y-Y_0} \]

Equation 1.

Where:

\[ \begin{align*}
\text{MU} & = \text{Multiple Units corresponding to } Y, \\
Y_r & = \text{Year at which MU is computed,} \\
Y_0 & = \text{Year corresponding to } \text{MU}_0, \\
\text{MU}_0 & = \text{Earliest existing data point for a multiple unit at a section}, \\
g & = \text{Growth Factor}
\end{align*} \]
For example, a comparison between estimated and measured values of MU for milepost 340.77 on I-57 is shown in Figure 2. The measured values are shown as bars and the values estimated from the regression analysis are shown as points.

**Single Units**

Single Unit volumes for each section and year were estimated in the same manner as the Multiple Units. It should be noted that a discontinuity occurs in the SU curve in 1980 due to the exclusion of pickups and vans from the Single Unit classification.

MU and SU values estimated for 1986 were checked against actual data collected at various locations by District One. The estimated values are close to the actual values. The 1986 values conform about as well to the estimated values as the values measured in other years.

**Passenger Cars**

Finally, Passenger Car (PC) volumes for District One were obtained by subtracting the estimated Single Units and Multiple Units from the ADT. ADT data exist for almost all sections for each year. For sections with missing ADT data, regression was used to fill in the missing values. Estimated values for MU's SU's and PC's are included in the final data set.

**Missing Data**

There is no traffic information available for I-94 (Kennedy Expressway) from I-90 to I-55 (Stevenson Expressway). There is also insufficient information on the supplemental expressways to estimate traffic volumes using this procedure. Traffic information for the I-94 gap and the supplemental expressways will have to be estimated by experienced traffic engineers in District One in the same manner that downstate traffic data for long gaps in traffic maps were estimated.

**ESAL CALCULATION**

One-direction 18-Kip ESAL applications in the design lane for each year at each section were calculated using the following equation:

\[
ESAL = EFFECT1 \times PC \times PPC + EFFECT2 \times SU \times PSU \\
+ EFFECT3 \times MU \times PMU
\]

Where:
- EFFECT1 = Mean 18-kip ESAL of PC \times 365
- EFFECT2 = Mean 18-kip ESAL of SU \times 365
- EFFECT3 = Mean 18-kip ESAL of MU \times 365
- PC = Passenger cars (average daily)
PPC = Percent passenger cars in design lane
SU = Single Units (average daily)
PSU = Percent Single Units in design lane
MU = Multiple Units (average daily)
PMU = Percent Multiple Units in design lane

Values for EFFECT1 were taken from the IDOT Design Manual and are given below:

<table>
<thead>
<tr>
<th>YEAR</th>
<th>EFFECT1</th>
<th>EFFECT2</th>
<th>EFFECT3</th>
</tr>
</thead>
<tbody>
<tr>
<td>58-75</td>
<td>0.146*</td>
<td>44.895*</td>
<td>421.575*</td>
</tr>
<tr>
<td>76-79</td>
<td>0.146</td>
<td>45.625</td>
<td>492.750</td>
</tr>
<tr>
<td>80-82</td>
<td>0.150</td>
<td>116.070</td>
<td>549.330</td>
</tr>
<tr>
<td>83-87</td>
<td>0.150</td>
<td>143.810</td>
<td>696.420</td>
</tr>
</tbody>
</table>

* These values are 365 times the mean 18-kip ESAL/vehicle. The mean 18-Kip ESAL per vehicle (sometimes referred to as truck factors) for a multiple unit in 1975 was 421.575 / 365 = 1.155. The mean ESAL vehicle factors were obtained from the IDOT Design Manual which is the best estimate available during these time periods. Weigh-in-motion (WIM) data recently taken indicates that a substantial difference between current W-4 vehicle factors and WIM measured factors. Thus, the estimated ESAL's as reported in this document could be substantially lower than what has actually passed over the pavements (20 - 50% low):

The increase in the multiple unit truck factor is shown in Figure 3. This trend may continue and should be considered in future pavement design.

Multiple Units and Single Units contribute to ESAL's far more than passenger cars, as can be observed from the values for EFFECT3 and EFFECT2 compared to the value for EFFECT1. Passenger cars contribute almost nothing to the loss of serviceability of a pavement. That is why efforts were focused on estimating the Single Units and the Multiple Units to the highest degree of accuracy possible.

Values for the percentages of Passenger Cars, Single Units, and Multiple Units in the design lane are based on the total number of lanes and the rural or urban location of the pavements. These values were taken from the IDOT Design Manual as shown in the table below:

<table>
<thead>
<tr>
<th>Classification</th>
<th>Percent in Design Lane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
</tr>
<tr>
<td>Passenger Cars</td>
<td>4</td>
</tr>
<tr>
<td>Passenger Cars 6</td>
<td>4</td>
</tr>
<tr>
<td>Single Units</td>
<td>6</td>
</tr>
<tr>
<td>Single Units 4</td>
<td></td>
</tr>
<tr>
<td>Multiple Units</td>
<td>6</td>
</tr>
</tbody>
</table>
Cumulative ESAL's since original pavement construction were calculated for the design lane in one direction for each section for each year since construction. Results are plotted for each route in Figures 4 through 13. Some sections have accumulated large amounts of traffic (>50 million ESALs).

ESAL applications just for the year 1986 for each section along each route are plotted in Figures 14 through 23. These results show a wide variation of 1986 annual 18-kip ESALs in the outer lane. Some examples follow for I-57.

<table>
<thead>
<tr>
<th>Location</th>
<th>1986 ESAL/year/outer lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cairo</td>
<td>500,000</td>
</tr>
<tr>
<td>Marion</td>
<td>1,100,000</td>
</tr>
<tr>
<td>I57/I70 Effingham</td>
<td>3,000,000</td>
</tr>
<tr>
<td>Champaign</td>
<td>700,000</td>
</tr>
<tr>
<td>Kankakee</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Chicago</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>

The lowest 1986 annual ESAL highway (in one direction in the outer lane) was I-72 with about 300,000, and the highest highways were: I-80 Chicago area 7,000,000, I-90 Chicago area 3,000,000 and I-94 Dan Ryan at 5,000,000.

DISCUSSION OF RESULTS

Preliminary analysis of Interstate ESAL data indicates that pavements have been subjected to far greater heavy traffic loadings than the original design. Figure 24 shows average annual ESAL loadings on all Interstate highways since 1956. Annual traffic loadings of 300,000 ESALs in the late 1950's and early 1960's have grown to nearly 1,200,000 in 1986. Some sections have carried over 50 million ESALs. In terms of accumulated 18-kip ESALs, this represents a compound growth rate of over 8 percent, about triple the expected growth rate of 2 to 3%. This increase is due to both greater volume and heavier loaded trucks. The average truck factors for SU and MU trucks has increased greatly over time. For example, from 1959 to 1975 the MU traffic factor was 421.575 / 365 = 1.155, and from 1983 to 1987 it was 696.42 / 365 = 1.908 as illustrated in Figure 3.

As a result of the higher than anticipated ESAL growth rate, pavements received from 2.7 to 4.0 times the design ESALs over their 20 year design period. This is illustrated in Figure 25 which shows the average accumulated ESALs by pavement age. For example the design ESALs for 8-inch continuously reinforced concrete pavements (CRCP) and 10-inch jointed reinforced concrete pavements (JRCP) are 4.8 million. The average actual cumulated ESAL loading at 20 years is about 12 million.
CONCLUSION

This study provides an evaluation of heavy truck loadings on the Illinois Interstate highway system. Results show that these highways have been subjected to far higher levels of heavy traffic than was planned. The Illinois Interstate system appears to be a focal point for heavy truck travel for a variety of geographical and economic reasons. Both volume and weight of heavy trucks have contributed to the growth of over 8 percent per year of 18-kip ESAL loadings over the past 20 years.

Traffic volume, classification, and ESAL data are crucial in performing pavement evaluation, design and rehabilitation studies. Currently, some pavements are being loaded with less than 300,000 18-kip ESALs per year (one direction, outer lane) while others are being loaded with over 5,000,000 per year. Some sections of original pavement have received over 50 million 18-kip ESALs. The compiled data have already been used in detailed pavement performance studies conducted as a part of the Illinois Pavement Feedback project(2).

RECOMMENDATIONS

It is recommended that the Illinoi DOT study the procedures used to estimate future ESAL for pavement design. Past estimation procedures have underestimated ESALs by a factor of two to three times. Potential future increases in the mean 18-kip ESAL/truck over the design period should be considered. The past annual growth rate of accumulated 18-kip ESALs of over 8 percent may well continue on in the future, and should be considered in pavement design and rehabilitation.

REFERENCES


Figure 1  Multiple unit traffic along I-55 in 1976
Figure 2 Multiple unit traffic at I-57 milepost 340.77 from 1968 to 1986
Figure 3 Change in multiple unit truck factor (18-kip ESAL/truck over time on Illinois Interstate highways)
ILLINOIS INTERSTATE 24
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

ESALs, MILLIONS

MILEPOST

Figure 4 Accumulated 18-kip ESALs along I-24 through 1986
ILLINOIS INTERSTATE 55
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

ESALs, MILLIONS

District 1
Chicago

St. Louis

MILEPOST

0  50  100  150  200  250  300

Figure 5  Accumulated 18-kip ESALs along I-55 through 1986
Figure 6  Accumulated 18-kip along I-57 through 1986
Figure 7 Accumulated 18-kip ESALs along I-64 through 1986
ILLINOIS INTERSTATE 70
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

ESALs, MILLIONS

St. Louis

Indiana State Line

MILEPOST

0 20 40 60 80 100 120 140 160

0 5 10 15 20

Figure 8 Accumulated 18-kip ESALs along I-70 through 1986
Figure 9  Accumulated 18-kip ESALs along I-72 through 1986
ILLINOIS INTERSTATE 74
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

Figure 10 Accumulated 18-kip ESALs along I-74 through 1986
ILLINOIS INTERSTATE 80
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

Figure 11 Accumulated 18-kip ESALs along I-80 through 1986
ILLINOIS INTERSTATE 90
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

ESALs, MILLIONS

All sections are located
in District 1

MILEPOST

0 5 10 15 20 25 30
76 77 78 79 80 81 82 83 84 85 86

Figure 12 Accumulated 18-kip ESALs along I-90 through 1986
ILLINOIS INTERSTATE 94
ACCUMULATED ESALs FROM
CONSTRUCTION THROUGH 1986

ESALs, MILLIONS

All sections are located in District 1

Figure 13  Accumulated 18-kip ESALs along I-94 through 1986
ILLINOIS INTERSTATE 24
ESAL APPLICATIONS DURING 1986

Figure 14  18-kip ESAL applications along I-24 during 1986
ILLINOIS INTERSTATE 55
ESAL APPLICATIONS DURING 1986

ESALs, MILLIONS

District 1
Chicago
St. Louis

Figure 15 18-kip ESAL applications along I-55 during 1986
Figure 16 18-kip ESAL applications along I-57 during 1986
ILLINOIS INTERSTATE 64
ESAL APPLICATIONS DURING 1986

Figure 17  18-kip ESAL applications along I-64 during 1986
Figure 18 18-kip ESAL applications along I-70 during 1986
ILLINOIS INTERSTATE 72
ESAL APPLICATIONS DURING 1986

ESALs, MILLIONS

Springfield

Champaign

MILEPOST

Figure 19 18-kip ESAL applications along I-72 during 1986
Figure 20 18-kip ESAL applications along I-74 during 1986
Figure 21 18-kip ESAL applications along I-80 during 1986
Figure 22 18-kip ESAL applications along I-90 during 1986
ILLINOIS INTERSTATE 94
ESAL APPLICATIONS DURING 1986

ESALs, MILLIONS

All sections are located
in District 1

MILEPOST

Figure 23  18-kip ESAL applications along I-94 during 1986
Figure 24 Mean 18-kip ESAL applications per year for all Interstate highways
Figure 25 Accumulated 18-kip ESAL applications by age of pavements for downstate Interstate highways