Overview of SafetyAnalyst: Software Tools for Safety Management of Specific Highway Sites

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ABSTRACT

SafetyAnalyst is a set of computerized analytical tools being developed for the Federal Highway Administration to assist state and local highway agencies in highway safety management. The main purpose of SafetyAnalyst is to improve a highway agency’s systemwide programming of site-specific safety improvements. SafetyAnalyst applies advanced statistical techniques for safety management in four main analytical tools: Network Screening, Diagnosis and Countermeasure Selection, Economic Appraisal and Priority Ranking, and Countermeasure Evaluation. This paper presents a general overview of the SafetyAnalyst program features.

The Network Screening tool includes six algorithms to identify sites with potential for safety improvement: peak searching for high accident frequencies, sliding window for high accident frequencies, high proportion of target accident types, steady increase in accident frequency, sudden increase in accident frequency, and corridor analysis. This tool uses traditional screening techniques as well as new statistical methodologies such as the empirical Bayes (EB) approach.

The Diagnosis and Countermeasure Selection tool enables users to investigate the nature of safety concerns at specific sites through accident summary statistics, collision diagrams, and statistical tests for specific accident patterns. Through the use of an expert system, this tool also assists users in the diagnosis of specific accident patterns as well as the identification and selection of countermeasures that address these specific accident patterns.
The Economic Appraisal and Priority Ranking tool performs economic appraisals of alternative countermeasures for a specific site or group of sites. Several economic criteria are available for use within SafetyAnalyst: cost-effectiveness, benefit-cost ratio, or net present value. This tool also provides the ability to determine an optimal set of countermeasures for a group of sites that will maximize the safety benefits of the improvements with a user-specified improvement budget.

The Countermeasure Evaluation Tool provides the ability to conduct well-designed before-after evaluations of implemented safety improvement projects. Two statistical approaches are provided for such evaluations: an EB approach for determining changes in accident frequencies and a nonparametric test for shifts in the proportions of specific accident severity levels or accident types.

**Key words:** countermeasure effectiveness—economic analysis—empirical Bayes—network screening—safety management—software
INTRODUCTION

SafetyAnalyst is a set of computerized analytical tools being developed for the Federal Highway Administration (FHWA) to assist state and local highway agencies in highway safety management. The main purpose of SafetyAnalyst is to improve a highway agency’s systemwide programming of site-specific safety improvements. SafetyAnalyst incorporates state-of-the-art safety management approaches for guiding the decision-making process to identify safety improvement needs and has a strong basis in cost-effectiveness analysis. SafetyAnalyst will help highway agencies gain the greatest possible safety benefit from each dollar spent in the name of safety.

SafetyAnalyst addresses site-specific safety improvements that involve physical modifications to the highway system. SafetyAnalyst is not intended for direct application to non-site-specific highway safety programs that can improve safety for all highway travel, such as vehicle design improvements, graduated licensing, occupant restraints, or alcohol/drug use programs. However, SafetyAnalyst has the capability to identify accident patterns at specific locations and determine whether those accident types are overrepresented. In addition, SafetyAnalyst has the capability to determine the frequency and percentage of particular accident types along specified portions of the highway system.

SafetyAnalyst incorporates advanced statistical techniques for safety management approaches in four main automated analytical tools: Network Screening, Diagnosis and Countermeasure Selection, Economic Appraisal and Priority Ranking, and Countermeasure Evaluation. SafetyAnalyst development is being sponsored by the FHWA as a pooled fund project that has received financial support from over 20 state highway agencies (FHWA 2007). The SafetyAnalyst development work has been guided by a Technical Working Group (TWG) with representatives from each participating state highway agency. Two FHWA contractor teams are developing the software. An engineering team, led by Midwest Research Institute, is responsible for developing functional specifications for the software and testing the software to assure that it conforms to the functional specifications. A software development team, led by ITT Industries, has designed and developed the software. An interim version of the SafetyAnalyst software has been completed and is being tested by TWG members. The first public release version of SafetyAnalyst is expected in 2008.

This paper is organized as follows. Following this introduction, the paper presents an overview of the empirical Bayes (EB) methodology, which lies at the heart of many of the SafetyAnalyst methodologies. The paper then reviews the data requirements for using the software and provides a general overview of the capabilities found in the tools. This paper concludes with summary and key advantages of the software.

EMPIRICAL BAYES METHODOLOGY

The statistical approaches for most of the analytical procedures in SafetyAnalyst are based on the EB methodology. This technique was first reduced to practice in the highway safety field by Hauer (1997) to overcome the shortcomings of safety studies relying solely on observed accident data or accident rates. A brief background of the related issues and an introduction to this methodology are presented in this section.

There are several potential drawbacks to traditional safety studies based solely on observed accident frequencies or accident rates. Such studies may be biased due to regression to the mean. This phenomenon can be described as a characteristic of repeated measures data, in which high short-term accident frequencies are likely to decrease or low short-term accident frequencies are likely to increase,
i.e., returning to the mean. It is important that such natural decreases (or increases) in accident frequency resulting from regression to the mean, which may lead to an overestimation (or underestimation) of safety, not be mistaken for the effect of a countermeasure.

The use of accident rates can also lead to biased results. Traffic volumes, or annual average daily traffic rates (AADTs), are used directly in the computation of this measure, i.e., accident rate = accident frequency/AADT (or some scalar multiple of this). The relationship between accident frequency and traffic volume is known to be nonlinear, and problems can occur when procedures based on accident rates treat that relationship as if it were linear. The nonlinearity in the relationship implies that equal accident rates do not mean equivalent level of hazard if different AADTs are involved, since the accident rate is expected to be lower at higher traffic volumes.

To remedy these issues, SafetyAnalyst uses an EB approach that combines observed and expected accident frequencies to provide estimates of the safety performance of specific sites that are not biased by regression to the mean. The EB approach incorporates nonlinear regression relationships between traffic volume and expected accident frequency.

Regression equations to predict accident frequency, typically developed by assuming that accidents follow a negative binomial distribution, are commonly known as safety performance functions (SPFs). SPFs are developed from a reference population of sites that share the same characteristics and have been generated for 90 combinations of site types and accident severity levels in SafetyAnalyst. Separate equations were generated for total accidents and fatal and all injury accidents for the site types listed in Table 1 (Harwood et al. 2004).

Table 1. Site types for which safety performance functions are included in SafetyAnalyst

<table>
<thead>
<tr>
<th>Roadway Segments</th>
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</thead>
<tbody>
<tr>
<td>Rural two-lane roads</td>
</tr>
<tr>
<td>Rural multilane undivided roads</td>
</tr>
<tr>
<td>Rural multilane divided roads</td>
</tr>
<tr>
<td>Rural freeways, 4 lanes</td>
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<tr>
<td>Rural freeways, 6+ lanes</td>
</tr>
<tr>
<td>Rural freeways within interchange area, 4 lanes</td>
</tr>
<tr>
<td>Rural freeways within interchange area, 6+ lanes</td>
</tr>
<tr>
<td>Urban two-lane arterial streets</td>
</tr>
<tr>
<td>Urban multilane undivided arterial streets</td>
</tr>
<tr>
<td>Urban multilane divided arterial streets</td>
</tr>
<tr>
<td>Urban one-way arterial streets</td>
</tr>
<tr>
<td>Urban freeways, 4 lanes</td>
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<tr>
<td>Urban freeways, 6 lanes</td>
</tr>
<tr>
<td>Urban freeways, 8+ lanes</td>
</tr>
<tr>
<td>Urban freeways within interchange area, 4 lanes</td>
</tr>
<tr>
<td>Urban freeways within interchange area, 6 lanes</td>
</tr>
<tr>
<td>Urban freeways within interchange area, 8+ lanes</td>
</tr>
</tbody>
</table>
Table 1. Continued

Intersections

Rural three-leg intersection with minor-road STOP control
Rural three-leg intersection with all-way STOP control
Rural three-leg intersection with signal control
Rural four-leg intersection with minor-road STOP control
Rural four-leg intersection with all-way STOP control
Rural four-leg intersection with signal control

Urban three-leg intersection with minor-road STOP control
Urban three-leg intersection with all-way STOP control
Urban three-leg intersection with signal control
Urban four-leg intersection with minor-road STOP control
Urban four-leg intersection with all-way STOP control
Urban four-leg intersection with signal control

Ramps

Rural diamond off-ramp
Rural diamond on-ramp
Rural parclo loop off-ramp
Rural parclo loop on-ramp
Rural free-flow loop off-ramp
Rural free-flow loop on-ramp
Rural free-flow outer connection ramp
Rural direct or semidirect connection

Urban diamond off-ramp
Urban diamond on-ramp
Urban parclo loop off-ramp
Urban parclo loop on-ramp
Urban free-flow loop off-ramp
Urban free-flow loop on-ramp
Urban free-flow outer connection ramp
Urban direct or semidirect connection

Two functional forms of default SPFs provided with SafetyAnalyst were developed using Highway Safety Information System data from four states. Level 1 default SPFs use traffic volume and roadway segment length as the primary explanatory variables to predict accidents. Level 2 SPFs also include other geometric and traffic control characteristics as explanatory variables. The interim version of SafetyAnalyst uses only the Level 1 SPFs, but both the Level 1 and Level 2 SPFs are expected to be used in the first public release version. Calibration procedures are available in the software to adjust default SPFs to reflect local conditions. SafetyAnalyst also provides the capability for user-defined SPFs to be entered for use with the software.

DATA REQUIREMENTS

SafetyAnalyst utilizes an agency’s highway system inventory, accident data files, and data on implemented countermeasures. The data included in these files pertain to individual sites or locations within an agency’s highway network. Additionally, other data files are maintained by the software for
computational purposes when analyzing a site. The information within these files does not pertain to individual sites, but instead to a collection of sites or to all sites. The datasets in Table 2 are used within SafetyAnalyst:

**Table 2. SafetyAnalyst datasets**

<table>
<thead>
<tr>
<th>Highway agency data files</th>
<th>Internal data files used in computations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway segment inventory</td>
<td>Safety performance functions (SPFs)</td>
</tr>
<tr>
<td>Intersection inventory</td>
<td>Accident proportions</td>
</tr>
<tr>
<td>Ramp inventory</td>
<td>Countermeasures</td>
</tr>
<tr>
<td>Accident characteristics</td>
<td>Accident costs</td>
</tr>
<tr>
<td>Implemented countermeasures</td>
<td>Equivalent property damage only (EPDO) weights</td>
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<tr>
<td></td>
<td>Beta distribution parameters</td>
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</tbody>
</table>

SafetyAnalyst has been developed to be flexible enough to fit into diverse highway agency operating environments. There are data importing methods supporting multiple commercially available database management software packages, including an embedded database packaged with the software to store and manage the data. All methods available to deploy the software require that specific data items from the highway agency file format and coding are converted to a common SafetyAnalyst format and coding. The exception to this requirement is that SafetyAnalyst can accommodate multiple location identifier systems. Location identifier data are used to describe the exact location of a site within the highway network. Highway agencies have adopted different location identifier systems for their inventory highway data and other data files. Five basic systems of location identifier information are used by most highway agencies. These basic location identifier systems include the following:

- Route/county/milepost
- Route/milepost
- Route/segment identifier/distance
- Segment identifier/distance
- Link/node

SafetyAnalyst can accommodate data files that utilize any one of these systems to link the respective data to a particular location within the highway network. GPS coordinate systems may also be used, but must include an underlying linear referencing system to represent locations in one of the five basic systems.

Location identifier data also fulfill one of three vital requirements for agency data to be sufficient for use with SafetyAnalyst. The first requirement is that accident data must be able to be exactly associated with one roadway segment, intersection, or ramp record. This assignment can be automated in SafetyAnalyst via the location identifier data. The second requirement is that each location to be analyzed has at least one year of traffic volume data. The final requirement is that there are enough inventory or characteristic data available to classify locations into one of the site type categories listed in Table 1. The ability to assign an SPF appropriate to the type of site directly affects the ability to employ procedures based upon the EB methodology.

To facilitate testing and demonstration of the SafetyAnalyst software package, a test dataset has been developed from actual data for state highways in a five-county area of a particular state. These data include urban and rural areas as well as data for all types of facilities.
OVERVIEW OF THE ANALYTICAL TOOLS

_SafetyAnalyst_ is comprised of four analytical tools that, when packaged together, incorporate all stages of the highway safety management process:

- Network Screening tool
- Diagnosis and Countermeasure Selection tool
- Economic Appraisal and Priority Ranking tool
- Countermeasure Evaluation tool

The technical capabilities and functionality of these analytical tools are summarized in the following sections.

Network Screening Tool

The purpose of the Network Screening tool is to review the entire roadway network or portions of the roadway network, under the jurisdiction of a highway agency, and identify and prioritize those sites that have potential for safety improvement. Identification of a site by one of the network screening tools means that an opportunity to improve safety may exist at the site, but this does not necessarily indicate that there is a correctable safety problem at the site.

The network screening tool provides four types of screening to identify sites with potential for safety improvement:

- Basic network screening for high accident frequency
- Screening for a high proportion of specific target accident types
- Detection of safety deterioration
- Screening for extended roadway corridors

Each of these screening techniques is summarized below.

**Basic Network Screening**

The basic network screening methodology utilizes EB principles to estimate the potential for safety improvement (PSI) of a site. This is the only network screening methodology that uses EB concepts. In general terms, the basic network screening approach combines observed accident frequencies with predicted accident frequencies from regression relationships (i.e., SPFs) to estimate the expected accident frequency for a site. The _SafetyAnalyst_ user may select whether the PSI is expressed in terms of (a) an expected accident frequency or (b) an excess accident frequency (i.e., amount by which the expected accident frequency exceeds a normal or typical frequency for that type of site). The EB-adjusted expected accident frequency is normalized on a per-mile or per-site basis for ranking and comparing the PSI among sites. Sites with higher expected or excess accident frequencies (i.e., PSI values) are ranked higher in terms of their potential for safety improvement.

The basic network screening methodology may be applied to all site types (i.e., roadway segments, intersections, and ramps). The EB calculations are similar for all site types, with slight variations. When the site list includes roadway segments, the user must choose to perform basic network screening from among two approaches: peak searching or sliding window.
In the peak searching approach, each roadway segment is divided into windows, which are incrementally increased in size until they cover the entire site. In the peak searching approach, the windows are always contained within a given roadway segment and never overlap adjacent roadway segments. For each window, the expected accident frequency (or excess accident frequency) is calculated on a per-mile basis. Based on the statistical reliability of the expected value, the maximum expected accident frequency (or excess accident frequency) across all windows within a roadway segment is used to rank the PSI of that site relative to the other sites in the site list.

In the sliding window approach, the unit of analysis for a roadway segment is a window of constant user-specified length. This window is incrementally moved along contiguous roadway segments in geographical sequence that makes up a route within the highway system. At any position along the route, the sliding window may overlap previous windows if the length of the user-specified increment by which the window moves forward is less than the user-specified window length. Since a window does not necessarily end at the end of a site, window locations may bridge contiguous roadway segments. At each window location, the expected accident frequency (or excess accident frequency) is calculated on a per-mile basis. The maximum expected accident frequency (or excess accident frequency) for any window position within or overlapping that roadway segment is used to rank the PSI of that segment for comparison to the other segments being evaluated.

**High Proportions Test of Target Accidents**

The objective of this screening method is to identify sites that have a higher-than-expected proportion of specific target accident types and to rank those sites based on the difference between the observed proportion and the expected proportion for that specific target accident type. A site is identified for further investigation if the probability that the observed proportion of the specific target accident type at a site is greater than the expected proportion for similar sites. This approach strives to identify locations with an overrepresentation of particular accidents, which may facilitate the selection of countermeasures and identify locations that are good candidates to be cost effectively treated. In particular, sites not identified by the basic network screening algorithm due to a low accident frequency, but having a well-defined accident pattern, would benefit from this type of screening.

**Detecting Safety Deterioration**

The objective of this screening methodology is to identify sites where the mean accident frequency has increased over time by more than would be attributed to changes in traffic volume or general trends. Two types of increases can be detected:

- A steady but gradual increase in mean accident frequency
- A sudden increase in mean accident frequency

Both steady and sudden increases in accident frequency are detected by a statistical test of significance for the difference between the means of two Poisson random variables.

With the steady increase approach, sites are flagged for further investigation if the slope to the regression model fit to data of observed accident frequency versus year is greater than a user-selected limiting value. In essence, this detects whether the average accident frequency for a site in recent years appears significantly larger than in the preceding years. The sudden increase approach is similar to screening for steady increases in mean accident frequencies, with one exception. Rather than specifying a limiting value
for the slope, the user specifies a limiting value of a percentage increase in mean accident frequency from one year to the next that might be indicative of a safety concern.

Output for this screening methodology consists of the list of sites identified for their PSI. With the other network screening methodologies, all sites included in output report are ranked relative to the others as to their potential for safety improvement.

**Corridor Screening**

Screening for extended roadway corridors is a unique approach among the analyses that are performed within the Network Screening tool. All other types of analyses are performed on a site-by-site basis. However, within a corridor analysis, sites are aggregated to investigate the accident history for a group of roadway segments, intersections, and/or ramps. Thus, sites with a common corridor number are analyzed as a single entity.

The user has the option to rank corridors by one or both of two basic measures: accidents per mile per year or accidents per million vehicle miles of travel per year. The first measure is an accident frequency value expressed on a per-mile basis. Thus, this first measure does not fully consider traffic exposure within a corridor. The second measure is an accident rate that does take into consideration the traffic volume exposure within a corridor.

**Diagnosis and Countermeasure Selection Tool**

The purpose of the Diagnosis and Countermeasure Selection tool is to enable users to investigate the nature of safety concerns at specific sites through accident summary statistics, collision diagrams, and statistical tests for specific accident patterns. Through the use of an expert system, this tool also assists users in the diagnosis of specific accident patterns as well as the identification and selection of countermeasures that address these specific accident patterns.

The diagnosis of safety problems at a site begins by analyzing accident history data to identify accident patterns of interest. Three tools are provided within SafetyAnalyst for identifying accident patterns: accident summary reports, collision diagrams, and statistical tests of accident frequencies and/or accident proportions. An accident summary report presents the frequency distribution for various accident characteristics using observed accident history. The user may choose to view the results in tabular form, bar charts, or pie charts so that overrepresentation of accidents can be easily seen. Similarly, a collision diagram can be generated to provide a visual representation of accident patterns. A basic collision diagramming capability that is not interactive or extensively modifiable is included within SafetyAnalyst. However, links to commercially available collision diagramming software packages are provided for software vendors who chose to make their products available through SafetyAnalyst. The final accident pattern identification method, the statistical tests for frequencies and/or proportions, utilizes an EB-based methodology rather than observed accidents alone.

Having identified one or more accident patterns of interest, the diagnostic investigation of those patterns can be continued through an expert system tool. This tool guides the analyst through appropriate office and field investigations to identify particular safety concerns at a site by posing a series of detailed questions intended to identify countermeasures that could potentially ameliorate specific accident patterns of interest at the site. These diagnostic questions include both traditional engineering considerations as well as a strong human factors component. Based upon the user’s responses to the diagnostic questions, recommended countermeasures will be identified for further consideration within SafetyAnalyst. The user
has the option to modify the list of recommended countermeasures resulting from the diagnostic questions. The user also has the capability to select countermeasures for further consideration without going through the diagnostic questions.

The final selection of countermeasures as candidates for implementation will be made by the user, not by the software. The logic that identifies appropriate countermeasures will consider the accident patterns and related site conditions investigated in the diagnostic process. The user can then select one or more of the suggested countermeasures for further consideration or can add other countermeasures that they consider appropriate. To aid in this process, a BenefitCost (B/C) calculator is available to the user. The user enters a target percentage reduction in accidents, a countermeasure service life, a rate of return, a desired B/C ratio, and an analysis period; the B/C calculator will estimate the maximum cost for a countermeasure that would provide the desired B/C ratio. This tool is useful to decide the appropriate scale of safety investment at a site (e.g., low-cost, medium-cost, or high-cost countermeasures).

**Economic Appraisal and Priority Ranking Tool**

The purpose of the Economic Appraisal and Priority Ranking tool is to enable the analyst to conduct an economic analysis of a specific countermeasure or combination of countermeasures at a specific site. The tool also assists in cost-effective programming of safety countermeasures across a roadway network. Uses for economic appraisal results include the comparison of alternative countermeasures for a particular site as well as development of improvement priorities across sites. This tool also includes an optimization program that is capable of selecting a set of safety improvements that maximizes the safety benefits of a program of improvements within a user-specified improvement budget.

The user begins an economic appraisal by selecting the countermeasure (or countermeasures) to be considered for implementation at each site. Recommended countermeasures from the Diagnosis and Countermeasure Selection tool, user-specified countermeasures, and any other countermeasures, which are considered appropriate for a specific facility type, are available for the user to select. Economic analysis of specific countermeasures uses default values of accident modification factor, service life, and construction cost. The user can use these default values or provide values more appropriate for their own agency’s experience.

There are several economic criteria and ranking measures available to assess alternative countermeasures. Multiple criteria may be selected for consideration, which allows for the comparison of results from the different approaches. These criteria include the following:

- Cost-effectiveness: dollars spent per accident reduced (i.e., the present value of constructing the countermeasure divided by the total number of accidents reduced)
- EPDO-based cost-effectiveness: dollars spent per weighted number of accidents reduced (i.e., the present value of constructing the countermeasure divided by a weighted estimate of accidents reduced by severity type)
- Benefit-cost ratio: ratio of the monetary present value of the estimated annual accidents reduced to the present value of the construction cost of the countermeasure
- Net benefits: monetary present value of the estimated annual accidents reduced minus the present value of the construction cost of the countermeasure
- Construction costs: present value of the construction cost of the countermeasure
- Safety benefits: monetary present value of the estimated annual accidents reduced
- Total accidents reduced: number of total accidents reduced during the analysis period
- FI accidents reduced: number of fatal and injury accidents reduced during the analysis period
Additionally, the user can customize output to display and rank all countermeasures considered or only the highest ranked countermeasure for each site.

In addition to establishing the priority ranking of countermeasures for each site evaluated, the priority ranking tool enables the user to rank countermeasures across multiple sites when the net benefits economic criterion has been selected. This ranking is accomplished through a mathematical optimization technique called integer programming (IP).

IP is a linear programming technique that maximizes or minimizes an objective function, taking into account integer valued constraints. In the case of this tool, the total net benefits for all sites considered are maximized, subject to the following constraints:

- Only one countermeasure can be selected for each site, including the no-build alternative
- The total construction cost for the above selected countermeasures does not exceed the available budget

The available construction budget is entered by the user at the time of the analysis. The user may also elect to run the optimization with a nonlimiting budget value so that the countermeasures with the highest net benefits are determined for each site.

The computations involved for integer programming are quite laborious and repetitive. Therefore, algorithm options, such as the time to run, iterations used, and tolerance limits for comparisons, are available for the user to adjust within the priority ranking tool.

**Countermeasure Evaluation Tool**

The purpose of the countermeasure evaluation tool is to estimate the safety effect of countermeasures implemented at specific sites. The tool is capable of assessing the safety effectiveness of a single countermeasure at specific sites or the collective effectiveness of a group of countermeasures in which the same countermeasures were implemented at a specified list of sites. In most cases, the effectiveness measures are expressed as a percentage change (decrease or increase) in accident frequencies or in specific target accident types or severity levels. In other cases, the change of interest might be a shift in the proportion of specific collision types or in the distribution of accident severity levels.

The effectiveness of countermeasures is determined through statistical before-after evaluations. SafetyAnalyst performs two basic types of before-after evaluations of implemented countermeasures: (1) estimation of the percent change in accident frequencies due to an implemented countermeasure or (2) estimation of the change in proportion of a target collision type or accident severity level due to an implemented countermeasure. When multiple countermeasures are evaluated, they are analyzed as a single treatment. Thus, a single safety effectiveness value is calculated for the group of countermeasures as a whole. The safety effectiveness of the individual countermeasures is not calculated.

The primary before-after evaluation technique is to estimate the percent change in accident frequency due to an implemented countermeasure. This technique implements an EB approach to compensate for regression to the mean. This technique uses SPFs developed from a set of reference sites similar to the improved site(s) to estimate the change in accident frequency that would have occurred at the improved site(s) had the improvement not been made. The basic steps in the EB approach are as follows: (1) estimation of the number of accidents in the before period, (2) estimation of the number of accidents in
the after period in the absence of a treatment, and (3) comparison of the observed number of accidents after the treatment is implemented to the estimated number of accidents in the after period in the absence of a treatment.

The countermeasure evaluation tool also provides the capability to test for shifts in the proportion of specific target collision types and testing for shifts in the proportion of specific target accident severity levels. For such evaluations, a nonparametric approach is used to assess whether the treatment (i.e., countermeasure) affected the proportion of accidents of the collision type under consideration. In statistical terms, this is done by calculating the average difference in proportions across all sites and a confidence interval around that difference at a pre-specified confidence level (e.g., 90%). The statistical test performed is the Wilcoxon signed rank test, a nonparametric test that does not require that the differences follow a normal distribution. This test is rather conservative; it is also relatively insensitive to outliers in the data.

The primary output results from a countermeasure evaluation include an estimate of the effectiveness, precision estimates of the effectiveness, and indication of statistical significance. For the nonparametric test, the estimated effectiveness is an estimated median treatment effect rather than mean difference in proportions, since the test only uses those sites with an observed non-zero change in proportion.

**SUMMARY AND KEY ADVANTAGES OF SAFETYANALYST**

The FHWA is developing a set of new computer software tools, known as SafetyAnalyst, which can be used by highway agencies for safety management of a roadway system. SafetyAnalyst focuses on identifying the need for improvements at specific highway sites, identifying the most appropriate improvements for those sites, and making cost-effective choices to set priorities among the potential improvements. SafetyAnalyst can also make reliable estimates of the safety effectiveness of countermeasures that are implemented by highway agencies. The key advantages of highway agencies using SafetyAnalyst include the following:

- SafetyAnalyst integrates all parts of the safety management process and automates portions of the process that have been performed manually in the past. This will increase the efficiency with which highway agencies can perform safety management, leading to better decisions at lower total costs.
- SafetyAnalyst applies state-of-the-art analytical procedures in the safety management process. Many of the current analytical procedures used by highway agencies as part of the safety management process are deficient and can be improved. SafetyAnalyst incorporates analytical procedures that are scientifically and statistically sound and that overcome many of the deficiencies of current practice. Thus, SafetyAnalyst provides results that lead to better selections of safety improvement projects.
- SafetyAnalyst has a strong cost-effectiveness component, allowing highway agencies to develop safety improvement programs that provide the maximum safety benefit within any given budget for safety improvements. This can provide assurance to highway agency management and the general public that safety improvement funds are being spent wisely.
- SafetyAnalyst provides safety engineers and planners with all of the information needed to make safety management decisions efficiently, but does not presume to make those decisions for them. While automating the entire safety management process, SafetyAnalyst does not make decisions that require technical expertise and judgment. Highway agencies retain full flexibility to choose projects and safety improvements that best meet the needs of the traveling public.
• *SafetyAnalyst* encourages collection and use of improved highway inventory data. Many highway agencies currently have the inventory data needed to apply *SafetyAnalyst* to roadway segments between intersections. *SafetyAnalyst* can also be applied to safety management of at-grade intersections and interchange ramps where inventories of these features are available. Many highway agencies will have access to improved inventory data in the future through ongoing development of geographic information systems and asset management inventories. *SafetyAnalyst* has the capability to allow highway agencies to take a broader look at the entire highway network during the safety management process than most agencies currently do. By providing a platform for effective use of newly collected data, *SafetyAnalyst* provides an incentive for highway agencies to develop expanded inventory databases for a more comprehensive approach to safety management.

• *SafetyAnalyst* software will be available from the FHWA at no cost to highway agencies. The FHWA will also provide training and technical support.
ACKNOWLEDGMENTS

The development of SafetyAnalyst is being sponsored by the Federal Highway Administration and 20 participating state highway agencies.

REFERENCES