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KTC-99-1**

**Development of ESAL Forecasting
Procedures for Superpave Pavement Design**

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and

**Federal Highway Administration
U.S. Department of Transportation**

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16. Abstract This report documents the analysis methods used to develop the Equivalent Single Axle Load (ESAL) forecasting program for Superpave projects. In addition, this report discusses the procedures used in the ESAL forecasting program to forecast ESALs in the design lane for pavement resurfacing/overlay projects which are consistent with the Superpave process of asphaltic mixture design.			
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EXECUTIVE SUMMARY

This report documents the analysis methods used to develop the Equivalent Single Axle Load (ESAL) forecasting program for Superpave projects. In addition, this report discusses the procedures used in the ESAL forecasting program to forecast ESALs in the design lane for pavement resurfacing/overlay projects which are consistent with the Superpave process of asphaltic mixture design.

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1.0 INTRODUCTION

In 1985, a procedure was developed by the Kentucky Transportation Center (report UKTRP 85-30) to estimate Equivalent Single Axle Loads (ESALs) for the purposes of flexible pavement design. Maximum use was made of historical data and well-accepted procedures were used in developing the prediction model. This model was based on a series of computer programs that summarized truck-weight and classification data such that traffic characteristics could be estimated from a matrix of data classified by geographic area, Federal highway system, volume, and extent of coal haulage. In addition, an equation was developed to calculate average daily ESALs using the following seven traffic parameters as independent variables; annual average daily traffic volume (AADT), percent trucks in the traffic stream (%T), number of coal hauling trucks in the traffic stream (CT), average number of axles per coal truck (A/CT), average number of axles per non-coal truck (A/T), average number of equivalent axleloads per coal-truck axle (ESAL/CA), and average number of equivalent axleloads per non-coal truck axle (ESAL/A). The equation to calculate average daily ESALs can be viewed in equation 1 below.

$$[1] \text{ (AADT} \cdot (1 - \%T) \cdot .005) + (((\text{AADT} \cdot \%T) - \text{CT}) \cdot \text{A/T} \cdot \text{ESAL/A}) + (\text{CT} \cdot \text{A/CT} \cdot \text{ESAL/CA})$$

The prediction model developed in UKTRP 85-30 is still used by the Cabinet's traffic forecasting function. However, the advent of Superpave as the Cabinet's asphalt pavement mix has been the impetus for this study since all Superpave mixes require an ESAL value. Therefore, it was necessary to develop a simplified model to be used for Superpave projects. The model developed uses the same traffic parameters used by the Cabinet's traffic forecasting function, but makes several simplifying assumptions to arrive at a forecasted ESAL value. These assumptions consist of applying growth rates to the present independent variables (AADT, %T, A/T, ESAL/A, A/CT, and ESAL/CA) based on the functional class growth rates provided in the Aggregated 1997 ESAL table (Appendix A.). Note, a default growth rate of 2 percent is used for the AADT growth rate for all functional classes in this model. The functional class growth rates are applied to the present independent variables using the compound interest equation at the median forecast year, i.e. present %T * [(1 + growth rate)^(number of forecasted years/2)]. After the application of all growth rates, the new independent variables are substituted into equation 1 to calculate a total median year daily ESAL value. Next, ESALs are forecasted in the design lane for Superpave projects, by taking the product of the total median year daily ESAL calculation and multiplying it by (365 days * number of forecasted years * a lane distribution factor) (equation 2). Note, it is not recommended to use this procedure of forecasting ESALs for the Superpave Mix Design except for a "ballpark" estimate.

$$[2] \text{ (Total median daily ESALs)} \cdot 365 \cdot (N) \cdot (\text{Lanedist})$$

$$N = \text{number of forecasted years}$$

Lanedist = lane distribution factors are based on report UKTRP 85-30, modifications have been made for 6 and 8 lane roads (Table 1).

Table 1: Lane distribution factors or equations

Lane layout	Lane distribution factor or equations
1 lane, 1 way	1
2 or 3 lanes, 2 way	.5
4 lanes, 1 way	.35
4 or 5 lane, 2 way	$.497 - (1.84 + 1.42 * (\% \text{trucks})) * (\text{AADT}) * (10^{-6})$
5 lane, 1 way	.3
6 lane, 1 way	.325
> 6 lane, 1 way	$(1 / \# \text{ of lanes}) + 0.1$
6 lane, 2 way	.325
> 6 lane, 2 way	.25

2.0 ANALYSIS METHOD

This program was designed to give the user two different functions for forecasting ESALs in the design lane for Superpave projects. The first function will allow the user to forecast ESALs in the design lane using collected traffic data, collected by the Division of Planning. In order to forecast ESALs in the design lane using collected traffic data the user will perform a search on the data base by typing in the county name, route prefix, route number, route suffix, beginning milepoint, ending milepoint, and the number of forecasted years. The second function of the program will allow the user to forecast ESALs in the design lane, using user defined data input. Both procedures for forecasting ESALs in the design lane will be discussed in detail in the, "Procedures for using the ESAL Forecasting program" in section 4.0 of this report.

In order to forecast ESALs using collected traffic data, five databases of traffic information provided by the Division of Planning were combined into one master database using Microsoft Excel. The five databases consisted of: Volume.dbf; Class97b.txt; Sta_tonsC.xls; the lane file (Countsta.xls) from the Highway Inventory System (HIS) database; and the Aggregated 1997 ESAL table with three-year averages with smoothed growth rates. A brief description of each database, a sample of the databases, and where they can be located for future reference is listed in Appendix A.

"Volume.dbf" was used as the base file for the master database to which the other four databases were attached. The "Volume.dbf" file provided county number, station number, route prefix, route number, route suffix, beginning milepoint, ending milepoint, and an estimated annual average daily traffic volume (AADT) for 23,237 stations located in the 120 counties in Kentucky. The second database used was "Class97b.txt" which matched up to "Volume.dbf" by county and station number. "Class97b.txt" contained actual multiple year AADT counts, percent trucks, axles per trucks, percent coal trucks, and axles per coal truck for various station numbers. For each station number, the latest actual data for (percent trucks, axles per trucks, percent coal trucks, and axles per coal truck) was matched to the "Volume.dbf" file. The third database used was "Sta_tonC.xls" which matched up to "Volume.dbf" by county and station number. This database contained annual coal tonnage hauled on coal hauling routes in Kentucky. The

annual coal tonnage hauled was divided by (365 days * 40 tons per truck) to obtain the number of coal trucks per day. This calculated number of coal trucks per day was compared to the number of coal trucks per day found in the "Class97b.txt" database in which the higher of the two values was used in the master database. The fourth database used was the lane file "Countsta.xls" obtained from the HIS database housed at the Division of Planning. This database matched to "Volume.dbf" file by county and station number and provided the number of lanes and functional classification for each station number in the master database. The last database used was the 1997 aggregated ESAL table with three-year averages with smoothed growth rates. This database was used in two ways. First, in the insistence that the "Class97b.txt" database did not provide data on percent trucks, axles per truck, or axles per coal truck to be attached to the "Volume.dbf" database--values for these categories were based on matching the functional classification. Second, the equivalent single axle loads per axle for both trucks and coal trucks (ESAL/A, ESAL/CA) were used based on the matching functional classification of the two databases.

After completing the master database in Microsoft Excel, it was then imported into Microsoft Access 97. The completed master database can be viewed in the ESAL Forecasting program by holding down the shift key on the keyboard as the program is loading. The data file name is **combine 22**. However, precaution should be taken as to not alter the original data. The column headings used in the master database are as follows: county number, station number, route prefix, route number, route suffix, starting milepoint, ending milepoint, ADT, percent trucks, axles per truck, ESAL/axle, functional classification, number of lanes, number of coal trucks, axles per coal truck, ESAL/coal axle, lane adjustment factor, an indication if percent trucks is actual or estimated data, an indication if axles per truck are actual or estimated, an indication if the number of coal trucks is actual or estimated, and a RSE_UNIQUE code so that this database can be used with Arc View software.

This program can be updated, on a yearly base, by importing an identical database as described above into the program. Data formatting should parallel that of the combine 22 master database, which can be viewed in the design view of the combine 22 database. To update the query, the new database would replace the combine 22 database in the calculate ESAL's query. To update or change growth rates for the Aggregated 1997 ESALs table, simply go to the 3-year average table and update. To change lane distribution factors go to the lane table and update. To change the AADT growth rate go to the ADT growth rate table and update.

3.0 PROCEDURES FOR ACCESSING THE "ESAL FORECASTING" PROGRAM

To access the ESAL forecasting program, there are a few hardware and software requirements. The requirements are listed below as well as on the inside jacket of the CD case.

Hardware/Software:

- 1.) i486 or Pentium processor.
- 2.) Windows 95, 98 or Windows NT.
- 3.) If using the CD version from the CD reader the CD-ROM drive must be 10x or higher. If the CD-ROM drive is less than a 10x it is recommended that the ESAL forecasting program be copied to the hard-drive.
- 4.) The hard drive will need a total of 100-MB, and approximately 6 MB of hard disk space to store the program.
- 5.) A minimum of 16 MB of RAM is required.
- 6.) Screen resolution set at either 800x600 or 1024x768.
- 7.) Microsoft Access 97.

Instructions to access the ESAL forecasting program from the CD are listed below and on the inside jacket of the CD case.

- 1.) Insert ESAL forecasting program CD into CD-ROM drive.
- 2.) From start menu go to programs.
- 3.) Click on Windows Explorer
- 4.) Select the CD-ROM drive containing the ESAL forecasting program CD.
- 5.) If your computer satisfies numbers 3 & 5 above in the Hardware/Software requirements then double click on the ESAL forecasting program. If your computer does not satisfy numbers 3 & 5 above then copy the ESAL forecasting program to the hard drive.
- 6.) After opening the program a pop up screen displays "Database is a read-only" click O.K.
- 7.) In introduction screen (Figure 1) of program click button to enter into program.

Instructions to install the ESAL forecasting program from the 3.5" diskettes to the hard-drive are listed below and on the front label of the diskettes. Note: in order to copy the ESAL forecasting program to your hard drive the program must be unzipped. The diskettes have a self-extracting program loaded on them called PKUNZIP version 2.60. This program is a SHAREWARE product, and is being used as an evaluation copy.

- 1.) In Windows, go to "My Computer".
- 2.) Insert ESAL Forecasting diskette number 1 into the A drive, and double click on the A drive icon.
- 3.) Double click on ESAL Forecasting Program.exe, and follow the on-screen instructions.
- 4.) After both diskettes have been read; define a directory where the ESAL Forecasting program will be extracted to.

- 5.) After choosing the proper directory, click "Extract" button. If the user has not already created the directory to extract the program to, click Yes to create directory.
- 6.) Follow the on-screen instructions and insert diskettes.
- 7.) The program will be extracted when the (A) drive directory is displayed.
- 8.) Go to the directory where the ESAL forecasting program has been stored.
- 9.) Double click on the ESAL Forecasting program.
- 10.) In introduction screen (Figure 1) of program click button to enter into program.

This program forecasts Equivalent Single Axle Loads (ESALs) in the design lane for Superpave projects

The collected traffic data used in this program is from the Kentucky Transportation Cabinet, Division of Planning.

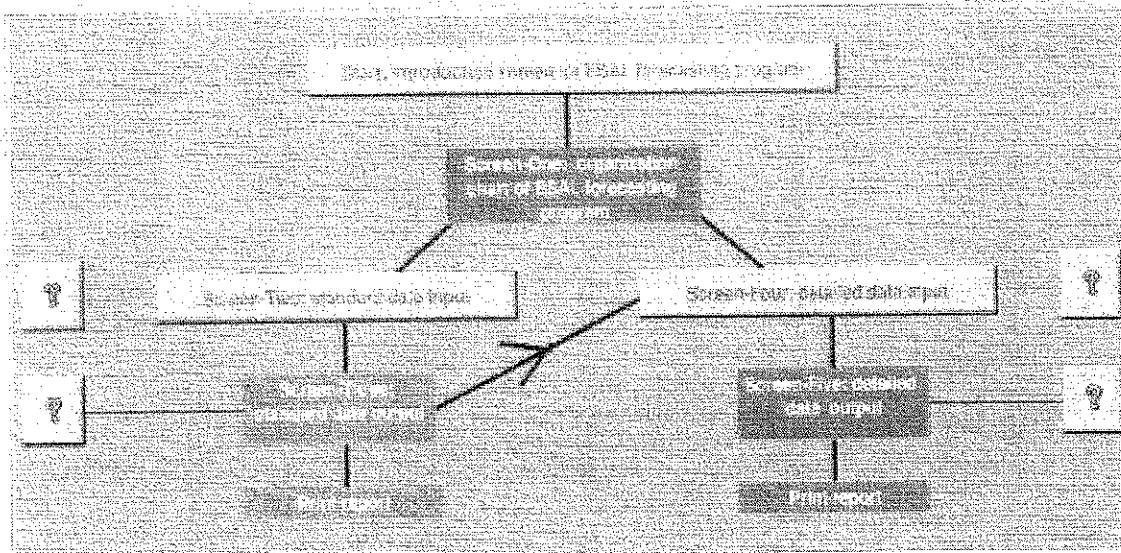


Figure 1: Introduction Screen—(Start Screen)

4.0 PROCEDURES FOR USING THE "ESAL FORECASTING" PROGRAM

The next section will outline the procedures for using the ESAL forecasting program to forecast ESALs in the design lane for pavement resurfacing/overlay projects which are consistent with the Superpave process asphaltic mixture design. When opening the program, the first screen that will appear is the Introduction Screen (labeled Start in the database) (Figure 1). After arriving at this screen, the user will need to click on the box "Click: to open program". This will take the user to Screen One (Figure 2).

This screen displays the organization chart of the ESAL forecasting program and Help (?) buttons for each Screen used in the program.



Click raised buttons to proceed

Figure 2: Screen One

Screen One displays the organization chart or layout of the ESAL forecasting program. At the bottom of Screen One, the statement "Click raised buttons to proceed" indicates that the user can go to multiple sections of the program from Screen One by clicking on any of the raised buttons. The buttons consist of; Start Screen which takes the user back to the Introduction Screen, Screen Two—standard data input, Screen Four—detailed data input, or any of the Help screens. Note: after entering Screen Three the user has the option of going to Screen Four, and the Help screens can be accessed inside any of the other screens.

Screen Two is the standard data input screen (Figure 3). The purpose of this screen is to forecast ESALs in the design lane using the master database. First, the user

will need to identify the search criteria for searching the master database. The search criteria are the seven yellow boxes located on Screen Two; county name, route prefix, route number, route suffix, beginning milepoint, ending milepoint, and number of forecast years. Second, after identifying the search parameters the user will click on the button labeled "Click: to find matching records". This will take the user to Screen Three (Figure 4).

Yellow boxes indicate that the user must input a value:

Enter county name:	<input type="text"/>	example: Boone	<table border="1"> <thead> <tr> <th>PARKWAY</th> <th>ROUTE PREFIX</th> <th>ROUTE NUMBER</th> </tr> </thead> <tbody> <tr> <td>MERSON</td> <td>00</td> <td>0000</td> </tr> <tr> <td>MOUNTAIN</td> <td>01</td> <td>0000</td> </tr> <tr> <td>HIGHWAY</td> <td>02</td> <td>0000</td> </tr> <tr> <td>CARDINAL</td> <td>03</td> <td>0000</td> </tr> <tr> <td>THUNDERBOLT</td> <td>04</td> <td>0000</td> </tr> <tr> <td>MOUNTAIN</td> <td>05</td> <td>0000</td> </tr> <tr> <td>HERRING</td> <td>06</td> <td>0000</td> </tr> <tr> <td>REDWATER</td> <td>07</td> <td>0000</td> </tr> <tr> <td>WESTVALE</td> <td>08</td> <td>0000</td> </tr> <tr> <td>THE HATCHER</td> <td>09</td> <td>0000</td> </tr> </tbody> </table>	PARKWAY	ROUTE PREFIX	ROUTE NUMBER	MERSON	00	0000	MOUNTAIN	01	0000	HIGHWAY	02	0000	CARDINAL	03	0000	THUNDERBOLT	04	0000	MOUNTAIN	05	0000	HERRING	06	0000	REDWATER	07	0000	WESTVALE	08	0000	THE HATCHER	09	0000
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WESTVALE	08	0000																																		
THE HATCHER	09	0000																																		
Enter route prefix:	<input type="text"/>	example: 1																																		
Enter route number:	<input type="text"/>	example: 75																																		
Enter route suffix:	<input type="text" value="Na"/>	example: Na																																		
Enter beginning milepoint:	<input type="text"/>	example: 170																																		
Enter ending milepoint:	<input type="text"/>	example: 185																																		
Enter number of years:	<input type="text" value="20"/>	example: 20																																		

Previous screen

Click: to find matching records

Figure 3: Screen Two

The details for filling in the seven yellow boxes found on Screen Two are listed below and on the Help screen for Screen Two in the Program.

1. Enter county name: in this box the user will type in one of the 120 county names in Kentucky. In addition, there is a drop down box that will allow the user to pick from a list of county names in Kentucky if desired.
2. Enter route prefix: in this box the user will type in the route prefix. There is a list of route prefixes for all of the Parkways in Kentucky located on the right side of Screen-Two.
3. Enter route number: in this box the user will type in the route number. There is a list of route numbers for all of the Parkways in Kentucky located on the right side of Screen-Two.
4. Enter route suffix: in this box the user will type in a route suffix if applicable. Applicable route suffixes for this box are located in the drop down menu. If a route suffix is not applicable to the route the user is evaluating, then the user must leave the default value of "Na" in this box. The following is a list of route suffixes that appear in the drop menu: A,

B, C, E, ED, EN, EX, H, J, M, N, Na, RA, RP, S, T, U, W, WB, WN, X, XN.

5. Enter beginning milepoint: in this box the user will type in the beginning milepoint of the section of roadway to be evaluated. Note that the beginning milepoint must be less than the ending milepoint.
6. Enter ending milepoint: in this box the user will type in the ending milepoint of the section of roadway to be evaluated. Note that the ending milepoint must be greater than the beginning milepoint.
7. Enter number of years: in this box the user will type in an integer value from 1 to 50 to represent the number of years the user would like to forecast the design ESALs in the critical lane.
8. Click to find matching records: by clicking this button the program will query the database for the records that match the criteria input in numbers 1-7 above, and send the user to Screen-Three. Screen-Three will allow the user to view all of the matching records, print preview all of the matching records, and go to Screen-Four to calculate ESALs, if the data shown in Screen-Three is inadequate or if no matching records were found for the criteria.

Screen Three is the standard data output screen (Figure 4). This screen shows the results of the search criteria defined in Screen Two. As an example, Figure 4 shows actual output that was obtained from a search on I-75 in Fayette County.

Standard data output: displays the records that match your search criteria

If no values are displayed below, there are no matching records. Therefore, you will have to calculate your own ESALs. To calculate your own ESALs, click button to the right.

HIGHWAY DETAILS		ESAL CALCULATING INFORMATION			
County number:	34	ADT:	54,000	FC:	1
Station number:	34P90	Percent trucks:	A 17.700	A/T:	A 4.53
Route prefix:	1	# of coal trucks/day:	E 7	A/CT:	E 4.778
Route number:	75	ESAL/A:	0.217	ESAL/CA:	0.88
Route suffix:	na	Data type: A = actual data, E = estimated data, I = insufficient data			
Beginning Milepoint:	98.516	Total median daily ESALs: (rounded)			
Ending Milepoint:	103.69	9,640			
# of lanes:	4				
Lane distribution factor:	0.384				

Years: Forecast of Design ESALs in Critical Lane:

Use arrows below to scroll through matching records

Figure 4: Screen Three

To look at all of the matching results, the user can use the small arrow buttons located at the bottom left hand corner of the Screen Three to scroll through the matching records. Note: the scroll arrows are not shown in Figure 4 in this report. The user is also given the opportunity to print preview all of the matching forecasts that met their search criteria on Screen Three by clicking "Print preview" button. An example of the print preview page is located in Appendix B. Once in the print preview page, the user can print the forecasted ESALs to any printer that is connected to the personal computer, or publish the print preview page in Microsoft Word or Excel.

The following describes what is displayed on Screen Three. The descriptions can also be found on the Help screen for Screen Three in the program.

Note: Screen-Three displays the records that match the criteria that were entered on Screen-Two. If there were no matching records for the specified criteria then the user can go back to Screen-Two to perform a new search or go to Screen-Four to calculate ESALs with user defined data.

Disclaimer: This procedure of forecasting ESALs uses default information (example functional class defaults and growth rate default assumptions) to produce ESALs for Superpave Mix Design. It is not recommended for use in producing ESALs for Pavement Design except for a "ballpark" estimate.

1. Highway details: displayed in the highway details box are the items such as: county number, station number, route prefix, route number, route suffix, beginning milepoint, ending milepoint, number of lanes, and lane distribution factor for the records that match the search criteria.

Lane distribution factors are based on Kentucky Transportation Research report UKTRP-85-30. Modifications have been made for 6 and 8 lane roads (Table 2).

Table 2: Lane distribution factors or equations

Lane layout	Lane distribution factors or equations
1 lane, 1 way	1
2 or 3 lanes, 2 way	.5
4 lanes, 1 way	.35
4 or 5 lane, 2 way	$.497 - (1.84 + 1.42 * (\% \text{trucks})) * (\text{AADT}) * (10^{-6})$
5 lane, 1 way	.3
6 lane, 1 way	.325
> 6 lane, 1 way	$(1 / \# \text{ of lanes}) + 0.1$
6 lane, 2 way	.325
> 6 lane, 2 way	.25

2. ESAL calculating information: displayed in the ESAL calculating information box are values such as: AADT, functional class, percent trucks, axles/truck, ESAL/axle, number of coal trucks per day, axles/coal truck, ESAL/coal truck axle. The Division of Planning collected the base data that produced this information. The Division of Multimodal Programs is responsible for the base data being converted to traffic forecasting information. Any questions about the input information should be addressed to the Division of Multimodal Programs at (1-502-564-7686).
3. The factors for percent trucks, axles per truck, number of coal trucks/day, and axles per coal trucks are defined with either a A for actual collected data, E for estimated data based on the functional class using the three-year averages from the aggregated 1997 ESALs developed by the Kentucky Transportation Center, or I for insufficient data. Forecasted

ESALs in coal hauling regions should be checked with the Division of Multimodal Programs for the accuracy of the number of coal trucks per day.

- The equation to calculate total median daily ESALs is

$$(AADT*(1-\%T)*.005)+((AADT*\%T)-CT)*(A/T)*(ESAL/A)+(CT*A/CT*ESAL/CA)$$

where growth rates have already been applied to (AADT, %T, A/T, ESAL/A, A/CT, and ESAL/CA) based on the Functional Classification growth rates provided in the Aggregated 1997 ESALs table. Note: in order to get median year daily ESALs, the growth rates are calculated at the median year using the compound interest equation i.e.: $\%T*[(1+\text{growth rate})^{(N/2)}]$. The growth rate for AADT was assumed to be 2 percent for all functional classes. The Aggregated 1997 ESALs table with growth rates can be viewed below.

Table 3: Functional class growth rates.

Functional Class	Growth Rates (%)					
	AADT	%T	A/T	ESAL/A	A/CT	ESAL/CA
1	2	1	0.092	1	0	1.989
2,6	2	1	0.535	1	0	2
7,8,9	2	1	0.983	0	0	0
11	2	1	1	0	0	1.989
12,14	2	1	0.398	0.556	0	0
16,17,19	2	1	0.946	0	0	0

The equation to forecast design ESALs in the Critical Lane is

$$(\text{Total median daily ESALs}) * 365 * (N) * (\text{Lanedist})$$

AADT = Annual average daily traffic
 %T = Percent trucks
 CT = Number of coal trucks per day
 A/T = Axles per truck
 ESAL/A = Equivalent single axle loads per truck axle
 A/CT = Axles per coal truck
 ESAL/CA = Equivalent single axle load per coal truck axle
 N = Number of forecast years
 Lanedist = Lane distribution factor

- Mainline or ramp indicates where the data was collected.
- “Insufficient data, either no lanes or no AADT”, message indicates that the values needed to forecast ESALs are not complete.
- Print preview allows the user to view the matching records on the computer screen. Once in the print preview, click the printer icon to print out the report, or click close to go back to Screen-Three.
- To scroll through all of the matching records, use the right and left arrows located in the bottom left hand corner of Screen-Three.

Screen Four is the detailed data input screen (Figure 5). The purpose of this screen, and with the addition of Screen Five (Figure 6), is to forecast ESALs in the design lane based on user defined data. This function of the program can be used if the information obtained from a forecast on Screen Three proves to be inadequate, if no information is available from the master database to forecast ESALs in Screen Three, or for a widening project where the lane information provided from the master database would be inadequate.

Yellow boxes mean that the user must input in a value:

	Functional Classes	
Enter functional classification: example: 7	1 - Rural Interstate 2 - Rural Principal Arterial 3 - Rural Minor Arterial 7 - Rural Major Collector 8 - Rural Minor Collector 9 - Rural Local	11 - Urban Interstate 12 - Urban Freeway or Expressway 14 - Urban Principal Arterial 15 - Urban Minor Arterial 17 - Urban Collector 19 - Urban Local
Enter lane distribution factor reference #: example: 42 Click to calculate ESALs	Lane Distribution Factor Reference #	
	11 - 1 lane, 1 way 22 - 2 or 3 lane, 2 way 41 - 4 lane, 1 way 42 - 4 or 5 lane, 2 way 51 - 5 lane, 1 way	61 - 6 lane, 1 way 62 - 6 lane, 2 way 61A - > 6 lane, 1 way 62A - > 6 lane, 2 way
	Previous screen	Y

Figure 5: Screen Four

The details of using Screen Four are listed both below and in the Help screen for Screen Four in the program.

1. Enter functional classification: the user must enter a numeric value in this yellow box. The different functional classes are located on the right side of Screen-Four. There is a drop-down box located in the yellow box to allow the user to pick the functional class from a list.
2. Enter lane distribution factor reference #: the user must enter a value from the lane distribution factor reference # list located on the right side of the screen. The values correspond to the type of lane layout the user is evaluating. A value must be entered into the yellow box. There is a drop-down box located in the yellow box to allow the user to pick the lane distribution factor reference # from a list.
3. Click to calculate ESALs: after both one & two above have been completed, click this button to go to Screen-Five to complete the ESAL calculating process with user defined data.

Screen Five is the continuing screen to forecast ESALs using user-defined data (Figure 6). The values entered on both Screen Four and Screen Five will be used to forecast ESALs on Screen Five.

ADT:

Years: Lane configuration:

ESALs per axle of ADT truck (if you are entering it separately)

of coal trucks per day: Annual coal tonnage:

Use from 1997 aggregated ESALs 3-year averages with smoothed growth rates

Functional classification:

Percent trucks:

Axes per truck:

ESALs per axle:

Axes per coal truck:

ESALs per coal axle:

Total median daily ESALs:

Lane distribution factor:

Calculate your own ESALs with your own values

Percent trucks (including coal trucks):

Axes per truck:

ESALs per axle:

Axes per coal truck:

ESALs per coal axle:

Total median daily ESALs:

Lane distribution factor:

ESALs per coal axle

Type in reference location

Figure 6: Screen Five

The details of using Screen Five are listed both below and in the Help screen for Screen Five in the program.

1. Enter ADT: in this box an ADT value as specified in the adjacent box "Enter one way ADT", or "Enter two way ADT" must be entered.
2. Enter number of years: in this box a numeric value greater than zero must be entered to forecast ESALs.
3. Enter a value for one of the following if applicable: if the user is calculating ESALs in a coal-hauling region, there are two different ways to input in the number of coal-trucks per day. The user can enter the number of coal trucks per day or the annual coal tonnage. If annual coal tonnage is entered, the number of coal trucks per day is derived by dividing annual coal tonnage by (365 days * 40 tons). NOTE: only enter coal information in one box; leave the other box defaulted to zero. If there are no coal trucks on the studied route, leave both values equal to zero. Questions pertaining to annual coal tonnage on a particular route should be addressed to the Division of Multimodal Programs at (1-502-564-7686).

4. If lane configuration is (> 6 lane, 1 way) then Enter number of lanes in box. If lane configuration is not (> 6 lane, 1 way) leave the default value of 1 in the box: this box should always have the default value 1 in it, unless the user has picked the (> 6 lane, 1 way) configuration on Screen-Four. If the user has picked the (> 6 lane, 1 way) configuration then the user must input in the number of lanes in the yellow box.
5. ESALs can be calculated for two different scenarios on Screen-Five. The user can use the values from the 1997 aggregated ESALs 3-year average values based on functional class, or the user can calculate ESALs with user defined data. NOTE: if the user calculates ESALs with user defined data, all yellow boxes (percent trucks, axles per truck, ESALs per axle, axles per coal truck, ESALs per coal axle), must have a value entered.
6. Lane distribution factors are determined by the lane distribution factor reference # the user entered on Screen-Four. Lane distribution factors are based on Kentucky Transportation Research report UKTRP-85-30. Modifications have been made for 6 and 8 lane roads (Table 3).

Table 4. Lane distribution factors or equations

Lane layout	Lane distribution factors or equations
1 lane, 1 way	1
2 or 3 lanes, 2 way	.5
4 lanes, 1 way	.35
4 or 5 lane, 2 way	$.497-(1.84+1.42*(\%trucks))*(ADT)*(10^{-6})$
5 lane, 1 way	.3
6 lane, 1 way	.325
> 6 lane, 1 way	$(1/\# \text{ of lanes}) + 0.1$
6 lane, 2 way	.325
> 6 lane, 2 way	.25

7. The equation used to calculate total median daily ESALs is

$$(ADT*(1-\%T)*.005)+((ADT*\%T)-CT)*(A/T)*(ESAL/A)+(CT*A/CT*ESAL/CA)$$

where growth rates have already been applied to (ADT, %T, A/T, ESAL/A, A/CT, and ESAL/CA) based on the Functional Classification growth rates provided in the Aggregated 1997 ESALs table. Note: in order to get median year daily ESALs, the growth rates are calculated at the median year using the compound interest equation i.e.: $\%T*[(1+\text{growth rate})^{(N/2)}]$. The growth rate for ADT was assumed to be 2 percent for all functional classes. The Aggregated 1997 ESALs table with growth rates can be viewed below.

Table 5: Functional class growth rates

Functional Class	Growth Rates (%)					
	ADT	%T	A/T	ESAL/A	A/CT	ESAL/CA
1	2	1	0.092	1	0	1.989
2,6	2	1	0.535	1	0	2
7,8,9	2	1	0.983	0	0	0
11	2	1	1	0	0	1.989
12,14	2	1	0.398	0.556	0	0
16,17,19	2	1	0.946	0	0	0

The equation to forecast design ESALs in the Critical Lane is

$$(\text{Total median daily ESALs}) * 365 * (N) * (\text{Lanedist})$$

ADT = Average daily traffic
 %T = Percent trucks

CT	=	Number of coal trucks per day
A/T	=	Axles per truck
ESAL/A	=	Equivalent standard axle loads per truck axle
A/CT	=	Axles per coal truck
ESAL/CA	=	Equivalent standard axle load per coal truck axle
N	=	Number of forecast years
Lanedist	=	Lane distribution factor

- Type in Reference Location: this box is optional. It allows the user to type in the location of calculated ESALs so a reference name will be included on the printed output.

5.0 ACCESSING THE REPORT FROM CD

An electronic copy of this report is located on the CD version of the ESAL Forecasting Program. In order to view the report, ADOBE ACROBAT READER software must be installed on the user's computer. ADOBE ACROBAT READER is a free shareware program that can be distributed with word-processed documents that are saved in PDF format. Most computers have ADOBE ACROBAT READER already installed if the user views reports published on the Internet. If the user has ADOBE ACROBAT READER software already installed on their computer, then simply double click on the ESAL-Report.PDF file when viewing the directories on the CD to view the report.

If the user does not have ADOBE ACROBAT READER installed on their hard-drive the user can install ADOBE ACROBAT READER version 3.02 by double clicking on the directory "AR302.exe" on the CD, or going to the ADOBE ACROBAT READER website at <http://www.adobe.com/prodindex/acrobat/readstep.html>. After installing the software, the user will then go back to the ESAL Forecasting Program CD and double click on the ESAL-Report directory.

6.0 CONCLUSIONS AND RECOMMENDATIONS

It is encouraged that the user consult with the Division of Multimodal programs (1-502-564-7678) when using the ESAL forecasting program to forecast ESALs in the design lane for pavement resurfacing/overlay projects. The information used in the ESAL forecasting program uses default information to produce ESALs for Superpave Mix Design. It is not recommended for use in producing ESALs for Pavement Design except for a "ballpark" estimate.

In the event that this program will become a tool in future ESAL forecasting, it is recommended that the collected traffic data utilized in this program be standardized, and updated annually. Also, consideration should be given to editing the forecasting equation. Applying growth rates only to the median year does not fully estimate the total ESAL value in the design lane for the full design life of the Superpave project. A suggested measure would be to integrate the equation as follows (present independent variable $\int_0^x a^x dx = a^x / \ln a$) where $a = (1 + \text{growth rate})$ and $x = \text{years}$. By integrating the application of the growth rates, a more accurate total ESAL value would be obtained, thus allowing for a more accurate ESAL forecast.

**APPENDIX A
(database files)**

Volume.dbf

Volume.dbf file came from the Division of Planning's "historic.dbf" file that is stored on the mainframe Traffic Volume Summary file. The data contact person is Greg Witt from the Division of Planning (1-502-564-7183). The ADT value used from this database is located in column VOL1. The last number in the four-digit number in the VOL1 column is a power of ten number. For example the number 6581, is $658 \times 10^1 = 6580$, and 1302 is $130 \times 10^2 = 13,000$. When receiving this file, the last number in the VOL1 column will need to be separated from the first three. In Excel, highlight the VOL1 column, then go to the data command. In the data command list pick fixed width, then separate the first three numbers from the fourth. In the adjacent column write an equation that will multiply the first three numbers by the fourth raised to the tenth power. This will give the ADT value for this record. Copy the equation down for all ADT values.

For the files from the other database to match to this "Volume.dbf" database, the county number must be combined with the station number. To do this, make a separate column adjacent the station number. Write an equation using the concatenate function to combine both county number and station number into one. NOTE: the station number has three values. It can be three numbers or a mixture of numbers and text values.

Volume.dbf

CONUMBER	STATION	RTPREFIX	RTNUMBER	RTSUFFIX	STARTMPT	ENDINGMPT	VOL1
1	A57	KY	55		9.335	10.059	6581
1	A47	KY	55		10.059	10.316	1302
1	A46	KY	55		10.316	10.47	1272
1	A43	KY	55		10.47	10.614	2002
1	A41	KY	55		10.614	10.72	2452
1	A58	KY	55		10.72	10.84	1912
1	A26	KY	55		10.84	11.17	1962
1	A13	KY	55		11.17	11.19	2592

Class97b.txt

Class97b.txt was a text file that was originally called "Class97.prn". This file comes from the processed classification summary data developed by the Traffic & Safety Section at the Kentucky Transportation Center. The data contact person is Greg Witt from the Division of Planning (1-502-564-7183). In this file the county number must be combined with the station number. However, the station number does not have three values in all cases. The length (len) function combined with an (IF) statement must be used in Excel to add a leading zero or zeros to any station number that does not have three values. The length function would be used to tell how many values were present in each cell in the station number column. The (IF) statement would be used after the length function. If the station number length equaled 1, then add two zeros, if the station number length equaled 2, then add one zero, and if the station number equaled 3 then put

the station number as it exists in the cell. Then copy this equation down for all station numbers.

Next, the latest year data was saved in each identical county number/station number combination. This gave the most up-to-date information for each station number. This saved data was copied to a blank sheet in the "Volume.dbf" file where an (Vlookup) equation was used to match identical station numbers between both files. The (Vlookup) equation was used to match the percent truck "TR", axles per truck "A_T", percent coal trucks "CTR", and axles per coal truck "A_CT" values to the "Volume.dbf". If there was not a match between station numbers, a "N/A" value was placed in the cell. To eliminate the "N/A" value the (ISERROR) function was used to put a zero in for all cells that had the "N/A" value.

Class97b.txt

CoNumber	Station#	Rt.Prefix	Rt.#	Milepoint	ADT	TR	CTR	A_T	A_CT	FC	AF	Year
1	A54	0		0	745	0.015	0	2	0	9	1	86
1	8	KY	55	12.5	9150	0.113	0	3.257	0	6	0.932	96
1	A07	KY	55	11	5961	0.078	0	2.492	0	6	0.981	79
1	A07	KY	55	11	3925	0.093	0	2.667	0	6	0.97	80
1	A07	KY	55	11	7716	0.088	0	3.104	0	6	0.954	83
1	A07	KY	55	11	7716	0.064	0	2.905	0	6	0.972	86
1	A07	KY	55	11	5961	0.078	0	2.492	0	6	0.981	79
1	A07	KY	55	11	3925	0.093	0	2.667	0	6	0.97	80
1	A07	KY	55	11	7716	0.088	0	3.104	0	6	0.954	83
1	A07	KY	55	11	7716	0.064	0	2.905	0	6	0.972	86
1	A13	KY	55	10.5	10800	0.044	0	3.835	0	6	0.961	92
1	A13	KY	55	10.5	10800	0.044	0	3.835	0	6	0.961	92

Sta_tonsC.xls

Sta_tonsC.xls was an Excel file that came from the "Coalseg.lst database. The "Coalseg.lst", file comes from the Division of Planning's coal haul team. This coal haul team converted the "Coalseg.lst" to a format that included station numbers along with the annual tons hauled.

To determine how many coal trucks were hauling daily through these station numbers, the yearly tonnage was divided by 365 days * 40 tons per truck. The combined county number/station number was compared to the station numbers of the "Volume.dbf" file. In the "Volume.dbf" file, the number of coal trucks provided from the "Class97b.txt" file and the "Sta_tons.xls" were compared. The value that gave the largest number of coal trucks per day was used.

Sta_tonsC.xls

County #	Station #	Route pre	Route #	Beg mile	End mile	tons
1	1288	CU	9008	48.9	57.791	16931
1	1A47	KY	55	10.1	10.316	16931
1	1A46	KY	55	10.316	10.47	16931

Countsta.xls

Countsta.xls was an Excel file that came directly from the Division of Planning's Highway Information System (HIS) database. The data contact person is Greg Witt from the Division of Planning (1-502-564-7183). This file matched to the "Volume.dbf" by the combination of county and station number. The (Vlookup) function was used to bring in the functional class information (FC) and the number of lanes.

Countsta.xls

County #	route	Route #	start. Mp	End mp	station #	F.C.	# of lanes
1	CR	1026	0	2.722	1053	9	2
1	CR	1041	0	2.064	1095	9	1
1	CR	1043	0	0.849	1122	9	1
1	CR	1045	0	0.44	1121	9	1
1	CR	1046	0	1.477	1096	9	1
1	CR	1046	1.477	1.887	1074	9	1
1	CR	1046	1.887	2.3	1074	9	1
1	CR	1049	0	1.856	1069	9	1

Aggregated 1997 ESALs – Three-year averages using smoothed growth rates

Aggregated 1997 ESALs – The three-year averages using the smoothed growth rates table comes from the Traffic and Safety Section at the Kentucky Transportation Center. The data contact person is Dave Cain (1-606-257-4513). The table is generated each June with the latest year traffic data.

The data for percent trucks (%T), axles per truck (A/T), and axles per coal truck (A/CT) are matched based on functional class to the records in the "Volume.dbf" file if the values for these categories are zero. The values for EALs/A and EALs/CA are matched between the two files by functional classification.

After the master database is completed the (ISERROR) function is run on all cells to take out any "N/A" values since Microsoft Access will not recognize "N/A" values. In the event that a blank space is found in the database, a zero value is entered because Microsoft Access cannot recognize blank spaces. Also, four columns are created to determine if the percent trucks, number of coal trucks per day, axles per truck, and axles per coal truck are actual or estimated data.

Aggregated 1997 ESALs – Three-year averages using smoothed growth rates

Agg. Class	FCs	T%	GR	A/T	GR	EALs/A	GR	A/CT	GR	EALs/CA	GR
I	1	28.653	1.000	4.493	0.092	0.217	1.000	4.778	0.000	0.880	1.989
II	2,6	11.635	1.000	3.490	0.535	0.251	1.000	4.956	0.000	2.639	2.000
III	7,8,9	7.770	1.000	2.936	0.983	0.219	0.000	4.595	0.000	1.235	0.000
IV	11	13.406	1.000	4.076	1.000	0.183	0.000	4.778	0.000	0.880	0.000
V	12,14	6.262	1.000	3.042	0.398	0.209	0.556	4.590	0.000	1.048	0.000
VI	16,17,19	5.238	1.000	2.772	0.946	0.171	0.000	4.083	0.000	0.594	0.000

**APPENDIX B
(sample output)**

Data type

A = actual data E = estimated data I = insufficient data

Forecasted ESALs

County Fayette

County#	Station	Rt.Prefix	Rt.#	Rt.Suffix	Milepoints		ADT	%T	Data type	A/T	Data type	ESAL/A	FC	Lanes	Daily # of coal trucks	Data type	A/CT	Data type	ESAL/C	Lane dist.	Years	Forecasted ESALs
					Star	End																
34	34P90	I	75	na	98.516	103.69	54000	17.70	A	4.530	A	0.217	1	4	7	E	4.778	E	0.88	0.384	20	40,156,077
34	34336	I	75	na	103.69	108.2	35700	28.30	A	4.456	A	0.217	1	4	101	A	4.906	A	0.88	0.417	20	46,299,338
34	34250	I	75	na	108.2	109.70	50600	13.41	E	4.076	E	0.183	11	6	7	E	4.778	E	0.88	0.325	20	18,695,649
34	34392	I	75	na	109.70	111.22	55800	20.90	A	4.331	A	0.217	1	6	140	A	5.257	A	0.88	0.325	20	41,237,517

