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Application of New Accident Analysis Methodologies

Volume II: A Users Manual for BEATS

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FOREWORD

This research was initiated by a request from the Federal Highway Administration's Office of Safety and Traffic Operations R&D. The study developed methodology to correct for one of the most serious problems in accident analysis -- the regression-to-the-mean bias. Regression-to-the-mean is the phenomenon where the number of accidents at a high-accident location decreases even if no safety improvements are made. In addition, a menu-driven microcomputer program was developed to allow easy application of this new analysis technique. The method developed in this study provides a better estimate of the expected safety for a site.

The report is in three volumes. Volume I presents an intuitive, non-technical explanation of the regression-to-the-mean methodology. The required assumptions and data requirements are defined in lay terms for ease of comprehension to the highway engineer. Technical, statistical explanations are relegated to Volume III. Volume II of the report briefly describes the computer program and presents examples of the computer output, focusing on interpretation of the output results. Parties interested in receiving the computer program should contact Michael S. Griffith of the Federal Highway Administration on (703) 285-2382.

Volumes I and II will be distributed with two copies to each Region and six copies to each Division Office. Four of the Division copies should be sent to the State. Volume III will be distributed on a limited basis, one copy to each Region and two copies to each Division Office. One of the Division copies should be sent to the State. All volumes of the report will be sent to the Transportation Research Information Service Network, Department of Transportation Library, and the National Technical Information Service (NTIS) in Springfield, Virginia, to be available for interested parties.

R. J. Betsold
Director, Office of Safety and
Traffic Operations Research
and Development

NOTICE

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16. Abstract

Researchers in the field of accident analysis have long been aware of the problems associated with drawing statistical inference on safety using accident data. Aside from the problems of accessibility and quality, accident data present a real challenge when it comes to statistical analysis. One of the most serious problems in accident analysis is the regression-to-the-mean bias which occurs due to the non-random site selection process in safety measure evaluation studies. This study presents a new empirical Bayes method (EBEST) which adjusts for regression-to-the-mean bias. Three typical applications in accident analysis are considered for regression-to-the mean bias, namely: 1. the evaluation of safety treatments; 2. the identification of high hazard locations; and 3. the assimilation of information from multiple safety measure studies (meta-analysis). A computer program was developed to execute these analyses as a part of this study. This manuscript describes the EBEST (Empirical Bayes Estimation of Safety and Transportation) methodology and presents examples of how the method works for each of the three accident analysis applications. This report appears in three volumes. Volume I, General Methodology, FHWA-RD-90-091, is a non-statistical review of the study, Volume II, A Users Manual for BEATS, FHWA-RD-91-014, is a user's manual for the BEATS computer program, and Volume III, Theoretical Development of New Accident Analysis Methodology, FHWA-RD-91-015, contains the theoretical development of the procedure.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: *Volumes greater than 1000 L shall be shown in m^3.*

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fL	foot-Lamberts	3.426	candela/m^2	cd/m^2

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fL

* SI is the symbol for the International System of Measurement

(Revised July 1989)

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VOLUME I - (Con't.)

VOLUME II

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VOLUME II - (Cont'd.)

VOLUME II - (Cont'd.)

VOLUME III

This manual contains documentation for assisting users in the operation and interpretation of the computer program, BEATS, Bayesian Estimation of Accidents in Transportation Studies. This program implements the statistical methods developed in Volume I, Application of New Accident Analysis Methodologies. A brief description of the methodology is provided here for the purposes of review, only. The first time user is strongly encouraged to read volume I before using BEATS and to refer to this manual only as a refresher.

As with any easily implemented software, use of this program without a comprehensive understanding of the data requirements, assumptions of the methodology, and interpretation of results can lead to erroneous conclusions. This manual and the tutorial available during the program execution will provide a brief summary. However, these sources will not be sufficient to ensure proper application of the analyses for the first time user.

BEATS can accommodate each of the three accident analyses described in volume I, namely:

1. The estimation of effectiveness of a highway safety treatment.

2. The identification and ranking of high accident locations.

3. The combining of safety treatment effects from multiple sources.

The program, written in Turbo Pascal, can be run on any DOS-driven IBM or IBM compatible PC. The program is pre-compiled and can be executed on a computer without a hard disk drive, such as a lap-top. Memory limitations are controlled by the size of the data set being analyzed. To execute the program, the diskette need only be inserted and the word BEATS entered in the same drive where the disk was inserted.

The menu screens direct the user from this point with complete instructions. For each of the accident analysis applications, the user may request more information in the way of tutorials or the user may opt to bypass the tutorials and go directly to data analysis. Since the tutorials contain information vital to the appropriateness of the EBEST method, i.e., assumption and data requirements, first time users are encouraged to go through them. The bypass option is designed primarily for frequent users.

Chapter 2 presents a brief overview of the methodologies including data needs and assumptions. An example of the menu screens and tutorial information will be presented in chapter 3. These screens are the ones that would be seen if the user opted for the Safety Treatment Tutorials and Analysis using data with exposure measures and with both comparison and reference group information in the before and after time periods. Chapter 4 contains sample outputs from the BEATS program and a detailed explanation of the computer output. Chapter 5 addresses potential problems which the user may encounter in the program execution.

The methodologies developed in volume I, namely EBEST and MACEST, require certain basic data assumptions and the availability of critical data elements. In this chapter, these will be reviewed. However, first time users of this method should refer to volume I for comprehensive details.

The EBEST method is an Empirical Bayes methodology for preforming two of the three accident analysis applications listed in chapter 1:

1. Evaluation of highway safety measures.

2. Ranking and identification of high hazard locations.

The MACEST method is an Empirical Bayes methodology for performing the third accident analysis application:

3. Combining safety information from multiple studies.

Data needs and assumptions

reference group

For safety evaluation, the EBEST method requires that reference group data be available. The reference group is a sample of sites which , together with the treatment sites, represent the population of potential treatable sites. Accident data for the same time period as the treatment *before* period is necessary. Data from the reference group for the after period is desirable but not necessary if:

- Data is available for estimating other confounding effects such as time - i.e., comparison group data.

- It can be assumed that there is no time effect or any extraneous variables which could compromise the estimation of a treatment effect.

In the ranking and identification of high hazard locations, the entire set of sites to be ranked form this sample of potential treatable sites. Hence, for this application, the reference group is inherently available.

The EBEST method cannot be used unless reference group data is available. Failure to provide this data will result in failure of the BEATS program. Also, for both frequentist and EBEST methods, if the denominator of the crossproduct ratio is zero, it is undefined and an estimate cannot be obtained. This will happen whenever the treatment group before or after data has zero accidents **or** the comparison or reference group after data has zero accidents at all sites.

<u>exchangeability and exposure</u>

For both EBEST and MACEST, the underlying assumption of exchangeability must be satisfied. Exchangeability means that the measure of effectiveness being estimated (accident counts, accident rates, etc.) must come from populations whose true means are independent and identically distributed. That is, the true accident rate for one site must be a random variable from a distribution which has some mean and the true accident rate for any other site in the data set must come, randomly, from that same distribution. Stated another way, there should be no reason, a priori, to know that one site's true mean rate is higher (or lower) than any others.

For the MACEST procedure, the data being analyzed consists of safety treatment estimates or cross-product ratios. The assumption of exchangeability here means that there should be no reason to believe, a priori, that one study's estimate of the safety effectiveness is higher (or lower) than any other in the group of studies being combined in a synthesis study analysis.

The variable which most critically affects the assumption of exchangeability is exposure or a site's relative accident risk. If sites vary tremendously in their exposure, as represented by vehicle miles traveled (VMT), for example, yet VMT is not available, using the accident counts in an EBEST procedure, violates the assumption of exchangeability. The reason: it would be obvious to guess, a priori, which sites had the highest accident counts - the ones with more traffic. If, on the otherhand, VMT is available, accident rates as accidents per unit VMT can be analyzed and these rates <u>are</u> exchangeable. The reason: there is no reason, a priori, to suspect which sites would have higher (or lower) true mean <u>rates</u>.

Exposure is a key variable and its definition depends upon the problem. For sites of varying section length, section length is an exposure measure. For sites of varying before or after treatment periods, such as construction project safety studies, the time periods are a measure of exposure. Basically, both the EBEST and MACEST procedures allow information from sites with greatest exposure, or potential accident risk, to be given more weight than information from sites with low exposure.

In applying the MACEST procedure, careful consideration should be given as to what variables represent <u>study</u> exposures. Obviously, the number of <u>sites</u> in a study is an exposure measure and it would be desirable to give the safety treatment effectiveness estimates from studies based on a larger number of sites <u>more</u> weight.

Data are needed on all variables which might cause sites to vary in their exposure or accident risk potential. Since sites rarely have the same traffic volumes, it is highly recommended that data always be available on traffic volumes and used in this procedure. Rarely will omission of traffic volume be justified as explained in volume I. However, this program allows the user the option of not entering an exposure variable. Emphatic warnings are expressed if this option is selected.

The availability of comparison group data is also optional, if reference data is available during the after period to adjust for time change. If both are available, the program will estimate the treatment effect both ways.

The BEATS program is pre-compiled. On an IBM-PC with hard disk drive, C, and one floppy drive, B, the user would insert the diskette in the B drive and type:

B:

After which, from the B drive the user enters:

BEATS

From this point on, the computer prompts the user. An example of the menu screens will now be presented for the user who wants to perform a safety treatment evaluation and has accident and exposure data available for reference, treatment, and comparison groups before and after treatment. All tutorials will also be presented for completeness.

Tables 1 through 3 list the first three menu screens to appear. The non-indented line on table 3 denotes the line being highlighted. Movement of the up and down cursor key allows changing the selection. For the desired selection, either press the enter key when the desired menu item appears or depress the function key (Fl through F8) for the desired action. Table 3 signifies that the Introduction is desired and the Fl key is pressed to view table 4. Tables 4 through 7 contain introductory information with very brief summary reviews of the methodologies and assumptions. After table 7, the user is returned to the main menu (table 8) and allowed to make another selection. At this point, the seasoned user may opt to bypass the tutorials (F2 through F4) and go directly to the methods (F5 through F7). The first time user should proceed through the short tutorials. For this example F2 is depressed and the next screen viewed (table 9). Tables 9 through 20 contain the safety treatment tutorials.

Table 21 returns the user to the main menu. The ranking and meta-analysis tutorials are presented in tables 22 through 30. The treatment evaluation example begins with table 31. Table 32 specifies the data requirements and table 33 asks whether or not exposure data is available. If the user says no, the analysis continues; however, the user is strongly cautioned on the risks of not having exposure data. For this example, the user enters 1 for yes and proceeds to table 34 and is queried as to whether or not the reference group after data will be entered. Again, for this example the response is 1, yes, and the user is asked, in table 35, if comparison group data will be available. Another 1, yes response produces table 36 which describes the data input procedure.

Data must be stored in an ASCII file. Input and output files must use the format:

(Drive):\(File Name)

Table 37 describes the ASCII file which contains the data and the required format. The format is a free-format, i.e., data elements need not follow an exact format, but all data elements must be numeric and variables separated by at least one space. The maximum field size is 5 digits for all variables except exposure which can cover 18 fields with as many as 8 digits to the right of the decimal point. Missing data, such as no exposure for a site if the exposure option was selected or no accident information for one site, is not accepted by this program. These sites must be edited from the data file prior to program execution.

Assuming an ASCII file exists and has been copied to the BEATS diskette, the user enters the name on the file as requested in table 38. For this example, the file is called:

m19smz5

The program then requests the user to specify the name of the file which will contain the program results. The BEATS program does not print the data results to the screen but rather to a file on the diskette. To print the results, the user must print the output file after the program has executed. The name of the output file given for this example is:

outsmz5

Table 39, the last screen for the execution of this example, asks for specific details which the user might request for the output. Since some data sets may be quite large, options are given for printing only the top 20 sites by accident count or accident rate, or listing only the global (overall) statistics. Since this data set is small, the option was to list estimates for all sites (F1).

Description of the input data

The data file must contain the following elements, depending on the selected options:

- Identification (site number) - a numeric variable five digits or less.
- Treatment period - 1 before, 2 after.
- Group type - 1 treatment, 2 reference group, 3 comparison group.
- Number of accidents.
- Exposure.

The exposure variable is assumed to be one number. That is, if more than one exposure factor exists, the number entered as "exposure" should be the product of all of the numbers. For example, suppose the study included sites of varying section lengths. Then, the product of AADT and section length needs to be computed and the result of this product is the single value entered here as exposure. The BEATS program will not accept multiple exposure variables separately. That is, if section length and AADT are both recorded separately, the computer program will not work. Exposure units may be scaled to whatever dimensions desired such as AADT/10,000, miles, etc.

A typical record would be:

220 2 1 550 2234.56

This would represent site 220, a treatment site after treatment, with 550 accidents per year and 2234.56 average annual daily traffic.

After program execution for one data set, other data sets may be analyzed sequentially by returning to the main menu. Care should be taken to rename the output file so the previous data analysis is not overwritten. That is, if a new data set is defined in table 38 as

m19smz6,

the output file should have a different label as well, like

outsmz6.

The BEATS output will be contained in an ASCII data file created during the program's execution. The file will reside in the same directory as the BEATS program and will have the name assigned by the user in table 38.

The BEATS output includes:

- A narrative summary of the study results.
- Descriptive statistics about the study data.
- Data listings and rankings as requested by the user.
- Statistical details of the parameter estimates and test statistics from which the narrative is based.

In this chapter, the output for the safety treatment example of chapter 3 will be described. Since the output for the ranking procedure is similar to that of the safety treatment procedure, the only other output that will be explained in this chapter is that from MACEST.

The safety treatment evaluation results for the example in chapter 3 was stored in the file outsmz5. To print this, the user would type:

```
PRINT B:outsmz5
```

assuming the program was executed from the B drive. (Note: PRINT commands will vary with computers and printer types. If this command is not recognized, the user must find out what the PRINT command is for that particular PC set-up).

The print out from this command is shown in figure 1 and tables 40 through 42. Figure 1 is a narrative which explains the results of this analysis. This table should be read while referring to the descriptive statistics output of table 40. The descriptive statistics columns are:

group	-	labels referring to treatment (trt.), comparison (comp.) and reference (ref.) groups.
time period	-	before or after treatment.
no. of sites	-	number of sites in each group and time period.
total freq.	-	total number of accidents in each group and time period.
max. freq.	-	the maximum number of accidents at any one site for each group and time period.

min. freq. - the fewest number of accidents at any one site for each group and time period.

total exp. - the total (sum) of all exposure over all sites (e.g., total VMT).

max. exp. - the maximum exposure for any one site.

min. exp. - the minimum exposure for any one site.

rate - the total accidents divided by the total exposure for each group and time period.

Table 41 gives detailed statistical estimates from which the narrative of figure 1 was derived. Much of what is in this table is only of interest to the statistical researcher and can be ignored by those who are primarily interested in the interpretation of the study results (figure 1). The specific items will be identified here but the reader is referred to Volume III, Theoretical Development of New Accident Analysis Methodologies, for a more detailed explanation.

max (z) - the maximum number of accidents among the treated sites before treatment.

min (z) - the minimum number of accidents among the treated sites before treatment.

avg (e) - the average exposure for the treated sites before treatment.

ratio (e) - the ratio of the maximum exposure to the minimum. (This will affect the amount of shrinkage and variability in the assumed prior distribution.)

mu (mom) - the method of moments estimate of the mean of the gamma distribution.

r (mom) - the method of moments estimates of the exposure (variability factor) of the gamma distribution.

The last two statistics are used as initial estimates in the numerical iterative procedure to compute the maximum likelihood (EBEST) estimates. The mu (mom) is equivalent to Hauer's estimate if all exposures are equal (r (mom) = 1). Using the method of moments estimates as initial guesses has generally resulted in faster convergence. However, these estimates can be negative for some data sets and if this happens they are not good starting values. When this happens, the computer program automatically resets them to one and proceeds with the maximum likelihood procedure.

avg (y) and var (y) - the mean estimated mean and variance of the accident rates, y.

bavg. - the average of the shrinkage coefficients, B_i.

no. iter. - the number of iterations required to converge to the maximum likelihood solution.

expected after - the expected number of total accidents for the treated sites accidents after treatment based on EBEST(EB) and based on the classical (FREQ) procedures.

The following statistics use the comparison group data:

$trteEB_c$ - estimation of the cross product ratio using the EBEST estimate (this value minus one times 100 gives the percentage of increase or reduction due to treatment in percent).

$trtef_c$ - the estimation of the cross product ratio using the classical estimate.

tEB_c and zf_c - the test statistics for testing the significance for testing the significance of the effect. These are compared to standard normal z-values at some desired level of significance for testing the hypothesis that there is no treatment effect.

The next line of statistics correspond to the same items as above but use the reference group for adjusting for time trends. If there is a big difference in the conclusions drawn using the reference group versus the comparison group, the user should carefully consider which is more appropriate in adjusting for time effects, etc.

Table 42 lists the data for each site in the treatment group. The column heading are defined as:

id - the number of the site (identification).

count - the total accidents at the site.

exposure - the exposure for that site.

rate - the accident rate, z/e.

exp. rate - the EBEST estimate of the accident rate for that site.

exp. count - the EBEST estimate of the total accidents.

B_i - the shrinkage coefficient (Those sites with values close to one are being shrunk more toward the group mean. The more values in this column near one, the more r-t-m bias in the data).

diff. count - the difference between the observed number of accidents at the site and the estimated number of accidents.

diff. rate - the difference between the observed and estimated accident rates.

LB,UB - the upper and lower 95-percent confidence interval about the estimated accident rate at that site.

The last two columns should be compared to the observed site accident rates, y. When the observed rates fall outside of this interval, it means that the accident rate for these sites is significantly higher (or lower) than expected. This can be a criteria for identifying high hazard locations (volume I, 3.2).

The numerical complexities of obtaining the maximum likelihood estimates for this problem can result in computational problems and program failure. An iterative numerical algorithm which requires initial estimates is necessary. Many algorithms exist, and the one selected here was compared to others and found to be superior to other alternatives.[1] Nonetheless, computational handicaps exist and are a function of the quality and quantity of data available.

These computational problems are in addition to the problems that could occur when EBEST assumptions are violated or certain data elements are not available. In these cases, the BEATS program cannot find a numerical solution. This happens when the data for whatever reasons, seem to represent an unusual likelihood function where a unique maximum cannot be found. When this occurs, the algorithm will not converge to a solution. A limitation of 25 iterations is built into the program to prevent it from executing continuously. After 25 iterations, if convergence is not obtained, a message to this effect will be printed.

Unfortunately, there is no simple solution to this problem. There is some incompatibility between the data and the assumed models, and only with the assistance of a statistician can it sometimes be resolved. Experience to date indicates that this phenomenon is rare and not likely to occur. It did occur occasionally during the simulation study. These instances seemed to occur when the number of sites was small and the variability in exposures was large or when exposures were large relative to the number of accidents.

The user should be alerted to the possibility of this problem. When it occurs, the data should be scrutinized for violations of assumptions of the model. If the problem cannot be corrected, the EBEST method cannot be used. This can occur with any statistical method when the data is not compatible with the assumed model. Whereas most other statistical methods will still numerically provide a solution, though incorrect, without warning, the EBEST method will simply fail and no solution will result. Perhaps this is preferable to providing a solution but a wrong one.

Table 1. Screen 1.

```
Bayesian Estimation of Accidents in Transportation Studies

BBBB    EEEE      A      TTTTT    SSS
B   B   E        A A       T     S
B   B   E       A   A      T     S
BBBB    EEE     AAAAA      T      SSS
B   B   E       A   A      T         S
B   B   E       A   A      T         S
BBBB    EEEE    A   A      T      SSS

Press any key to continue
```

Table 2. Screen 2.

```
Development and implementation of this methodology was conducted
under the auspices of the Texas Transportation Institute (TTI)
under a contract with the Federal Highway Administration.  Dr. Olga
Pendleton was Principal Investigator.  Dr. Carl Morris, University
of Texas Center for Statistical Science was consultant to the project.
Dr. Morris developed the Empirical Bayes (EBEST) methodology and
conducted data analysis with assistance from graduate students Mary
Bishop and Cindy Christiansen. The computer program and data analysis
were conducted by Dr. Ofelia Gonzalez and Dr. Horacio Duarte.

Press any key to continue
```

Table 3. Screen 3.

```
BEATS
Menu

F1  Introduction
F2  Treatment Evaluation Tutorial
F3  Ranking Tutorial
F4  Meta-Analysis Tutorial
F5  Treatment Eval. Data Analysis
F6  Ranking Data Analysis
F7  Meta-Analysis
F8  Quit
```

Table 4. Screen 4.

```
This program provides a method for obtaining expected accident
rates or frequencies for a given data set. The statistical methodology
used (the EBEST method) is a procedure which uses prior information
to adjust for potential regression-to-the-mean effects. EBEST stands
for Empirical Bayesian Estimation of Safety in Transportation.

                              Press
        any key - next screen; ESC - main menu
```

Table 5. Screen 5.

```
Regression-to-the-mean

     Regression-to-the-mean can be a confounding factor in accident
analysis. This is specially true when evaluating the effectiveness
of a safety treatment.

     Since treatment sites are not generally selected at random, but
rather according to high accident experience, these sites may
represent a biased sample-biased in the direction of high accident
rates. Therefore, a reduction in accident rates in subsequent years
could be anticipated apart from any treatment effect simply because
the future accident rate is moving (regressing) toward the true mean
rate of the population of potential treatment sites.

     In order to isolate true treatment effects in accidents from
regression-to-the-mean effects, a more realistic estimate for the
expected accident rate at the treated sites is needed.

                              Press
  any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 6. Screen 6.

```
Empirical Bayes Estimation of Safety in Transportation - EBEST

     Empirical Bayes estimates are based on knowledge about the
entire population of potential treatment sites. This knowledge
is obtained from data representing this population. With this
knowledge, the expected accident rate for the treated sites can
be adjusted for any sampling bias due to the treatment site
selection process. This then provides a more realistic estimate
of the expected number of accidents apart from any treatment
effect.

                              Press
  any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 7. Screen 7.

```
Short tutorials are available to assist you in understanding
how BEATS works and what are its data requirements.

            BEATS can perform three tasks:

         1. Evaluate the effectiveness of a safety
            treatment in a before/after study.

         2. Rank sites according to their safety as might
            be desired to identify high hazard locations.

         3. Combine estimates of safety treatments from
            multiple sources (studies).

                Press any key to go back to the main menu
```

Table 8. Screen 8.

```
                    BEATS
                    Menu

        F1   Introduction
        F2   Treatment Evaluation Tutorial
        F3   Ranking Tutorial
        F4   Meta-Analysis Tutorial
        F5   Treatment Eval. Data Analysis
        F6   Ranking Data Analysis
        F7   Meta-Analysis
        F8   Quit
```

Table 9. Screen 9.

```
Data requirements:

     In order to adequately evaluate a safety treatment using
BEATS you will need to consider the validity of certain
assumptions required of the method (EBEST).  Also, you will
need to satisfy certain minimal data requirements.

                                   Press
              any key - next screen; ESC - main menu
```

Table 10. Screen 10.

```
Treatment group:

     The treatment group is defined as a collection of locations
which have received some safety treatment.  Accident counts for
some designated period before and after treatment are required.

     The duration of these time periods, before and after, need
not be equal but you will need to specify the periods in some
unit (months, years, etc.).  Additional information about these
sites, such as traffic volume, section length, etc. may be very
vital to adequately evaluate the treatment.  This will depend on
the assumption of exchangeability which will be defined in future
prompts.

                                   Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 11. Screen 11.

```
Reference group:

     The reference group and treatment group collectively
represent the entire population of potential treatment sites.

     The quality of the reference group has significant impact
on the quality of the EBEST estimates and subsequently on
conclusions about the treatment effectiveness.

                                   Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 12. Screen 12.

```
     Basically, the reference group is providing additional
information on the entire population of sites which may have
been candidates for the treatment.  If the treatment group is
biasedly sampled, the reference group would form the complement
of the treatment group.  In that sense, the reference group may
be biased as well but in the oppossing direction, i.e. toward
lower accident rates.  Information from the reference and
treatment groups can then be used to estimate the amount of
bias in the treatment group.  The treatment group alone cannot
provide this information.

any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 13. Screen 13.

```
     Although you will need data on the treatment sites both
before and after treatment, you will only need data on the
reference group for the before period for the analysis about
to be considered.  If reference group data is available for
the after period, this data may, under certain conditions,
be used in lieu of a comparison group.

                              Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 14. Screen 14.

```
Comparison Group:

       A comparison group is defined as a group of sites which
is independent of the treatment.  The comparison group need
not be a separate group of sites but may be the same sites under
a different condition which is not affected by the treatment
(weather, time of day, etc.).  The comparison group provides
information about the anticipated accident change from the before
to after periods.  The estimate of this anticipated change is then
used to adjust the expected accident counts at the treated sites
in order to reflect a trend in time.

                              Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 15. Screen 15.

```
     A comparison group is not a reference group.  It provides
information only about time trend, not regression-to-the-mean.
Comparison groups are selected not because they represent a good
sample from the same population of potential treatment sites, but
because the change in accidents from before to after time periods
for the comparison group is considered to be a good estimate of
the anticipated change in accidents for the treatment group apart
from any treatment effect.

     A typical example would be using dry weather accidents before
and after a resurfacing treatment as a comparison group for wet
weather accidents at those same sites.  The change in dry weather
accidents would serve as an estimate for the change anticipated
in wet weather accidents apart from any resurfacing.  Although
this might be a good comparison condition, dry weather accidents
would not form an appropriate reference group for wet weather
accidents since they do not represent the same populations.

                              Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 16. Screen 16.

```
     The reference group may be used in place of a comparison group
if sufficient data is available for both before and after periods.
The EBEST procedure adjusts for regression bias in the reference
group the same way it adjusts for bias in the treatment group.

     Whether you use reference group data or comparison group data
is optional.  However, at least one of these is required to adjust
for the time trend.  You will need, then, treatment group data
before and after and either reference group data before and after
or comparison group data before and after.

                                 Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 17. Screen 17.

```
Exchangeability Assumption:

     A critical assumption in using EB methods is exchange-
ability.  Basically, this means that we have no reason, in advance
of data collection, to know which sites in our data set would have
higher accident rates.  This assumption can be best defined using
an example.

                                 Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 18. Screen 18.

```
Example of exchangeability:

     Suppose that the only data available for a group of sites is
their accident counts.  Without any other measures of exposure,
such as traffic volume, the accident count must serve as a
surrogate for accident rate as it is the only available measure of
safety.  Suppose, now, that some very busy urban intersections are
combined with low volume residential intersections in the treatment
group.  Before any accident data is even observed one could guess
which intersection would have more accidents.  In this example, the
exchangeability assumption about the true site means is violated.
To satisfy it, traffic volume data is needed.  In this way, the
amount of information contributed by each site can be weighted by
traffic volume.

                                 Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 19. Screen 19.

Although traffic volume is the most obvious variable which affects exchangeability, other variables can be a factor. For example, section length may vary among sites in some treatment studies. Another factor might be time periods. For construction zone treatments, duration of the construction period may vary. Collectively, these factors can be termed as exposure factors. If sites vary in their exposures, data on the amount of exposure is essential to the analysis.

Press any key - next screen; PgUp - previous screen; ESC - main menu

Table 20. Screen 20.

Asking BEATS to evaluate a safety treatment for sites with different traffic volumes but not providing the volumes is like trying to evaluate a diet where the dieters ate substantially different quantities but not specifying how much each person ate.

Press any key to go back to the main menu

Table 21. Screen 21.

BEATS
Menu

F1 Introduction
F2 Treatment Evaluation Tutorial
F3 Ranking Tutorial
F4 Meta-Analysis Tutorial
F5 Treatment Eval. Data Analysis
F6 Ranking Data Analysis
F7 Meta-Analysis
F8 Quit

Table 22. Screen 22.

```
Data requirements:

     In order to adequately rank the sites according to their
safety potential  using the EBEST method you will need to consider
the validity of certain assumptions required of the method and you
will need to satisfy certain minimal data requirements.

                              Press
            any key - next screen; ESC - main menu
```

Table 23. Screen 23.

```
Exchangeability Assumption:

     A critical assumption in using EB methods is exchange-
ability.  Basically, this means that we have no reason, in advance
of data collection, to know which sites in our data set would have
higher accident rates.  This assumption can be best defined using
an example.

                              Press
  any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 24. Screen 24.

```
Example of exchangeability:

     Suppose that the only data available for a group of sites is
their accident counts.  Without any other measures of exposure,
such as traffic volume, the accident count must serve as a
surrogate for accident rate as it is the only available measure of
safety.  Suppose, now, that some very busy urban intersections are
combined with low volume residential intersections in the treatment
group.  Before any accident data is even observed one could guess
which intersection would have more accidents.  In this example, the
exchangeability assumption about the true site means is violated.
To satisfy it, traffic volume data is needed.  In this way, the
amount of information contributed by each site can be weighted by
traffic volume.

                              Press
  any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 25. Screen 25.

```
     Although traffic volume is the most obvious variable which
affects exchangeability, other variables can be a factor.  For
example, section length may vary among sites in some treatment
studies. Another factor might be time periods.  For construction
zone treatments, duration of the construction period may vary.
Collectively, these factors can be termed as exposure factors.
If sites vary in their exposures, data on the amount of exposure
is essential to the analysis.

                              Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 26. Screen 26.

```
     Asking BEATS to rank a group of sites with different
traffic volumes but not providing the volumes is like trying
to rank dieters who ate different quantities according to
their weight loss without specifying how much each person ate.

Press any key to go back to the main menu
```

Table 27. Screen 27.

```
                  BEATS
                  Menu

     F1   Introduction
     F2   Treatment Evaluation Tutorial
     F3   Ranking Tutorial
    F4   Meta-Analysis Tutorial
     F5   Treatment Eval. Data Analysis
     F6   Ranking Data Analysis
     F7   Meta-Analysis
     F8   Quit
```

Table 28. Screen 28.

Meta-analysis refers to the science of obtaining quantitative information from a collection of scientific studies. In relation to countermeasure evaluation using accident data, a specific application of meta-analysis would be the combining of treatment effect estimates from more than one study for a particular safety treatment.

Press
any key - next screen; ESC - main menu

Table 29. Screen 29.

Combining information on many studies is typically the objective of synthesis reports on specific safety treatments. However, these studies often fail to provide a quantitative estimate of the overall effect when combining studies.

It is important to note that meta-analysis is applicable when only a portion of the study data are available, such as means, variances and other descriptive statistics. Given the handicap of not having the raw data for each study, meta-analysis provides the best statistical estimate possible using the reduced data. If the raw data is available, it is always better to use all of the data than just a portion of it.

Press
any key - next screen; PgUp - previous screen; ESC - main menu

Table 30. Screen 30.

In practice, decisions often need to be based on data which is provided in some condensed form. These decisions are typically made subjectively because quantitative estimates are not available. Meta-analysis can provide such estimates.

Press any key to go back to the main menu

Table 31. Screen 31.

```
BEATS
Menu

F1   Introduction
F2   Treatment Evaluation Tutorial
F3   Ranking Tutorial
F4   Meta-Analysis Tutorial
F5   Treatment Eval. Data Analysis
F6   Ranking Data Analysis
F7   Meta-Analysis
F8   Quit
```

Table 32. Screen 32.

```
Data Requirements:

     Data are needed on all variables which might cause sites to
vary in their exposure or accident risk potential.

     Since sites rarely have the same traffic volumes, it is highly
recommended that data always be available on traffic volumes and
used in this procedure.  Rarely will omission of traffic volume be
justified.

     The exchangeability assumption for the expected true accident
rate is extremely important and significant violation of this
assumption will produce erroneus results and conclusions.

                              Press
          any key - next screen; ESC - main menu
```

Table 33. Screen 33.

```
Do you have exposure data for the sites in your
analysis which will result in satisfying the
exchangeability assumption?

Please enter:

        1 -  Yes, I have exposure

        2 -  No, I do not have exposure

     1

                              Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 34. Screen 34.

```
Do you have reference group data for the after
period to estimate the time trend?

Please make a selection:

                  1 -  Yes

                  2 -  No

     1

                            Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 35. Screen 35.

```
Do you have comparison group data for the after
period to estimate the time trend?

Please enter:

                  1 -  YES

                  2 -  NO

     1

                            Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 36. Screen 36.

```
Your file must be in ASCII format and contain the following data
items (allow at least one space between entries):

-  Identification (site number, year, county, etc).

-  1 if before treatment period, 2 if after treatment period.

-  1 if treatment group, 2 if reference group, 3 if comparison  group.

-  number of accidents (z).

-  exposure (traffic volume, section length, number of months, or
     the product of more than one exposure variable).  Exposure
     units may be scaled to whatever dimensions desired such as
     AADT/10,000, miles, etc.

                            Press
any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 37. Screen 37.

```
A typical record would be:
                        1  1  1  550  2234.56

representing site 1, a treatment site before treatment, with 550
accidents per year and 2234.56 average annual daily traffic.

                                    Press
   any key - next screen; PgUp - previous screen; ESC - main menu
```

Table 38. Screen 38.

```
Please enter the name of your input file

cribchl

Please enter the name of your output file

outcrib

                     Press any key to continue
```

Table 39. Screen 39.

```
              Treatment Evaluation Output Data
                          Menu

     F1 List estimates for all sites by id
      F2 List estimates for top 20 sites by rate
      F3 List estimates for top 20 sites by count
      F4 List global statistics only
      F5 Quit
```

EBEST Method using both Comparison Group and Reference Group as Comparison Group with Exposure Data

SUMMARY OF SAFETY TREATMENT EVALUATION RESULTS

In this study there were 20 treatment sites, 20 comparison sites, and 80 reference sites. The total number of accidents at these sites during this period are listed in the Descriptive Statistics Table. This table also lists the maximum and minimum site accident frequencies, the total exposures, the maximum and minimum exposures, and the accident rate, i.e. accidents per unit exposure.

Three methods were used to estimate the treatment effect: the EBEST method using the comparison group (if available), the frequentist or cross product ratio, and the EBEST method using the reference group in place of the comparison group, if available.

Using the frequentist method and the comparison group, the expected number of accidents at the treatment sites after is assumed to equal the number before, namely, 111. There was a -67.28% change in accidents using this method which is statistically significant at the 5% level of significance if -4.09 is greater than 1.96 in absolute value.

Using the EBEST method and the comparison group, the expected number of accidents at the treatment sites after adjusted for regression -to-the-mean is 64.9. There was a -44.06% change in accidents using this method which is statistically significant at the 5% level of significance if -3.38 is greater than 1.96 in absolute value.

Using the frequentist method and the reference group, the expected number of accidents at the treatment sites after is assumed to equal the number before, namely, 111. There was a -74.63% change in accidents using this method which is statistically significant at the 5% level of significance if -6.29 is greater than 1.96 in absolute value.

Using the EBEST method and the reference group, the expected number of accidents at the treatment sites after adjusted for regression -to-the-mean is 64.9. There was a -56.63% change in accidents using this method which is statistically significant at the 5% level of significance if -4.86 is greater than 1.96 in absolute value.

The method you select to use depends upon several things and if you are not aware of these issueh you should review the tutorials in this program. Basically, to evaluate the amount of regression-to-the-mean which may be present in this data set, compare the average shrinkage in your data set, namely, 0.95, to 1.0. If this number is close to 1.0, you have substantial regression-to-the-mean and should use one of the EBEST methods. If the average shrinkage is close to zero, you do not have much of a regression-to-the-mean problem and the three methods should yield comparable results.

Deciding between the EBEST method with the comparison group versus the reference group depends upon which data set you feel best reflects the expected change in accidents over time independent of any treatment.

The other statistics on this output pertain to the EBEST estimates for the prior distribution parameters, muhat and rhat, the method of moments estimates for these quantities (MOM) which were used as starting values for the maximum likelihood solution, max and min observed frequencies in the treatment plus reference groups (z), average exposures for this group, (Avg(e)), and the ratio of the maximum to minimum exposures for this group (ratio(e)). The number of iterations required in the maximum likelihood procedure is also given. The estimates of treatment effect using the EBEST procedure with comparison group (trteEB), the frequentist method (trtef), the EBEST procedure using the reference group (trteEBr) and their respective test statistics, tEB and tf are also listed.

A listing of before treatment site data is then given ordered by site ID. The data includes the observed accident frequencies, z, the exposure e, the observed rate, y=z/e, the estimated true site mean using EBEST, lhat, the estimated accident frequency using EBEST, zhat, the shrinkage coefficient, Bi, the difference between observed and expected accidents, zdif, the difference between observed and expected rates, yhat, and the upper and lower 95% confidence bounds about the estimated true site rate, LB and UB. If the observed rate, y, falls outside of this interval, it can be considered as significantly different from the rate one would have expected at that site. This information can be useful in identifying high hazard locations, i.e. sites which are experiencing unusually high numbers of accidents.

Figure 1. Safety treatment evaluation narrative computer output.

Table 40. Safety treatment evaluation descriptive statistics computer output.

EBEST Method using both Comparison Group and Reference Group as
Comparison Group with Exposure Data

Descriptive Statistics

Group	Time period	No. of sites	Total Freq.	Max. Freq.	Min. Freq.	Total Exp.	Max. Exp.	Min. Exp.	Rate (freq/exp)
trt.	before	20	111	7	4	280.5	24.6	10.2	0.3958
trt.	after	20	35	4	0	280.5	24.6	10.2	0.1248
comp.	before	20	55	8	0	281.0	26.7	10.1	0.1957
comp.	after	20	53	7	0	281.0	26.7	10.1	0.1886
ref.	before	80	181	4	0	1034.7	25.7	10.0	0.1749
ref.	after	80	225	11	0	1034.7	25.7	10.0	0.2175

Table 41. Safety treatment evaluation detailed statistical results.

EBEST Method using both Comparison Group and Reference Group as Comparison Group with Exposure Data

Empirical Bayes Statistics

Max(z)	Min(z)	Avg(e)	ratio(e)
7	0	13.15	2.57

mu(mom)	r(mom)	Avg(y)	Var(y)
0.2268	101.347	0.2268	0.02026

MuHat	RHat	Bavg	No. Iter
0.2224	228.980	0.946	7

Expected After Accidents

EB	FREQ
64.93	35

Treatment effect and test statistic using comparison group

trteEBc	trtefc	tEBc	zfc
-44.06	-67.28	-3.38	-4.09

Treatment effect and test statistic using Reference Group as a Comparison group

trteEBr	trtefr	tEBr	zfr
-56.63	-74.63	-4.86	-6.29

Table 42. Safety treatment evaluation data listing.

EBEST Method using both Comparison Group and Reference Group as Comparison Group with Exposure Data

EB statistics for all sites ordered by ID

id	count	expo-sure	rate	exp. rate	exp. count	Bi	diff. count	diff. rate	LB	UB
1	4	13.0	0.3072	0.2269	3.0	0.95	1.05	0.08	0.1790	0.2796
2	4	10.2	0.3910	0.2296	2.3	0.96	1.65	0.16	0.1811	0.2828
3	5	10.7	0.4686	0.2333	2.5	0.96	2.51	0.24	0.1845	0.2869
4	5	18.0	0.2778	0.2264	4.1	0.93	0.92	0.05	0.1790	0.2784
5	5	10.5	0.4757	0.2335	2.5	0.96	2.55	0.24	0.1846	0.2871
6	5	24.6	0.2029	0.2205	5.4	0.90	-0.43	-0.02	0.1743	0.2711
7	5	10.8	0.4617	0.2332	2.5	0.95	2.47	0.23	0.1844	0.2867
8	5	14.6	0.3429	0.2296	3.3	0.94	1.65	0.11	0.1815	0.2823
9	5	14.8	0.3376	0.2294	3.4	0.94	1.60	0.11	0.1814	0.2821
10	5	12.6	0.3981	0.2315	2.9	0.95	2.09	0.17	0.1830	0.2847
11	5	11.0	0.4525	0.2330	2.6	0.95	2.43	0.22	0.1842	0.2865
12	5	19.4	0.2575	0.2251	4.4	0.92	0.63	0.03	0.1780	0.2768
13	6	11.7	0.5128	0.2365	2.8	0.95	3.23	0.28	0.1874	0.2903
14	6	12.7	0.4710	0.2355	3.0	0.95	3.00	0.24	0.1866	0.2891
15	6	12.2	0.4902	0.2360	2.9	0.95	3.11	0.25	0.1870	0.2897
16	7	13.2	0.5283	0.2391	3.2	0.95	3.83	0.29	0.1899	0.2930
17	7	10.2	0.6890	0.2422	2.5	0.96	4.54	0.45	0.1923	0.2968
18	7	13.7	0.5121	0.2387	3.3	0.94	3.74	0.27	0.1896	0.2925
19	7	14.2	0.4923	0.2382	3.4	0.94	3.61	0.25	0.1891	0.2919
20	7	22.2	0.3157	0.2306	5.1	0.91	1.89	0.09	0.1831	0.2826

References

1. Gonzalez, O., H. Duarte and O. J. Pendleton. (1990). "On the computational efficiency of MLE for the negative binomial distribution." Technical report in Press. Texas Transportation Institute. College Station, Texas.

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