TRUCK WEIGHT ENFORCEMENT M.O.E USER GUIDE

1.0 INTRODUCTION

A paper presented at the 1996 National Traffic Data Acquisition Conference (NATDAC 96) in Albuquerque, New Mexico addressed the development and field validation of truck weight enforcement effectiveness Measures of Effectiveness (M.O.E.s).

The background work for this effort was conducted under NCHRP Project 20-34. The effort first analyzed goals and objectives of truck weight enforcement activities as the initial basis for M.O.E. development. Candidate M.O.E. concepts resulted from this exercise. Final M.O.E.s were determined via their ranked abilities to meet highway and enforcement agency needs. Developed M.O.E.s were then validated in a four-state study to confirm their sensitivity to actual enforcement activity. M.O.E sampling procedures, applicable to evaluate statewide/regional truck weight enforcement programs, were then developed via a statistical analysis of nationwide data.

The result of this research effort was applied to develop a User Guide, which is the subject of the current paper. This User Guide provides practitioners with procedures to evaluate truck weight enforcement activity and applies validated M.O.E.s that were developed and tested in the current research project. The User Guide consists of two parts: sampling guidelines and a software data analysis tool.

2.0 M.O.E. USER GUIDE

This M.O.E. User Guide provides practitioners with techniques to evaluate truck weight enforcement activity and applies validated M.O.E.s, which are listed and defined in Table 1. The user guide consists of two parts: sampling guidelines and a software data analysis tool.

> ***Sampling (Data Collection) Guidelines*** are applied to estimate the number of WIM data collection sites and required sample sizes required to measure an enforcement effect. This guideline provides users with estimates for specified roadway classification and truck percentage conditions.
>
> ***Software (Data Analysis) Tool*** calculates and statistically compares M.O.E. values between two observed enforcement conditions. This procedure also allows users to conduct an automated pavement design life analysis, estimating the theoretical pavement-life effect resulting from differences produced by the two observed enforcement activities.

Table 1. Designated Measures of Effectiveness (M.O.E.s)
and their Definitions

Truck Weight Enforcement M.O.E.	Definition
Gross Weight Violation, Proportion	The fraction (or percentage) of the total observed truck sample which exceeds the legal gross weight limit.
Gross Weight Violation, Severity	The extent to which average measured gross weights for the observed sub-sample of gross weight violators exceeds the legal gross weight limit.
Single-axle Weight Violation, Proportion	The fraction (or percentage) of the total observed truck sample with one or more axles which exceeds the legal single-axle weight limit.
Single-axle Weight Violation, Severity	The extent to which average measured single-axle weights for the observed sub-sample of single-axle weight violators exceeds the applicable legal limit.
Tandem-axle Weight Violation, Proportion	The fraction (or percentage) of the total observed truck sample with one or more tandems which exceeds the legal tandem-axle weight limit.
Tandem-axle Weight Violation, Severity	The extent to which average measured tandem-axle weights for the observed sub-sample of tandem-axle weight violators exceeds the applicable legal limit.
Bridge Formula Violation, Proportion	The fraction (or percentage) of the total observed truck sample which exceeds the legal Bridge Formula weight.
Bridge Formula Violation, Severity	The extent to which average measured Bridge Formula weights for the observed sub-sample of Bridge Formula violators exceeds the legal weight.
Excess ESALs, Proportion	The fraction (or percentage) of the total observed truck sample exhibiting Excess ESALs; i.e., ESALs attributable to the illegal portion the individual single or tandem axle group.
Excess ESALs, Severity	The average value of Excess ESALs observed for the truck sub-sample exhibiting Excess ESALs.

It is important to distinguish between procedural *guidelines* and a methodological *tool.* A *guideline* (i.e., a method by which to undertake a course of action, which may be modified at the discretion of the user) provides the user in this case with the starting point for determining site number and data-collection sample sizes. However, final sampling requirements in the applied evaluation will depend upon observed data characteristics, due to statistical requirements for data stability (i.e., degree of measured variance).

On the other hand, a *tool* (i.e., an instrument to perform an operation in a specified manner) is to be strictly applied throughout the evaluation. In fact, the software tool in this case is designed to refine site-number requirements, on the basis of measured data characteristics, and to advise the user of final sampling requirements.

2.1 M.O.E Sampling (Data Collection) Guidelines

Sampling guidelines described in this section provide practitioners with straightforward data-collection requirements to measure enforcement effects using the validated M.O.E.s. This guideline provides users with estimates of observation site numbers and associated truck sample sizes. These estimates are provided for specified roadway classification and truck percentage conditions. While the sampling guidelines are directed toward WIM database gathering, they are equally applicable to any data collection method capable of gathering M.O.E. data.

Statistical M.O.E. sampling requirements were based on an analysis of nationwide LTPP data. This developmental analysis examined M.O.E. data generated for representative locations (i.e., exhibiting prerequisite highway functional classification and truck mix criteria) and determined the minimum number of observation sites required to produce representative M.O.E. distributions. Based on these results, M.O.E. sampling guideline procedures were developed to enable users to estimate equivalent sampling requirements.

Users of this Sampling Guide are not expected to apply expertise in the area of statistics. However, due to the fact that this guide was developed via the application of various statistical concepts that affect its output, two statistical concepts and their application in the guide's development are briefly explained as follows.

Sampling requirements contained in the guide utilized two statistical concepts, *Level of Significance*, and *Power of Test.* Each of these terms is defined as follows, only as a matter of information for users of this guide.

Level of Significance refers, in this case, to the probability that the user is willing to risk the error of rejecting a valid change in M.O.E. occurrence. In statistical jargon, the Level of Significance is the maximum probability with which we would be willing to risk a *Type 1 error*. A Type 1 error occurs when a true hypothesis is rejected, i.e., that baseline (no enforcement) versus enforcement M.O.E. variable sets are statistically different. The .05 Level of Significance was applied in the development of this guide.

Power of Test refers to the likelihood of making a correct statistical assessment, i.e., that the proper hypothesis is accepted, statistically speaking. The issue is to what extent is the user willing to risk accepting an invalid change in M.O.E. occurrence. In statistical jargon, the Power of a Test is the maximum probability with which we would be willing to risk a *Type 2 error*. A Type 2 error occurs when a false hypothesis is accepted, i.e., that baseline versus enforcement M.O.E. variable sets are not statistically different. The .80 Power of Test was applied in the development of this guide.

2.1.1 Sampling Observation Levels

Separate observation levels for sampling truck-weight violations were devised in order to meet the diverse evaluation requirements of varied truck weight enforcement operations. Three designated sampling observation levels are as follows: (1) statewide or regional, (2) highway corridor or local level, and (3) spot or location-specific. Figure 1 is a conceptual representation of the three designated observational levels.

Figure 1. Illustration of Varied Data-sampling Observation Level Concept

At the broadest level, the implementation of revised regional or statewide policy may require sampling over a vast geographic area, covering hundreds of square miles. At the opposite end of the spectrum, spot truck-weight enforcement procedures are frequently required due to location-specific factors, e.g., pertaining to local hauling conditions. Finally, a major concern for enforcement and highway agencies is weight-law compliance along specific highway corridors. The critical nature of weight monitoring along corridors stems from a number of factors, including trucker avoidance of weight enforcement and costly pavement damage to local highways.

2.1.2 Statewide or Regional M.O.E. Sampling

Statewide or regional M.O.E. sampling is applied to evaluate any truck weight enforcement program that affects large geographic areas that exceed the bounds of a definable highway corridor. The derivation of sampling requirements was based on actual observed statewide M.O.E. distributions; however, this guide is also applicable for smaller geographic regions. Site number requirements contained in this guide indicate minimum numbers to produce representative results for a designated region. Data collection site requirements are designated on the basis of regional characteristics, i.e., highway functional class and associated truck percentage combinations, which comprise the area under study. An example application of this procedure is shown in Section 2.1.3 of this paper.

WIM Data Site Number Requirements The number of required observation sites for a statewide/regional study of truck weight enforcement effectiveness was determined on the basis of observed M.O.E. distributions from representative nation-wide locations. Site number requirements for a designated region are based on the region's composition in terms of specified highway functional classification and associated truck percentage criteria. The determination of study site numbers is accomplished via the application of the guidelines shown in Table 2, which specifies site number requirements for each functional-class/truck-percentage category.

Table 2. Recommended Minimum Site Numbers for Selected M.O.E.s in State/Regional Truck Weight Enforcement Evaluations

FUNCTIONAL CLASS and Truck Percentage	**GROSS WEIGHT VIOLATIONS**	**TANDEM AXLE VIOLATIONS**	**SINGLE AXLE VIOLATIONS**	**EXCESS ESALs**
Rural Interstate < 15 % Trucks	3	3	8	9
15 to 30 % Trucks	6	6	21	32
> 30% Trucks	3	3	13	32
Rural Primary Arterial < 9 % Trucks	3	3	11	2
9 to 30 % Trucks	7	7	24	15
> 30% Trucks	2	2	5	15
Rural Minor Arterial	3	3	9	9
Urban Interstate < 9% Trucks	2	2	2	10
≥ 9% Trucks	2	2	6	15
Urban Primary Arterial < 9% Trucks	2	2	7	10
≥ 9% Trucks	3	3	8	14

The statewide/regional M.O.E. sampling procedure involves two preparatory steps. First, the geographic area, e.g., jurisdictional territory, to be affected by the enforcement program under study must be clearly defined. Second, the highway network within the defined study region must be reviewed to determine its composition, in terms of route functional classification and associated truck percentage as a function of overall traffic volume, on each affected route.

The number of required study sites is then determined on the basis of corresponding site-number designations shown in Table 2. The total number of study sites in a given region will be the sum of those applied in each functional class and truck-ratio which are represented in the region, as demonstrated in the next paragraph. Each functional class represented in the region under study must be included in the array of designated observation sites.

Assuming that the primary M.O.E. of interest is the "Proportion of Gross Weight Violations", then the number of required sites for each highway category will be derived from numbers shown in the left-most column of Table 2. For example, at least three data collection sites are required to represent Rural Interstates with less than 15 percent trucks, six to represent Rural Interstates with 15 to 30 percent trucks, etc. The total number of sites for the study region will be equal to the sum of site numbers for all functional-class/truck-percentage categories represented in the region, i.e., 36 sites. An example application of a regional sampling plan development is shown in the following section of this paper.

It is important to note a number of user precautions and associated considerations underlying the development of site numbers contained in Table 2. These caveats relate to the analysis and application of nationwide representative data used to estimate requirements for conducting a regional truck weight enforcement evaluation.

First, the nationwide analysis determined that a *single* observation site, within selected functional-class/truck-percentage categories, was sufficient to statistically detect certain enforcement effects. However, application of sound sampling strategy to a regional enforcement study requires a significant degree of generality to ensure its validity; therefore, Table 2 mandates a minimum of two sites for each functional highway classification condition.

Second, site number requirements outlined in Table 2 were based on observed M.O.E percentage reductions found to be associated with enforcement activity. However, for situations in which an observed enforcement activity may produce greater or lesser percentage M.O.E differences, an appropriate adjustment to the number of observation sites may be required to statistically measure the effect. Importantly, with the current application, the user will be appropriately informed of the level of affected M.O.E. change (and the associated number of required sites to validly observe this effect) via application of the software package accompanying this guide. The software application is explained in Section 2.2 of this paper.

Third, site numbers designated in Table 2 were based on measured statistical M.O.E. distribution. By taking into account normal sample sizes and associated variability of these M.O.E.s, they indicate the number of observation sites required to capture representative M.O.E. distributions. However, a number of application-specific considerations are necessary in the user's interpretation of the table. Specifically, truck weight surveillance over a large geographical area may *logically* require larger site numbers than indicated in the table. For example, many cells in the table indicate the necessity of only 2 or 3 study sites, given certain highway classification and truck ratio conditions. Yet, in the case of a statewide enforcement program over a very large area, the limitation of 2 or 3 study sites may be considered inadequate.

Importantly, the final designation of observation sites must consider prevalent conditions, e.g., specific hauling and commodity demands that affect truck-loading operations and the sub-regional areas to which they apply. Specifically, the user is cautioned against combining sites characterized by known non-homogenous loading conditions when applying the sampling procedure.

Finally, as previously noted, Table 2 is a *guideline* (i.e., a procedure by which to undertake a course of action, which may be modified at the discretion of the user) to provide the user with the starting point for determining site number and data-collection sample sizes. Its final application relies on engineering judgement in the context of specific study situations.

Designation of Data Collection Periods In view of known commodity shipping patterns, both weekend and weekday data collection periods are recommended in applied regional M.O.E. sampling efforts to evaluate truck weight enforcement programs. Importantly, designated data collection periods need to be sensitive to seasonal conditions, e.g., agricultural commodity hauling patterns. A minimum two-day data collection duration is required at each site for each observed enforcement condition.

Based on NCHRP Project 20-34 findings, the user is advised to expect maximum violation to occur during the early morning hours, e.g., 3 a.m. to 7:30 a.m. on weekdays, and during the late evening hours on Sundays.

Minimum site-specific truck sample sizes are shown in Table 3 on the next page for designated combinations of highway functional class and associated truck percentages for designated M.O.E.s. Sample size estimations shown in the table are based on the requirement to detect differences in truck proportions exhibiting the array of generally applied M.O.E.s at the .05 level of statistical confidence.

2.1.3 Example of a Regional M.O.E. Sampling Application

Consider the hypothetical example of a geographic region with a distribution of 100 WIM data collection sites as shown in Table 4 on the next page. This distribution was estimated on the basis of traveled vehicle-miles by functional classification[1] with adjustments for traffic monitoring prioritization.

The assignment of available WIM sites to monitor an ongoing regional truck weight enforcement program, according to the scheme previously shown in Table 2, produces the sampling scheme shown in Table 5 on the next page.

[1] U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Washington, D.C. 1996

Table 3. Minimum Site-specific Number of Required Truck Observations

FUNCTIONAL CLASS and Truck Percentage	**MINIMUM*** **SAMPLE**
Rural Interstate < 15 % Trucks	175
15 to 30 % Trucks	300
30% Trucks	200
Rural Primary Arterial < 9 % Trucks	225
9 to 30 % Trucks	325
> 30% Trucks	100
Rural Minor Arterial	200
Urban Interstate < 9% Trucks	100
≥ 9% Trucks	200
Urban Primary Arterial < 9% Trucks	125
≥ 9% Trucks	100

* Over a minimum 2-day data collection period.

Table 4. Available WIM Monitoring Locations in Example Sampling Application

FUNCTIONAL CLASS and Truck Percentage	**AVAILABLE WIM** **DATA SITES**
Rural Interstate < 15 % Trucks	4
15 to 30 % Trucks	8
> 30% Trucks	4
Rural Primary Arterial < 9 % Trucks	7
9 to 30 % Trucks	7
> 30% Trucks	14
Rural Minor Arterial	15
Urban Interstate < 9% Trucks	8
≥ 9% Trucks	18
Urban Primary Arterial < 9% Trucks	5
≥ 9% Trucks	11
TOTAL	100

An examination of Table 5 indicates that of the 100 available WIM-monitoring sites, only 36 sites are required for region-wide monitoring of two M.O.E.s, i.e., Gross Weight Violations, and Tandem Axle Violations, on all highway functional-class/truck-percentage categories. In order to obtain a non-biased estimation of truck weight enforcement effects, the user agency is advised to assign data collection locations in a *random* fashion (within appropriate functional-class/truck-percentage categories) when all available WIM installations are not statistically required for the evaluation.

A larger number of data collection sites is required within a region to statistically represent less-frequently-occurring M.O.E.s. Consequently, in the current example, the latter two M.O.E.s required more data collection sites within certain functional-class/truck-percentage categories than were available. In these instances, the percentage of available WIM sites is indicated in the appropriate cells of Table 5. For example, while 8 sites were previously suggested in the Table 2 Guide as the minimum number of sites to detect enforcement effects in terms of Single-Axle Violations, the 4 available sites comprise 50% of this requirement. In such instances, the regional evaluation is necessarily limited by WIM-site availability, and the issue site selection bias defers to applied site-location decision rationale.

Table 5. Recommended WIM Data Collection Site Distribution
for Example State/Regional Sampling Scheme

FUNCTIONAL CLASS and Truck Percentage	**GROSS WEIGHT VIOLATIONS**	**TANDEM AXLE VIOLATIONS**	**SINGLE AXLE VIOLATIONS**	**EXCESS ESALs**
Rural Interstate < 15 % Trucks	3	3	4 (50%)	4 (44%)
15 to 30 % Trucks	6	6	8 (38%)	8 (25%)
> 30% Trucks	3	3	4 (31%)	4 (12%)
Rural Primary Arterial < 9 % Trucks	3	3	7 (64%)	2
9 to 30 % Trucks	7	7	7 (29%)	7 (47%)
> 30% Trucks	2	2	14 (58%)	14 (93%)
Rural Minor Arterial	3	3	9	9
Urban Interstate < 9% Trucks	2	2	2	8 (80%)
≥ 9% Trucks	2	2	6	15
Urban Primary Arterial < 9% Trucks	2	2	5 (71%)	5 (10%)
≥ 9% Trucks	3	3	8	11 (79%)
TOTAL	36	36	74	87

The non-availability of 100 percent of the Sample Guide's recommended site numbers does not necessarily mean than the region can not be evaluated in terms of the latter two M.O.E.s in this instance. Conversely, more sites may be needed in some instances than indicated by the Table 2 Guide. The reason is that the exact number of required sites is determined by the data variance that is actually measured. Again, we emphasize that site numbers indicated in Table 2 are guidelines, based on nationwide observations of expected M.O.E.s variances, and these estimates are prescribed as the starting point for development of the final sampling plan.

Precise site number requirements are determined via application of the data analysis software developed in this project, the Truck Weight Enforcement Evaluation Tool (TWEET), described in Section 2.2 of this paper. This software computes customized site number requirements based on the user's collected data. Specifically, it performs site-number requirement calculations based on actual measured variances, as is statistically appropriate. Thus, this process provides the necessary site-number refinement calculation to define final sampling requirements. However, it can not replace the Table 2 Guide, as the user needs initial estimates for evaluation study planning purposes.

The data analysis software contains a "Sampling Guide" dialog box that computes site number requirements for various levels of statistical precision (see Figure 2 on the next page). The example dialog box in the figure hypothetically considers data collected at 36 sites. This is the minimum number of prescribed sites in Table 2 assuming that the study region contains sites in all eleven functional-class/truck-percentage categories. This software sampling aid prescribes site-number requirements as a function of the specific enforcement-program effectiveness threshold, i.e., designated percent change in specific M.O.E.s, that the user wishes to consider. For example, looking at site-number requirement shown in the figure for Gross Weight Violators M.O.E., we see that if users want to detect an enforcement effect based on an expected 40-percent violation reduction, only two data collection sites are required. However, to apply a more rigorous statistical requirement, for example a statistical test that is sensitive to a ten-percent reduction, seven sites would then be required.

2.1.4 Corridor or Local-Level M.O.E. Sampling

Truck weight enforcement efforts often concentrate on a corridor surrounding a specific route, e.g., commonly used for commodity hauling. Applied enforcement strategies involve monitoring primary routes as well as potential diversion routes within the corridor.

Designation of WIM Data Collection Sites The corridor or local-level M.O.E. sampling procedure first involves designation of the potentially-affected roadways surrounding the primary route of interest. Routes in this area obviously need to be targeted (and WIM data sampled) by the corridor-specific enforcement program. Second, the highway network within the diversion area must be examined to determine the functional classification and associated truck percentage on each affected route. Initial numbers of required data collection sites on each functional class of highway within the region can then be determined via the application of Table 6 guidelines on the next page. While Table 6 is similar in appearance to Table 2, previously shown for wider-area regional truck weight enforcement programs, it does indicate routes on which a single observation site is suitable for collection of designated M.O.E.s. Unlike wider-area, regional weight-enforcement efforts, a single observation site may suitable for use in a corridor-specific enforcement activity evaluation.

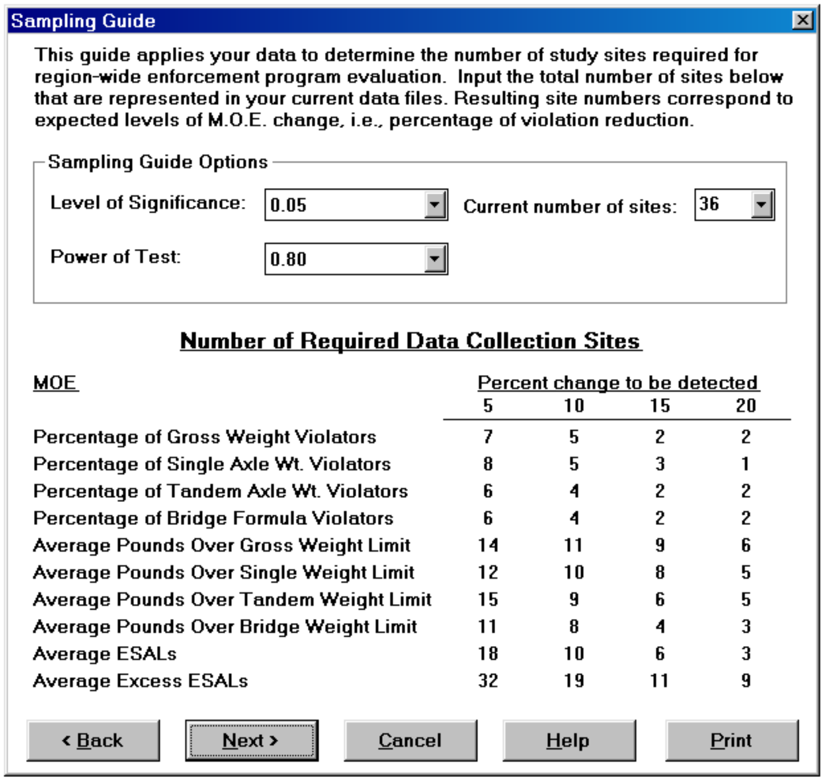


Figure 2. Sampling Guide Dialog Box Applied to Example Sampling Application

Site number requirements contained in Table 6 were based on observed nationwide M.O.E percentage reductions to be associated with enforcement activity. As previously shown in the regional evaluation example, final sample size requirements will be confirmed via application of the TWEET software.

Table 6. Recommended Minimum Site Numbers for Selected M.O.E.s in Corridor-specific Truck Weight Enforcement Evaluations

FUNCTIONAL CLASS And Truck Ratio	**GROSS WEIGHT VIOLATIONS**	**TANDEM AXLE VIOLATIONS**	**SINGLE AXLE VIOLATIONS**	**EXCESS ESALs**
Rural Interstate				
< 15 % Trucks	3	3	8	9
15 to 30 % Trucks	6	6	21	32
> 30% Trucks	3	3	13	32
Rural Primary Arterial				
< 9 % Trucks	3	3	11	2
9 to 30 % Trucks	7	7	24	15
> 30% Trucks	1	1	5	15
Rural Minor Arterial	3	3	9	9
Urban Interstate				
< 9% Trucks	1	1	2	10
≥ 9% Trucks	2	2	6	15
Urban Primary Arterial				
< 9% Trucks	2	2	7	10
≥ 9% Trucks	3	3	8	14

Designation of Data Collection Periods The same data-collection period sampling principles apply to the corridor and local-level M.O.E. application as were noted with regard to statewide and regional M.O.E. sampling strategy above. That is, truck observation periods should include both weekday and weekend periods. First, emphasis should be given to pre-dawn weekday and Sunday evening observation times. Second, scheduled data collection periods need to be sensitive to seasonal commodity hauling. Third, minimum data collection durations of two days are required for each enforcement condition. Finally, minimum site-specific sample sizes requirements are the same as previously indicated in Table 3.

2.1.5 Location-Specific M.O.E. Sampling

M.O.E. sampling to evaluate a specific enforcement activity can involve data collection at a single observation site. The site would be designated as a feasible permanent or portable WIM installation at a highway location affected by trucks subjected to the enforcement procedures under study. A minimum data collection duration of two days is required for each enforcement condition. Care must be taken that WIM instrumentation be installed and operated in an unobtrusive manner so as not to interfere with an objective evaluation procedure.

Ideally, such an evaluation would be conducted at a location where no potential overweight-truck diversion route is possible. However, at sites other than long desert highways, bridges between two islands, or a few select routes along the Florida Keys, enforcement agencies are advised to monitor any parallel highways for increased truck volume. Furthermore, as an internal validity check with regard to the enforcement evaluation effort, user agencies are advised to compare truck volumes, time-of-day flow rates, and violation percentages between enforcement and non-enforcement data collection periods. Direct application of the TWEET software accommodates this task.

2.2 M.O.E. Software (Data Analysis) Tool

This software guide consists of a user-friendly Windows program, Truck Weight Enforcement Effectiveness Tool (TWEET), which calculates and statistically compares M.O.E. values between two observed enforcement conditions. It also allows users to conduct an automated pavement design life analysis, estimating the theoretical pavement-life effect resulting from differences in the two observed enforcement activities. The software will be available to users on the Internet and will automatically self-install on the user's computer.

As the user starts the program, the *Main Window* (Figure 3) dialog box will appear. The button marked "Start Analysis" allows the user to start a truck-weight and enforcement-effects analysis. The user can then designate English or Metric units via the *Set Legal Weight Limits* dialog box (see Figure 4 on the next page). Current default values, easily modified by the user, are shown in the figure.

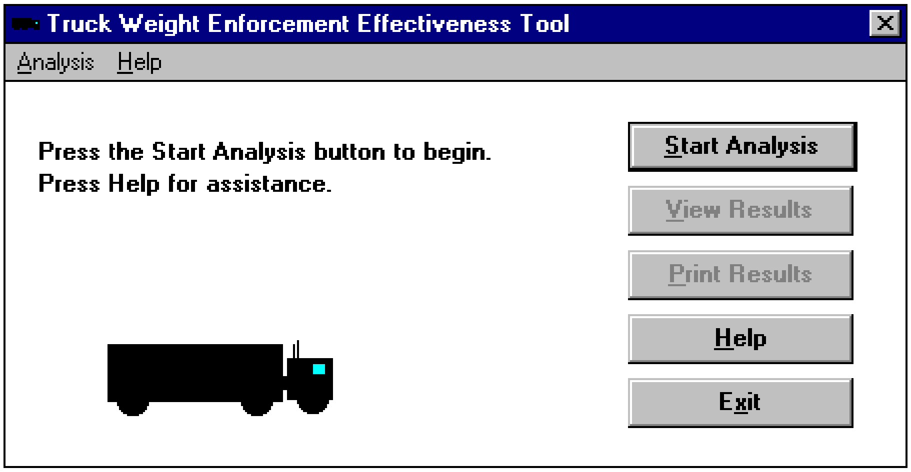


Figure 3. "Main Window" on M.O.E. Application Software

Depending upon whether the user selects Flexible or Rigid pavement, different variables appear in the Pavement Characteristics portion of the dialog box. This box will prompt the user for appropriate pavement design parameters. A comprehensive "Help" screen associated with the Pavement Analysis Dialog boxes explains the design theory, including the AASHTO design equations, underlying the computations embedded in the software

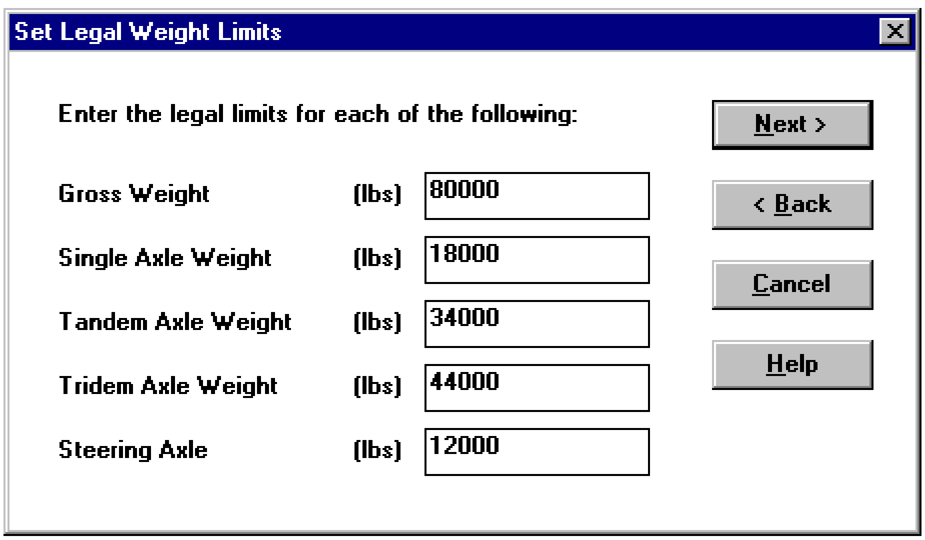


Figure 4. The "Set Weight Limits" Dialog Box

The *Select Truck Classification* dialog box (See Figure 5) dialog box allows selection of the user's choice of truck classification system. Choices are FHWA 13-Type or Custom. The 1995 FHWA *Traffic Monitoring Guide* 13-Type scheme is a standard 13-type vehicle classification system that should be adequate for most users. At the time this software was developed, many states applied the FHWA Card-7 format. If data are in the FHWA Card-7 format, the user can click on the default standard 13-type classification option and the program will run normally.

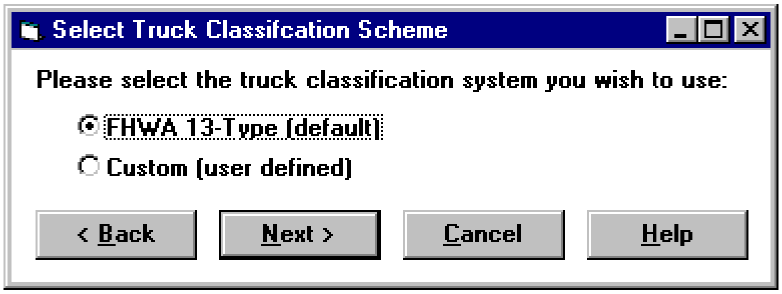


Figure 5. “Select Truck Classification Scheme” Dialog Box

The *File Conversion* dialog box (Figure 6) is designed to assist agencies whose data format does not conform to either the 1995 FHWA *Traffic Monitoring Guide* 13-Type scheme or Card-7 classification formats. If the user’s data are not in either one of these formats, the Convert button is applied to display the *TWEET Conversion Utility* dialog box which provides an efficient way to convert data files from other formats to the 1995 FHWA Truck Weight Record format. An associated dialog box will then prompt the user for specific information regarding customized input and output information required for operating the software given the user’s unique data format requirements.

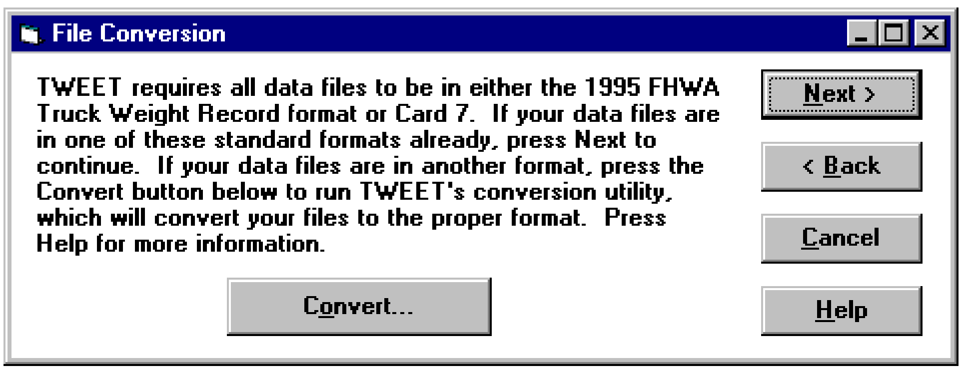


Figure 6. The “Data File Conversion” Dialog Box

The user then defines observed enforcement conditions providing input to the *Enforcement Condition 1 of 2* dialog box (Figure 7). For each condition, the user will be asked to enter information descriptive of of the enforcement effort. The user will also provide similar information in the *Enforcement Condition 2 of 2* dialog box (not shown).

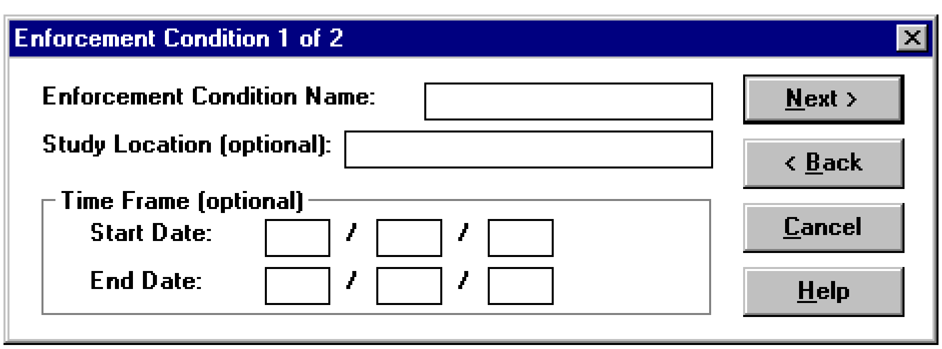


Figure 7. The “Enforcement Condition” Dialog Box

The *Pavement Analysis* dialog box (Figure 8) provides the user with an option to conduct a pavement design-life enforcement-effects analysis. The program asks for specific (and detailed) pavement design data. Because of the complexity of the pavement design-life analysis, the user has the option of skipping the pavement analysis simply by clicking the 'skip pavement analysis' option.

Depending upon whether the user selects Flexible or Rigid pavement, different variables appear in the Pavement Characteristics portion of the dialog box. This box will prompt the user for appropriate pavement design parameters. A comprehensive "Help" screen associated with the Pavement Analysis Dialog boxes explains the design theory, including the AASHTO design equations, underlying the computations utilized in the software

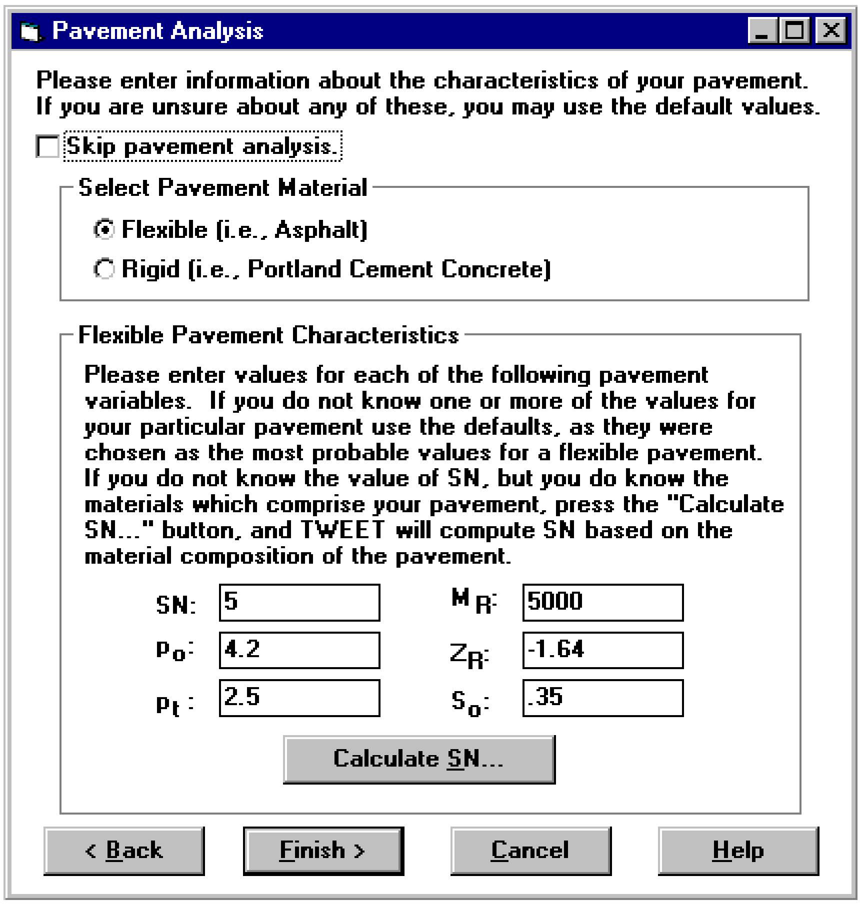


Figure 8. The "Pavement Analysis" (Flexible Example) Dialog Box

Flexible pavements are discussed first. Default values are shown on the dialog box for the following parameters.

SN Pavement Structural Number. TWEET offers the option of computing this variable based on input values provided by the user.

p_o Initial Serviceability Index

p_t Terminal Serviceability Index
M_R Default function of Serviceability Index
Z_R Standard Normal Deviate corresponding to deign reliability
S_O Standard Deviation associated with pavement performance prediction

The above parameters are defined and their design implications are explained in detailed ‘Help’ screens in the software.

Because of the importance of the pavement’s Structural Number (SN), TWEET provides the user with alternative approaches to its calculation. First, the user may accept the commonly applied value shown as the default. Second, the user may apply a known value for SN, based on his knowledge of the site. Third, if the user knows the material composition of the pavement, TWEET can automatically calculate the SN value. In this case, the user clicks on 'Calculate SN', and the *Automatic Calculation of SN* dialog box appears as shown in Figure 9.

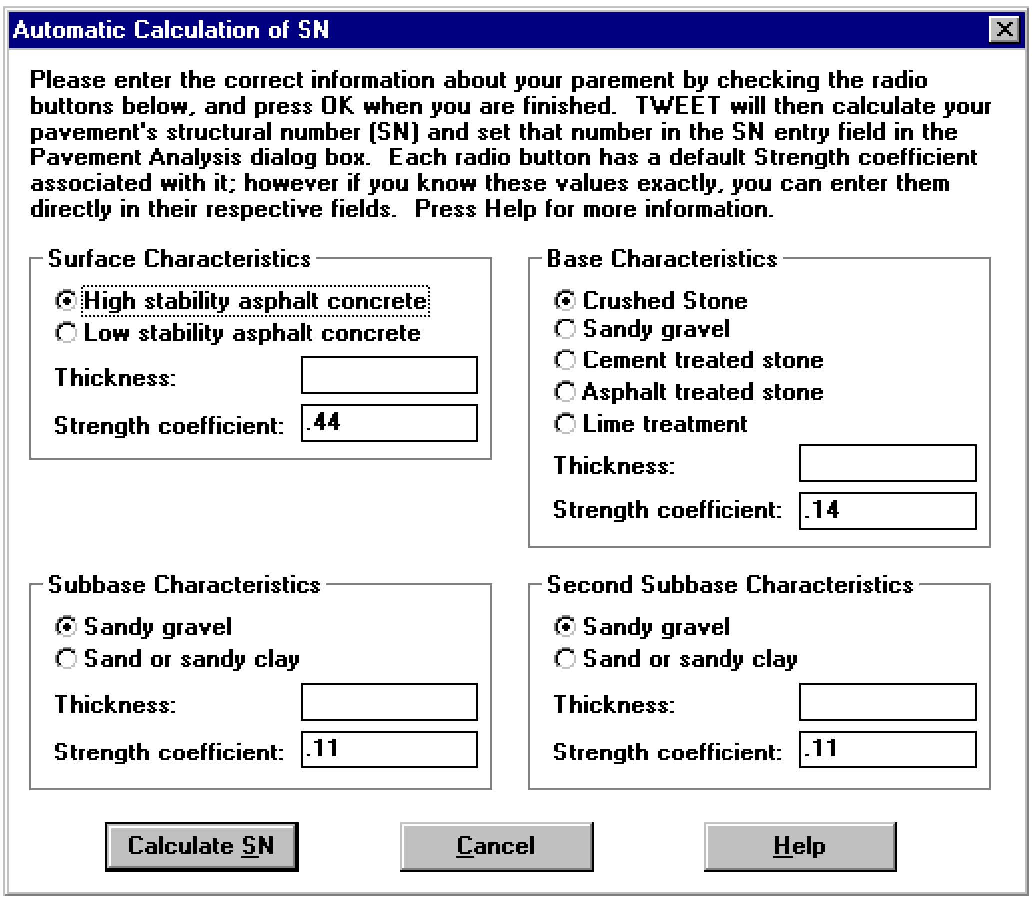


Figure 9. The “Automatic Calculation of SN” Dialog Box

The dialog box shown in the above figure allows the user to select the appropriate surface, base, and sub-base characteristics, i.e., pavement layer thickness (in inches), and strength coefficient. According to the specified material type, the program will suggest the most appropriate *default* Strength Coefficient. Pavement materials and design personnel who run this software have the option of overriding default values, depending upon their own knowledge of pavement materials and design procedures along with specific pavement characteristics associated with the truck weight enforcement location.

In the event the user had selected Rigid Pavement, the *Pavement Analysis (Rigid Pavement)* dialog box would appear as shown in Figure 10.

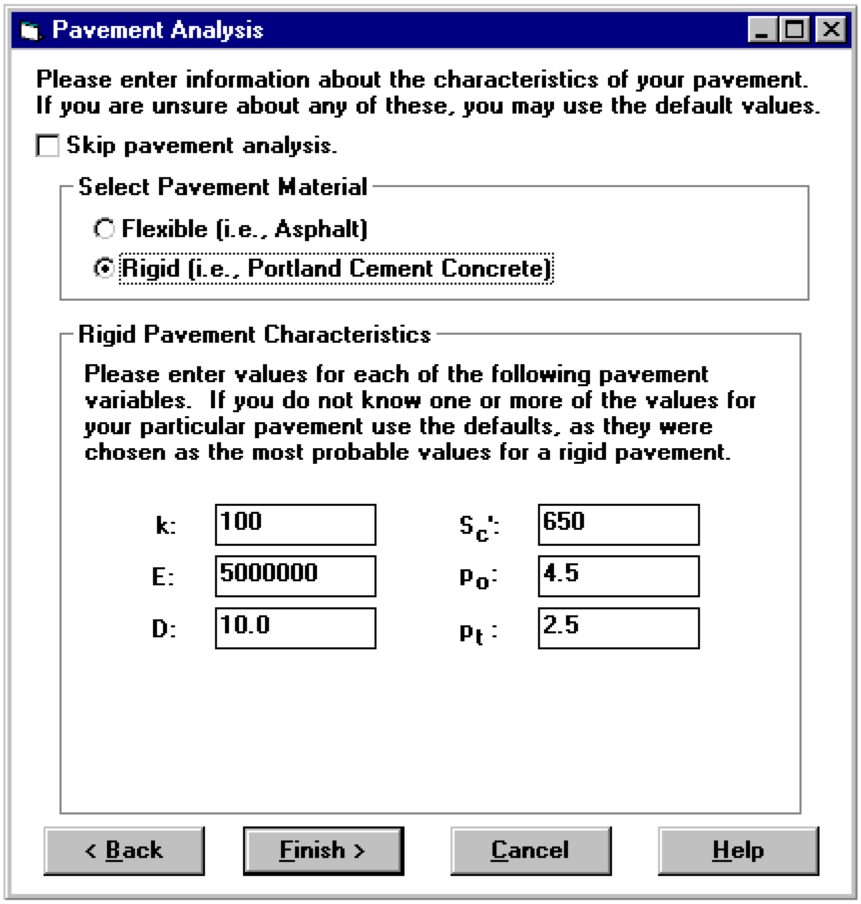


Figure 10. “Pavement Analysis” (Rigid Example) Dialog Box

This dialog box, provides the following design values for user application:

k	Modulus of Subgrade Reaction
E	PCC Elastic Modulus
D	Slab Thickness (inches)
s_o	Standard deviation associated with pavement performance prediction
p_0	Initial Serviceability Index
p_t	Terminal Serviceability Index

As was the case with the Flexible Pavement Characteristics box, the most likely default design values have been provided in the case of Rigid Pavements. The user has the option of manually entering values specific to the highway study site.

The program will then read the WIM data files and perform all calculations. Unless data files are extraordinarily large, these calculations should take no more than a few seconds. An animated graphic *Status* dialog box (Figure 11) will appear to advise of the program's progress on the computational process. The truck on the screen moves from left to right on the roadway section as the calculation is completed.

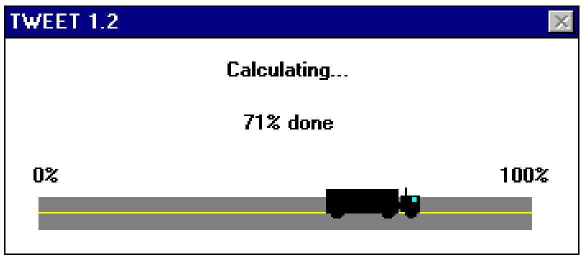


Figure 11. "Calculation Status" Dialog Box

Once the calculations are completed, the user will be presented with a series of "output" dialog boxes that display calculated values based on input data. The first M.O.E. output dialog box, *Severity of Violations* (not shown), also reports summary information, i.e., enforcement condition, highway type, total vehicle, and truck sample. The violator numbers and average overweight values are indicated. Then, *Calculated Percentages of Overweight Trucks* dialog (not shown) displays the calculated percentages of overweight trucks in the sample. It lists four calculations based on the data files: (1) Percentage of trucks over the legal gross weight limit, (2) Percentage of trucks over the tandem axle weight limit, (3) Percentage of trucks violating the Bridge Formula, and (4) Percentage of trucks over the single axle weight limit.

The *Violation Data by Truck Classification* dialog box (Figure 12) indicates violators, by truck number and percentage, for each class of truck. This dialog box displays violation information, broken down by truck classification. This information is useful in determining violation distributions according to truck type.

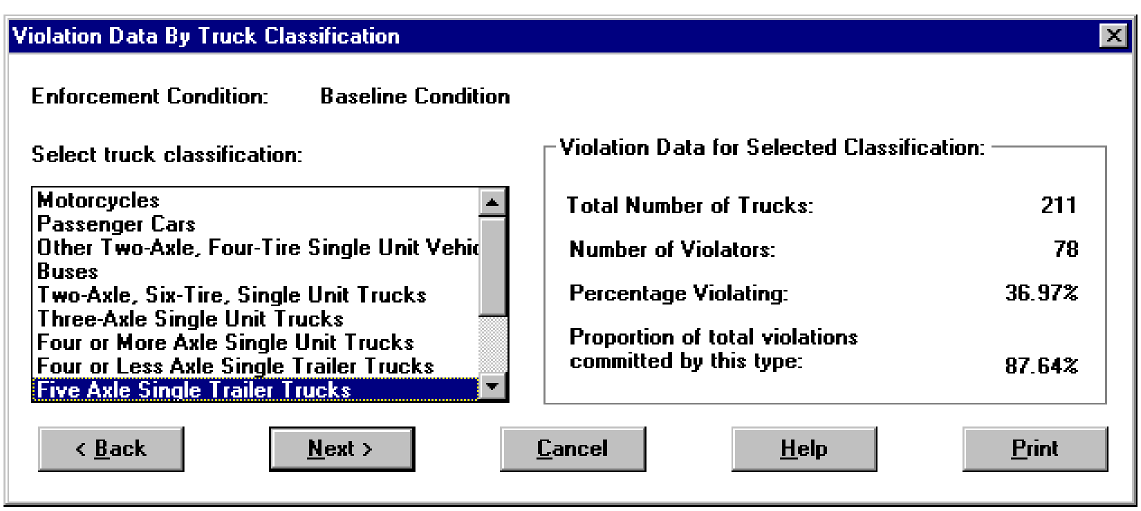


Figure 12. "Violation Data by Truck Classification" Dialog Box

The dialog consists of two parts:

Truck Classification List Box This box lists all of the truck classifications which were input by the user during the beginning of the analysis, or if the default was selected, the FHWA 13-type classifications.

Violation Data This part of the dialog lists violation data for the currently selected truck classification. First, the Total Number of Trucks field displays the number of trucks of the selected type which were in the sample (regardless of whether they were violators). Second, the Number of Violators field lists the number of trucks of the selected type that violated the weight limits. Third, the Percentage Violating field lists the percentage of trucks of the selected type which were violators (this percentage is simply the Number of Violators divided by the Total Number of Trucks). Finally, this part of the dialog indicates the total violator proportion presented by truck classification. (It should be noted that the percentage in this example is higher than normal due to an over-calibrated WIM scale.) In the figure above, while only 37 percent of Type 9 trucks were violators, this sample comprised 87 percent of the violators due to their high representation in the overall traffic stream.

The *Breakdown of Violations by Day-of-Week* dialog box displays (not shown) the percentage of violations occurring on each day of the week. Then, the *Breakdown of Violations by Time-of-Day* dialog (not Shown) displays the percentage of violations occurring at different hours of the day.

The *ESAL Data* dialog box (Figure 13) indicates average ESAL calculations using the FHWA *Traffic Monitoring Guide* procedure according to the number of axles. This dialog also indicates computed Excess ESAL violations by truck axle-count.

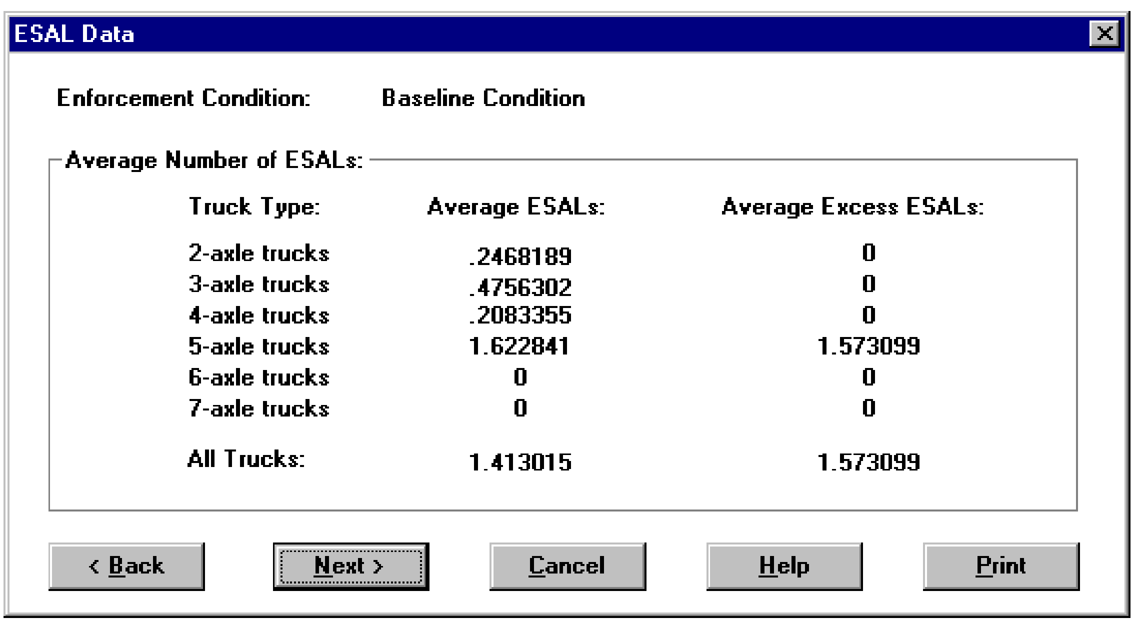
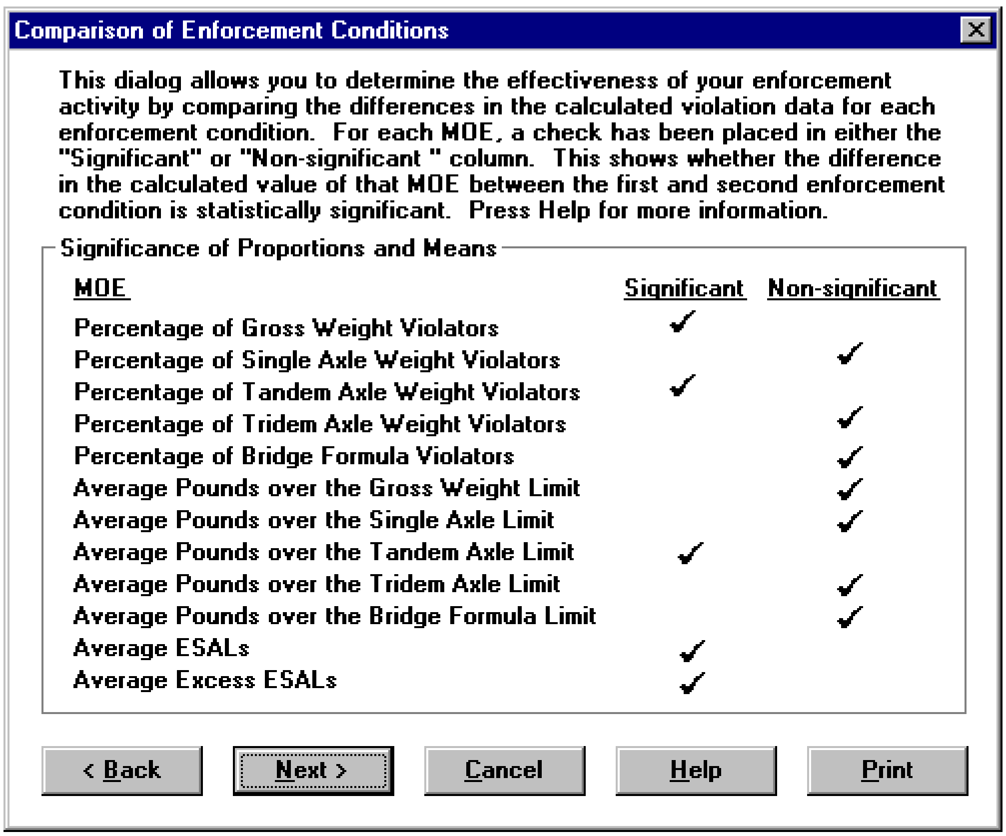


Figure 13. The “ESAL Data” Dialog Box

Now, TWEET goes into its 'What does it all mean?' mode! The *Comparison of Enforcement Conditions* dialog (Figure 14 on the next page) indicates to the user whether or not the observed M.O.E. differences are significant. This dialog box contains results of applied statistical significance tests to the computed M.O.E.s and indicates to the user whether or not the observed differences are significant. Separate tests of statistical significance are applied to M.O.E.s depending upon whether the measure was calculated as a mean (i.e., average gross weight violation) or a proportion (i.e., proportion of gross weight violators). Significance tests are applied at the .05 level of statistical confidence.

The *Sampling Guide* dialog box (Figure 15 on the next page) shown on the next page is an aid to determine how many sites will be needed to be surveyed in order to detect regional changes for designated M.O.E.s given specified levels of statistical confidence. The user is first presented with a "Sampling Guide Options" table, allowing the option of specifying two parameters related to the precision of the statistical estimate. These are the desired *Level of Significance* and the *Power of Test*, explained as follows.



Comparison of Enforcement Conditions

This dialog allows you to determine the effectiveness of your enforcement activity by comparing the differences in the calculated violation data for each enforcement condition. For each MOE, a check has been placed in either the "Significant" or "Non-significant " column. This shows whether the difference in the calculated value of that MOE between the first and second enforcement condition is statistically significant. Press Help for more information.

Significance of Proportions and Means

MOE	Significant	Non-significant
Percentage of Gross Weight Violators	✓	
Percentage of Single Axle Weight Violators		✓
Percentage of Tandem Axle Weight Violators	✓	
Percentage of Tridem Axle Weight Violators		✓
Percentage of Bridge Formula Violators		✓
Average Pounds over the Gross Weight Limit		✓
Average Pounds over the Single Axle Limit		✓
Average Pounds over the Tandem Axle Limit	✓	
Average Pounds over the Tridem Axle Limit		✓
Average Pounds over the Bridge Formula Limit		✓
Average ESALs	✓	
Average Excess ESALs	✓	

< Back | Next > | Cancel | Help | Print

Figure 14. "Comparison of Enforcement Conditions" Dialog Box

Level of Significance refers, in this case, to the probability that the user is willing to risk the error of rejecting a valid change in M.O.E. occurrence. In statistical jargon, the Level of Significance is the maximum probability with which we would be willing to risk a *Type 1 error*. A Type 1 error occurs when a true hypothesis is rejected, i.e., that baseline versus enforcement M.O.E. variable sets are statistically different. In practice, a significance level of .05 or .01 is customary.

Power of Test refers to the likelihood of making a correct statistical assessment. This is achieved when the proper hypothesis is accepted. At issue is the extent to which the user is willing to risk accepting an invalid change in M.O.E. occurrence. In statistical jargon, the Power of a Test is the maximum probability with which we would be willing to risk a *Type 2 error*. A Type 2 error occurs when a false hypothesis is accepted, i.e., baseline versus enforcement M.O.E. variable sets are not statistically different.

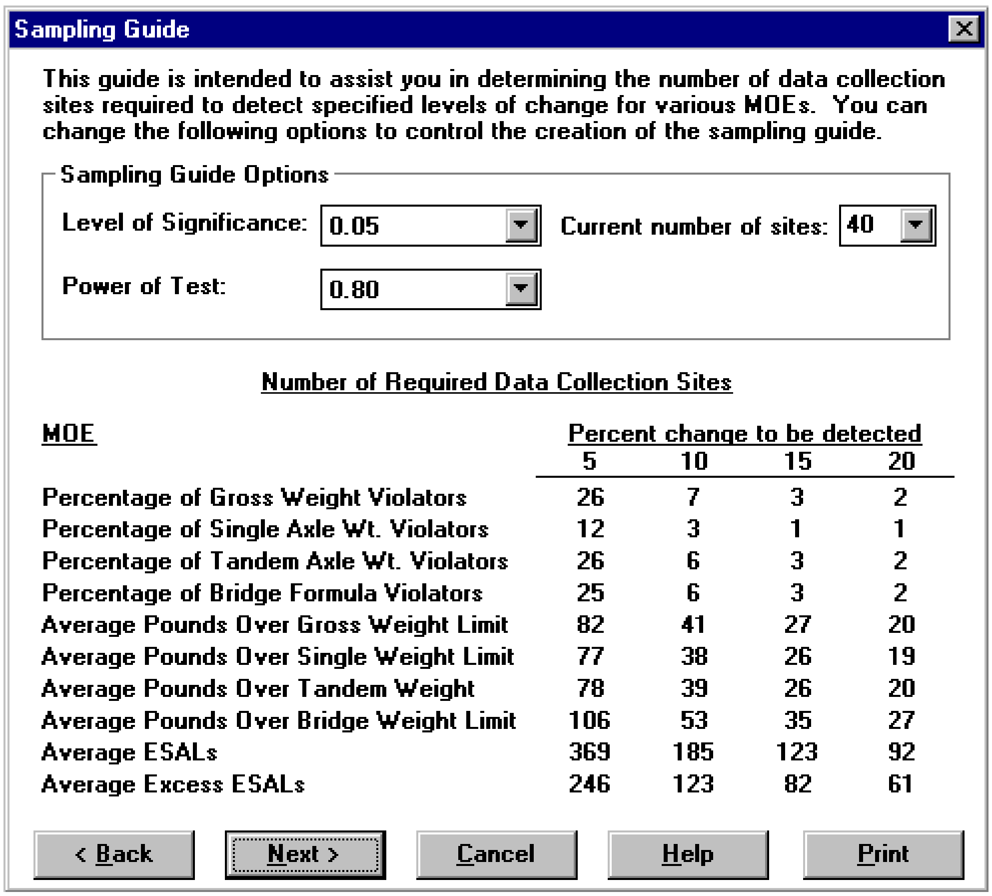


Figure 15. “Sampling Guide” Dialog Box

The main feature of the *Sampling Guide* dialog box is a table indicating the number of sites which are required for data collection if specified levels of M.O.E.s changes (i.e., 5, 10, 15, or 20 percent) are to be detected. These numbers are based on TWEET’s analysis of the measured statistical characteristics (e.g., variance) of the observed M.O.E.s. The user will note that fewer sites are necessary for larger differences. This effect is due to the fact that smaller differences in real-world truck-weight enforcement compliance are subtler and therefore require more statistical rigor to detect.

The final dialog box (Figure 16) presents results of the *Pavement Effects Analysis*. Results contained in this dialog box are based on a theoretical pavement design-life effect, associated with differential enforcement-related ESAL loading conditions. Had the user opted to include the pavement design-life effect computation, this screen would be displayed. Displayed information consists of the calculated pavement ESAL capacity, the estimated pavement life under both observed enforcement conditions, and estimated percentage pavement-life change due to the observed ESAL-loading difference associated with the enforcement activity.

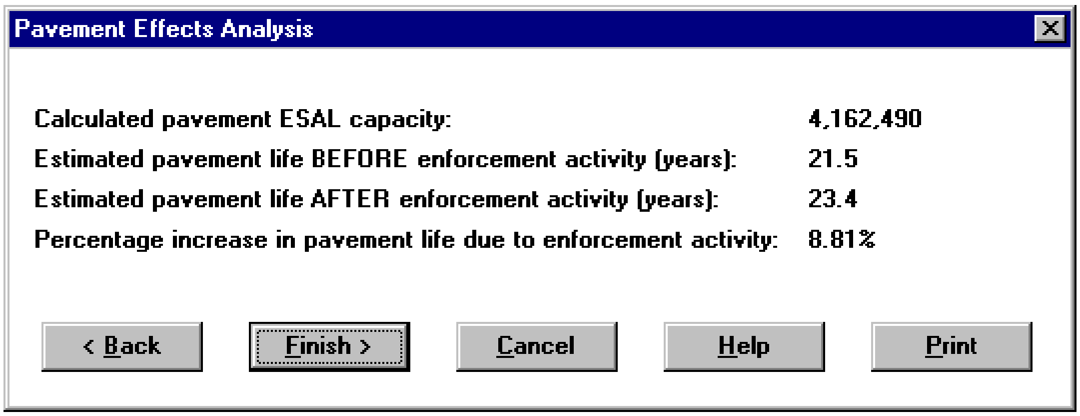


Figure 16. The “Pavement Effects Analysis” Dialog Box