EVALUATION OF HIGHWAY SAFETY PROJECTS

SUMMARY

U.S.DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

OCTOBER 1978

SUMMARY

Introduction

Highway accident statistics indicate that the annual number and rate of traffic accident deaths have declined to the lowest levels since the early 1960's. This, along with the fact that annual vehicle miles of travel have generally increased through the same period, gives an indication that positive gains are being achieved from recent highway safety efforts. In general, programs aimed at improving the safety environment of the highway, the vehicle and the driver are responsible for the increase in highway safety.

Transportation programs administered by the Federal Highway Administration (FHWA) are aimed at reducing traffic accident fatalities, injuries and property damages attributable to highway system failures as opposed to vehicle or driver failures. To create a hazard free highway system, FHWA has a comprehensive set of highway safety programs consisting of a full range of possible projects and improvement types, which includes rail-highway crossing, pavement marking, high hazard and removal of roadside obstacle projects.

On an aggregate basis, safety projects have produced reductions in the number and severity of traffic accidents. However, it is not fully known to what extent individual projects and improvement types contribute to this overall reduction. Thus, the effectiveness of individual projects and improvements need to be determined. This can be accomplished by conducting effectiveness evaluations. In recent times, the need for evaluation is required for all Federal aid safety projects. However, the interpretation of such evaluations are often erroneous due to the selection of an inappropriate experimental plan, lack of statistical testing procedures or misinterpretation of evaluation results. It is important that the quality and completeness with which effectiveness evaluations are conducted be improved to insure that evaluation results are valid and usable to the profession.

Why Evaluate?

The highway safety engineer is constantly faced with crucial decisions involving selection and implementation of safety countermeasures. To facilitate decisions regarding the continuation, addition and deletion of various types of highway safety programs, it is critical that valid evaluations of completed safety projects be conducted. Quantitative answers to whether or not the project is accomplishing its intended purpose, how efficiently the purposes are being accomplished and whether the project is producing unexpected or contrary results are all critical to the decision making process. Without evaluation of individual projects, the effectiveness of highway safety programs cannot be determined. If this determination is not made, limited safety funds may not be allocated to those projects which are most effective in saving lives and reducing injuries and property damage.

Federal-aid requirements make the reporting of accident exposure, frequency, severity and cost data for all types of highway safety projects mandatory. This data is used in the effectiveness evaluation of the Federal-aid highway safety improvement programs on a nationwide basis. However, it is desirable that the State and local agency personnel improve their ability to select and implement those improvements which provide the highest safety pay-off based on evaluation results of past experiences. This manual has been developed to provide both State and local highway engineers and technicians with a methodology for evaluating highway safety projects and improvements.

Evaluation Methodology

A highway safety project, in the context of this evaluation methodology, may be defined as a roadway or roadside safety improvement, implemented to impact the frequency, rate and/or severity of traffic accidents. The improvement of traffic operations may exist as a secondary impact of the project. However, traffic accident reduction must be the primary reason for project implementation. A project may be composed of one or more countermeasures, implemented at an intersection or on an extended roadway section. A project may also consist of several locations, each of which has been treated with a similar countermeasure or set of countermeasures.

Evaluation requires a logical procedure for assessing the effectiveness of a highway safety project. The methodology presented in this manual consists of six functions. Each is formulated into a series of systematic steps which lead the evaluator through the activities and decision making processes of a properly designed evaluation study. The evaluation methodology presented in this manual is based totally on existing state-of-the-art technology and practices. Both a literature review and current practices survey provided the basis for all evaluation functions.

The six functions which comprise the evaluation methodology are:

Function A: Develop Evaluation Plan

Function B: Collect and Reduce Data

Function C: Compare measures of Effectiveness (MOE's)

Function D: Perform Tests of Significance

Function E: Perform Economic Analysis

Function F: Prepare Evaluation Documentation

Function A addresses all necessary planning activities which must be considered prior to performing the evaluation study. The purpose of the project, the evaluation objectives and measures of effectiveness, the analytical framework for the evaluation (experimental plan) and data requirements are examined in this function. The function is designed as a guide for establishing future evaluation activities for current or programmed projects as well as for organizing a plan for evaluating completed projects. Function B provides guidance in the collection and reduction of field data and data which must be obtained from existing sources. Function C presents the various methods for comparing measures of effectiveness according to the experimental plan selected for the evaluation. Function D provides a framework for testing the statistical significance of the changes in the measures of effectiveness (MOE). In Function E, standard economic analysis techniques are performed to enable a fiscal evaluation of project effectiveness. The effectiveness of the project and conclusions on the success or failure of the safety project are documented following the procedure presented in Function F.

Summary of the Evaluation Methodology

A summary of the evaluation methodology is provided in this section. It is intended for use by persons who have completed a thorough coverage of the evaluation methodology as contained in the student manual.

FUNCTION A - DEVELOP THE EVALUATION PLAN

Evaluation studies should follow a detailed evaluation plan. The plan should be developed as a first step in evaluating completed highway safety projects. For future safety projects the evaluation plan should be developed and incorporated with other planning activities.

Step A1 - Select project to be evaluated (pages A.4 - A.8)

More projects may need to be evaluated than can be handled by the resources available to an agency. Therefore, projects should be selected which provide the most useful results to the evaluating agency. The selection criteria recommended should include: 1) Current and future highway safety project efforts, 2) Project implementation dates, 3) Data availability, 4) Sufficiency of accident data and 5) Project purpose.

Determine the purpose of the project (pages A.6 - A.8)

The selection of the experimental plan and identification of data needs depends on the stated purpose of the highway safety project. It is essential, therefore, that the purpose be clearly stated prior to initiating the evaluation.

The purposes may include:

- to reduce accidents (in general or specific types)
- to reduce accident severity (overall or for specific types of accidents)
- to reduce hazard potential

- to improve traffic performance characteristics

The purpose will primarily be based on a review of both the before accident data and the nature of the implemented improvement. List all purposes on the Project Purpose Listing form (Figure S-1, page S.5).

Step A2 . Stratify projects (pages A.8 - A.12).

If the type of project to be evaluated has been applied at several locations, it may be advantageous to aggregate similar projects into groups.

The groups should be similar with respect to countermeasure types and geometric and environmental characteristics of the project sites. Depending on the composition of any group, the evaluation may be performed in one of the following ways:

- by combining all projects together and evaluating the entire group as a single project.

- by evaulating each project within a group and combining the evaluation results.

- by sampling a portion of the group and evaluating on a combined basis. The Project Sampling Worksheet may assist in performing the sampling procedure (Figure S-2, page S.6).

Step A3 . Select evaluation objectives and measures of effectiveness (MOE's) (pages A.12-A.16).

Evaluation objectives are necessary to test the effect of the improvement on the safety characteristics of the highway location.

Four fundamental objectives should be specified for all evaluations. They are:

- determine the effect of the project on total accidents.

- determine the effect of the project on fatal accidents.

- determine the effect of the project on injury accidents.

- determine the effect of the project on property damage accidents.

Additional objectives may be selected which relate specifically to the project being evaluated. These should generally relate to one or more of the project purposes.

PROJECT PURPOSE LISTING

Evaluation No. ____________________

Date/Evaluator ____________________ Checked by ____________________

Project No. ____________________

Project Description and Location(s) ____________________

____

Countermeasure(s)/Codes ____________________

____

____

Project Purpose	Justification
1.	1.

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FIGURE S-1

PROJECT SAMPLING WORKSHEET

Evaluation No. ____________________________

Date/Evaluator ___________________________ Checked by ________________

Departure From Mean, Error: ____

Sample Size: ____________ Sites

Site No.	Location	Total Accidents Xi	$(X_i-\mu)^2$
$n_g=$		$\Sigma X_i =$ $\mu =$ $\sigma =$	$\Sigma (X_i-\mu)^2$ $=$

$$\mu = \frac{\Sigma X_i}{n_g} \qquad \sigma = \sqrt{\frac{\Sigma (X_i-\mu)^2}{n_g-1}} \qquad n_s = \frac{4\ \sigma^2}{\text{Error}^2}$$

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FIGURE S-2

Appropriate MOE's are to be stated for each objective to provide quantifiable units of measurement. Recommended exposure factors are provided in Table S-1 (pages S.8, S.9).

All objectives and MOE's are to be recorded in the Objective and MOE Listing form (Figure S-3, page S.10).

Step A4 . Select the experimental plan (pages A.16-A.28).

An experimental plan is an analytical evaluation framework which can be used to measure the impact of the highway safety project in terms of the selected MOE's. Each plan attempts to accomplish the same objectives. That is, to compare the accident experience after project implementation (A_{PF} or A_{PR}) with the expected accident experience had no improvement been implemented (E_F or E_R). In order to determine this expected value each plan is based on different underlying assumptions. The experimental plan should be consistent with the nature of the project and the completeness and availability of data.

The four experimental plans and the corresponding assumptions are:

A. Before and after study with control sites.

- The accident experience at the project site, in the absence of the improvement, is similar to the accident exprience at the control site(s)

- Any difference in the accident experience between the project and control sites is attributable to the project.

B. Before and after study.

- The accident experience before and after implementation remains at the same level in the absence of the improvement.

- Any difference in the accident experience between the before and after period is attributable to the project.

C. Comparative parallel study.

- The accident experience at the project site and the control site(s) is similar in the absence of the improvement.

Project Type	Recommended Exposure Factor*
1. Intersection Projects	
10-Channelization, including left turn bays	V
11-Traffic Signals, installed or improved	V
12-Combination of 10 and 11	V
13-Sight distances improved	V
19-Other intersection work (except structures)	V
2. Cross Section Projects	
20-Pavement widening, no lanes added	VM
21-Lanes added, without new median	V or VM
22-Highway divided, new median added	V or VM
23-Shoulder widening or improvement	VM
24-Combination of 20,21,22 and 23	V or VM
25-Skid Treatment/Grooving	VM
26-Skid Treatment/Overlay	VM
27-Flattening and/or clearing of side slopes	V or VM
29-Other cross section work or combinations of above categories	V or VM
3. Structures	
30-Widening existing bridge or other major structure	V
31-Replacing of bridge or other major structure	V
32-Construction of new bridge or major structure (except to eliminate a railroad grade crossing or one for pedestrians only)	V
33-Construction or improvement of minor structure	V
34-Construction of pedestrian over- or under-crossing	V
39-Other Structure work	V

*V = number of vehicles
VM= vehicle-miles of travel

Table S-1: Recommended Exposure Factors

Project Type	Recommended Exposure Factor
4. Alignment Projects	
40-Horizontal alignment changes (except to eliminate highway grade crossing, Code 52)	V or VM
41-Vertical alignment changes	V or VM
42-Combination of 40 and 41	V or VM
49-Other alignment work	V or VM
5. Railroad Grade Crossing Projects	
50-Flashing lights replacing signs only	V
51-Elimination by new or reconstructed grade separation	V
52-Elimination by relocation of highway or railroad	V
53-Illumination	V
54-Flashing lights replacing active devices	V
55-Automatic gates replacing signs only	V
56-Automatic gates replacing active devices	V
57-Signing and/or marking	V
58-Crossing surface improvement	V
59-Other railroad grade crossing improvement	V
6. Roadside Appurtenances	
60-Installation or upgrading of traffic signs	V or VM
61-Breakaway sign or lighting supports	V or VM
62-Installation or improvement of road edge guardrail	V or VM
63-Installation or improvement of median barrier	V or VM
64-Installation of striping and/or delineators	V or VM
65-Roadway lighting installation	V or VM
66-Improvement of drainage structures	V or VM
67-Installation of fencing	V or VM
68-Impact attenuators	V
69-Other roadside appurtenances	V or VM

Table S-1: Recommended Exposure Factors (Cont.)

OBJECTIVE AND MOE LISTING

Evaluation No. ____________________

Date/Evaluator ____________________ **Checked by** ____________________

Evaluation Objective	Measure of Effectiveness (MOE)
Determine the effect of the project on: (fundamental)	Percent change in: (check one) Rate ________ or Frequency ________ (fundamental)
1. Total Accidents	1. Total Accidents/
2. Fatal Accidents	2. Fatal Accidents/
3. Injury Accidents	3. Injury Accidents/
4. PDO Accidents	4. PDO Accidents/
(project purpose)	(project purpose)
5.	5.

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FIGURE 3

- Any difference in the accident experience between the project site and control site(s) is attributable to the project.

D. Before, during and after study.

- The accident experience before, during and after implementation remains at the same level in the absence of the improvement.

- Any differences in the accident experiences between the before and during, the during and after, and the before and after periods is attributable to the project (or absence of it).

Figure S-4 (page S.12) illustrates the selection criteria and experimental plan selection process.

If plan A or B is selected, several years of the total accident MOE should be analyzed to investigate the feasibility of using trend analysis.

Step A5 . Determine the data to be collected (pages A.28-A.30).

The evaluation of highway safety projects and improvements requires data for comparison of MOE's interpretation of project effectiveness and economic analysis. The nature and extent of these data are dependent on the previous decisions made in this function, as well as on the ability of the evaluator to identify other safety aspects which may be impacted (positively or negatively) as a result of the project.

All data required to conduct the evaluation should be established based on:

- objectives and MOE's

- anticipated impacts

- project cost

- environmental or locational characteristics which may be affected by the project

As a minimum, the following data should be collected:

- complete accident history for at least three years before and after implementation

- vehicle exposure data

- project cost

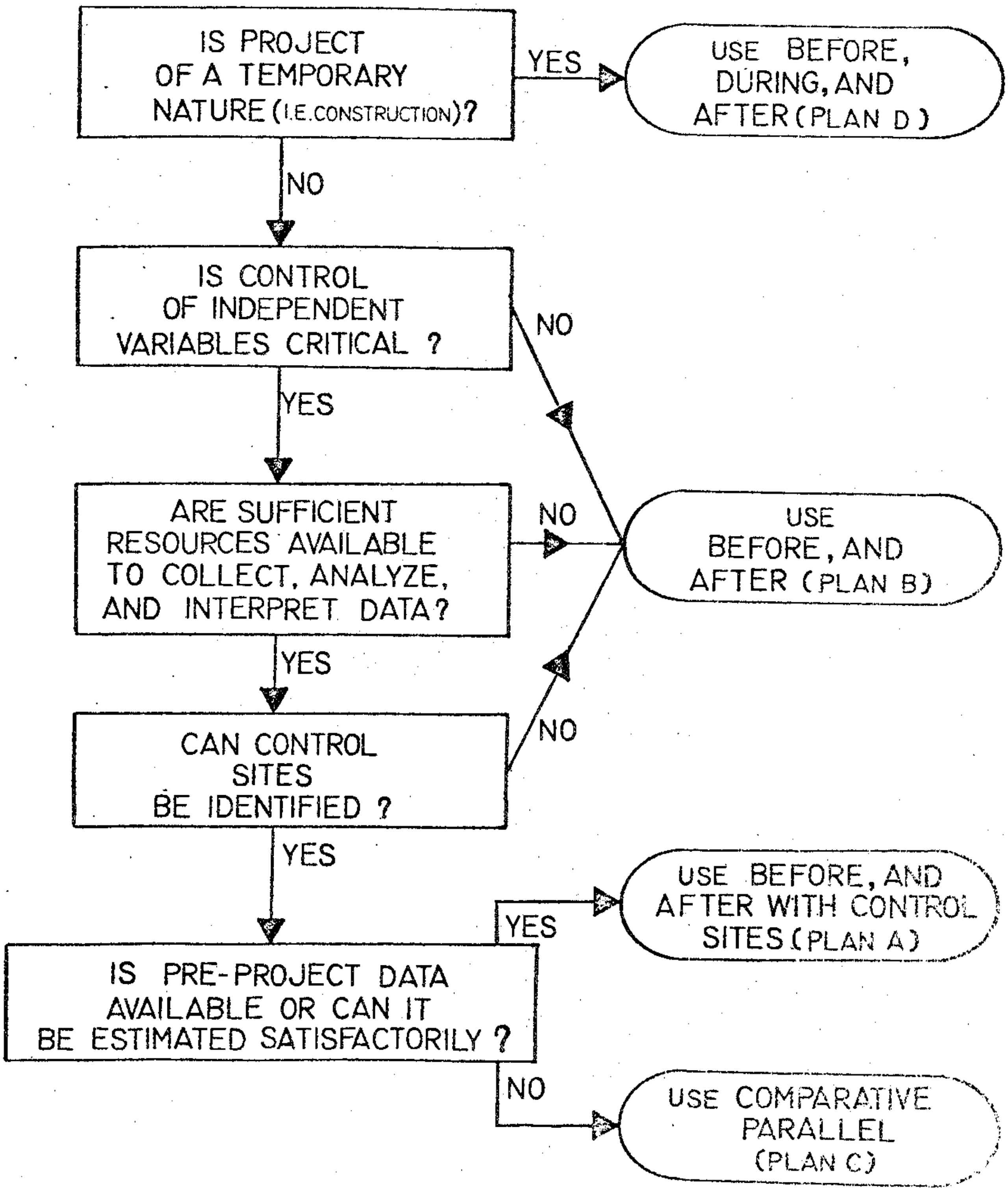

Figure S-4 Experimental Plan Selection Process

Step A6 . Determine the magnitude of data requirements (pages A.30- A.32).

The experimental plan selected in Step A4 partially determines the magnitude of data to be collected at various locations and points in time.

An estimate of the magnitude of the data collection effort is necessary to complete the detailed data collection scheme. Data analysis periods should be specified along with the required number of data sets for each MOE. Sample size, accuracy requirements and study period lengths must be specified using the "Manual of Traffic Engineering Studies"or other standard traffic engineering references. The Data Requirements Table (Figure S-5, page S.14) should be used to record data needs and magnitudes.

FUNCTION B - COLLECT AND REDUCE DATA

Accident severity, exposure and other traffic data are the basic inputs for evaluating the effectiveness of any safety improvement. The nature and magnitude of data requirements are dependent on the objectives of the evaluation, the MOE's and the experimental plan, each of which has been established in Function A.

Data collection activities should be performed using traffic engineering procedures and use appropriate equipment to ensure data accuracy and consistency. References such as the "Manual of Traffic Engineering Studies" are recommended in this respect.

Step B1 . Select control sites (pages B.2-B.4).

The selection of control sites is necessary only when the seleted experimental plan is either "The Before and After Study with Control Sites" (Plan A) or "The Comparative Parallel Study" (Plan C). For these plans, the evaluator must select one or more locations to serve as control sites.

Control sites must be similar to the project site in terms of MOE's, geometric and other environmental characteristics.

Step B2 . Collect before data (pages B.4-B.7).

The boundaries of the project site should be carefully delineated before data collection. Within these boundaries, accident data should be obtained from computerized accident reports. Collision diagrams may facilitate the identification of specific accidents (related to objectives and MOE's) to be considered in the evaluation. Environmental and highway features inventories should also be performed to detect possible locational changes which may affect project effective-

DATA REQUIREMENTS LISTING

Evaluation No. ________________

Date/Evaluator ________________ Checked by ________________

Experimental Plan ________________________________

Data Needs	Magnitude (Number of Sites, Time Period, Dates)
1.	1.

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FIGURE S-5

ness. The Accident Summary Table and Exposure Worksheet (Figures S-6, page S.16 and S-7, page S.17) should be used to tabulate these data.

Step B3 . Collect after data (pages B.7-B.9).

Data collection activities similar to those used in the before period should be used for after data collection. However, a 6 to 8 week period following implementation should be allowed before traffic performance data is collected. If plan D (before, during and after study) is used, data representing the temporary project period should be collected.

FUNCTION C - PERFORM COMPARISONS OF MOE'S

Step C1 . Prepare data summary tables (page C.2-C.6).

All accident, severity and traffic performance variables which comprise the list of MOE's should be tabulated to facilitate the comparison of MOE's according to the selected experimental plan. Data related to the MOE's should be tabulated in the MOE Data Comparison Worksheet (Figure S-8, page S.18).

Step C2 . Calculate the percent change in the MOE's (pages C.6-C.22).

This step addresses the determination of the percent change in each MOE and the expected accident frequency (E_F) at the project site if no improvement had been made.

The percent change requires a two-step process. 1) An estimate is made of the expected value of the MOE if the project has not been implemented. This estimate is based on the underlying assumption to each experimental plan. 2) The percent change is computed by comparing the actual (observed) value of the MOE following project implementation and the expected value of the MOE.

Since MOE's may be accident frequencies or rates, the expected value of the MOE if an improvement had not been made may also be frequencies or rates. When calculating expected frequency-related MOE's, project and control site before accident frequencies must be adjusted for traffic volume changes and unequal time lengths between the before and after periods. When traffic volumes are not available or can not be estimated by the procedure given in Function C (pages C.15-C.16), this adjustment can not be made. The adjustment is not necessary for calculating the expected values for rate-related MOE's.

The expected accident frequency (E_F) may be calculated directly if the MOE is frequency-related or may be calculated from the expected rate-related MOE (E_R). The expected accident frequency is an input to the statistical testing proce-

ACCIDENT SUMMARY TABLE

Evaluation No. ______________

Date/Evaluator ______________ **Checked by** ______________

Data Source ______________

Location ______________ Check one: [Project Site(s): Before ______ or After ______]

Time Period ______ **to** ______ [Control Site(s): Before ______ or After ______]

Accident Category	Total Accidents	Fatal Acc.	Fatalities	Injury Acc.	Injuries	PDO Acc.	Invol.
Surface Condition							
Dry							
Wet							
Snowy/Icy							
Other							
Total							
Accident Type							
Overturn							
Collision with:							
Motor veh.							
Pedestrian							
Pedal cycle							
Animal							
Fixed Object							
Other							
Total							
Two Veh. Accidents							
Opposite Direction							
Same direction							
One Veh. stopped							
One Veh. entering ramp							
One Veh. exiting ramp							
Other							
Total							
Two Veh. Accident Types							
Head-on							
Rear-end							
Sideswipe							
Angle							
Other							
Total							

Acc. = Accidents
Invol. = Number of Vehicles Involved in PDO accidents.

FIGURE S-6

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EXPOSURE WORKSHEET

Evaluation No. ____________________

Date/Evaluator ____________________ Checked by: ________________

Data Source ____

Location ____

Time Period ______________ to ______________________

Check one: Project Site(s) Before ________ or After ________

Control Site(s) Before ________ or After ________

Site	Project* Length	Length of Time Period	AADT	Exposure Veh.____ or Veh. Mi.____
1.	1.	1.	1.	1.
Total				

*For vehicle-mile units of exposure (only)

FIGURE S-7

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MOE DATA COMPARISON WORKSHEET

Evaluation No. ______________________

Date/Evaluator ______________________ **Checked by** ____________

Experimental Plan ______________________________________

	Control		Project		Expected After Rate ___ or Freq. ___	Percent Reduction (%)
	Before	After	Before	After		
MOE Data Summary	(B_{CF})	(A_{CF})	(B_{PF})	(A_{PF})		
Accidents:						
(Fundamental)						
Total Accidents						
Fatal Accidents						
Injury Accidents						
PDO Accidents						
(Project Purpose)						
Exposure						
units: ___V, or ___VM						
MOE Comparison Rate ____ or Frequency ____	$B_{C\_}$	$A_{C\_}$	$B_{P\_}$	$A_{P\_}$	E_	(%)
Total Accidents/						
Fatal Accidents/						
Injury Accidents/						
PDO Accidents/						

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FIGURE S-8

dure for accident changes and must be calculated for all evaluations.

If the MOE accident data indicates that there may be an increasing or decreasing trend over time, a regression technique should be considered for use to determine the expected value of the MOE. The least square regression technique is recommended for the trend analysis of the MOE.

Two tests should be performed to determine whether an observed trend is significant or is due to random variations in the data. The first test should be an evaluation of the correlation coefficient (r^2). If the correlation coefficient, r^2 is greater than .8, then use of the regression results should be considered. If r^2 is less than .8, then the average (single point) value of the MOE should be used.

The second test is a determination of the significance of the regression coefficient (b). This test is used to determine whether the slope of the line is significantly different from zero. If the value of "t" from this equation exceeds the value in Table S-2 (page S.20), then the regression equation should be used to obtain the estimated value of MOE. The Linear Regression Summary Table will assist in performing the above tests (Figure S-9, page S.21).

Linear regression is applicable to the before and after study with control sites plan (plan A) and the before and after study (plan B). When used with plan A, the trend equation should be based on control site MOE's for the entire analysis period (before and after) and project site MOE's for the before period. When used with plan B, use only project site MOE's for the before period.

The MOE Data Comparison Table shown in Figure S-8 (page S.18) should be used to tabulate the values used to calculate the expected MOE's and the percent change for each MOE.

FUNCTION D - PERFORM STATISTICAL TEST OF SIGNIFICANCE

The observed percent change in each of the MOE's must be analyzed to determine whether the change occurred by chance or because of the project.

Step D1. Test accident MOE variables (pages D.3-D.8.)

The Poisson technique is used to determine whether an observed reduction in accident frequency constitutes a significant reduction within a specified degree of confidence. This technique is based on the fact that differences between the mean value of two samples randomly selected from a common distribution have known characteristics. If, by using the Poisson technique, it is concluded that the two samples are from diff-

Table S-2 "t" Statistic for Various levels of Confidence and Sample Sizes

Years	"t" Values at Level of Confidence		
n	.8	.9	.95
4	0.941	1.533	2.132
6	0.906	1.440	1.943
8	0.899	1.397	1.860
10	0.879	1.372	1.812
12	0.873	1.356	1.782
14	0.866	1.345	1.761

LINEAR REGRESSION WORKSHEET

Evaluation No. ______________________

Date/Evaluator ______________________ **Checked by** ______________________

Check one: Frequency MOE _____ **or Rate MOE** _____

X_i Eval. Period (Yrs.) (1)	Y_i Meas. of MOE (2)	$X_i - \bar{X}$ Col. (1)-$\bar{X}$ (3)	$(X_i - \bar{X})^2$ $(\text{Col. }(3))^2$ (4)	$Y_i - \bar{Y}$ Col. (2)-$\bar{Y}$ (5)	$(X_i - \bar{X})(Y_i - \bar{Y})$ Col. (3) X Col. (5) (6)	X_i^2 $(\text{Col. }(1))^2$ (7)	Y_i^2 $(\text{Col. }(2))^2$ (8)	$X_i Y_i$ Col. (1) X Col. (2) (9)
Σ = $\bar{X}$ =	Σ = $\bar{Y}$ =		Σ =		Σ =	Σ =	Σ =	Σ =

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FIGURE S-9

erent distributions, then it can be said that the implemented project affected a change in the tested MOE. If, on the other hand, the conclusion is that the samples are from the same distribution, then it can be stated that the project had no effect on the tested MOE (Figure S-10, page S.23).

Confidence level selection is dependent on the initial cost of implementing the project. High levels of confidence such as 95% or 99% are justified for high cost projects whereas less expensive projects justify the use of lower levels such as 80% or 90%.

Figure S-11 (page S.24 shows a Poisson chart for various levels of confidence. The ordinant of Figure S-11 is entered with the percent change in the MOE as determined in Function C. The expected number of accidents in the before period is entered on the horizontal axis of the chart. For preliminary evaluations (conducted at the end of the first and second year following project implementation), the number of accidents should be in terms of before period accidents per year. For final evaluations (conducted for at least three years of after data), the number of accidents should be in terms of total accidents for the entire before period.

Step D2. Perform other statistical tests (pages D.9-D.11).

MOE's for a highway safety project may be related to other than accident variables. Therefore, statistical tests are, provided for use in evaluating the significance of changes in MOE's related to traffic performance characteristics. The statistical tests include:

- test of proportions for testing the significance of change between the two count data sets (discrete data)
- t-test for testing the significance of change between two continuous data sets
- F-test for testing the significance of change between variances of two data sets

FUNCTION E - PERFORM ECONOMIC ANALYSIS

For the purpose of this manual present worth of benefits and costs and equivalent uniform annual benefits and costs will be the only approaches considered.

Step E1. Select economic analysis technique (pages E.2-E.3).

An economic analysis should be performed whenever a statistically significant reduction in an MOE was observed in previous Function D.

STATISTICAL TEST WORKSHEET

Evaluation No. ________________________________

Date/Evaluator ____________ Checked by ____________________

Confidence Level ____________ Statistical Test Technique ____________

Evaluation Objective	After Frequency ____ Years		Percent Reduction		Significant For ____ yrs
	Observed (A_{PF})	Expected (E_F)	Observed	Required	Yes or No*
(Fundamental)					
Total Accidents					
Fatal Accidents					
Injury Accidents					
PDO Accidents					
(Project Purpose)					

* Too small to test

FIGURE S-10

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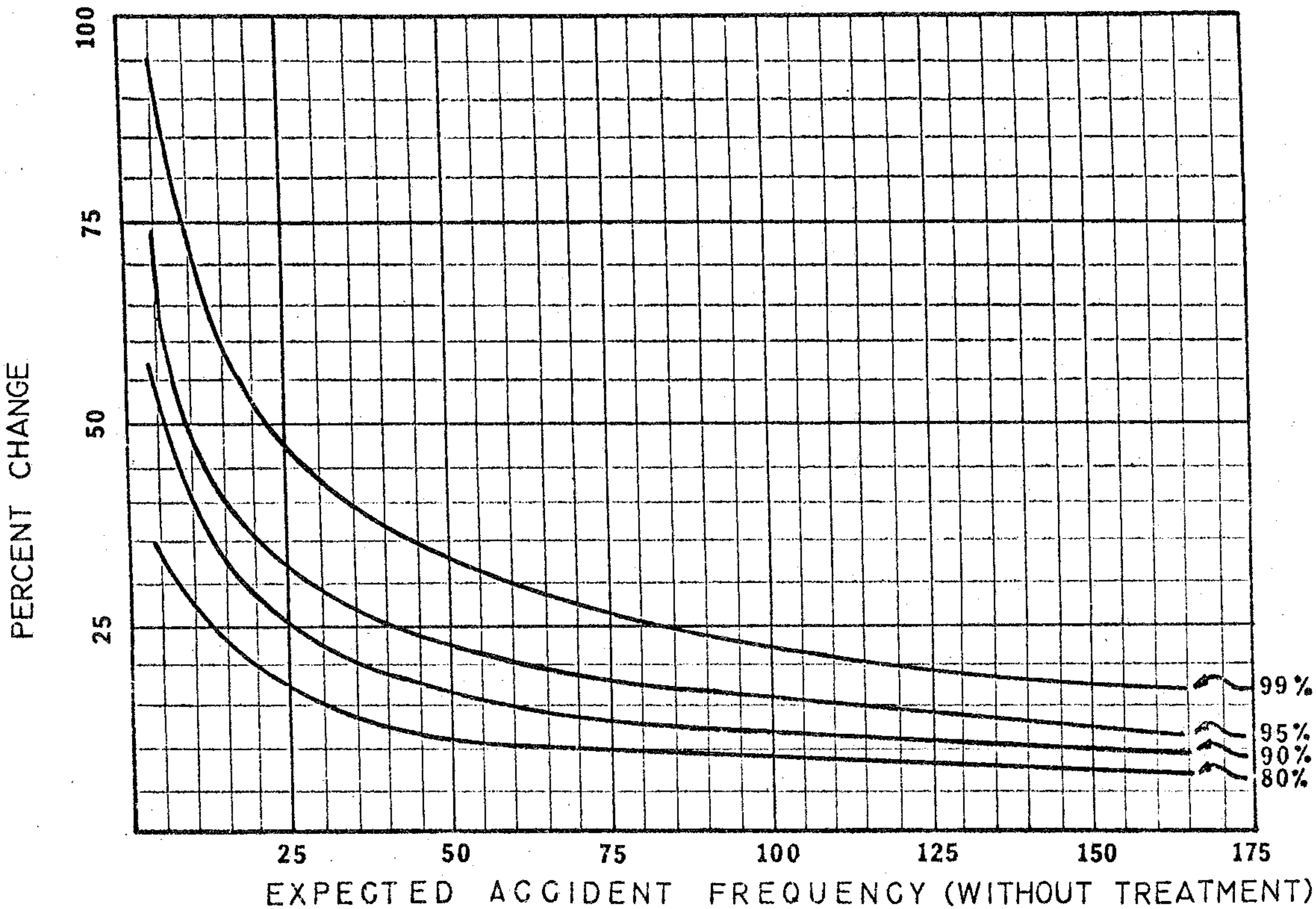

Figure S-11 Poisson Curves

The benefit/cost (B/C) ratio technique should be used when the evaluating agency has an established set of accident cost values. Also, if the MOE of major interest is related to accident severity, the B/C technique provides the most meaningful results since reductions in accident severity categories are the primary measures of economic effectiveness for the technique.

When accident cost figures are not available for use by the agency, the cost/effectiveness (C/E) technique is appropriate. Also when the MOE of major interest is related to specific accident types (as opposed to severity), the C/E technique provides the most meaningful results since the economic effectiveness is measured by the cost of preventing one accident and does not necessarily relate to accident severity.

Step E2. Perform the benefit/cost ratio technique (pages E.3-E.14).

The benefit/cost method may be performed for either individual projects or for the project groups established in Function A. The B/C technique may be performed in two ways; using equivalent uniform annual costs and benefits or using present worth of costs and benefits. Either method is capable of valid results. However, for projects consisting of countermeasures with unequal service lives, the use of present worth of costs and benefits is not appropriate. Equal or unequal service life of countermeasures may be used in with equivalent uniform annual costs and benefits.

The B/C technique consists of the following steps:

- determine initial implementation costs.
- determine net annual operating and maintenance costs.
- determine the annual safety benefits in terms of the number of fatal, injury and property damage accidents prevented.
- assign a dollar value to each benefit category. Recent NHTSA accident cost figures are $287,175, $3,185 and $520 per fatality, injury and property damage involvement, respectively. NSC accident cost figures are $125,000, $4,700 and $670 for fatal, injury and property damage accidents, respectively. Any other set of costs may be used.
- estimate the service life (see Appendix VIII, page AP.40).

- estimate the salvage value.

- determine an interest rate.

- calculate the components of the B/C ratio

The B/C Worksheet (Figure S-12, pages S.27-S.28) should be used to perform the analysis.

Step E3 . Perform the cost/effectivenss technique (pages E.15-E.16).

The cost/effetiveness (C/E) technique may be calculated in two ways; using equivalent uniform annual costs or using present worth of costs. For projects consisting of countermeasures with unequal service lives, do not use present worth of costs. Equivalent uniform annual costs are appropriate for both equal and unequal service lives.

Benefits are expressed in terms of the number of accidents prevented and are not given a monetary value.

The following procedure is used:

- determine initial implementation costs.

- determine net annual operating and maintenance costs.

- determine annual safety benefits in terms of the average number of acccidents prevented per year since project implementation.

- estimate service life (see Appendix VIII, page AP.20).

- estimate salvage value.

- determine an interest rate.

- calculate the components of the C/E value.

The C/E Worksheet (Figure S-13, pages S.29-S.30) should be used in performing the economic analysis.

FUNCTION F - PREPARE EVALUATION DOCUMENTATION

The evaluator has determined the statistical significance of the effectiveness and economic impact of the highway safety project. The evaluator should now review all activities of the evaluation study to determine the appropriateness of utilizing the results and other findings for future highway safety decisions.

B/C ANALYSIS WORKSHEET

Evaluation No:

Project No:

Date/Evaluator:

1. Initial Implementation Cost, I: $ ____________

2. Annual Operating and Maintenance Costs Before Project Implementation: $ ____________

3. Annual Operating and Maintenance Cost After Project Implementation: $ ____________

4. Net Annual Operating and Maintenance Costs, K (3-2): $ ____________

5. Annual Safety Benefits in Number of Accidents Prevented:

Severity	Expected - Actual = Annual Benefit
a) Fatal Accidents (Fatalities)	
b) Injury Accidents (Injuries)	
c) PDO Accidents	

6. Accident Cost Values (Source ____________):

Severity	Cost
a) Fatal Accident (Fatality)	$
b) Injury Accident (Injury)	$
c) PDO Accident	$

7. Annual Safety Benefits in Dollars Saved, $\bar{B}$:

5a) x 6a) =

5b) x 6b) =

5c) x 6c) =

Total = $

Figure S-12 Sample B/C Analysis Work Sheet

8. Services life, n: ______________ yrs

9. Salvage Value, T: $ ______________

10. Interest Rate, i: ________ % = 0.__________

---

11. EUAC Calculation:

CR_n^i = ___________

SF_n^i = ___________

EUAC = $I\ (CR_n^i) + K - T\ (SF_n^i)$

12. EUAB Calculation:

EUAB = $\overline{B}$

=

13. B/C = EUAB/EUAC =

---

14. PWOC Calculation:

PW_n^i =

SPW_n^i =

PWOC = $I + K\ (SPW_n^i) - T\ (PW_n^i)$

15. PWOB Calculation:

PWOB = $\overline{B}(SPW_n^i)$

16. B/C = PWOB/PWOC =

Figure S-12 Sample B/C Analysis Work Sheet (Cont'd.)

C/E ANALYSIS WORKSHEET

Evaluation No:

Project No:

Date/Evaluator:

1. Initial Implementation Cost, I: $ ______

2. Annual Operating and Maintenance Costs Before Project Implementation: $ ______

3. Annual Operating and Maintenance Costs After Project Implementation: $ ______

4. Net Annual Operating and Maintenance Costs, K (3-2): $ ______

5. Annual Safety Benefits in Number of Accidents Prevented, $\overline{B}$: ______

Accident Type	Expected	- Actual	= Annual Benefit
Total	______	______	______
			= ______

6. Service Life, n: ______ yrs.

7. Salvage Value, T: $ ______

8. Interest Rate: ______ % = 0. ______

9. EUAC Calculation:

CR_n^i = ______

SF_n^i = ______

$$EUAC = I\ (CR_n^i) + K - T\ (SF_n^i)$$

=

Figure S-13 Sample C/E Analysis Work Sheet

10. Annual Benefit:

$\bar{B}$ (from 5) =

11. C/E = EUAC/$\bar{B}$ =

12. PWOC Calculation:

PW_n^i= ____________

SPW_n^i= ____________

PWOC= $I + K\ (SPW_n^i) - T\ (PW_n^i)$

13. Annual Benefit

n (from 6) = yrs.

$\bar{B}$ (from 5) = accidents prevented per year

14. C/E = $PWOC(SF_n^i)/\bar{B}$

Figure S-13 Sample C/E Analysis Work Sheet

Step F1. Organize evaluation study materials (pages F.2-F.3).

The final determination of the effectiveness of the project and the validity of the evaluation study requires all data and findings to be brought together to facilitate a systematic review.

The listings, forms, worksheets, data, calculations, intermediate documentation and decision criteria developed over the course of the evaluation study must be organized to facilitate reference to all elements of the study and allow the evaluator to arrive at the final conclusions regarding the effectiveness of the project. Figure S-14, (page S.32) lists the various elements of the evaluation study which must be available to the evaluator for final documentation.

Step F2. Examine effectiveness (page F.3).

Assess project in terms of its degree of success. The effectiveness of the project is primarily dependent on the decisions and calculations made during the comparison of MOE's statistical testing and economic analysis. Therefore, a careful review of the activities within Functions C, D, and E is warranted.

Step F3. Determine reasons for project failure (page F.3).

Critically review each aspect of the evaluation process for appropriateness. If any of MOE's showed unexpected change, or resulted in extremely unusual economic responses, the evaluator should investigate the reasons for such unexpected results. Many failures are not the result of the project but rather a consequence of an inappropriate decision on the part of the evaluator or implementing agency, inadequate sample size (i.e, the number of accidents of a specific type is too low to statistically evaluate) or simply the project was inappropriate for the identified safety problem, or problem identification was inaccurate.

Step F4. Build the aggregate database (page F.3).

The aggregate database should be developed to assist the agency in selecting remedial countermeasures for specific highway safety problems and supplying expected accident reduction factors which may be utilized in evaluating alternative countermeasures for implementation. If all elements of the evaluation are determined to be appropriate, the accident reductions (or increases) which were statistically significant at the selected level of confidence should be included into the aggregate database of project effectiveness. The database should stratify only significant reductions and increases in accident and severity by improvement type, traffic volume ranges, facility type, urban vs. rural setting and other stratifications of interest to the evaluating agency.

- ____ Justification Statement
- ____ Project Description
- ____ Funding Level
- ____ List of Project Purposes (Function A)
- ____ List of Evaluation Objectives and MOE (Function A)
- ____ Experimental Plan Uses with Justification (Function A)
- ____ List of Data Variables (Function A)
- ____ List of Control Sites with Selection Criteria (Function B)
- ____ Raw Data (Function B)
- ____ Reduced Data (Function B)
- ____ Data Collection Techniques Used (Function B)
- ____ Data Collection Personnel
- ____ Parametric Comparison Tables (Function C)
- ____ Percent Changes in MOE with Calculations (Function C)
- ____ Statistical Test Utilized (Function D)
- ____ Statistical Results (Function D)
- ____ Economic Data Including Implementation, Operation, Maintenance, etc. (Function E)
- ____ Economic Analysis Technique Used with Assumptions (Function E)
- ____ Economic Analysis Results (Function E)

Figure S-14 Evaluation Study Materials Checklist

Step F5. Discuss and document the evaluation study results (F.8-F.9).

Document all evaluation study results in the final report and disseminate to individuals who will benefit from such results.

The Final Report Form shown in Figure S-15 (pages S.34-S.37) should be completed for the final report.

FINAL REPORT

Introduction

Evaluation No:

Project No:

Date/Evaluator:

Project Location(s):

Countermeasure(s):

Code(s):

Initial Implementation Cost:

Annual Maintenance Cost:

Executive Summary

List Major Findings and Conclusions of the Evaluation Study.

Figure S-15 Final Report Form

Identification and Discussion of the Problem

Administrative Evaluation

List personnel and role in the evaluation study.

Person	Role

Estimate man-hours devoted to the evaluation by activity.

Activity	Man-hours
. Data Collection and Reduction	
. Data Analysis	
. Report Writing	

Time period over which the evaluation spanned:

Estimated cost of evaluation study:

Effectiveness Evaluation

List purposes:

Figure S-15 Final Report Form (Cont'd.)

List objectives and MOE's

List experimental plan used:

Discuss data collection activities, techniques, equipment used, analysis periods.

List % change in each MOE and statistical significance at selected level.

Discuss economic analysis technique used and results.

Figure S-15 Final Report Form (Cont'd.)

Discuss problems encountered, conclusions and recommendations for future evaluation studies.

Figure S-15 Final Report Form (Cont'd.)