MODULE 7

ESAL FLOW MAPS

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Instructional Objectives

- **Basic concepts of Equivalent Single Axle Loads (ESAL)**
- **Estimate of ESALs considering daily, monthly and seasonal truck flows**
- **Use in PMS and pavement design**

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Load Equivalency

LEF=No. of 18 kip ESAL to cause loss of serviceability
No. of X kip axle loads to cause same loss

Where:

X = Axle load for which equivalency is calculated.

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Load Equivalency

Example:

- 100,000 reps of a 18 kip (SAL)
- 14,347 reps of a 30 kip load (SAL)
- Find LEF 30 kip SAL
- $LEF_{30\text{-kip single}}$ = 100,000/14,347 = 6.97

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Estimate of Relative Damage Fourth Power *Law*

Relative Damage = (Ratio between axle loads)^4

Example :

Relative damage 30 kip single axle compared to 18 kip single axle.

LEF = $(30{,}000/18{,}000)^4$ = **7.71**

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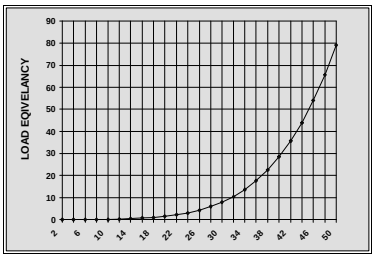
Single Axle Load Equivalency



Truck Factor

- Average amount of damage done by one vehicle in terms of ESALs
- May be for all trucks (ie. 1 ESAL / Truck)
- Best if expressed for various vehicle classes

Example of Increase In Truck Factor

Rural Interstate Flexible Pavement

Year	T F (ESAL /Truck)
1971	0.595
1975	0.691
1979	0.766
1982	0.929
1985	0.992

Truck Weight Data Collection

- Permanent weigh stations
- Portable static scales
- Weigh-in-motion (WIM)

Components of a Monitoring System

- Truck volume by classification
- Volume growth rate for each truck class
- Truck factor for each truck class and growth rate
- Lane distribution for the truck traffic
- Variation in average weight of each truck type
- Percent of ESAL occurring each month

ESAL Flow Maps

- Development of a truck flow map or ESAL traffic load file for PMS
- Florida and Washington data used

ESAL Flow Maps Calculation

- Determine number and distribution of AVC and WIM devices
- Adjust data from short duration AVC and WIM to estimate average annual conditions
- Appropriate length of short duration counts to meet required needs

Truck Flows and Loads

Variability in Truck Travel Patterns

- Site Specific Variation
- Time of Day Variation
- Day of Week Variation
- Season of Year
- Geographic Location
- Group Mean Variation

Truck Flows and Loads

- Site specific estimates of truck loads are better than system means estimates
- Number of data collection sites limited by cost and available workforce

Design of a Continuous Data Collection Program for Vehicle Classification and Weight

- Determine number of continuously operating WIM sites needed
- Determine number of continuously operating AVC sites needed
- Develop truck load (ESAL) file for road network based on annual estimates using data measured on "similar" roads

To Determine the Number of WIM Sites Needed

Step 1: Create Groups of Roads
Step 2: Determine homogeneity of groups
Step 3: Determine number of sites needed

Create Groups of Roads

- Divide network into reasonably homogeneous truck populations and patterns
- Subdivide to get lower variability

Determine Homogeneity of Groups

- Examine similar travel patterns
- Plot the daily damage factors over time and compare plots for different sites within each group

Determine the Number of Sites Needed

$n = [(Z)(S_o)/d]^2$

where:
n = number of sites required.
Z = Z-score for the desired level of confidence
S_o = Standard deviation of the group damage factor
d = desired precision or allowable error expressed in damage factor units (ESALs)

Determine the Number of AVC Sites Needed

Step 1: **Calculate Seasonal & Day-of-Week Adjustment Patterns**

Step 2: **Create Groups of Roads.**

Step 3: **Determine Homogeneity of Groups.**

Step 4: **Determine number of sites needed.**

Calculate Seasonal and Day of Week Adjustment Pattern

- **Calculate seasonal and day-of-week adjustment patterns for all sites**

Create Groups of Roads

- **Develop groups with relatively similar truck volume patterns**
- **Road groups may be different from the damage factor groups developed for WIM site development**

Determine Homogeneity of the Groups

- **Determine acceptability of initial road groups by computing mean and standard deviation of seasonal factors**

Determine the Number of Sites Required

$n = [(Z)(S_o)/d]^2$

where:
n = number of sites required
Z = Z-score for desired level of confidence
S_o = Standard deviation of group damage factor
d = Allowable error expressed as fraction of mean seasonal factor for group

Develop ESAL File

- Develop ESAL file in same processes and same file format as annual daily traffic volume file

Cost Estimate

- Based on WSDOT Highway Network
- Following Guidelines which were first developed by a Data Rationalization Study

Cost Estimate

- 21 WIM sites needed for 10,000 kilometer Network across all functional classes
- Initial Cost approximately $1,000,000 for installation of 21 WIM Sites
- Annual Operations cost about $750,000 with staff of 12

Cost Estimate

- Installation costs based on 19 Piezo Cable systems and 3 Bending Plate Systems with two lanes monitored at each site
- Operational costs based on costs to calibrate sites, maintain sites and replace sites as they fail, plus occasional pavement repair to provide smooth approach to weight system

Cost Estimate

- Approximately 60 permanent AVC Sites also required to be placed on all functional class highways
- Installation and operational costs about same for AVCs as for WIMs; AVC cost less and are more durable but 3 times number required
- AVCs already an integral part of monitoring program for AADT files

Summary

- Module focuses on how to obtain accurate traffic data
- Rough costs to develop and maintain WIM System to meet these guidelines
- Input data for use in PMS affect reliability of prediction models and pavement designs

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