SCHOOL OF
CIVIL ENGINEERING

INDIANA
DEPARTMENT OF TRANSPORTATION

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-91/11

Final Report

ACCIDENT REDUCTION FACTORS FOR INDIANA

Daniel J. Ermer
Jon D. Fricker
Kumares C. Sinha

PURDUE UNIVERSITY

JOINT HIGHWAY RESEARCH PROJECT

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TO: K. C. Sinha, Associate Director
Joint Highway Research Project

FROM: J. D. Fricker, Research Engineer
Joint Highway Research Project

May 29, 1991
Revised April 21, 1992
Project No.: C-36-59Z

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Attached is the Revised Final Report on the HPR Part II Study entitled, "Development of Accident Reduction Factors for Indiana." This report, presenting the results of the study, was prepared by Daniel Ermer under my direction and that of Prof. K. C. Sinha.

The report is forwarded for acceptance by INDOT and FHWA in fulfillment of the objectives of the research.

Respectfully submitted,

Jon D. Fricker

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Final Report

ACCIDENT REDUCTION FACTORS FOR INDIANA

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16. Abstract

This report presents the results of a study conducted to develop appropriate accident reduction factors associated with various highway improvement projects in Indiana. The factors were developed through a before-and-after analysis of accident data from 1983 to 1987.

Disclaimer: This report presents the results of statistical analyses applied to available data. The accident reduction factor values do not imply any endorsement of any particular project types by the Federal Highway Administration or the Indiana Department of Transportation or the Joint Highway Research Project of Purdue University.

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CHAPTER 1. INTRODUCTION

An Accident Reduction Factor is simply a measure of the effectiveness of an improvement in reducing the number of accidents at a location, or group of locations of the same improvement type. Accident reduction factors are often used to estimate user benefits due to reduced accidents and are a key portion of any program to optimize the use of safety funds.

Currently the Indiana Department of Transportation (INDOT) uses reduction factors developed outside Indiana. However, there has been some concern over the applicability of these factors to Indiana highways. A research project was commissioned to develop reduction factors from Indiana construction and accident records. This report is the distillation of that research and it is organized as discussed below.

Chapter 2 of this report contains the literature review for this research project and discusses some of the methods available for calculating accident reduction factors. Methods discussed are the benefit-cost ratio, the cost-effectiveness ratio, the percentage reduction method, and the adjusted percent reduction method.

Chapter 3 introduces the steps used to identify improvement types that would be investigated for this study, the construction contracts associated with those improvement types, the identification of an improvement site for an automated search of the Indiana State Police accident records, and the scheme used to search the accident records.

Chapter 4 describes the statistical analysis performed on the accidents extracted from the data, the caveats associated with the chosen model (a before and after study), and the formulas used to perform the analysis.

Chapter 5 contains the results of the analysis for the thirty-eight improvement types chosen for study and offers comments about those results; and Chapter 6 contains the conclusions and recommendations that can be made from this research study, as well as suggestions for future research.

CHAPTER 2. METHOD REVIEW

An accident reduction factor is an attempt to quantify the effectiveness of an improvement in reducing either the number or the severity of accidents at a location. Several methods are in use to calculate the safety impact of an improvement program, either indirectly (through benefit-cost or cost-effectiveness ratios) or directly (through accident reduction, or adjusted reduction methods). This report is concerned with the latter two methods.

Accident Reduction Method

$$Reduction\ Factor = \frac{NAB - NAA}{NAB}$$

NAB and NAA are defined to be the number of accidents occurring at an improvement site before and after (respectively) the improvement was constructed.

This method of calculating accident reduction factors computes the fraction of reduction in the number of accidents that occurred at a site after an improvement was implemented. This method is useful because no costs need to be calculated (as in the indirect methods) to determine the effectiveness of a project. However, some adjustment should be made to account for traffic growth, such as in the following method (Box and Oppenlander 1976).

Adjusted Percent Reduction Method

$$Adjusted\ Reduction\ Factor = \frac{(NAB/fb) - (NAA/fa)}{(NAB/fb)}$$

NAB and NAA are defined as above and fb and fa are defined to be adjustment factors applied to the numbers of accidents, usually developed from changes in traffic volumes at the improvement site.

This method computes a fraction of reduction of accidents at a site but adjusts for growth in traffic volume (Kaji 1980). Kaji used this method in previous research for the Indiana State Highway Commission when he developed 22 accident reduction factors from Indiana data as part of his cost-effectiveness approach for evaluating safety improvements. This is the most appropriate method for this study, because the accuracy of the accident reduction factor is improved by adjusting it for traffic growth.

Unfortunately, a large quantity of data is needed to achieve the desired accuracy with this method (ADT values) and these data are not available in sufficient quantity or quality. Consequently, an alternate volume adjustment method was considered as suggested by INDOT personnel.

The suggested method is based on the known value of Indiana's statewide twenty year traffic growth factor (1.875). This means that in twenty years INDOT expects 1.875 times the current amount of traffic on its roads. Next the nineteenth root of the twenty year traffic growth factor was calculated ($1.875^{0.052631579}$) = 1.03363805. Raising this number to the ±2 and ±1 powers (for each year of the two year study period before (-) and after (+) the improvement was constructed), yielded the following adjustment factors:

Year (n)	Adjustment Factor
-2	0.9359
-1	0.9674
Year of construction	1.0000
+1	1.0336
+2	1.0684

These numbers were then used as adjustment factors in the following manner: the number of accidents occurring at the improvement site in year n were divided by the n-year adjustment factor, increasing (in years before construction) or decreasing (in years after construction) the apparent number of accidents occurring during year n.

For example, pavement markers were installed along a section of US 50 in Martin County in 1987. The following accidents were associated with this location:

Year	Accidents
1985	26
1986	33
1988	34
1989	30

The above unadjusted data would yield an accident reduction factor of -0.08 as shown below:

$$\text{Accident Reduction Factor} = \frac{NAB - NAA}{NAB}$$

$$= \frac{(26 + 33) - (34 + 30)}{(26 + 33)}$$

$$= -0.08$$

Year (n)	Accidents
1985 (-2)	(26/0.9359) = 27.8
1986 (-1)	(33/0.9674) = 34.1
1988 (+1)	(34/1.0336) = 32.9
1989 (+2)	(30/1.0684) = 28.0

After volume adjustment, the adjusted numbers of accidents were: The adjusted accident reduction factor was then 0.02 indicating a 2 percent reduction in the number of accidents that may be attributed to the installation of pavement markers, as shown below.

$$\text{Adjusted Reduction Factor} = \frac{(NAB/fb) - (NAA/fa)}{(NAB/fb)}$$

$$= \frac{(27.8 + 34.1) - (32.9 + 28.0)}{(27.8 + 34.1)}$$

$$= 0.02$$

Another key source of information for this project was the Kentucky Report, "Development of Accident Reduction Factors" (Creasey and Agent 1985). The Kentucky researchers conducted an extensive literature review of existing accident reduction factors, performed a survey of the accident reduction factors used by various highway agencies, and calculated reduction factor values for improvement projects in Kentucky (using an unspecified accident reduction method).

CHAPTER 3. DATA COLLECTION AND ANALYSIS

The first step in any data gathering exercise is to determine the type of data that are needed, and the best way to acquire those data. Since the purpose of this project was to determine the accident reduction factors for various improvements, it was necessary to define what projects were of interest. An initial list of 89 desirable improvement types developed by INDOT is provided below.

INITIAL PROJECT TYPES

Pavement Markings

- Lane Use Pavement Arrows
- Upgrading Marking of NO PASSING ZONES
- Raised Pavement Markers
- General Pavement Markings
- Right Edge Lanes
- Pedestrian Crosswalks
- Stop Bar

Pavement Treatments

- Rumble Strips
- Pavement Grooving
- Resurfacing
- Deslicking Treatments

Signs

- Post Delineators
- Variable Message Signs
- Install Breakaway Signs
- Control of Commercial Signing
- Upgrade Signs, General
- Overhead Lane Signs

Overheard Warning Signs
Four-Way Stop Signs
Special Curve Warning Signs (Chevrons)
Directional or Warning Signs at Intersections
Advance Road Name Signs
Prepare to Stop or Stop Ahead when Flashing Signs
Warning Signs on Sections

Regulations

Change Angle Parking to Parallel Parking
Eliminate Parallel Parking
Eliminate Angle Parking
Lower or Raise Posted Speed Limit Without Modifying Road
Required Seat Belt Use
Eliminate Parking
Change Two-Way Operations to One-Way
Prohibit Left Turn
No Turn on Red

Channelization

Intersection Overall
Add Deceleration Lane
Add Acceleration Lane
Add Passing Blister
Improve Turning Radii at Intersection
Install Median Barriers
Add Painter Non-Mountable Raised Median (40 mph or less)
Add Mountable Raised Medians
Install Two-Way Left Turn Lanes
Right Turn Lane With or Without Island
New Left Channelization at Signalized Intersections With
and Without Left Turn Phase
New Left Channelization at Unsignalized Intersections

Access Control

Close Private Drive Access, Install Frontage Road
Close Median Openings
Relocate Drives

Signalization

- Add Protected Left Turn to Existing Signal
- Increase Clearance Interval, Utilize All-Red Phase
- Install Flashing Beacons (red-yellow)
- Install Flashing Beacons (all way red)
- Flashing Beacons at Railroad Crossings
- Advance Warning Flashers
- Install Signals
- Improve Signals
- Add Left Turn Signal Without Turning Lane
- Add Turn Lane, Signal, and Illumination
- Add Pedestrian Signals
- Improve Timing
- Actuate Signals
- Remove Signal

Lighting

- Install Lighting at Interchange
- Install Lighting on Section
- Install Lighting at Interchange
- Upgrade Lighting at Intersections
- Install Lighting at Railroad Crossing
- Install Lighting at Bridge Approach
- Install Lighting at Underpass

General Improvements

- Add Truck Climbing Lane
- Add Travel Lanes
- Add Flashing Median Left-Turn Lane(s):
    1. Continuous Left-Turn Lanes
    2. Continuous Two-Way Left-Turn Lane
    3. Alternating Left-Turn Lane
- Widen Travel Shoulders
- Install Reversible Lane
- Upgrade Bridge Roadway Width
- Change from At-Grade Intersection to Interchange
- Upgrade Interchange (change from diamond to cloverleaf)
- Upgrade Intersection Configuration, General

Improve or Change Superelevation
Flatten Roadside Slope, Provide Adequate Clear Zones
Install Crash Cushion
Install Guardrail
Install Automatic Gates at Railroad Crossings
Improve Sight Distance
Relocate Fixed Object
Realignment
Reconstruction

FINAL PROJECT TYPES

Upon further study, it became apparent that some of the improvement types would be difficult or impossible to study, because (a) the information needed to determine a reduction factor was not recorded on the accident forms, (b) there were no examples of this improvement type identifiable from the construction records, or (c) the improvement was always performed along with some other improvement type at the same location and at the same time. Consequently, some of the improvement types were dropped and a revised list of thirty projects was prepared. Following is a listing of project types that were studied:

Signs

* Sign Installation
  Includes all improvement sites where guidance signs were newly installed.
* Overhead Sign Installation
  As above, but the signage was mounted over the roadway.
* Sign Modernization
  Includes all signage upgrades, except the three types listed immediately below.
* Sign Illumination
  Includes the addition of lighting to existing signage.
* Illuminated Sign Installation
  Includes the installation of new signage with illumination.
* Sign and Guardrail Installation
  Includes the installation of both signage and guardrail at the same location on a highway.

Signals

* Signal Installation
  Includes all improvement sites where a new signal was installed at an intersection.
* Signal Modernization
  Includes all improvement sites where an existing signal was upgraded to meet new standards.
* Signal Installation and Channelization
  Includes all improvement sites where a new signal was installed at an intersection and the intersection was channelized (dedicated right or left turn lanes to improve traffic flow).
* Signal Modernization and Channelization
  Includes all improvement sites where an existing signal was modified to meet new standards and the intersection was channelized (dedicated right or left turn lanes to improve traffic flow).
* Signal Installation, Channelization and Signs
  Includes all improvement sites where a new signal was installed at an intersection, the intersection was channelized (dedicated right or left turn lanes to improve traffic flow), and guidance signage was installed.
* Signal Installation, Channelization & Illumination
  Includes all improvement sites where a new signal was installed at an intersection, the intersection was channelized (dedicated right or left turn lanes to improve traffic flow), and intersection lighting was installed.
* Flashing Beacon Installation
  Includes those improvement sites where a new beacon was installed at a formerly uncontrolled intersection.
* Flashing Beacon Modernization
  Includes those improvement sites where an existing flashing beacon was modified to meet current standards.

Delineation

* Intersection Striping
  Includes those sites where striping was placed on an intersection to delineate turning lanes and the paths that vehicles should follow through the intersection.
* Raised Pavement Marker Installation
  Includes the installation of raised pavement markers on state highways.

Channelization

* Construct Channelization

Includes those sites where channelization was performed without any other intersection improvements.

* Turn Lane Construction

Includes those sites where a lane was added to an intersection for channelization.

* Turn Lane Reconstruction

Includes those improvement sites where a turn lane was rebuilt to current standards.

Construction/Reconstruction

* Construct Passing Blister

Includes those improvement sites where a passing blister was constructed to allow through traffic to pass queueing left turns.

* Shoulder Construction

Includes those improvement sites where a shoulder of unspecified width was added to an existing two lane highway.

* Shoulder Repair

Includes all those improvement sites where a substandard or damaged shoulder was rebuilt to current standards.

* Improve Sight Distance

Includes all those improvement sites where earth moving was performed at an intersection to increase the sight distance for at least one of the approaching lanes of traffic.

* Construct Travel Lane

Includes those improvement sites where a travel or truck climbing lane was added to an existing 2 lane highway.

* Bridge Widening

Includes those improvement sites where an existing bridge was widened an unspecified amount.

Pavement Treatments

* Resurfacing

Includes those improvement sites where a deteriorated pavement was overlaid.

* Wedge and Level

Includes those improvement sites where spot resurfacing was done along a section of highway. Used as a stopgap measure to delay resurfacing.

Safety Barriers

* Guardrail Installation

  Includes those improvement sites where a new section of guardrail was installed at a location.

* Guardrail Replacement

  Includes those improvement sites where a program of regular maintenance leads to the replacement of old or weakened sections of guardrail.

* Bridge Railing and Deck Repair

  Includes those improvement sites where a bridge's deck was either repaired or replaced and the railing structure replaced or upgraded during the process.

Illumination

* Lighting Installation

  Includes those improvement sites where a section of highway was newly lit.

* Lighting Modernization

  Includes those improvement sites where the lighting along a section of highway has been improved.

* Luminaire Replacement

  Includes those improvement sites where high-masted luminaire groups have been replaced during periodic maintenance.

* Bridge Lighting Installation

  Includes those improvement sites where new lighting was added to an existing bridge.

Railroad Projects

* Railroad Signal Installation

  Includes those improvement sites where a connection was made between railroad and highway signal systems to detect the presence of an approaching train and modify the traffic signals so as to prevent conflicts.

* Railroad Grade Crossing Removal

  Includes those improvement sites where an abandoned grade crossing was removed and the former crossing resurfaced.

Regulation

* Upgrade No-Passing Zones

  Includes those improvement sites where a no-passing zone was established or reaffirmed along a length of state highway.

* Elimination of Parking Zones

Includes those improvement sites where a no-parking zone was established or reaffirmed along a length of state highway.

SITE IDENTIFICATION

With the project types identified, the next step was to identify contracts that contained projects of interest to this study. Since the contract listings from 1974 to 1987 encompassed an estimated 8000 entries, the process of scanning prospective contracts was automated. A FORTRAN program was developed to perform this procedure. Two difficulties were encountered in following this course - the unorthodox selection process and the lack of standard abbreviations for the project types in the construction records.

The scheme chosen for the contract selection program consisted of input data (the contract data), a list of projects that were known to be unwanted, and a decision algorithm that compared the line of input data to the list. This scheme was chosen because we were uncertain as to the type of projects contained in the contract data. This screening process eliminated a large number of inapplicable projects, but the output still had to be hand edited to remove the less obviously inappropriate contract types.

The second problem was the lack of a uniform set of abbreviations used by the Indiana Department of Transportation for the contract descriptions. An iterative process was applied by the study team to find all the variations used, as follows:

* Develop the initial program
* Run the contract data through the selection program
* View the output
* Update the program as needed to provide a clearer filtering of the input data, usually by the addition of more line to the list of unwanted project types.

Without a uniform set of abbreviations, the program tripled in size and became unmanageable. It was then decided to rewrite the program to take advantage of the similarities between some of the abbreviations. This shortened the program to a reasonable length.

Another criterion for whether a contract was investigated was the contract year of construction. Because there was a difference in the type and structure of the information available in the pre-1981 and post-1980 accident records (location of an accident, type of accident, etc.), the decision was made to study only those sites with accident records available from 1981 to 1989. Because we required at least two years of accident data on either side of an improvement project, 576 improvement contracts were selected from the years 1983 - 1987.

Once the contracts were selected from the construction records, other means were needed to locate some of the regulatory improvements. The Indiana Department of Transportation Official Action (OA) listings were searched for changes in passing zones and parking regulations. Also, the resurfacing projects were added at this time.

Because the construction records provided to us by the INDOT did not contain complete information on each of the sites studied, trips to Indianapolis and regional offices were necessary to capture all the information needed to locate a site. This process took the largest block of time in the entire project, because it was extremely tedious to locate each site where work was performed in the 576 contracts that were selected for study.

SITE CODING FOR EXTRACTION

The Indiana State Police Accident Records locate accident sites by a combination of pseudo codes (unique road identifiers) of the road on which the accident occurred, the pseudo code of a reference road, the distance and direction from the reference road to the accident site, either the city or township code of the accident site, and other additional information.

The next step in the site identification process was to divide the contracts into individual sites where work was performed, and then identify each site by its unique combination of county location and pseudo code pairs, or county location and township or city code pairs. The accident records were then searched for any accidents that could be extracted by matching either of two identifying schemes.

For spot improvements, pseudo-code pairs were most effective in identifying and recovering project sites. This method was tried for strip projects (resurfacing, raised pavement markers, etc.) and rejected because of the large amount of information needed to identify all of the intersections along the length of a multi-mile improvement project. For this type of improvement, the accident records were searched for a pseudo code-township pair, pseudo code-city code pair, or both. While this search strategy recovered all of the accidents along a strip project site, it also lead to increased hand editing as all of the recovered accidents had to be checked to see if they had occurred within the boundaries of the improvement site.

Further, it was tedious to find and track all the combinations of pseudo codes used to describe each location. It would be most helpful in the future if the state and local accident reporting agencies adopted a hierarchical usage for the roadways now identified with multiple pseudo codes. If a roadway can be coded as either a federal, state, or local highway, the pseudo code of the largest governing body with jurisdiction for the highway should be used.

The search process for roads that have multiple entries in the pseudo code listing for a particular county could be simplified if only one pseudo code is used to denote the accidents on that section. For example, the intersection of US 52 (Sagamore Parkway) and SR 26 (South Street) in Lafayette needs to be coded with four different combinations of pseudo codes (US 52/SR 26, US 52/South Street, Sagamore Parkway/SR 26, Sagamore Parkway/South Street) rather than one if just the Federal and State codes were used (US 52/SR 26).

After the site selection and coding processes were completed, a total of 1511 sites remained to be investigated for their accident reduction properties. The Indiana State Police Accident data tapes were then searched for all accidents that matched those coded by either the pseudo code pairs, pseudo code - township code pairs, or pseudo code - city code pairs.

Trial use of this search method extracted approximately 30,000 and 60,000 accidents before fine tuning for the final search. This search recovered 104,882 accidents from among the 1,934,490 accidents that occurred within the state during the study period. These accidents were then hand verified to determine whether an accident occurred within an improvement site during the years of interest to that particular site. This checking primarily applied to the strip projects that only occupied portions of townships. Because we only studied the accidents that occurred at a site within two years (before and after) of improvement, accidents that occurred outside that time window may be ignored. After this step, only 39,209 accidents remained to contribute to the accident reduction factors study.

The filtered accidents were then processed by a set of programs that calculated an accident reduction factor for the total number of accidents, the nineteen different collision types that the State Police uses to diagram accidents, the number of persons killed, the number of persons injured, and the number of accidents involving property damage only for both individual sites and aggregates for each set of project types. Statistical testing was also performed at this time.

CHAPTER 4. STATISTICAL ANALYSIS

STATISTICAL MODEL

The statistical model for the accident reduction factor study was developed as more became known about the nature of the construction and accident records. Two statistical models were considered for use in this project: (1) a before and after model using a control group and (2) a before and after model without using a control group (Council et al. 1980). While a control group adds statistical robustness to the before and after statistical model (not as subject to outside causes, maturation, and regression to the mean) it was rejected for use because of the difficulty in matching the large number of construction sites (over 1500 at one point) with control locations of similar size, physical, and traffic characteristics. The matching procedure would have introduced unintended bias on the part of the researcher in choosing the control group locations (Council et al. 1980; Hauer, 1990). Therefore the before and after model without a control group was used. While this model is known to have problems their negative effects can be minimized. These problems and possible solutions are discussed below.

History

Problem: Other factors occurring at the same time as implementation of the improvement may influence the results. Examples of such factors are other improvement projects, a change in speed limit, etc.

Solution: Sites have been prescreened to eliminate factors that may affect the calculation. For example, locations with where multiple improvements have been performed were removed from consideration, as were interstate highway projects that would be affected by the changing of the speed limit.

Maturation

Problem: Trends occurring independently of the treatment may influence the results. Traffic growth is the primary example.

Solution: A scaling factor was applied to the extracted accidents to adjust for traffic growth, as discussed in Chapter 2.

Regression

Problem: If treatment sites are chosen based on a very recent accident history, regression to the mean becomes a problem. This is where a calculated drop in accidents is accredited to the treatment, rather than the site having been at a peak in its accident cycles. For example, a hypothetical intersection's accident history is given in Figure 1. The range of accident frequency of accidents is from 19 to 42, with an average of 28. Note that, for each extreme point, the frequency of accidents the following year tends towards the mean of 28, without any improvement being introduced. If an improvement is constructed in 1985 in response to the large number of accidents that occurred in 1984 and the results of the improvement are calculated at the end of 1985, a 36 percent decrease in the number of accidents is noted. Undoubtedly, the improvement had some effect, but some portion of the reduction in accidents was due to the regression to the mean phenomenon (Council et al. 1980).

Solution: From a conversation with members of INDOT staff it was determined that there is a multi-year backlog of improvements in need of funding. Since sites with high accident histories are known for several years, the problem of choosing improvement sites based on a short term increase in accidents is diminished.

STATISTICAL TESTS

The results of this study were tested to see if the adjusted frequency of accidents after an improvement is implemented are significantly different from the frequency of accidents before the improvement was made. This is referred to as a two-tailed test (Council et al. 1980).

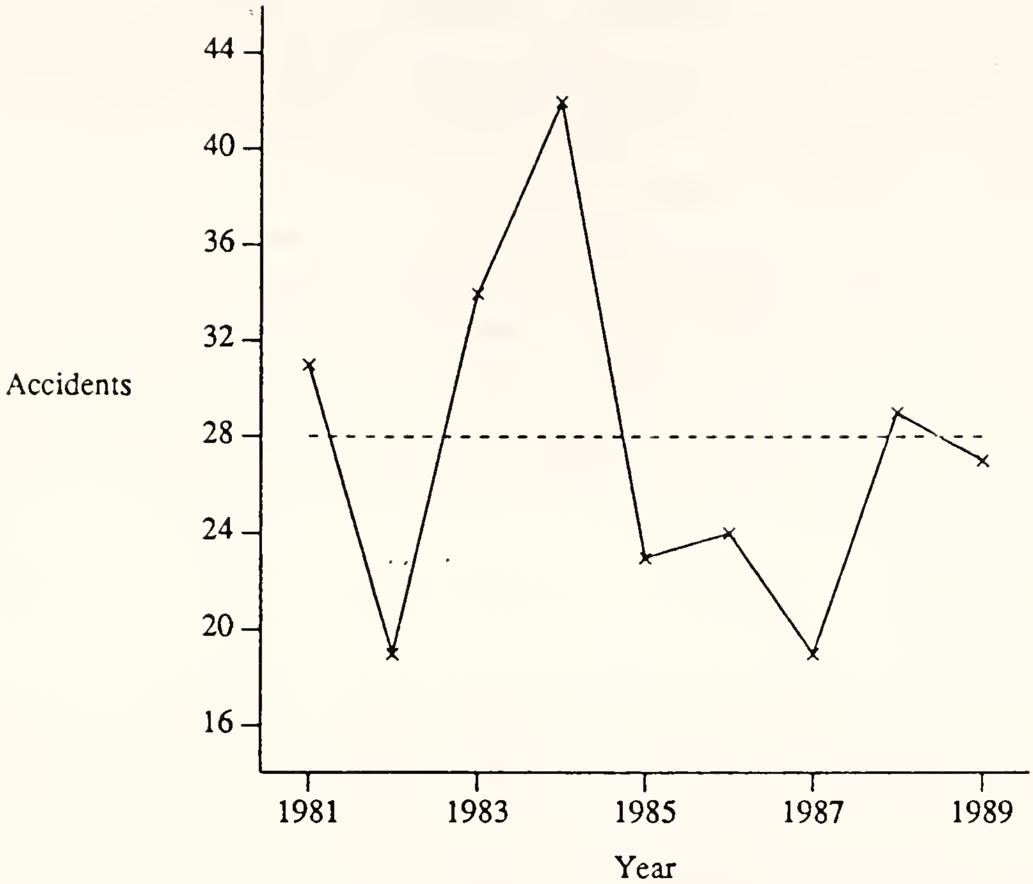

Figure 1. Regression to the Mean Example

The first step in the testing procedure is to decide on a test variable, then calculate a test statistic. The variable to be used in the statistical testing is the frequency of accident occurrence. Other measures, such as severity or cost of collision damage, may produce more meaningful results, but the difficulty in obtaining the necessary quantity of reliable data outweighed the precision gained.

The z-test was performed on individual improvement sites that have large amounts of accident data associated with them, or where an improvement type was represented by a single site. Improving the sight distance at an intersection, for example, was only performed at one site that met the site selection criteria of this study. While this is a helpful yardstick for the comparison of the significance of improvement within a group of the same type of improvement, it has little use outside that application. The value of z* is calculated as follows;

$$z^* = \frac{(NAB - NAA)}{\sqrt{(NAA + NAB)}}$$

Where NAB is defined as the number of accidents occurring at an improvement during the time period before an improvement is constructed and NAA is defined as the number of accidents occurring at an improvement site during an equal time period after an improvement is constructed (Box and Oppenlander 1976).

Using the data from the example in Chapter 2, we find that the the value of z* for the intersection is:

$$z^* = \frac{(61.9 - 60.9)}{\sqrt{(61.9 + 60.9)}} = 0.0902$$

The paired t-test (Council et al. 1980; Datta and Dutta 1990) was performed on the before and after groups of the same improvement type (for example, all cases of signal installation or all cases of pavement marking). Since this statistical procedure is applied to groups of improvement types rather than single sites, the effects of individual sites decrease and the overall accuracy of the measure is increased. The value of t* is calculated as follows:

$$t^* = \frac{Xb - Xa}{\frac{s_D}{\sqrt{N}}}$$

Where:

X_b = Mean number of accidents before

s_b = Standard deviation of accidents before

X_{bi}= Number of accidents before at site i

X_a = Mean number of accidents after

s_a = Standard deviation of accidents after

X_{ai}= Number of accidents after at site i

N = Number of sites

N-1= Degrees of freedom

$$s_D^2 = s_b^2 + s_a^2 - 2\left[\frac{1}{N-1} \sum_{i=1}^{N} (X_{bi} - X_b)(X_{ai} - X_a)\right]$$

$$s_b^2 = \frac{\Sigma(X_{bi} - X_b)^2}{N-1}$$

$$s_a^2 = \frac{\Sigma(X_{ai} - X_a)^2}{N-1}$$

Continuing our example using the entire group of pavement marking sites, we calculate the value of t* to be 0.45.

We can now use the values of the calculated test statistic as an indicator of the statistical significance of the results. This indicator is called the P-value. For example, if we would like to test our results to see if there is only a 5% probability that the results could be due to chance alone, defined as alpha = 0.05, we would compare the P-value found from the test statistic to 0.05. If the P-value is less than or equal to 0.05, then we would conclude that the results are significant at alpha = 0.05. The P-value is defined as the alpha level at which point the test statistic would be significant (Neter et al. 1988).

CHAPTER 5. RESULTS OF COMPUTATIONS

With the groundwork laid in the preceding chapters, it is now possible to present and discuss the results of this study. The first portion of this chapter deals with the results calculated from the INDOT Highway Safety Improvement Program data. Next, the results from the data extracted in the present study are presented.

SAFETY IMPROVEMENT ANALYSIS

The Highway Safety Improvement Program (HSIP) requires states to report to the Federal Highway Administration how their federal safety funds are being spent. These reports include accident counts, traffic volumes, and project costs.

Data from the INDOT HSIP were used to calculate accident reduction factors to compare with the results of this study. Accidents were adjusted using the traffic volumes instead of the statewide growth factors. For these calculations, the adjusted reduction method is:

$$Adjusted\ Reduction\ Factor = \frac{(NAB/fb) - (NAA/fa)}{(NAB/fb)}$$

NAB and NAA are defined to be the number of accidents of a certain type (total, property damage only (PDO), injury, or fatal) occurring at an improvement site before and after (respectively) the improvement was installed. fb and fa are defined to be adjustment factors applied to the numbers of accidents, namely the volume before and the volume after installation. For example, when a skid resistant overlay was constructed, the data were:

fb = 15827 AADT
fa = 16466 AADT
NAB = 20
NAA = 13

$$\textit{Adjusted Reduction Factor} = \frac{(NAB/fb) - (NAA/fa)}{(NAB/fb)}$$

$$= \frac{(20/15827) - (13/16466)}{(20/15827)} = 0.350$$

A summary of the findings is given in Table 1:

Table 1. Accident Reduction Factors Based on HSIP Data.

Project Type	Number of Sites	ARF Total	ARF PDO	ARF Injury	ARF Fatal
Signal Installation	23	0.424	0.972	0.982	1.000
Signal Modernization	21	0.333	0.968	0.985	1.000
Pavement Markers	3	0.152	0.694	0.900	inf
Channelization	19	0.295	0.242	0.536	inf
Skid-Resistant Overlay	1	0.350	0.388	0.176	1.000

It should be noted that the P-values for all but one of the reduction factors in this table are less than alpha = 0.05, demonstrating both the large values of the accident reduction factors and their strong statistical significance.

HISTORICAL DATA ANALYSIS

The accident reduction factors computed on the basis of the historical data extracted from the accident record files are presented in Table 2. The information includes all improvement types studied and the value of the number of sites (NS), number of accidents (NA), and the total accident reduction factor (ARF). The values are presented as a decimal fraction (0.12 = 12%). Negative numbers denote an increase in accidents and "inf" denotes division by zero (no accidents during the before, or total study period). Detailed discussion of the individual project types can be found in the latter portion of this chapter.

Table 2
Accident Reduction Factors Based on Study Data

Project Type Studied	NS	NA	ARF
SIGNS			
Sign Installation	8	111	-0.12
Overhead Sign Installation	11	350	0.00
Sign Modernization	7	374	-1.44
Sign Illumination	8	173	0.00
Illuminated Sign Installation	15	841	-0.16
Sign and Guardrail Installation	2	180	-0.11
SIGNALS			
Signal Installation	137	3865	0.03
Signal Modernization	110	2968	0.11
Sig Inst and Channelization	34	1183	0.13
Sig Mod and Channelization	2	127	-0.90
Sig Inst, Channel & Signs	1	20	0.01
Sig Inst, Channel & Illumin.	2	11	0.70
Flashing Beacon Installation	8	151	0.07
Flashing Beacon Modernization	1	15	0.09
DELINEATION			
Intersection Striping	1	18	0.18
Raised Pavement Marker Inst	61	8159	0.04
CHANNELIZATION			
Construct Channelization	3	24	0.17
Turn Lane Construction	4	333	-0.18
Turn Lane Reconstruction	2	17	0.26

Table 2, continued

Project Type Studied	NS	NA	ARF
CONSTRUCTION/RECONSTRUCTION			
Construct Passing Blister	10	497	-0.01
Shoulder Construction	1	2	0.09
Shoulder Repair	9	200	-0.52
Improve Sight Distance	1	8	-1.72
Construct Travel Lane	1	36	-5.04
Bridge Widening	8	329	-0.09
PAVEMENT TREATMENTS			
Resurfacing	73	5615	0.07
Wedge and Level	164	5680	0.06
SAFETY BARRIERS			
Guardrail Installation	3	222	-0.65
Guardrail Replacement	6	326	0.07
Bridge Railing and Deck Repair	1	141	0.13
ILLUMINATION			
Lighting Installation	4	61	-0.03
Lighting Modernization	1	17	-0.13
Luminaire Replacement	9	86	0.16
Bridge Lighting Installation	1	12	0.59
RAILROAD PROJECTS			
Railroad Signal Installation	1	4	-2.50
Railroad Grade Crossing Removal	10	257	0.18
REGULATION			
Upgrade No-Passing Zones	34	4099	-0.01
Elimination of Parking Zones	12	835	0.08

DISAGGREGATE ANALYSIS

Initially, efforts were made to develop accident reduction factors by highway class, volume, location and project type. As the study progressed, however, it was found that it would not be possible to do this without compromising the results, because the data available were not of sufficient quantity to represent various classifications. Consequently, accident reduction factors were analyzed only by improvement project types. A detailed presentation of the results from the disaggregate analysis are given in the Appendix. Some of the major observations that can be made on the basis of these results are presented below.

1. Installation of guidance signs indicated a 12% *increase* in accident rates, compared to a 14% reduction in total accidents in Kansas and a 22% drop in accident rates in Arizona, as cited in Creasey and Agent (1985). However, the data in the present study revealed that there is a statistically significant reduction (61%) in right angle accidents due to sign installation.

2. While the present study found no difference in the total number of accidents in the before and after groups due to overhead sign installation, Creasey and Agent (1985) cited a 20% reduction from a 1970 source. Although not high, statistically most significant accident type to be reduced in Indiana was sideswipe (82%). A probable reason for this discrepancy may be the use of growth rates and urban growth rates, which were larger than those predicted statewide. The increased growth leads to underadjusted "after" accidents which in turn affects the calculation of the reduction factor.

3. Creasey and Agent (1985) recommend using a 10% reduction factor for the total number of accidents due to sign modernization, but no data were cited to support that value. The present study found *increases* in almost all accident types.

4. Sign illumination provided no change in the total number of accidents in the present study, and no data outside of this could be found.

5. The installation of illuminated signs, while showing no benefit in total or property damage accident reduction, indicated a decrease of 24% for injury accidents and 9% for fatal accidents.

6. Sign and guardrail installation indicated an increase in accidents by 11% while showing a slight decrease in injury accidents. This trend was consistent with the

observation of Creasey and Agent (1985) and Kaji (1980). The data showed that such an improvement can also eliminate certain left turn accidents.

7. The total accident reduction was 3% due to signal installation, much less than the 10% to 80% reductions found in the literature. However, there were strongly significant reductions in right angle (17%) and sideswipe accidents (27%). Kaji (1980) found a reduction in accident rates of 23% at 48 sites. Creasey and Agent recommended a 20% accident rate reduction.

8. Signal modernization caused significant reductions for total (11%), injury (11%) and PDO (23%) accidents consistent with the range of values found by Creasey and Agent (1985).

9. Signal installation and channelization produced a 13% overall reduction in accident rates. However, some left turn accidents were reduced by as much as 91%. Reductions were also found in PDO, injury and fatal accidents.

10. With only 2 sites, the results for signal modernization and channelization were mostly statistically insignificant. However, head-on collisions were found to decrease 29% with high statistical significance. Kaji (1980) found a 43% decrease in accident rates, while Creasey and Agent (1985) indicated a drop of 48%.

11. No meaningful conclusions can be drawn from the data on signal installation, channelization and signs, because the total number of accidents available was only 20 from 2 sites. Kaji (1980), with only one site, found similar difficulties. Creasey and Agent (1985) did not include this combination of improvement types.

12. Although the results indicated significant reduction in total (70%), PDO (70%) and right angle (100%) accidents due to signal installation, channelization and illumination, the data size was not large enough to make definite conclusions. The same situation occurred with Kaji's (1980) data.

13. The calculated accident reduction factors for fatal (100%) and injury (24%) accidents associated with flashing beacon installation were found to match closely those generated by Kaji (1980) and Creasey and Agent (1985). Total (7%) and PDO (1%) factors were below the 10 to 30% reductions preducted by previous researchers. The largest and statistically most significant reductions were in certain types of left turn.

14. The calculated accident reduction factors associated with flashing beacon modernization for total (9%) and PDO (8%) were somewhat below those predicted by Kaji (1980) and Creasey and Agent (1985), but the reductions in fatal (100%) and injury (82%) were as expected. Although a moderately significant reduction was observed, the calculations were based on limited data from only one improvement site.

15. Intersection striping caused significant reductions in PDO (30%), injury (78%) and right angle (63%) accidents, but the results are questionable since they were based on limited data.

16. The installation of raised pavement markers on rural highway reduced total (4%), PDO (5%), injury (3%) and fatal (17%) accidents. A significant reduction was also observed in some left turns. These results were consistent with those detected in other states.

17. The limited data made the analysis of channelization construction questionable, however, the reduction factors were found to be nearly the same as those from other sources.

18. The available data on turn lane construction did not provide relevant reduction factors, due to low statistical significance as well as negative values. However, reduction factors calculated from the HSIP data indicated an average of 30% decrease in accidents, while the lower and upper ranges reported by Creasey and Agent (1985) were 15% and 33%, respectively.

19. Turn lane reconstruction indicated a 26% decrease in total accidents. However, the significance was very low due to the small sample size.

20. The construction of a passing blister had little effect on the total number of accidents. However, there were 19%, 42%, and 100% decrease in accidents associated with head-on, sideswipe and left turn Type 10, respectively. Except for sideswipe, the results were of low to moderate statistical significance.

21. In the sample data, only two accidents were found to be associated with shoulder construction at a site. No conclusion could be drawn from the results. Creasey and Agent (1985) reported a 5-33% decrease in accident rates due to the addition of a shoulder to an existing road.

22. While the shoulder repair indicated significant increases in total, PDO and injury accidents, fatal accidents showed 55% decrease, although with much lower significance. Creasey and Agent (1985) reported 8-19% decreases in accident rates.

23. No statistically valid results could be obtained from the limited data on the improvement of sight distance. Creasey and Agent (1985) suggested 29-47% decreases in accident rates.

24. No appropriate accident reduction factors could be determined for constructing a travel lane, due to the lack of sufficient accident data. Creasey and Agent (1985) indicated 5-33% decreases in accident rates due to this improvement.

25. Bridge widening on rural roads reduced fatal accidents by 15%, but the statistical significance was very low. Some left turn and rear end accidents were also found to have been reduced, but with low statistical significance. Creasey and Agent (1985) reported an average of 37% decrease in accident rates.

26. Resurfacing of rural highways provided an accident reduction of 7% which compared well with the value (10%) reported by Creasey and Agent (1985), but was below the value (35%) computed on the basis of HSIP data. One probable reason for this discrepancy may be due to the fact that HSIP projects are primarily safety related (skid resistant overlay), while a majority of the projects included in the sample data was merely structural.

27. The activity of wedge and level showed a 6% decrease in the total accidents. There was a positive reduction for rear end (20%) and also for some left turn (49%) and right turn (67%) accidents.

28. Guardrail installation showed moderately significant increases in all types of accidents. Creasey and Agent (1985) reported an overall 4-9% decrease in accident rates.

29. The data indicated that a program of guardrail maintenance can reduce the severity of accidents. Some of the reduction factors were computed, however, on the basis of only a few accidents.

30. The calculated values for the accident reduction factors associated with bridge

railing and deck repair showed a larger decrease, but with low statistical significance, than 3% reported by Creasey and Agent (1985).

31. No statistically significant reduction factors could be determined for lighting installation. Creasey and Agent (1985) reported a 6-37% reduction in accident rates and Kaji (1980) observed a 37% reduction in all accidents, as well as 38% in PDO, 53% in injury and 100% in fatal accidents.

32. Although a 40% reduction was noted in injury accidents due to lighting modernization, the statistical significance was very low, primarily due to insufficient data. Creasey and Agent (1985) found that upgrading the existing lighting reduces the overall number of accidents 24 to 50%.

33. Luminaire replacement showed a positive effect on reducing the total number of accidents, but at low statistical significance.

34. Given a 28% to 50% reduction of total accidents from the Kentucky report Creasey and Agent (1985), the calculated reduction factor of 59% due to bridge lighting installation compared favorably. However, the calculations were based on only 12 accidents at one location.

35. It is difficult to draw any statistically significant conclusions for railroad signal installation from calculations based on 4 accidents at one location. Creasey and Agent (1985) suggested 50% to 70% reduction of vehicle-train accident rates.

36. Railroad grade crossing removal indicated results consistent with what can be expected. Reduction factors for total accidents, PDO and fatal accidents were computed as 18%, 17% and 67% respectively, but with very low statistical significance. Creasey and Agent (1985) suggested a 39% reduction in accident rates.

37. The data indicated that upgrading of no-passing zone can reduce fatal and head-on accidents, but with low significance. Most turning movements were also reduced with low to moderate significance. Creasey and Agent (1985) cited 30% reductions in total accidents.

38. The data indicated that the elimination of parking zones can reduce accident of all severity types with moderate statistical significance. The Kentucky report by Creasey and Agent (1985) suggested a 30-32% reduction in the total number of

accidents.

SUGGESTED REDUCTION FACTORS

Since most counterintuitive results were derived from improvement types with a small number of sites or limited accident data, replacement factors were sought from a larger data set. For that purpose, the reduction factors developed earlier for Indiana by Kaji (1980) and the Kentucky factors developed through an extensive literature review were consulted. The Missouri data available in the FHWA publication on accident analysis (FHWA 1976) were also reviewed for possible adoption. The resulting accident reduction factors that are suggested for use in Indiana are given in Table 3. It should be noted that these are average rates and should be used for systemwide planning and programming purposes. They may not be applicable to evaluate the safety impact of improvement types at specific sites. Furthermore, these rates represent the percentage reduction of accidents relative to the number of accidents occurring before an improvement is undertaken. For example, signal modernization has an accident reduction rate of 0.11 or 11% of the accidents that occurred (for a given traffic volume) with an old signal can be eliminated, on the average, by upgrading the signal. On the other hand, signal installation, channelization and illumination can reduce, on the average, 70% of the accidents that occurred at a site without this improvement package. These two reduction factors cannot be directly compared because their initial conditions are not the same.

Table 3

Suggested Reduction Factors for Use in Indiana

Project Types Studied	Suggested ARF
SIGNS	
Sign Installation	0.15
Overhead Sign Installation	0.00
Sign Modernization	0.15
Sign Illumination	0.00
Illuminated Sign Installation	0.15
Sign and Guardrail Installation	0.15
SIGNALS	
Signal Installation	0.13
Signal Modernization	0.11
Signal Inst and Channelization	0.13
Signal Mod and Channelization	0.11
Signal Inst, Channel & Signs	0.50
Signal Inst, Channel & Illumin.	0.70
Flashing Beacon Installation	0.07
Flashing Beacon Modernization	0.09
DELINEATION	
Intersection Striping	0.18
Raised Pavement Marker Installation	0.04
CHANNELIZATION	
Construct Channelization	0.17
Turn Lane Construction	0.20
Turn Lane Reconstruction	0.26

Table 3, continued

Project Types Studied	Suggested ARF
CONSTRUCTION/RECONSTRUCTION	
Construct Passing Blister	0.20
Shoulder Construction	0.09
Shoulder Repair	0.20
Improve Sight Distance	0.30
Construct Travel Lane	0.10
Bridge Widening	0.40
PAVEMENT TREATMENTS	
Resurfacing	0.07
Wedge and Level	0.06
SAFETY BARRIERS	
Guardrail Installation	0.04
Guardrail Replacement	0.07
Bridge Railing and Deck Repair	0.13
ILLUMINATION	
Lighting Installation	0.37
Lighting Modernization	0.25
Luminaire Replacement	0.16
Bridge Lighting Installation	0.59
RAILROAD PROJECTS	
Railroad Signal Installation	0.80
Railroad Grade Crossing Removal	0.18
REGULATION	
Upgrade No-Passing Zones	0.30
Elimination of Parking Zones	0.08

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

The Indiana Department of Transportation had been using accident reduction factors developed outside Indiana, and had some concern over their applicability. This research project sought to produce a set of accident reduction factors from Indiana data for the Indiana highway network.

A literature review was performed to identify different methods of calculating accident reduction factors. It was decided to use the adjusted percentage reduction method (adjustment factors based on state traffic volume growth) on the Indiana data.

It was necessary to use this form of volume adjustment because reliable volume data for all sites are not available on a yearly basis. While it is true that volume data are being collected, the data were not available in the quantity needed for this research. The incomplete volume data would have to have been scaled in the same manner as used to scale the accidents. Therefore, it was decided to adjust the accidents directly. It would be a tremendous improvement if the Indiana Department of Transportation collected volume data before and after the construction period at a site scheduled for an improvement. This would provide some basis to scale accident data on an location by location basis.

The drawback to using the statewide growth factor is that improvement sites with traffic growth greater than the state average tend to have underadjusted "after" accidents, i.e., the number of after accidents should have been reduced more than the growth factors that we used did. This situation reduced the calculated effectiveness of the improvement and lowered the improvement's statistical significance.

Many project types in this study suffer because of the restrictive site selection process. The selection process was such that no other construction projects occurred at the same site during a period 2 of years before and after the improvement to be studied was implemented. The small number of improvement sites remaining for use in the calculation of the reduction factor led to a reduction of the statistical significance of those improvement types. Two possible solutions may be useful in alleviating this problem. One possible way is to reduce the before and after periods to one year. However, this will also reduce the number of accidents used to calculate the reduction factor. Another possible solution is to try to account for the influence of the other projects that occurred during the before and/or after period.

Flashing Beacon Modernization showed the greatest accident reduction of all projects studied. Signal Modernization, Railroad Crossing Removal, and Parking Elimination projects also had appreciable accident reduction capabilities.

The Indiana Department of Transportation should continue to use reduction factors developed outside the state of Indiana until volume data are available to permit a more accurate calculation of accident reduction factors that provide a better measure of the exposure to accidents. Currently the Highway Safety Improvement Program is collecting the data necessary to adequately perform these calculations (including the cost of projects on a site-by-site basis and more importantly, traffic volumes before and after construction of the improvement.).

As mentioned in Chapter 3, a standardized set of abbreviations used in coding construction projects would be useful for future ease in conducting automated searches of the construction records that are stored electronically.

When a reorganization of computerized record formats is next done, some effort should be made so that the new format will be compatible with the old record data fields, to insure that future research or data analysis will not be hampered by having only a few years of data available in a usable format.

Suggested Future Research

This study should be performed again where there are sufficient data available to scale the before and after ccidents by traffic volume. At that time, a corresponding study could make use of the scaled accident data to determine the zone of influence of an improvement. Statistical testing of the accident data would define more precisely the region in which an improvement will alter the accident history of a location or a region or a location. For example, if intersection AB is signalized, the researcher would extract all accidents identified by intersection AB. The data would then be analyzed by distance from the intersection and the distance noted where the number of accidents differs from an expected value, hence defining a zone of influence.

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APPENDIX A: RESULTS OF DISAGGREGATE ANALYSIS

The presentation of the results from the disaggregate analysis are organized in the format described below:

Major Improvement Grouping <Signs, Signals, Pavement Marking, Channelization, Construction/Reconstruction, Pavement Treatments, Safety Barriers, Illumination, Railroad Projects, Regulation>

Project Type: IMPROVEMENT TYPE

Number of sites: <number>

Accident Reduction Factors - by Severity

Name	Note	ARF	Statistic	P-value
Total	[1]	<aa>	<ss>	<pv>
PDO	[2]	<aa>	<ss>	<pv>
INJ	[3]	<aa>	<ss>	<pv>
FTL	[4]	<aa>	<ss>	<pv>

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	<aa>	<ss>	<pv>
Rear-end (01)	<aa>	<ss>	<pv>
Right Angle (06)	<aa>	<ss>	<pv>
Sideswipe (04)	<aa>	<ss>	<pv>
Left Turn (08)	<aa>	<ss>	<pv>
Left Turn (09)	<aa>	<ss>	<pv>
Left Turn (10)	<aa>	<ss>	<pv>
Left Turn (11)	<aa>	<ss>	<pv>
Left Turn (12)	<aa>	<ss>	<pv>
Left Turn (13)	<aa>	<ss>	<pv>
Right Turn (14)	<aa>	<ss>	<pv>
Right Turn (15)	<aa>	<ss>	<pv>
Right Turn (16)	<aa>	<ss>	<pv>
Right Turn (17)	<aa>	<ss>	<pv>
Right Turn (18)	<aa>	<ss>	<pv>

Notes:

[1] Reduction factor values for all collision types.

[2] Reduction factor values for collisions involving property damage only.

[3] Reduction factor values for collisions involving injuries.

[4] Reduction factor values for collisions involving fatalities.

<aa> The calculated value of the adjusted accident reduction factor expressed as a decimal fraction (0.48 = 48%). Negative numbers denote an increase in accidents and ''inf'' denotes a division by zero (no accidents occurred during the ''before'' period). It should be remembered that from the formulation of the equations, a reduction factor value of 1.000 means that no accidents occurred at the improvement site during the two year period after construction. A reduction factor value of -1.000 means that the number of accidents during the period after construction is double that of the two year period prior to the construction of the improvement.

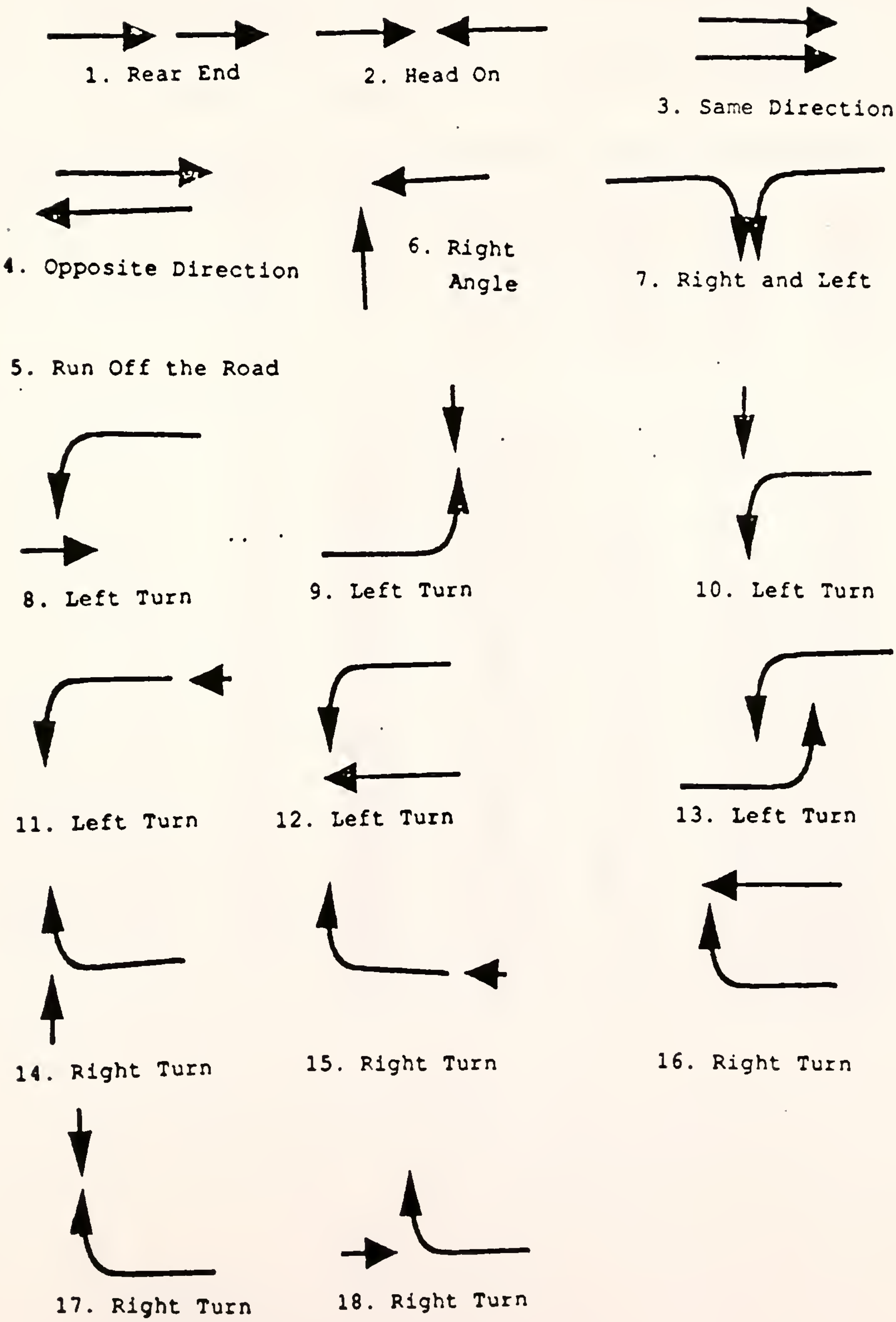
<ss> The calculated value of the statistical test (z-test if number of sites = 1, else t-test). "N/A" denotes that the statistical test was not be performed because calculation halted when the value of the adjusted accident reduction value was found to be incalculable.

<pv> The P value of the statistical test. (P-values are more fully explained in Chapter 4.)

Collision Type (number) Calculations performed on the different collision types defined by the Indiana State Police accident reporting form (see Figure A.1 for diagrams).

Discussion: Discussion of the results compared to those of other studies and the result's statistical significance. References to accidents within the discussion section refer to accidents adjusted by growth factors as explained in Chapter 2.

Figure A.1
Indiana State Police Collision Diagram



SIGNS

Project Type: Sign Installation

Number of sites: 8

Number of accidents: 111

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.12	-0.65	0.536
PDO	-0.13	-0.59	0.572
INJ	-0.47	-0.92	0.388
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Heaa-on (02)	-0.08	-0.14	0.892
Rear-end (01)	-0.12	-0.23	0.824
Right Angle (06)	0.61	2.13	0.070
Sideswipe (04)	1.00	1.00	0.352
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	0.12	0.09	0.930
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	0.06	0.04	0.972
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Overhead Sign Installation

Number of sites: 11

Number of accidents: 350

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.00	-0.03	0.976
PDO	-0.02	-0.13	0.900
INJ	-0.47	-2.39	0.038
FTL	0.06	0.04	0.968

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.02	-0.04	0.968
Rear-end (01)	-0.22	-1.06	0.314
Right Angle (06)	-0.02	-0.06	0.954
Sideswipe (04)	0.82	1.85	0.094
Left Turn (08)	0.10	0.76	0.464
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	1.00	1.49	0.168
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	-1.63	-0.72	0.488
Right Turn (16)	-0.52	-0.56	0.588
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	1.00	1.00	0.340

Project Type: Sign Modernization

Number of sites: 7

Number of accidents: 374

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-1.44	-4.00	0.008
PDO	-1.42	-3.22	0.018
INJ	-0.92	-2.52	0.044
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-1.73	-2.82	0.030
Rear-end (01)	-0.91	-1.84	0.116
Right Angle (06)	-1.30	-3.76	0.010
Sideswipe (04)	-1.26	-1.99	0.094
Left Turn (08)	0.09	0.06	0.954
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Sign Illumination

Number of sites: 8

Number of accidents: 173

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.00	0.02	0.984
PDO	0.03	0.18	0.862
INJ	0.10	0.39	0.708
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.12	-0.34	0.744
Rear-end (01)	0.55	0.90	0.398
Right Angle (06)	-0.66	-3.11	0.018
Sideswipe (04)	1.00	1.00	0.350
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Illuminated Sign Installation

Number of sites: 15

Number of accidents: 841

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.16	-1.90	0.056
PDO	-0.16	1.78	0.080
INJ	0.24	1.78	0.080
FTL	0.09	0.18	0.858

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.13	-0.87	0.384
Rear-end (01)	-0.02	-0.09	0.930
Right Angle (06)	-0.49	-1.27	0.172
Sideswipe (04)	-0.25	-0.46	0.646
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	-2.56	-0.96	0.338
Right Turn (16)	0.09	0.07	0.944
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Sign and Guardrail Installation

Number of sites: 2

Number of accidents: 180

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.11	-0.25	0.844
PDO	-0.13	-0.36	0.780
INJ	0.01	0.01	0.994
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-6.49	-2.36	0.256
Rear-end (01)	0.03	0.13	0.918
Right Angle (06)	-1.84	-0.99	0.504
Sideswipe (04)	-0.19	-1.00	0.500
Left Turn (08)	0.70	1.00	0.500
Left Turn (09)	0.06	1.00	0.500
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	0.09	1.00	0.500
Left Turn (12)	1.00	4.53	0.140
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	-0.38	-0.80	0.570
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	0.55	1.00	0.500
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

SIGNALS

Project Type: Signal Installation

Number of sites: 137

Number of accidents: 3865

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.03	0.49	0.624
PDO	0.03	0.46	0.646
INJ	0.03	0.34	0.734
FTL	-0.77	-0.68	0.498

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.19	-1.12	0.264
Rear-end (01)	-0.05	-0.56	0.576
Right Angle (06)	0.17	2.26	0.026
Sideswipe (04)	0.27	1.88	0.062
Left Turn (08)	-0.33	-1.88	0.062
Left Turn (09)	0.18	0.66	0.510
Left Turn (10)	0.16	0.41	0.682
Left Turn (11)	0.09	0.18	0.858
Left Turn (12)	0.13	0.47	0.640
Left Turn (13)	0.31	0.42	0.676
Right Turn (14)	0.19	0.53	0.596
Right Turn (15)	-1.09	-1.27	0.206
Right Turn (16)	0.13	0.45	0.654
Right Turn (17)	0.60	1.56	0.122
Right Turn (18)	inf	N/A	N/A

Project Type: Signal Modernization

Number of sites: 110

Number of accidents: 2968

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.11	1.85	0.068
PDO	0.11	1.82	0.072
INJ	0.23	2.55	0.012
FTL	-0.37	-0.34	0.734

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.21	1.06	0.292
Rear-end (01)	0.10	1.09	0.278
Right Angle (06)	0.14	1.55	0.124
Sideswipe (04)	-0.09	-0.32	0.750
Left Turn (08)	0.27	2.15	0.034
Left Turn (09)	-0.21	-0.49	0.626
Left Turn (10)	0.58	1.88	0.062
Left Turn (11)	0.34	0.95	0.354
Left Turn (12)	-0.76	-1.75	0.082
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	0.23	0.55	0.584
Right Turn (15)	0.24	0.67	0.510
Right Turn (16)	0.30	1.03	0.306
Right Turn (17)	-2.71	-1.29	0.200
Right Turn (18)	inf	N/A	N/A

Project Type: Signal Installation and Channelization

Number of sites: 34

Number of accidents: 1183

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.13	1.21	0.334
PDO	0.12	1.07	0.396
INJ	0.08	0.45	0.656
FTL	0.69	0.85	0.402

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.20	0.67	0.508
Rear-end (01)	0.01	0.09	0.928
Right Angle (06)	0.07	0.46	0.648
Sideswipe (04)	0.51	1.73	0.092
Left Turn (08)	-0.38	-0.93	0.360
Left Turn (09)	0.91	2.77	0.008
Left Turn (10)	0.85	1.77	0.086
Left Turn (11)	0.32	0.50	0.620
Left Turn (12)	0.49	1.31	0.200
Left Turn (13)	1.00	1.00	0.342
Right Turn (14)	-1.45	-1.44	0.160
Right Turn (15)	0.11	0.11	0.914
Right Turn (16)	-0.13	-0.26	0.796
Right Turn (17)	1.00	1.00	0.324
Right Turn (18)	1.00	1.44	0.160

Project Type: Signal Modernization and Channelization

Number of sites: 2

Number of accidents: 127

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.90	-0.80	0.570
PDO	-0.91	-0.74	0.594
INJ	-0.01	-0.03	0.980
FTL	1.00	1.00	0.500

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.29	2.53	0.240
Rear-end (01)	-0.71	-0.53	0.690
Right Angle (06)	-0.65	-0.68	0.620
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	-3.56	-2.04	0.290
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Signal Installation, Channelization and Signs

Number of sites: 1

Number of accidents: 20

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.01	0.01	0.992
PDO	0.00	0.01	0.992
INJ	inf	N/A	N/A
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	inf	N/A	N/A
Rear-end (01)	-0.20	-0.24	0.810
Right Angle (06)	-1.78	-0.93	0.352
Sideswipe (04)	1.00	1.02	0.308
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	1.00	1.46	0.144
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Signal Installation, Channelization & Illumination

Number of sites: 2

Number of accidents: 11

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.70	16.83	0.038
PDO	0.70	16.83	0.038
INJ	inf	N/A	N/A
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	1.00	1.00	0.500
Rear-end (01)	-0.78	-1.00	0.500
Right Angle (06)	1.00	21.91	0.030
Sideswipe (04)	1.00	1.00	0.500
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	1.00	1.00	0.500
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Flashing Beacon Installation

Number of sites: 8

Number of accidents: 151

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.07	0.44	0.674
PDO	0.01	0.07	0.946
INJ	0.24	1.45	0.190
FTL	1.00	1.43	0.196

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-2.21	-1.31	0.332
Rear-end (01)	0.01	0.02	0.984
Right Angle (06)	-0.09	-0.42	0.688
Sideswipe (04)	-0.83	-1.40	0.204
Left Turn (08)	0.44	1.52	0.172
Left Turn (09)	0.82	1.91	0.098
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	1.00	1.00	0.350
Left Turn (12)	-1.69	-1.38	0.210
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	1.00	1.00	0.350
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	1.00	1.00	0.350
Right Turn (18)	1.00	1.00	0.350

Project Type: Flashing Beacon Modernization

Number of sites: 1

Number of accidents: 15

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.09	0.20	0.844
PDO	0.03	0.08	0.936
INJ	0.82	1.74	0.082
FTL	1.00	1.03	0.302

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	inf	N/A	N/A
Rear-end (01)	0.09	0.10	0.920
Right Angle (06)	0.55	0.66	0.510
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	1.00	1.03	0.302
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	0.09	0.07	0.944
Right Turn (17)	1.00	1.03	0.302
Right Turn (18)	inf	N/A	N/A

DELINEATION

Project Type: Intersection Striping
Number of sites: 1

Number of accidents: 189

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.18	0.44	0.660
PDO	0.30	1.11	0.266
INJ	0.78	1.44	0.150
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.12	0.09	0.928
Rear-end (01)	0.18	0.44	0.660
Right Angle (06)	0.63	1.24	0.214
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	0.09	0.07	0.944
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Installation of Raised Pavement Markers

Number of sites: 61

Number of accidents: 8159

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.04	0.45	0.654
PDO	0.05	0.50	0.618
INJ	0.03	0.31	0.758
FTL	0.17	0.61	0.544

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.08	-0.74	0.462
Rear-end (01)	0.03	0.28	0.780
Right Angle (06)	0.03	0.25	0.804
Sideswipe (04)	0.02	0.11	0.912
Left Turn (08)	0.18	0.86	0.394
Left Turn (09)	-0.52	-0.90	0.372
Left Turn (10)	0.40	1.20	0.234
Left Turn (11)	0.03	0.14	0.890
Left Turn (12)	0.13	0.59	0.558
Left Turn (13)	0.54	0.78	0.438
Right Turn (14)	-0.19	-0.41	0.684
Right Turn (15)	-0.41	-1.02	0.312
Right Turn (16)	0.23	0.91	0.364
Right Turn (17)	0.32	0.49	0.626
Right Turn (18)	-1.78	-0.94	0.350

CHANNELIZATION

Project Type: Construct Channelization

Number of sites: 3

Number of accidents: 24

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.17	-0.08	0.952
PDO	0.09	-0.31	0.786
INJ	-0.47	-1.11	0.370
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.77	0.00	1.000
Rear-end (01)	inf	N/A	N/A
Right Angle (06)	inf	N/A	N/A
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	1.00	0.00	1.000
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Turn Lane Construction

Number of sites: 4

Number of accidents: 333

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.18	-0.46	0.676
PDO	-0.29	-0.69	0.540
INJ	0.01	0.02	0.986
FTL	-0.78	-0.82	0.472

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.14	0.56	0.614
Rear-end (01)	-0.56	-1.19	0.320
Right Angle (06)	-0.63	-1.02	0.382
Sideswipe (04)	-1.08	-1.37	0.264
Left Turn (08)	-1.40	-2.47	0.090
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	1.00	1.00	0.390
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	0.63	0.72	0.524
Left Turn (13)	1.00	1.00	0.390
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	-0.37	-0.32	0.770
Right Turn (16)	0.55	1.13	0.340
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Turn Lane Reconstruction

Number of sites: 2

Number of accidents: 17

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.26	0.61	0.652
PDO	0.36	0.68	0.620
INJ	0.53	0.36	0.780
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	inf	N/A	N/A
Rear-end (01)	0.69	0.69	0.616
Right Angle (06)	0.12	0.07	0.956
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	0.06	0.03	0.980
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

CONSTRUCTION/RECONSTRUCTION

Project Type: Construct Passing Blister

Number of sites: 10

Number of accidents: 497

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.01	-0.05	0.962
PDO	-0.04	-0.30	0.772
INJ	0.11	0.94	0.372
FTL	-1.28	-1.29	0.230

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.19	0.94	0.372
Rear-end (01)	-0.07	-0.33	0.652
Right Angle (06)	-1.01	-1.30	0.226
Sideswipe (04)	0.42	2.61	0.028
Left Turn (08)	0.34	0.81	0.438
Left Turn (09)	-1.81	-1.50	0.168
Left Turn (10)	1.00	1.41	0.192
Left Turn (11)	-2.71	-1.96	0.082
Left Turn (12)	0.72	1.21	0.258
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	-1.66	-0.56	0.590
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Shoulder Construction

Number of sites: 1

Number of accidents: 2

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.09	0.07	0.944
PDO	0.09	0.07	0.944
INJ	inf	N/A	N/A
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	inf	N/A	N/A
Rear-end (01)	inf	N/A	N/A
Right Angle (06)	inf	N/A	N/A
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Shoulder Repair

Number of sites: 9

Number of accidents: 200

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.52	-2.80	0.024
PDO	-0.45	-2.56	0.034
INJ	-0.23	-1.99	0.082
FTL	0.55	1.00	0.346

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-2.41	-3.40	0.010
Rear-end (01)	-0.46	-0.90	0.394
Right Angle (06)	-0.13	-1.05	0.324
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	0.46	1.00	0.354
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Improve Sight Distance

Number of sites: 1

Number of accidents: 8

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-1.72	-1.30	0.194
PDO	-0.58	-0.75	0.454
INJ	0.09	0.07	0.944
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	inf	N/A	N/A
Rear-end (01)	1.00	1.03	0.310
Right Angle (06)	inf	N/A	N/A
Sideswipe (04)	1.00	1.03	0.310
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Construct Travel Lane

Number of sites: 1

Number of accidents: 36

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-5.04	-4.32	0.001
PDO	-6.22	-1.80	0.072
INJ	inf	N/A	N/A
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-2.62	-1.24	0.216
Rear-end (01)	-4.52	-1.80	0.072
Right Angle (06)	inf	N/A	N/A
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	1.00	1.02	0.308
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Bridge Widening

Number of sites: 8

Number of accidents: 329

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.09	-0.47	0.654
PDO	-0.12	-0.65	0.536
INJ	0.01	0.02	0.984
FTL	0.24	0.45	0.666

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.05	0.14	0.492
Rear-end (01)	0.15	0.63	0.548
Right Angle (06)	-0.43	-2.30	0.056
Sideswipe (04)	-0.02	-0.04	0.970
Left Turn (08)	-0.84	-0.49	0.640
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	-5.49	-1.83	0.110
Left Turn (12)	0.46	1.27	0.244
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	1.00	1.00	0.350
Right Turn (16)	0.06	0.04	0.970
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

PAVEMENT TREATMENTS

Project Type: Resurfacing

Number of sites: 73

Number of accidents: 5615

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.07	1.40	0.176
PDO	0.06	1.08	0.284
INJ	-0.06	-0.77	0.444
FTL	-1.06	-2.20	0.032

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.08	-0.91	0.366
Rear-end (01)	-0.01	-0.15	0.881
Right Angle (06)	-0.01	-0.07	0.944
Sideswipe (04)	0.22	1.56	0.124
Left Turn (08)	-0.28	-0.58	0.564
Left Turn (09)	0.02	0.04	0.968
Left Turn (10)	-0.18	-0.42	0.676
Left Turn (11)	0.24	0.82	0.414
Left Turn (12)	0.19	0.91	0.366
Left Turn (13)	1.00	1.00	0.320
Right Turn (14)	0.09	0.28	0.780
Right Turn (15)	-0.34	-0.67	0.506
Right Turn (16)	0.50	1.43	0.158
Right Turn (17)	-0.84	-0.51	0.612
Right Turn (18)	inf	N/A	N/A

Project Type: Wedge and Level

Number of sites: 164

Number of accidents: 5680

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.06	0.99	0.324
PDO	0.09	1.21	0.228
INJ	0.04	0.55	0.584
FTL	0.06	0.18	0.858

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.04	0.45	0.654
Rear-end (01)	0.20	1.46	0.146
Right Angle (06)	-0.05	-0.60	0.550
Sideswipe (04)	-0.04	-0.26	0.796
Left Turn (08)	0.27	1.77	0.078
Left Turn (09)	-0.88	-1.77	0.078
Left Turn (10)	-0.36	-0.77	0.442
Left Turn (11)	0.49	1.49	0.138
Left Turn (12)	0.05	0.23	0.818
Left Turn (13)	0.09	0.07	0.944
Right Turn (14)	0.15	0.36	0.720
Right Turn (15)	0.67	1.83	0.070
Right Turn (16)	0.19	0.55	0.584
Right Turn (17)	0.09	0.10	0.920
Right Turn (18)	inf	N/A	N/A

SAFETY BARRIERS

Project Type: Guardrail Installation

Number of sites: 3

Number of accidents: 222

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.65	-1.91	0.196
PDO	-0.54	-3.23	0.084
INJ	-0.40	-3.89	0.060
FTL	-1.75	-1.98	0.186

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-0.44	-0.75	0.532
Rear-end (01)	-0.43	-0.80	0.508
Right Angle (06)	-0.88	-3.17	0.086
Sideswipe (04)	-0.15	-0.09	0.936
Left Turn (08)	-0.81	-0.43	0.710
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	-0.75	-0.31	0.786
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Guardrail Replacement

Number of sites: 6

Number of accidents: 326

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.07	0.32	0.762
PDO	0.06	0.34	0.748
INJ	0.25	1.02	0.354
FTL	-3.56	-1.98	0.104

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.37	1.28	0.256
Rear-end (01)	0.25	1.02	0.354
Right Angle (06)	-1.07	-2.39	0.064
Sideswipe (04)	-0.10	-0.20	0.850
Left Turn (08)	0.78	0.73	0.498
Left Turn (09)	0.12	0.09	0.932
Left Turn (10)	-0.78	-0.45	0.672
Left Turn (11)	1.00	1.00	0.364
Left Turn (12)	-0.50	-0.64	0.550
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	1.00	1.00	0.364
Right Turn (18)	inf	N/A	N/A

Project Type: Bridge Railing and Deck Repair

Number of sites: 1

Number of accidents: 141

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.13	0.80	0.424
PDO	0.15	1.35	0.178
INJ	0.07	0.25	0.802
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.24	0.49	0.624
Rear-end (01)	0.17	0.53	0.596
Right Angle (06)	0.04	0.11	0.912
Sideswipe (04)	-1.66	-0.90	0.368
Left Turn (08)	-1.06	-1.09	0.276
Left Turn (09)	0.55	0.66	0.510
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	0.12	0.09	0.928
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	-0.34	-0.33	0.742
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

ILLUMINATION

Project Type: Lighting Installation

Number of sites: 4

Number of accidents: 61

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.03	-0.04	0.970
PDO	-0.16	-0.18	0.868
INJ	-0.09	-0.06	0.956
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.69	0.61	0.584
Rear-end (01)	-1.09	-1.31	0.282
Right Angle (06)	0.09	0.10	0.926
Sideswipe (04)	0.54	0.44	0.690
Left Turn (08)	-2.03	-0.82	0.472
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	1.00	1.00	0.390
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	1.00	1.00	0.390
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	1.00	1.00	0.390
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Lighting Modernization

Number of sites: 1

Number of accidents: 17

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.13	-0.25	0.804
PDO	-0.24	-0.46	0.646
INJ	0.40	0.55	0.582
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	-2.65	-1.25	0.212
Rear-end (01)	inf	N/A	N/A
Right Angle (06)	0.39	0.55	0.582
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Luminaire Replacement

Number of sites: 9

Number of accidents: 86

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.16	0.30	0.772
PDO	0.11	0.20	0.846
INJ	-0.58	-0.46	0.658
FTL	1.00	1.00	0.346

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.09	0.15	0.884
Rear-end (01)	0.20	0.23	0.824
Right Angle (06)	-0.65	-0.79	0.452
Sideswipe (04)	0.56	0.65	0.534
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	1.00	1.00	0.346
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	1.00	1.00	0.346
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	1.00	1.00	0.346
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Bridge Lighting Installation

Number of sites: 1

Number of accidents: 12

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.59	1.55	0.122
PDO	0.59	1.68	0.092
INJ	1.00	1.79	0.074
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.09	0.07	0.944
Rear-end (01)	inf	N/A	N/A
Right Angle (06)	0.06	0.05	0.960
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

RAILROAD PROJECTS

Project Type: Railroad Signal Installation

Number of sites: 1

Number of accidents: 4

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-2.50	-1.22	0.222
PDO	-2.50	-1.72	0.086
INJ	inf	N/A	N/A
FTL	inf	N/A	N/A

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	inf	N/A	N/A
Rear-end (01)	inf	N/A	N/A
Right Angle (06)	inf	N/A	N/A
Sideswipe (04)	inf	N/A	N/A
Left Turn (08)	inf	N/A	N/A
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	1.00	1.03	0.304
Left Turn (12)	inf	N/A	N/A
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	inf	N/A	N/A
Right Turn (16)	inf	N/A	N/A
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	inf	N/A	N/A

Project Type: Railroad Grade Crossing Removal
Number of sites: 10

Number of accidents: 257

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	0.18	0.34	0.742
PDO	0.17	0.34	0.742
INJ	-0.19	-0.26	0.800
FTL	0.54	0.67	0.520

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.19	0.35	0.734
Rear-end (01)	-0.05	-0.11	0.914
Right Angle (06)	0.15	0.20	0.846
Sideswipe (04)	0.46	0.93	0.376
Left Turn (08)	-0.21	-0.18	0.862
Left Turn (09)	inf	N/A	N/A
Left Turn (10)	inf	N/A	N/A
Left Turn (11)	inf	N/A	N/A
Left Turn (12)	0.09	0.09	0.930
Left Turn (13)	inf	N/A	N/A
Right Turn (14)	inf	N/A	N/A
Right Turn (15)	1.00	1.00	0.344
Right Turn (16)	0.06	0.04	0.968
Right Turn (17)	inf	N/A	N/A
Right Turn (18)	1.00	1.00	0.344

REGULATION

Project Type: Upgrade No-Passing Zones
Number of sites: 34

Number of accidents: 4099

Accident Reduction Factors - by Severity

Name	ARF	Statistic	P-value
Total	-0.01	-0.07	0.944
PDO	-0.02	-0.18	0.858
INJ	-0.09	-0.82	0.418
FTL	0.16	0.39	0.700

Accident Reduction Factors - by Collision Type

Collision Type	ARF	Statistic	P-value
Head-on (02)	0.05	0.34	0.536
Rear-end (01)	-0.11	-0.07	0.944
Right Angle (06)	-0.09	-0.99	0.330
Sideswipe (04)	0.22	1.08	0.292
Left Turn (08)	-0.27	-1.59	0.122
Left Turn (09)	-0.66	-1.89	0.068
Left Turn (10)	0.16	0.70	0.492
Left Turn (11)	0.21	1.09	0.284
Left Turn (12)	0.24	1.44	0.160
Left Turn (13)	-2.74	-1.74	0.092
Right Turn (14)	0.52	1.49	0.146
Right Turn (15)	0.17	0.40	0.692
Right Turn (16)	0.15	0.73	0.470
Right Turn (17)	0.10	0.20	0.842
Right Turn (18)	-0.87	-0.41	0.684

TECHNICAL SUMMARY

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ACCIDENT REDUCTION FACTORS FOR INDIANA

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FHWA/IN/JHRP-91/11

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Background

An Accident Reduction Factor (ARF) is a measure of the effectiveness of an improvement in reducing the number of accidents at a location or group of locations of the same improvement type. Because the Indiana Department of Transportation (INDOT) has been using reduction factors developed outside Indiana, this project was undertaken to develop reduction factors from Indiana construction and accident records.

Results

A list of 38 improvement types was developed and ten years of construction and accident records were examined. After ambiguous and otherwise unsuitable data were removed, and the effects of traffic volume changes were introduced, accident reduction factors were calculated for each improvement type. After appropriate statistical analyses were carried out, it was found that small sample sizes for certain improvement types led to counterintuitive values. In these cases, the values from the larger non-Indiana data bases were adopted. The suggested accident reduction factors are summarized in the accompanying table. The suggested reduction factors for use in Indiana are given in Table 1.

Conclusions

Although there was insufficient information to calculate statistically reliable accident factors for some improvement types, ongoing INDOT data collection activities will gradually solve this problem. Specific measures, such as collecting volume data before and after the construction period at a site scheduled for an improvement would make possible more accurate traffic volume adjustments than are currently possible. In the meantime, the accident reduction factors contained in the accompanying table will assist the Indiana Department of Transportation in incorporating accident reduction potential in the programming of highway improvement projects.

Contact

For further information the following persons can be contacted: Prof. Jon D. Fricker or Prof. Kumares C. Sinha, School of Civil Engineering, Purdue University, W. Lafayette, Indiana 47907.

Table 1

Suggested Reduction Factors for Use in Indiana

Project Types Studied	Suggested ARF
SIGNS	
Sign Installation	0.15
Overhead Sign Installation	0.00
Sign Modernization	0.15
Sign Illumination	0.00
Illuminated Sign Installation	0.15
Sign and Guardrail Installation	0.15
SIGNALS	
Signal Installation	0.13
Signal Modernization	0.11
Signal Inst and Channelization	0.13
Signal Mod and Channelization	0.11
Signal Inst, Channel & Signs	0.50
Signal Inst, Channel & Illumin.	0.70
Flashing Beacon Installation	0.07
Flashing Beacon Modernization	0.09
DELINEATION	
Intersection Striping	0.18
Raised Pavement Marker Installation	0.04
CHANNELIZATION	
Construct Channelization	0.17
Turn Lane Construction	0.20
Turn Lane Reconstruction	0.26

Table 1, continued

Project Types Studied	Suggested ARF
CONSTRUCTION/RECONSTRUCTION	
Construct Passing Blister	0.20
Shoulder Construction	0.09
Shoulder Repair	0.20
Improve Sight Distance	0.30
Construct Travel Lane	0.10
Bridge Widening	0.40
PAVEMENT TREATMENTS	
Resurfacing	0.07
Wedge and Level	0.06
SAFETY BARRIERS	
Guardrail Installation	0.04
Guardrail Replacement	0.07
Bridge Railing and Deck Repair	0.13
ILLUMINATION	
Lighting Installation	0.37
Lighting Modernization	0.25
Luminaire Replacement	0.16
Bridge Lighting Installation	0.59
RAILROAD PROJECTS	
Railroad Signal Installation	0.80
Railroad Grade Crossing Removal	0.18
REGULATION	
Upgrade No-Passing Zones	0.30
Elimination of Parking Zones	0.08

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