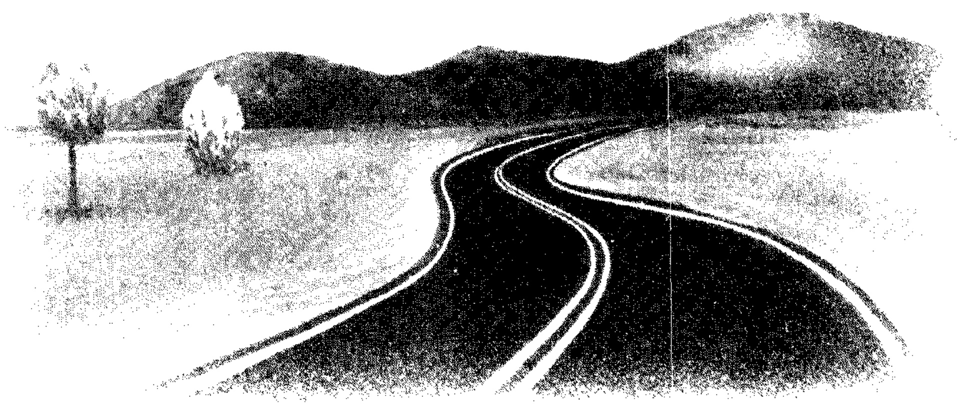
COST-EFFECTIVENESS AND SAFETY OF ALTERNATIVE ROADWAY DELINEATION TREATMENTS FOR RURAL TWO-LANE HIGHWAYS

VOL. V. APPENDIX C, STATISTICAL MODEL DEVELOPMENT



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FINAL REPORT

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FOREWORD

This six-volume report presents the findings of a research study to assess the effect of various delineation treatments on accident rates. Cost-benefit and cost models for evaluating specific delineation treatments were developed. Delineation guidelines were formulated by executing the cost-benefit models for selected delineation treatments.

The six volumes are:

Vol. I	Executive Summary
Vol. II	Final Report
Vol. III	Appendix A, Site Selection and Data Collection
Vol. IV	Appendix B, Development and Description of Computerized Data Base
Vol. V	Appendix C, Statistical Model Development
Vol. VI	Appendix D, Cost of Roadway Accidents and Appendix E, Cost and Service Life of Roadway Delineation Treatments.

Sufficient copies of the Executive Summary are being distributed to provide a minimum of two copies to each FHWA Regional Office, one copy to each Division Office, and five copies to each State highway agency. One copy of the Final Report is being provided to each FHWA Regional and Division Office and one to each State highway agency. Volumes III through VI are available only on request.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

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16. Abstract

Under this research study, the effect of various delineation treatments on accident rates was assessed by analyzing accident data from more than 500 roadway sites in 10 States for tangent, winding and isolated horizontal curve sections on two-lane rural highways. Cost-benefit and cost models for evaluating specific delineation treatments were developed and guidelines formulated by executing the cost-benefit models for selected delineation treatments.

This Volume describes in detail the statistical model development, descriptive statistics, evaluation of alternative dependent variables, and the results of the statistical analysis. Other volumes produced under this research study are:

Vol.	FHWA No.	Report Title
I	78-50	Executive Summary
II	78-51	Final Report
III	78-52	Appendix A, Site Selection and Data Collection
IV	78-53	Appendix B, Dev. & Descrip. of Computerized Data Base
VI	78-55	Appendix D, Cost of Roadway Accidents and Appendix E, Cost and Service Life of Roadway Delineation Treatments.

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PREFACE

This document and its appendices constitute the final report for the study "Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments." The study was conducted by Science Applications, Inc., with the assistance of Alan M. Voorhees and Associates, Inc., Dr. James Taylor, University of Notre Dame, and Mr. John Glennon, for the Federal Highway Administration under Contract DOT-FH-11-8587.

Science Applications, Inc., and FHWA wish to acknowledge the assistance of the many people who participated in this study, particularly Robert Felsburg of AMV, Sandra Morrow, SAI, and the key individuals in the ten states, listed below, where data collection took place. Without their cooperation this study would not have been possible.

States	Key Personnel
Arizona, Department of Transportation	Mr. Ross E. Kelley, Traffic Engineer, Safety Projects Services
California, Department of Transportation	Mr. Perry Lowden, Chief, Sign and Delineation Section
	Mr. James B. Dobbins, County Traffic Engineer for the County of Riverside
Connecticut, Department of Transportation	Dr. Charles E. Dougan, Chief of Research and Development
Georgia, Department of Transportation	Mr. Archie C. Burnham, Jr., State Traffic and Safety Engineer
	Mr. Arthur Durshimer, Jr., Traffic and Safety Engineer
Idaho, Department of Transportation	Mr. James L. Pline, Traffic Engineer

Louisiana, Department of Highways	Mr. Grady Carlisle, State Traffic and Planning Engineer
	Mr. John E. Evanco, Highway Planning and Needs Engineer
Maryland, Department of Transportation	Mr. Pierce E. Cody, III, Chief, Bureau of Highway Maintenance
	Mr. Paul S. Jaworski, Chief, Bureau of Accident Studies
Ohio, Department of Transportation	Mr. John LeGrand, Chief, Bureau of Transportation Safety
	Mr. John H. White, Assistant, System Facilities
Virginia, Department of Highways and Transportation	Mr. A.L. Thomas, Assistant, State Traffic and Safety Engineer
	Mr. P.J. Stenger, Associate Traffic Engineer
Washington, State Highway Commission	Mr. J.A. Gallagher, Traffic Engineer
	Mr. W.R. Curry, Traffic Operations Engineer

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Metric Conversion Factors

Several customary units appear in the text of this report. Generally, it is the policy of FHWA to express measurements in both customary and SI units. The purpose of this policy is to provide an orderly transition to the use of SI exclusively. It was decided that dualization of tables was not warranted because of the additional cost and delay in making this research available. Instead, the following conversion table is included.

To Convert	To	
in	mm	Multiply by 25.4*
ft	m	Multiply by 0.3048*
mi	km	Multiply by 1.609
mi/h	km/h	Multiply by 1.609
ft^2	m^2	Multiply by 0.0929
gal	L	Multiply by 3.785
^oF	^oC	Subtract 32 and multiply by 5/9
$\frac{Accidents}{MVm}$	$\frac{Accidents}{MVkm}$	Divide by 1.609
lb	kg	Multiply by 0.4536

The pound is a measure of force (weight) and the kilogram is a measure of mass. Mass and weight are not equivalent. For an object weighted under normal gravitational conditions, however, the above relationship may be used.

The Federal Highway Administration recognizes the "Standard for Metric Practice," E380 of the American Society for Testing and Materials, as the authority for SI usage.

*Denotes exact conversion factor

APPENDIX C

STATISTICAL MODEL DEVELOPMENT

C.1 INTRODUCTION

In the cost-benefit model developed within this study, the primary benefits of roadway delineation treatment were those resulting from a reduction in traffic accidents. Accident and roadway data collected from 514 test sites were analyzed to assess these benefits. This appendix describes the statistical analysis of these accident data. The selection of highway sites, collection of site specific data, and the development of a computerized data base are discussed in Appendices A and B.

For the purposes of this study, two types of highway sites were selected. The first, termed "matching-control" sites, were those for which the delineation treatment remained unaltered over the analysis period. The second, termed "before-after" sites, were those for which accident data were available for both before and after the installation of a particular delineation treatment. Although both types of sites were analyzed, the emphasis within this study was on the analysis of matching-control sites. For reasons more practical than theoretical, before-after sites were generally difficult to find. It was even more difficult to find corresponding matching-control sites for selected before-after sites, the available time and resources did not permit visits to individual test sites which would be required to select appropriate matching-control sites for selected before-after sites.

The statistical analysis presented can be broadly classified as follows:

1. Theoretical Modeling
2. Descriptive Statistics
3. Matching-Control Analysis
4. Before-After Analysis

It was decided that one of the dependent variables would be accident rate. However, within the matching-control analysis an additional investigative statistical analysis was conducted to determine if other forms of a dependent variable (e.g., severity index or accident rate based on nighttime-only accidents) might be more sensitive to the changes in roadway delineation treatments. This analysis and its results are discussed in the section on "Matching-Control."

C.2 THEORETICAL MODELING

Before starting the actual statistical analysis of the data base, models describing the distribution of accident rates based solely upon theoretical modeling were developed to assist in the selection of appropriate statistical procedures. This section describes the modeling of the accident rate distribution and demonstrates how these developed models were utilized to select a weighting scheme for the anlaysis of the data.

C.2.1 Distribution of Accident Rate

Accident rate, denoted here by $\lambda(\phi)$, can be defined by:

$$\lambda(\phi) = \frac{N(\phi)}{\phi}$$

where $N(\phi)$ is the number of accidents occurring over an exposure ϕ, and where (ϕ) is measured in units of million-vehicle miles (1.6 MVkm) longitudinal sections and million vehicles for isolated highway situations (e.g., isolated horizontal curves).

To model the distribution of $\lambda(\phi)$, the occurrence of traffic accidents can be thought of as events occurring as a result of repetitive type independent trials. The trials are the traversing of vehicles through the test sections, and the events are accidents. In modeling the accident rate, the following assumptions are therefore made:

- A trial corresponds to (a) the traversing of a vehicle through the test section for isolated highway situations such as isolated horizontal curves and (b) the traversing of a vehicle through one mile (1.6 km) of the test section for longitudinal situations.
- The event corresponds to the occurrence of an accident.
- For multiple-vehicle accidents (accidents involving more than one vehicle), all vehicles involved constitute one event.
- There is a fixed probability, denoted by p, that an individual trial would result in the occurrence of an event, i.e., there is a probability p that a vehicle would be involved in an accident while traversing the section (or traversing a mile (1.6 km) of the test section in the case of longitudinal situations).

Given the above assumptions, $N(\phi)$ will have a binominal distribution denoted:

$$P\left[N(\phi) = x\right] = \binom{\phi}{x} p^{x} (-p)^{\phi-x}$$

This distribution, for the present situation, can be approximated by other distributions as follows: The probability (p) of an individual vehicle getting involved is clearly very small, and exposure ϕ is very large, generally in the millions. Hence, the above binomial distribution can be approximated by a Poisson distribution[1] with mean and variance $c = \phi p$. Then using this Poisson model for $N(\phi)$ and the relationship $\lambda(\phi) = N(\phi)/\phi$, the distribution for the accident rate statistic $\lambda(\phi)$ is

$$P \; \lambda(\phi)=\ell \;=\; \frac{e^{-\lambda\phi}(\lambda\phi)^{\ell\phi}}{(\ell\phi)!} \qquad =0,\frac{1}{\phi},\frac{2}{\phi},\frac{3}{\phi},\ldots$$

with mean and variance

$$E\left[\lambda(\phi)\right] = \lambda$$

$$Var\left[\lambda(\phi)\right] = \lambda/\phi$$

where λ is the theoretical mean rate. This Poisson model is a key development of this study.

Yet another approximation is possible: If the mean total $c=\phi p=\lambda\phi$ is sufficiently large, both the binomial Poisson distributions can be approximated by a normal distribution[1][2]. In that case, it can be further shown that the statistical accident rate $\lambda(\phi)$ is also normal with mean λ and variance λ/ϕ, as before.

For all of the matching-control analysis and much of the before-after analysis, the c's (total number of accidents over the total exposure for each subcategory group of sites) are large enough to justify the normal approximation. Hence, because of the obvious advantages of assuming data points to be normally distributed, the accident data points were assumed normally distributed for these analyses. Some of the before-after analysis, however, reverted to the pure Poisson model.

C.2.2 Non-homogeneity of Variance

The accident rates computed for sites with varying exposures have non-homogeneous variance. Sites selected within this study have dissimilar exposures. The problem of non-homogeneous variance, therefore, is not a mere mathematical technicality but is of practical importance for the purpose of this study.

In its generality, consider n data points $X_1, X_2, \ldots, X_n$ which come from normal populations with the same mean μ but with different variances. Let the variances of $X_1, X_2, \ldots, X_n$ be $\sigma_1^1, \sigma_2^2, \ldots, \sigma_n^2$, respectively. Then the compound probability that "X_1 is derived from a normal population with mean μ and a variance of σ_1, X_2 is derived from a normal population with mean μ and variance σ_2, and so on" is given by the likelihood function L defined:

$$L = \left[\prod_{i=1}^{n} \left(\frac{1}{\sigma_i \sqrt{2\pi}}\right)\right] \cdot \left[e^{-\frac{1}{2}} \sum_{i=1}^{n} \left(\frac{X_i - \mu}{\sigma_i}\right)^2\right]$$

The maximum likelihood estimator $\hat{\mu}$ of the population mean μ is an estimator that maximizes the likelihood function L as a function of μ. Finding $\hat{\mu}$ is equivalent to finding the maximizer of log L. Therefore, taking the logarithm of L and setting

$$\frac{\partial \log L}{\partial \mu} = 0$$

yields

$$\sum_{i=1}^{n} \frac{x_i - \mu}{\sigma_i^2} = 0$$

or finally

$$\hat{\mu} = \frac{\displaystyle\sum_{i=1}^{n} \frac{X_i}{\sigma_i^2} = 0}{\displaystyle\sum_{i=1}^{n} \frac{1}{\sigma_i^2}}$$

The variance of $\hat{\mu}$ is obtained as follows:

$$\text{Var}\ [\hat{\mu}] = \text{Var}\left[\frac{\displaystyle\sum_{i=1}^{n} \frac{X_i}{\sigma_i^2}}{\displaystyle\sum_{i=1}^{n} \frac{1}{\sigma_i^2}}\right]$$

$$= \left[\frac{1}{\left(\displaystyle\sum_{i=1}^{n} \frac{1}{\sigma_i^2}\right)^2}\right]\left[\sum_{i=1}^{n} \left(\frac{1}{\sigma_i^2}\right)^2 \text{Var}\ X_i\right]$$

or finally

$$\text{Var}\,[\hat{\mu}] = \frac{1}{\sum_{i=1}^{n} \frac{1}{\sigma_i^2}}$$

To translate these results for the highway situation, suppose one wishes to estimate the mean accident rate $\hat{\mu}$ from n test sites. Let individual site accident rates be $\lambda_1(\phi)$, $\lambda_2(\phi_2)$, ..., $\lambda_n(\phi_n)$ which are computed from site exposures ϕ_1, ϕ_2,..., ϕ_n, respectively. The respective variances of the computed rates are $\frac{\lambda}{\phi_1}$, $\frac{\lambda}{\phi_2}$, ..., $\frac{\lambda}{\phi_n}$. Substituting $\lambda_i(\phi_i)$ for X_i, $\frac{\lambda}{\phi_i}$ for σ_i^2 and $\hat{\lambda}$ for $\hat{\mu}$, the estimated accident rate $\hat{\lambda}$ is given:

$$\hat{\lambda} = \frac{\sum_{i=1}^{n} \phi_i \cdot \lambda_i(\phi_i)}{\sum_{i=1}^{n} \phi_i} = \frac{\sum_{i=1}^{n} N_i(\phi_i)}{\sum_{i=1}^{n} \phi_i}$$

Then

$$\text{Var}\,[\hat{\lambda}] = \frac{\sum_{i=1}^{n} \phi_i \cdot \lambda_i(\phi_i)}{\left(\sum_{i=1}^{n} \phi_i\right)^2} = \frac{\sum_{i=1}^{n} N_i(\phi_i)}{\left(\sum_{i=1}^{n} \phi_i\right)^2}$$

Knowing the best estimator of the mean and its variance, simple statistical hypothesis testing such as the comparison of the means can be conducted as illustrated by the following example.

Let there be two subcategories of sites with two different delineation treatments, treatment 1 and treatment 2. Further, let

m_j = number of sites with treatment j, j=1, 2

ϕ_{ij} = exposure of the ith site with treatment j; i=1, ..., m_j, j=1, 2

$N_{ij}(\phi_{ij})$ = number of accidents occurring at the ith site with treatment j; i=1, ..., m_j j=1, 2

$\hat{\lambda}^j$ = estimated accident rate for sites with treatment j

$\hat{\lambda}^j$ = true accident rates for sites with treatment j

Then the hypothesis

$$H_0 : \lambda^1 = \lambda^2$$
$$H_1 : \lambda^1 > \lambda^2$$

can be tested: The random variable z, where

$$z = \frac{(\hat{\lambda}^1-\hat{\lambda}^2) - (\lambda^1-\lambda^2)}{\sqrt{\frac{\lambda^1}{\phi^1} + \frac{\lambda^2}{\phi^2}}} ,$$

will be normally distributed with mean 0 and variance 1 if H_0 is indeed true. Here $\hat{\lambda}^1$, $\hat{\lambda}^2$, ϕ^1 and ϕ^2 are given by

$$\hat{\lambda}^1 = \frac{\sum_{i=1}^{m_1} N_{i_1}(\phi_{i_1})}{\sum_{i=1}^{m_1} \phi_{i_1}} \qquad \phi^1 = \sum_{i=1}^{m_1} \phi_{i_1}$$

$$\hat{\lambda}^2 = \frac{\sum_{i=1}^{m_2} N_{i_2}(\phi_{i_2})}{\sum_{i=1}^{m} \phi_{i_2}} \qquad \phi^2 = \sum_{i=1}^{m_2} \phi_{i_2}$$

It is obvious that by a systematic theoretical modeling, the whole statistical analysis can conceptually be conducted precisely. But a detailed evaluation of the feasibility of such a procedure precluded its application to the large data base available for this study for several reasons:

- This procedure would have precluded the use of computerized statistical packages such as SPSS and BMD. The data base available could not be analyzed within the set time and cost frame without the use of a computerized package.
- The added benefits of following the theoretically modeled procedure were considered marginal at best. The models make several assumptions that are yet to be validated.
- A sophisticated analysis cannot compensate for the deficiencies in the data base. Due to the inherent problems associated with the collection of roadway accident data, the quality of available data was not considered good enough to warrant such an analysis.

An alternative procedure to address the non-homogeneity of variance of the data points is to assign a weight to each site through an appropriate weighting scheme. This is also computationally efficient as the computerized statistical subroutine package SPSS chosen for the analysis has provision to assign weights to each individual data point. Hence, various weighting schemes were investigated for their suitability.

The selected weighting scheme weights each site by the site exposure properly normalized. It was intuitively obvious that sites should be assigned weights in proportion to their site exposure, as the variance of the computed site accident rate is inversely proportional to the site exposure. The normalization was required to control the number of cases that would be utilized as a result of this weighting scheme. Within SPSS a data point X weighted by w is treated as w data points (cases) each with value X.

To develop this weighting scheme, suppose that a particular statistical analysis treats k subcategories of sites (k different delineation treatments for example) with m_1 sites available within subcategory 1 and m_k sites within subcategory k. Further, let ϕ_{ij} be the exposure and $\lambda_{ij}(\phi_{ij})$ the computed accident rate of the ith site with subcategory j. The weight assigned to the ith site within subcategory j is then given by w_{ij}, where

$$w_{ij} = \phi_{ij} \cdot \left[\frac{\ell}{\sum_{(ij)\in S} \phi_{ij}} \right]$$

The term within the bracket is the normalizing factor; ℓ and S will be defined below.

The weighted mean accident rate for the sites within subcategory j is then given by

$$\hat{\lambda}^j = \frac{\sum_{i=1}^{m_j} w_{ij} \cdot \lambda_{ij}(\phi_{ij})}{\sum_{i=1}^{m_j} w_{ij}}$$

On substituting the value of w_{ij} and simplifying, this yields

$$\hat{\lambda}_j = \frac{\sum_{i=1}^{m_j} \phi_{ij} \cdot \lambda_{ij}(\phi_{ij})}{\sum_{i=1}^{m_j} \phi_{ij}}$$

This indicates that whatever the value of ℓ and definition of S, the weighted mean is the maximum likelihood estimator of the accident rate for sites within subcategory j.

Proceeding in a similar fashion, the variance of the estimated mean $\hat{\lambda}_j$ (i.e., square of the standard error of estimate) is given by

$$\mathrm{Var}\,[\hat{\lambda}^j] = \left[\frac{\sum_{i=1}^{m_j} w_{ij} \left[\lambda_{ij}(\phi_{ij}) \right]^2}{\sum_{i=1}^{m_j} w_{ij}} - \left(\hat{\lambda}^j\right)^2 \right] \cdot \frac{1}{\sum_{i=1}^{m_j} w_{ij}}$$

which simplifies to

$$\mathrm{Var}\,[\hat{\lambda}^j] = \left[\frac{\sum_{i=1}^{m_j} \left[\phi_{ij} \cdot \lambda_{ij}(\phi_{ij})\right]^2}{\sum_{i=1}^{m_j} \phi_{ij}} - \left\{ \frac{\sum_{i=1}^{m_j} \phi_{ij} \cdot \lambda_{ij}(\phi_{ij})}{\sum_{i=1}^{m_j} \phi_{ij}} \right\}^2 \right]$$

$$\left[\frac{1}{\left(\frac{\ell}{\sum_{ij \in} \phi_{ij}} \right) \cdot \left(\sum_{i=1}^{m_j} \right) \phi_{ij}} \right]$$

Hence the standard error of estimate, contrary to the weighted mean, is very much dependent upon S and the value of ℓ. However, a hard look at this expression also indicates that the only term that depends on ℓ and S is the number of sample points utilized in computing the standard error of estimate of $\hat{\lambda}^j$ (square root of Var $[\hat{\lambda}^j]$). In subsequent discussions we shall term this number the "effective number of sites" utilized in the computation of standard error of estimate. It should be noted that in the absence of a normalization term in the weighting scheme, the effective number of sites would be

$$\sum w_{ij} = \sum_{i=1}^{m_j} {}_{ij}$$

which, in general, would be an inordinately large number. Through the normalization term

$$\frac{\ell}{\sum_{(ij)\in S} \phi_{ij}}$$

This effective number can be suitably adjusted. In addition, by choosing different values for ℓ and S, the effective number of sites within various subcategories of sites and the total effective number of sites utilized in the analysis can also be adjusted. Alternative weighting schemes developed by choosing different values of ℓ and S are presented below. The manner in which the effective number of sites relate to the actual number of highway sites under different weighting schemes is also discussed.

<u>Alternative 1:</u> Ignore the Problem (i.e., no weighting). This alternative assures that the variance of the estimated site accident rate is independent of the site exposure. Within a subcategory of sites, all accident rates can, therefore, be assumed to come from the same population with constant mean and constant variance, irrespective of the site exposure utilized to compute these rates.

<u>Alternative 2:</u> Ignore the Normalizing Factor. This is merely the weighting of each site by its site exposure and, in effect, assuming that a site (ij) is equivalent to ϕ_{ij} number of sites all with the same accident rate, namely $\lambda_{ij}(\phi_{ij})$. The effective number of available sites with treatment j are

$$\sum_{i=1}^{m_j} \phi_{ij}$$

The obvious drawback of this alternative is that it artificially creates a large number of sites. Certain statistics will appear significant merely because of the large number of weighted sites. Clearly if ϕ_{ij} sites were selected, each with a unit exposure, the computed accident rate would be different for each of these sites and not a constant $\lambda_{ij}(\phi_{ij})$ as is assumed here.

<u>Alternative 3:</u> ℓ = Total number of general (or horizontal curve) sites

S = All general (horizontal curve) sites

Under this alternative, the effective number of sites within a subcategory utilized to compute standard error of estimate would be in proportion to the total exposure available within that subcategory. Hence, if m_1 and m_2* are the actual number of sites available within subcategories 1 and 2 for horizontal curves, the effective numbers m_1^* and m_2^* utilized to compute the standard error of estimate are given by

$$m_1^* = \frac{\sum_{i=1}^{m_1} \phi_{i1} \cdot \text{(Total \# of Horizontal Curve Sites)}}{\text{(Total Exposure for Horizontal Curve Sites)}}$$

$$m_2^* = \frac{\sum_{i=1}^{m_2} \phi_{i2} \cdot \text{(Total \# of Horizontal Curve Sites)}}{\text{(Total Exposure for Horizontal Curve Sites)}}$$

It can be further verified that

$$m_1^* \neq m_1$$
$$m_2^* \neq m_2$$

and $m_1^* + m_2^* \neq m_1 + m_2$

<u>Alternative 4:</u> ℓ = Total number of sites within a subcategory
S = All sites within that subcategory

Under this alternative, if mean accident rate for several treatments is to be compared through one-way analysis of variance (or through t-test in the case of two treatments), the ith site with the jth treatment is assigned a weight

$$w_{ij} = \frac{\ell_j \cdot \phi_{ij}}{\sum_{i=1}^{m_j} \phi_{ij}}, \quad i=1, \ldots, m_j, \; j=1, \ldots, k, \; \ell_j=m_j$$

Hence, the normalizing factor of the weight depends upon the subcategory of the site. Following the notations of alternative 3, it can be easily verified that

$$m_1^* = m_1$$
$$m_2^* = m_2$$

The effective number of sites is, therefore, the same as the actual number of sites available within a subcategory. The sites within a subcategory are weighted in direct proportion to the site exposure.

Alternative 5: ℓ = Total number of sites available within the particular analysis

S = All sites available within that analysis

Within this alternative, the total number of sites available for the analysis remains unaltered. These sites, however, redistribute themselves within the subcategories in proportion to the total exposure available for each subcategory. The effective number of sites within a subcategory is proportional to the total subcategory exposure.

Following earlier notations, if there are k subcategories with m_j sites within subcategory j and

$$m = \sum_{j=1}^{k} m_j$$

then the weight assigned to site (ij) is

$$W_{ij} = \frac{m \cdot \phi_{ij}}{\sum_{j=1}^{k} \sum_{i-1}^{m_j} \phi_{ij}}$$

Here $m_j^* \neq m_j$

but $$\sum_{j=1}^{k} m_j^* = \sum_{j=1}^{k} m_j$$

It is obvious that if a particular analysis includes all general sites (horizontal curve sites), then this alternative is equivalent to alternative 3.

Prior to making a final selection, test runs were conducted to see how different weighting schemes altered the results. Only matching-control sites were utilized in these test runs. The results of these runs are presented in Tables 1 and 2. Table 1 presents the results of the t-tests, and the comparison of two sets of treatments (a) no treatment vs. centerline treatment and (b) centerline vs. centerline + edgeline utilizing different weights. The results, based on the theoretically modeled accident rate, are also included in Table 1. The related calculations for the mean and variance of accident rate are included in Tables 3 and 4. Table 2 condenses the results of one-way analysis of variance conducted with different weighting schemes for the treatment categories given below:

TREATMENT CATEGORIES FOR ANALYSIS

Treatment Category	General Situation	Horizontal Curve
1	no treatment	no treatment
2	painted CL	painted & RPM CL
3	RPM centerline	guardrail
4	CL + EL	CL + EL
5	CL + Post	CL + Post
6	CL + EL + Post	CL + EL + Post

Table 1. Comparison of t-test results under different weighting schemes.

Null Hypothesis: $H_0 : \lambda_1 = \lambda_2$

$H_1 : \lambda_1 = \lambda_2$

Treatments Compared	Site Types	Analytical Model	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
			Sig. at:	Sig. at:	Sig. at:	Sig. at:	Sig. at:
1. No Treatment	All General	Significant	.057	Sig.	.114	.005	.047
2. Center-line	Tangent	Significant	.094	Sig.	Sig.	.009	Sig.
	Winding	Significant	.158	Sig.	.195	.046	.090
	Horizontal Curves	Sig. at .025	.175	.041	.179	.072	.119
1. Center-line	All General	Significant	.298	Sig.	.109	.083	.139
2. Center-line/ Edgeline	Tangent	Significant	.446	Sig.	.096	.089	.198
	Winding	Not Sig.	.461	.424	.483	.478	.459
	Horizontal Curves	Not Sig.	.392	.164	.282	.270	.272

NOTE: Entries "significant" or "sig." with no numerical level means significance beyond .001.

Table 2. Comparison of one-way analysis of variance results under different weighting schemes.
Null Hypothesis: $H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6$

	Alternatives				
Site Types	1 (No Weighting)	2 (Weighting by Site Exposure)	3	4	5
All General Sites	Sig. at .011	Significant	Significant	Significant	Significant
Tangent Sites Only	Sig. at .007	Significant	Significant	Significant	Significant
Winding Sites Only	Sig. at .457	Significant	Sig. at .648	Sig. at .153	Sig. at .344
Horizontal Curves	Sig. at .200	Significant	Sig. at .028	Sig. at .037	Sig. at .0282

NOTE: "Significant" with no numerical level quoted means significance beyond .001 level.

Table 3. Computation of mean and variance of accident rate based upon the theoretical model - general sites.

Site Type	Treatment	Exposure (mvm)	Accident Frequency	Accident Rate (Accidents/mvm)	Variance
Tangent					
	No Treatment	18.02	68	3.7736	0.2094
	Paint CL	700.35	1567	2.2375	0.0032
	RPM CL	174.70	292	1.6714	0.0096
	CL + EL	1138.89	2230	1.9580	0.0017
	CL + Post	1647.99	1866	1.1323	0.0007
	CL + EL + Post	158.25	239	1.5103	0.0095
Winding					
	No Treatment	123.44	398	3.2242	0.0261
	Painted CL	599.47	1484	2.4755	0.0041
	RPM CL	17.56	73	4.1572	0.2367
	CL + EL	445.74	1111	2.4925	0.0056
	CL + Post	244.43	648	2.6511	0.0108
	CL + EL + Post	31.08	60	1.9305	0.0621
All General					
	No Treatment	141.46	466	3.2942	0.0233
	Painted CL	1299.82	3051	2.3472	0.0018
	RPM CL	192.26	365	1.8985	0.0099
	CL + EL	1584.63	3341	2.1084	0.0013
	CL + Post	1892.42	2514	1.3285	0.0007
	CL + EL + Post	189.33	299	1.5793	0.0083

Note: CL - Centerline
EL - Edgeline
Post - Post Delineators
mvm - Million Vehicle Miles

Metric conversion - $\left(\frac{\text{Accidents}}{\text{MVkm}}\right)$

1 mile = 1.609 km

Table 4. Computation of mean and variance of accident rate based upon the theoretical model - horizontal curves.

Treatment	Exposure (mv)	Accident Frequency	Accident Rate (#/Mvm)	Variance
No Treatment	13.27	26	1.9593	0.1476
CL	105.86	124	1.1714	0.0111
Guardrails	10.84	28	2.5830	0.2383
CL + EL	106.38	141	1.3254	0.0125
CL + Post	93.24	165	1.7696	0.0190
CL + EL + Post	65.86	65	0.9869	0.0150

Note: CL - Centerline
EL - Edgeline
Post - Post Delineator
mv - Million Vehicles

1 mile = 1.609 km

The results of these test runs together with the results of the analytical modeling were utilized to evalaute each weighting scheme. Advantages and disadvantages of each, in the context of available time and resources, were assessed. These were then discussed with the FHWA technical monitors prior to making the final selection. The alternative that was found conceptually appealing and most feasible was Alternative 5. The reasons for selecting Alternative 5 are summarized below:

- Alternative 1 was rejected because selected test sites had wide ranges of exposure. The resulting non-homogeneity in the variance of accident rate was, therefore, estimated to be a problem too large to be ignored.
- Alternative 2 artificially increased the effective number of sites by a disproportionate amount, resulting in significance of almost all of the results.
- Alternative 3 had no solid theoretical base although it kept the effective number of sites within bounds.
- Both Alternatives 4 and 5 kept the total number of sites unaltered and assigned a site a weight that was proportional to the site exposure. Alternative 5 also redistributed the total number of sites within the subcategories in proportion to the total category exposure. This was considered a very desirable feature and led to the selection of Alternative 5.

C.3 DESCRIPTIVE STATISTICS

Prior to the start of the statistical analysis, site statistics for the test sites were compiled. Accident statistics for these sites were also computed.

Tables 5 and 6 present the site statistics for all test sites by site type (tangent, winding, and horizontal curve site). Data provided for a site include:

Table 5. Summary of selected sites.

Jurisdiction	Type of Site			
	Tangent	Winding	Horizontal Curve	Total
Arizona	23	12	19	54
California	41	21	6	68
Connecticut	11	9	12	32
Georgia	5	24	3	32
Idaho	18	12	6	36
Louisiana	18	6	9	33
Maryland	11	10	81	102
Ohio	11	16	6	33
Virginia	17	25	14	56
Washington	17	13	38	68
Total	172	148	194	514

Table 6. Number of accidents, accident rate by type of section.

Type of Section	Number of Sections	Total Length (Miles)	Exposure	Number of Accidents	Accident Rate
Tangent	172	1139.5	4675.6	7479	1.6
Winding	148	901.1	1807.7	4932	2.7
Total (General Sites)	320	2040.6	6483.3	12411	1.9
Horizontal Curves	194	N/A	618.6	755	1.2
Total	514			13166	

Note: Exposure for Tangent and Winding Sites is Million Vehicle Miles (MVkm)

Exposure for Horizontal Curves is Million Vehicles

Accident Rate for Tangent and Winding Sites is Accidents Per Million Vehicle Miles (ACC/MVkm)

Accident Rate for Horizontal Curves is Accidents Per Million Vehicles

1 mile = 1.609 km

- length (in miles)
- total site exposure.

Over 2,000 miles (3,218 km) of tangent and winding sections and over 190 horizontal curves were included in the study.

The total site exposure in these tables is computed from the following formulas.

(a) For general highway sites

$$\text{Total Site Exposure} = L \times 365 \times \left[(ADT_1 \times f_1) + \sum_{i=2}^{n-1} ADT_i + (ADT_n \times f_n) \right]$$

(b) For horizontal curves

$$\text{Total Site Exposure} = 365 \times \left[(ADT_1 \times f_1) + \sum_{i=2}^{n-1} ADT_i + (ADT_n \times f_n) \right]$$

where

ADT_i = Average Daily Traffic for the year i

L = Length of the general site

f_1 = Fraction of the first year for which the accident data are available

f_n = Fraction of the last year for which the accident data are available

For some selected sites, the ADT data were unavailable for some years. Such missing data were approximated by interpolation or extrapolation. If ADT for both a preceding and a succeeding year were available, the missing ADT was estimated through linear interpolation. Therefore, as shown in Figure 1, the missing ADT for 1973 was obtained by joining the ADT's for 1972 and 1974 by a straight line. If the missing ADT was for an end year (the first or the last year of the analysis period), the ADT for the missing year was assumed to be the same as that of the adjacent year. Hence, in Figure 1, the ADT for 1975 was assumed to be the same as that for the year 1974.

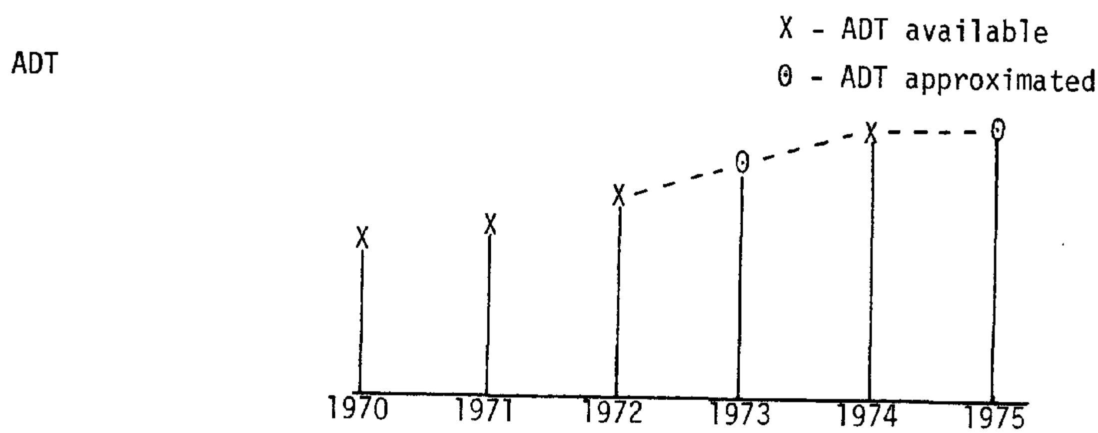

Figure C-1. Procedure for estimating missing ADT

The accident information shown in Table ·C indicates both the total number of accidents in the data base as well as the accident rate by section type. For general highway situations such as tangent and winding sites, only those accidents occurring within the test sites are included in the computations. For horizontal curve sites, accidents located within 750 feet (228.60 m) of the point of curvature (PC) and point of tangency (PT) are also included (the reasons for choosing 750 feet (228.60 m) criterion is discussed in Appendix B). Site length data were not available for some of the horizontal curve sites. For such sites, a site length of 0.4 mile (0.64 km) was assumed--a somewhat arbitrary decision.

As in site statistics, the accident statistics are also compiled according to state and site type (tangent, winding, and horizontal curves). The accident data are organized according to the following stratifications.

- All Accidents
- Delineation/Non-delineation Related
- Intersection/Non-intersection Related
- Time of Day
    - day
    - night/dusk/dawn
- Pavement Surface Condition at Time of Accident
    - dry
    - wet
- Nighttime Wet Pavement Accidents

- Accident Severity
    - fatality
    - injury
    - PDO
- Type of Accident
    - head-on
    - sideswipe opposite direction
    - rear-end
    - sideswipe same direction
    - angle
    - run-off-the-road

Tables 7 and 8 provide summaries of this information by section type.

Table 7. Number of accidents by location, environmental condition and type of section

Type of Section	Number of Accidents	Delineation Related	Non-Delineation Related	Intersection Related	Non-Intersection Related	Day	Night	M/O	Dry	Wet	Other	Night + Wet
Tangent	7,479	5,798	1,681	1,136	6,343	4,014	3,423	42	5,958	920	601	441
Winding	4,932	4,065	867	296	4,636	2,712	2,188	32	3,385	994	553	474
Subtotal	12,411	9.863	2,548	1,432	10,979	6,626	5,611	74	9,343	1,914	1,154	915
Horizontal Curves	775	593	162	76	679	346	404	5	537	129	89	67
Total	13,166	10,456	2,710	1,508	11,658	7,072	6,015	79	9,880	2,043	1,243	982

Table 8. Accident severity and type by type of section

Type of Section	Number of Accidents	Fatal Accidents	Injury Accidents	Property Damage Only Accidents	Head-On	Sideswipe Opposite Direction	Rear-End	Sideswipe Same Direction	Angle	ROR/ Overturn	Other	Missing
Tangent	7,479	264	3,033	4,182	193	329	879	396	1,081	3,168	1,293	140
Winding	4,932	114	1,845	2,973	207	363	285	145	358	2,885	560	129
Subtotal	12,411	378	4,878	7,155	400	692	1,164	541	1,439	6,053	1,853	269
Horizontal Curves	755	18	322	415	24	36	67	27	62	432	100	7
Total	13,166	396	5,200	7,570	424	728	1,231	568	1,501	6,485	1,953	276

C.4 MATCHING-CONTROL ANALYSIS

The matching-control analysis, for the purposes of this study, refers to the accident analysis of those test sites for which the delineation treatment remained unaltered during the analysis period. This analysis can be organized under the following steps:

- selection of test delineation treatment categories
- selection of test sites for the matching-control analysis
- statistical analysis with accident rate as the dependent variable
    - t-test and one-way analysis of variance
    - two-way and higher order analysis of variance and covariance analysis
    - regression analysis
- selection of alternative dependent variables
- statistical analysis with the selected alternative dependent variables.

The analysis required a consolidation of various test site delineation treatments into a manageable number. A selection of test sites appropriate for the matching-control analysis was needed. All selected highway sites were evaluated against a pre-established criterion. This included the stipulations that the site delineation treatment should remain unchanged over the analysis period and that the analysis period should be adequately large.

It was decided that accident rate would be one of the dependent variables of the statistical analysis. Hence, first an analysis designed to bring out the effect of test roadway delineation treatments on accident rate was conducted. This analysis included both "hypothesis testing" and "estimation" procedures. Several other dependent variables were tested for their sensitivity to roadway delineation treatments. The complete analysis was then repeated with these other dependent variables. The details of matching-control analysis follow.

C.4.1 Candidate Delineation Treatments

Because of possible variations within delineation treatment (e.g., dashed centerline vs. solid centerline), there were many treatments at the test sites. During the site selection and data collection phase of this study, all of these variations were recorded. The result, however, was an excessively large number of treatments. Past studies had shown that minor variations in treatments did not significantly change the roadway accidents. Therefore, the site delineation treatments were consolidated into a select few major treatment categories. This, in addition to reducing the treatments to a manageable number, also would increase the effective number of sites containing a specified treatment, thereby increasing confidence in the results.

The selected treatment categories are given in Table 9. The site delineation treatments condensed to form the selected treatment categories are also given in the table. All through the remaining analysis, it is these delineation treatment categories that are evaluated for their effect on roadway delineation treatment.

Table 9. Selected delineation treatment categories for analysis.

Site Type	Selected Treatment Category		
	Identification Number	Abbreviated Name	Detailed Description
General Sites	0	Other	If none of treatments 1-6
	1	No Treatment	No continuous treatment
	2	Paint CL	Painted Centerline only
	3	RPM CL	Raised pavement marker centerline only
	4	CL + EL	Any centerline (paint or RPM) and solid white paint edgeline
	5	CL + POST	Any centerline (paint or RPM) and continuous post delineators on right side of the road
	6	CL + EL + POST	Any centerline (paint or RPM) and white paint edgeline, and continuous post delineators on right side of the road
Horizontal Curves	10	Other	If none of treatments 11 - 16
	11	No Treatment	No continuous treatment
	12	CL	Centerline only (paint or RPM)
	13	Guardrails	Guardrails with any other treatment
	14	CL + EL	Any centerline (paint or RPM) and white paint edgeline
	15	CL + POST	Any centerline (paint or RPM) and continuous post delineators on right side of the road
	16	CL + EL + POST	Any centerline and white paint edgeline and continuous post delineators on right side of the road

Table 9. Selected delineation treatment categories for analysis (continued).

Site Delineation Treatments - Explanations
"Paint Centerline" includes Paint - dashed Paint - solid one side, dashed on other side Paint - double solid Paint - unknown pattern "Raised Pavement Marker" means RPM's - reflective markers only between paint gaps RPM's - reflective markers between paint gaps with ceramic markers on paint RPM's - continuous reflective markers RPM's - only ceramic markers "Continuous Post Delineators" include Continuous - crystal reflectors on one side Continuous - crystal reflectors on both sides Continuous - reflectorized paddles on one side Continuous - reflectorized paddles on both sides Continuous - crystal reflectors on paddles, one side Continuous - crystal reflectors on paddles, both sides The following post delineation systems are considered equivalent to <u>no</u> post delineation for tangent and winding sections Noncontinuous - delineators at culverts, bridges, hazards, etc. Noncontinuous - reflectors on sharp curves Noncontinuous - reflectorized paddles on sharp curves Noncontinuous - reflectors on paddles on sharp curves "Guardrails" include Galvanized Steel Rail Painted Steel Rail Cable Type Expandable Mesh Type

C.4.2 Selection of Matching-Control Sites

The matching-control analysis requires that

- The site delineation treatment remain unaltered over the analysis period.
- The analysis period be large enough to produce statistically reliable results.

To ensure these conditions, all the test sites were evaluated against an established criterion to ensure their suitability for MC (matching-control) analysis.

The initial review of test sites indicated that several of the sites originally designated MC sites did not meet the requirements listed above. On several sites, for example, the delineation treatment had changed within the period for which accident data were available. Although for most of the MC sites this change had occurred either at the beginning or the end of the period, an adjustment in the analysis period was required. Similarly, a check on sites originally designated BA sites (sites suitable for before-after analysis only), indicated that although they were generally suitable for BA analysis, some of these for which the change in delineation treatment had occurred either toward the beginning or the end of the analysis period were also suitable for matching-control analysis. Adequate accident data were available either for the before period or the after period to justify their inclusion in the matching-control analysis.

The criterion utilized to select sites for matching-control analysis from originally designated MC sites, BA sites, or undesignated sites follows.

Sites Originally Designated as MC Sites

Case 1. If there is no change in delineation, or the change is outside the period for which the accident data are available, accept the site as it is with the entire time period as the analysis period.

Case 2. If only the delineation treatment has changed during the period for which the accident data are available, select the sites as follows:

- If the change is from painted centerline to RPM centerline *and* the site is a general site *and* at least one other treatment is present, ignore the change and accept the site with the entire time period as the analysis period.
- If the change is from painted centerline to RPM centerline *and* the site is a general site *and* no other treatment is present, choose the larger period as the analysis period and designate the site by the treatment that existed over this period.
- If the change is from painted centerline to RPM centerline *and* the site is a horizontal curve, accept the site as it is with the entire time period as the analysis period.

Case 3. If two or more delineation treatments changed during the period for which the accident data are available, reject the site except for California Site #23 and Maryland Site #65. For these sites, adjust the analysis period to ensure that the delineation remained unchanged over this period.

Sites Originally Designated BA Sites

Case 1. If there is no change in delineation over the period for which the accident data are available, accept it as an MC site with the entire period as the analysis period.

Case 2. If only delineation treatment changed over the period for which the accident data are available, select the site as an MC site with the larger of the two periods as the analysis period provided the following conditions are met:

- If the period for which accident data are available is $\leq$ 5 years, the selected analysis period must be $\geq$ 3 years.
- If the period for which accident data are available is > 5 years, the selected analysis period must be $\geq$ 4 years.
- The difference between the "before" and "after" period must be $\geq$ 1 year.

Case 3. If two or more delineation treatments changed over the period for which the accident data are available, reject all such sites with a few exceptions. The exceptional sites with their modified analysis period dates are given in Table 10.

C.4.3 Statistical Analysis with Accident Rate as Dependent Variable

The objective of this analysis was to investigate the effect of roadway delineation treatment on accident rate to its fullest extent. To achieve this objective, both hypothesis testing and estimation procedures were utilized. Hypothesis testing procedures were used to assess whether or not the changes in accident rate resulting from changes in site delineation treatment are statistically significant.

Table 10. Sites with modified analysis period.

Site Number	Modified Analysis Period	
	Starting Date	Ending Date
California 48	1 July 71	Not changed
California 55	1 Jan 72	30 June 75
California 56	1 Jan 72	31 May 75
California 57	1 Jan 72	31 May 75
Virginia 20	Not changed	31 July 72
Maryland 66	Not changed	31 May 74

The site treatment during the selected analysis period would be the test treatments.

Undesignated Sites: Certain sites had not been designated as either matching-control or before-after on the data tape. All such sites were found unsuitable for matching-control analysis.

The procedures included t-test, one-way analysis of variance (one-way ANOVA), two-way and higher order analysis of variance (ANOVA), and covariance analysis.

One-way ANOVA and t-test provided a means to test for statistically significant differences in mean accident rates under different treatment categories. Two-way and higher order ANOVA and covariance analysis provided a means for studying how these differences were affected by other roadway geometric, operational, and climatic parameters. Estimation procedures included t-test and regression analysis. These were utilized to quantify the changes in accident rate resulting from the changing treatment, geometric, and traffic operational conditions.

The analysis was conducted by utilizing SPSS (Statistical Package for the Social Sciences) computerized subroutine package. It was conducted in the following order:

- one-way analysis of variance and t-tests
- two-way and higher order analysis of variance and covariance analysis
- regression analysis.

All through this analysis the weighting scheme for exposure, as discussed earlier, was utilized. A detailed description of the analysis follows.

C.4.3.1 One-Way Analysis of Variance and t-Test

One-way analysis of variance allows one to statistically test whether the means of subcategories into which the data are broken down are significantly different from each other. The null hypothesis tested is

$$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \ldots \lambda_k = \lambda$$

where λ_i's are subcategory means. If the means are found not to be significantly different, it *cannot* be assumed that the subcategory means are equal. If, however, the means are significantly different, it can be safely assumed that they are indeed different. The actual testing is done by comparing the computed F-ratio (F = between-groups mean square/ within-groups mean square), which is reported in this analysis of variance table, to the known sampling distribution of the F-ratio.

To make this comparison, the degrees of freedom associated with F are also required. In addition, a decision must be made relative to how often one is willing to reject the null hypothesis when it should not be rejected.

SPSS automatically computes the F value and provides the associated degrees of freedom. Level of significance (probability that the null hypothesis would be rejected when it should not be) is also provided.

One-way ANOVA was utilized to compare mean accident rate differences between (a) tangent and winding sites, and (b) various delineation treatment categories.

Table C-11 provides exposure data for sites utilized in this analysis. These data are stratified by site type and delineation treatment.

The results of the one-way ANOVA are presented in Tables 12 through 20. The upper portion of these tables provide the mean standard deviation and "effective number of sites" stratified according to the subcategories of the analysis. The lower part of the table is the actual ANOVA table. It should be recalled that the effective number of sites, in general, will be different from the actual number of highway sites utilized in the analyses. The chosen weighting scheme distributes the total number of sites utilized in a particular analysis among the subcategories in proportion to the total subcategory. Subcategory exposures are presented in Table 11.

The results contained in these tables are self-evident and do not require discussion. A few points are noted. Tables 14, 16, 18 and 20 were obtained by deleting some of the delineation treatment categories from Tables 13, 15, 17, and 19, respectively. The deleted categories had only a few effective sites and their deletion allowed for the remaining treatment categories to have a nearly equal number of effective sites. This strengthened the analyses of the remaining delineation treatments.

Further, from Table 12 it should be noted that mean accident rates for tangent and winding sites are significantly different. This result was utilized in the subsequent analysis by conducting separate analysis for the tangent and winding sites in parallel with the analysis of all general sites.

Although paired mean accident rates can be compared through one-way ANOVA (as was done above to compare the mean accident rate between tangent and winding sites), the statistic particularly suitable for this purpose is the t-statistic. Through the t-statistic, in addition to testing for significance, confidence intervals for mean differences can also be estimated. The t-statistic was therefore

Table 11. Exposure data for matching-control sites.

Situation/ Treatment Combination	Total Exposure	Mean Exposure	Standard Deviation	Variance	Actual Number of Sites
Tangent	3838.2005	25.7597	28.4595	809.9431	149
No Treatment	18.0180	2.2522	2.2700	5.1528	8
Paint CL	700.3481	15.9170	13.5180	182.7353	44
RPM CL	174.7037	21.8380	14.4298	208.2188	8
CL and EL	1138.8908	21.9017	13.4488	180.8692	52
CL and Post	1647.9891	56.8272	47.0785	2216.3864	29
CL, EL and Post	158.2507	19.7813	14.0422	197.1847	8
Winding	1461.7251	10.9904	8.7514	76.5869	133
No Treatment	123.4369	5.3668	5.9031	34.8471	23
Paint CL	599.4694	9.9912	7.1280	50.8077	60
RPM CL	17.5646	5.8549	2.7507	7.5661	3
CL and EL	445.7420	14.3788	10.5005	110.2606	31
CL and Post	244.4333	16.2956	8.3418	69.5862	15
CL, EL and Post	31.0789	31.0789	0	0	1
Horizontal Curve	395.4660	2.8047	2.0740	4.3015	141
No Treatment	13.2695	1.3270	.7083	.5017	10
CL	105.8647	2.0758	1.7700	3.1328	51
Guardrails	10.8440	2.7110	1.8042	3.2552	4
CL and EL	106.3871	3.3246	1.6105	2.5938	32
CL and Post	93.2395	3.1080	2.4988	6.2440	30
CL, EL and Post	65.8613	4.7004	2.1286	4.5310	14

Table 12. One-way analysis of variance (general sites) dependent variable - accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 Tangent	333.1904	1.6315	.9375	178.6331	204
2 Winding	200.8081	2.5819	1.3884	147.9899	78
Total	533.9985	1.8936	1.1591	377.4979	282

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	50.8749	1	50.8749
Within Groups	326.6230	280	1.1665
Total	377.4979	281	

F = 43.6129 Sig. = .0000

*N denotes the "effective" number of sites which is different from the actual number of sites (see section C-2)

Table 13. One-way analysis of variance (general sites) dependent variable - accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treatment	24.7951	3.2943	1.9208	24.0805	8
2 Paint CL	162.3385	2.3473	1.2624	108.6318	69
3 RPM CL	19.4210	1.8984	1.0505	10.1869	10
4 CL and EL	177.7689	2.1084	1.0938	99.6805	84
5 CL and Post	133.7657	1.3285	.7559	56.9631	101
6 CL, EL and Post	15.9093	1.5793	1.1456	11.9093	10
Total	533.9985	1.8936	1.1591	377.4979	282

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	66.0460	5	13.2092
Within Groups	311.4520	276	1.1284
Total	377.4979	281	
F = 11.7056	Sig. = .0000		

*N denotes the "effective" number of sites which is different from the actual number of sites (see section C-2)

Table 14. One-way analysis of variance (general sites) dependent variable - accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
2 Paint Cl	147.5403	2.3473	1.2634	98.7293	63
4 CL and EL	161.5641	2.1084	1.0945	90.5939	77
5 CL and Post	121.5720	1.3285	.7563	51.7706	92
Total	430.6763	1.8644	1.1163	286.5958	231

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	45.5021	2	22.7511
Within Groups	241.0937	228	1.0574
Total	286.5958	230	
F = 21.5155	Sig. = .0000		

*N denotes the "effective" number of sites which is different from the actual number of sites (see section C-2)

Table 15. One-way analysis of variance (tangent sites) dependent variable: accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treatment	2.6398	3.7740	0	0	1
2 Paint CL	60.8314	2.2375	1.0952	31.4115	27
3 RPM CL	11.3355	1.6714	.7714	3.4406	7
4 CL and EL	86.5692	1.9580	.8998	34.9865	44
5 CL and Post	72.4386	1.1323	.5163	16.7838	64
6 CL, EL and Post	9.2780	1.5103	1.2864	8.5108	6
Total	243.0926	1.6315	.9384	130.3290	149

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	35.1958	5	7.0392
Within Groups	95.1332	143	.6653
Total	130.3290	148	
F = 10.5810	Sig. = 0		

*N denotes the "effective" number of sites which is different from the actual number of sites (see section C-2)

Table 16. One-way analysis of variance (tangent sites) dependent variable - accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
2 Paint CL	56.1693	2.2375	1.0969	29.0041	25
4 CL and EL	79.9345	1.9580	.9007	32.3051	41
5 CL and Post	66.8869	1.1323	.5166	15.4975	59
Total	202.9907	1.6239	.9206	105.0920	125

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	28.2853	2	14.1426
Within Groups	76.8067	122	.6296
Total	105.0920	124	
F = 22.4642	Sig. = .0000		

*N denotes the "effective" number of sites which is different from the actual number of sites (see section C-2).

Table 17. One-way analysis of variance (winding sites) dependent variable - accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treatment	36.2134	3.2243	1.9229	37.8325	11
2 Paint CL	135.0268	2.4755	1.4364	110.4759	55
3 RPM CL	6.6422	4.1561	.8079	.3905	2
4 CL and EL	101.0881	2.4925	1.4233	80.1298	41
5 CL and Post	58.9605	2.6510	.7942	13.3972	22
6 CL, EL and Post	5.4593	1.9306	0	-.0000	3
Total	343.3901	2.5819	1.3846	253.0689	133

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	10.8431	5	2.1686
Within Groups	242.2258	127	1.9073
Total	253.0689	132	
F = 1.1370	Sig. = .3443		

*N denotes the "effective" number of sites which is different from the actual number of sites (see section C-2)

Table 18. One-way analysis of variance (winding sites) dependent variable - accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treatment	36.3334	3.2243	1.9226	37.9578	11
2 Paint CL	135.4741	2.4755	1.4364	110.8419	55
4 CL and EL	101.4230	2.4925	1.4232	80.3953	41
5 CL and Post	59.1558	2.6510	.7941	13.4416	22
Total	332.3863	2.5766	1.3929	248.3349	129

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	5.6983	3	1.8994
Within Groups	242.6366	125	1.9411
Total	248.3349	128	
F = .9785 Sig. = .4052			

*N denotes the "effective" number of sites which is different from the actual number of sites.

Table 19. One-way analysis of variance (horizontal curves) dependent variable: accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
11 No Treatment	9.2701	1.9594	1.5846	9.3691	5
12 CL	44.2111	1.1713	1.3290	64.9029	38
13 Guardrails	9.9832	2.5821	2.0826	12.4315	4
14 CL and EL	50.2723	1.3253	.9479	33.1853	38
15 CL and Post	58.8293	1.7696	1.1826	45.0939	33
16 CL, EL and Post	23.1752	.9869	.8963	18.0624	23
Total	195.7412	1.3882	1.1971	200.6430	141

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	17.5978	5	3.5196
Within Groups	183.0451	135	1.3559
Total	200.6430	140	
F = 2.5958 Sig. = .0282			

*N denotes the effective number of sites which is different from the actual number of sites. (see Section C-2)

Table 20. One-way analysis of variance (horizontal curves) dependent variable: accident rate.

	Sum	Mean	Std. Dev.	Sum of Sq.	N*
12 CL	42.4071	1.1713	1.3298	62.2546	36
14 CL and EL	48.2210	1.3253	.9485	31.8312	36
15 CL and Post	56.4288	1.7696	1.1834	43.2539	32
16 CL, EL and Post	22.2295	.9869	.8972	17.3254	23
Total	169.2865	1.3330	1.1422	164.3908	127

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	9.7258	3	3.2419
Within Groups	154.6651	123	1.2574
Total	164.3908	126	
F = 2.5782	Sig. = .0568		

*N denotes the effective number of sites which is different from the actual number of sites. (see Section C-2) utilized to test whether or not a difference in accident rate between a pair of delineation treatment categories was statistically significant. For statistically significant differences, confidence intervals for the mean difference were constructed.

Through the t-statistic, the hypothesis tested is

null (H_0): $\lambda_1 = \lambda_2$
alternate (H_1): $\lambda_1 > \lambda_2$

where λ_1 and λ_2 denote accident rate for sites with treatments 1 and 2 respectively. Accident rate is hypothesized to decrease with the installation of treatment 2.

SPSS was utilized to test the hypothesis. SPSS computes t-statistics under two assumptions; population with common variance and population with unequal variance. It also provides the F-statistic to test for the homogeneity of variance.

The F-statistic provided by SPSS indicated that the variance within a delineation treatment category varied from category to category. Hence, in computing the t-statistic, unequal population variance was assumed. Under this assumption, t, computed by

$$t = \frac{(\hat{\lambda}_1 - \hat{\lambda}_2) - (\lambda_1 - \lambda_2)}{s}$$

is t-distributed with the degrees of freedom df given by

$$df = \frac{\left[\left(\frac{s_1{}^2}{n}\right) = \left(\frac{s_2{}^2}{n_2}\right)\right]^2}{\left[\left(\frac{s_1{}^2}{n_1}\right)^2 \Big/ (n_1 - 1) + \left(\frac{s_2{}^2}{n_2}\right)^2 \Big/ (n_2 - 1)\right]}$$

where

$$s = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

$\hat{\lambda}_i$ = estimated mean accident rate under delineation treatment i

n_i = number of effective sites with treatment i

s_i = unbiased standard deviation of accident rate at site with treatment i

To test the hypothesis $\lambda_1 = \lambda_2$ against the alternate $\lambda_1 > \lambda_2$, it is necessary to compute the value of t utilizing the formula

$$t = \frac{(\hat{\lambda}_1 - \hat{\lambda}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

and compare it with $t_{1-\alpha}$, which is the value of t for a Student's t distribution with degrees of freedom (df) and α significance level. Here $t_{1-\alpha}$ represents the value of t such that the probability is $(1-\alpha)$ that $t > t_{1-\alpha}$. If the computed t exceeds $t_{1-\alpha}$, the null hypothesis can be rejected. There is only probability α (.05) that the computed t value would exceed $t_{1-\alpha}$ by chance if the null hypothesis is indeed true. The P percent confidence (P) limit for the difference in mean accident rate is computed from the probability

$$\text{Prob.} \left[\frac{(\hat{\lambda}_1 - \hat{\lambda}_2) - (\lambda_1 - \lambda_2)}{s} < t_{\frac{1-P}{2}} \right] = P$$

where $t_{\frac{1-P}{2}}$ represents the value of t such that the probability is $\frac{1-P}{2}$ that $|t| > t_{\frac{1-P}{2}}$. In other words, there is only (1-P) percent chance that $(\lambda_1 - \lambda_2)$ would fall outside of the limit defined by

$$(\hat{\lambda}_1 - \hat{\lambda}_2) - t_{\frac{1-P}{2}} \cdot s < (\lambda_1 - \lambda_2) < (\hat{\lambda}_1 - \hat{\lambda}_2) + t_{\frac{1-P}{2}} \cdot s$$

The results of the t-tests are given in Tables 21 through 25. Tables 21 through 24 provide the results of hypothesis testing; that is, the significance level at which the null hypothesis can be rejected--or, in other words, the probability of rejecting the null hypothesis when the mean accident rates are in fact the same. The results of the F-test to test for the homogeneity of variance are also included. One table is constructed for each highway type. The other data are self-evident.

Table 25 provides confidence intervals for mean accident rate differences for those delineation treatment pairs for which this difference is significant at the .05 level. Confidence limits for 60, 90, 95 and 99 percent confidence are provided.

The results of one-way ANOVA and t-test are consolidated in Tables 26 and 27; one for general sites and the other for horizontal curves. The only treatments that appear to have any effect on traffic safety are those installed on tangent highway sections. This, however, should not be construed to imply that delineation treatments installed on winding roads and isolated horizontal curves have no impact on traffic operations. It is quite possible that the driver compensates

Table 21. t-Test results for difference in mean accident rate (general sites) dependent variable - accident rate.

Treatments Compared	Effective Number of Sites	Mean	Standard Deviation	Standard Error	Test for Homogeneity of Variance		Test for Significance		
					F-Value	2-Tail Prob.	T-Value	Degree of Freedom	1-Tail Prob.
1. No Treatment 2. Painted CL	13 121	3.2943 2.3473	1.860 1.258	0.511 0.114	2.19	0.033	1.81	13.50	0.047
2. Painted CL 3. RPM CL	100 14	2.3473 1.8984	1.260 1.033	0.126 0.268	1.49	0.409	1.51	20.42	0.073
2. & 3. CL 4. CL + EL	96 101	2.2894 2.1084	1.239 1.093	0.126 0.108	1.29	0.214	1.09	189.51	0.139
2. & 3. CL 5. CL + Post	70 88	2.2894 1.3285	1.241 0.756	0.148 0.080	2.69	0.000	5.70	108.18	0.000
4. CL + EL 6. CL + EL + Post	82 9	2.1084 1.5793	1.094 1.147	0.121 0.366	1.10	0.745	1.37	10.83	0.098

Table 22. t-Test results for difference in mean accident rate (tangent sites) dependent variable - accident rate.

Treatments Compared	Effective Number of Sites	Mean	Standard Deviation	Standard Error	Test for Homogeneity of Variance		Test for Significance		
					F-Value	2-Tail Prob.	T-Value	Degrees of Freedom	1-Tail Prob.
1. No Treatment 2. Painted CL	1 50	3.7740 2.2375	0 1.086	0 0.152	0	1.000	10.08	49.70	0.000
2. Painted CL 3. RPM CL	41 10	2.2374 1.6714	1.088 0.749	0.169 0.233	2.11	0.233	1.97	20.54	0.031
2.& 3. CL 4. CL + EL	45 58	2.1244 1.9580	1.050 0.897	0.156 0.117	1.37	0.262	0.85	86.82	0.198
2.& 3. CL 5. CL + Post	28 52	2.1244 1.1323	1.057 0.517	0.199 0.071	4.18	0.000	4.69	34.13	0.000
4. CL + EL 6. CL + EL + Post	52 7	1.9580 1.5103	0.898 1.267	0.124 0.468	1.99	0.168	0.92	7.23	0.193

Table 23. t-Test results for difference in mean accident rate (winding sites) dependent variable - accident rate.

Treatments Compared	Effective Number of Sites	Mean	Standard Deviation	Standard Error	Test for Homogeneity of Variance		Test for Significance		
					F-Value	2-Tail Prob.	T-Value	Degrees of Freedom	1-Tail Prob.
1. No Treatment 2. Painted CL	14 68	3.2243 2.4755	1.904 1.434	0.506 0.173	1.76	0.135	1.40	16.38	0.09
2. Painted CL 3. RPM CL	61 1	2.4755 4.1561	1.435 0	0.183 0	0	1.000	-9.16	60.21	N.S.
2.& 3. CL 4. CL & EL	54 39	2.5234 2.4925	1.446 1.424	0.196 0.227	1.03	0.932	0.10	83.70	0.46
2.& 3. CL 5. CL & Post	55 22	2.5234 2.6510	1.446 0.794	0.193 0.169	3.31	0.004	-0.50	67.93	N.S.
4. CL & EL 6. CL & EL & Post	29 2	2.4925 1.9306	1.430 0.000	0.261 0.000	-	0.000	2.15	28.91	0.02

Table 24. t-Test results for difference in mean accident rate (horizontal curves) dependent variable - accident rate.

Treatments Compared	Effective Number of Sites	Mean	Standard Deviation	Standard Error	Test for Homogeneity of Variance		Test for Significance		
					F-Value	2-Tail Prob.	T-Value	Degrees of Freedom	1-Tail Prob.
11. No Treatment	6	1.9594	1.524	0.585	1.33	0.525	1.29	6.94	0.119
12. Centerline	54	1.1713	1.324	0.180					
12. Centerline	41	1.1713	1.327	0.206	1.97	0.034	-0.61	73.03	N.S.
14 CL & EL	41	1.3253	0.947	0.147					
12. Centerline	43	1.1713	1.327	0.202	1.26	0.472	-2.15	78.99	N.S.
15 CL & Post	37	1.7696	1.180	0.192					
14. CL + EL	28	1.3253	0.952	0.179	1.11	0.838	1.21	36.75	0.117
16. CL + EL + Post	17	0.9869	0.903	0.215					

Table 25. Confidence bands for mean accident rate difference for general sites dependent variable - accident rate.

Highway Situation	Treatment Combination	Effective Number of Sites	Mean	Standard Error of The Mean	Pooled Standard Error	Degrees of Freedom	Mean Difference	Confidence Bands p = 60: Deviation from Mean	p = 60: Band	P = 90: Deviation from Mean	P = 90: Band	P = 95: Deviation from Mean	P = 95: Band	P = 99: Deviation from Mean	P = 99: Band
General Sites	1. No Treatment	13	3.2943	0.511	0.523	13	0.947	±0.455	0.492	±0.927	0.020	±1.131	-0.184	±1.577	-0.630
	2. Painted CL	121	2.3473	0.114					1.402		1.874		+2.078		+2.524
	2.& 3. CL	70	2.2894	0.148	0.168	108	0.961	±0.142	0.819	±0.279	0.682	±0.334	0.627	±0.442	0.519
	5. CL + Post	88	1.3285	0.080					1.103		1.240		1.295		1.403
Tangent Sites	1. No Treatment	1	3.7740	0	0.152	50	1.536	±0.129	1.407	±0.255	1.281	±0.305	1.231	±0.407	1.129
	2. Painted CL	50	2.2375	0.152					1.665		1.791		1.841		1.943
	2. Painted CL	41	2.2375	0.169	0.288	21	0.556	±0.247	0.319	±0.495	0.071	±0.599	-0.033	±0.815	-0.249
	3. RPM CL	10	1.6714	0.233					0.813		1.061		+1.165		+1.381
	2.& 3. CL	28	2.1244	0.199	0.211	34	0.992	±0.180	0.812	±0.357	0.635	±0.430	0.562	±0.576	0.416
	5. CL + Post	52	1.1323	0.071					1.172		1.349		1.422		1.568
Winding Sites	4. CL + EL	29	2.4925	0.261	0.261	29	0.562	±0.223	0.339	±0.443	0.119	±0.534	0.028	±0.719	-0.157
	6. CL + EL + Post	2	1.9306	0					0.785		1.005		1.096		+1.281

Table 26. One-way analysis of variance and t-test results (general sites) dependent variable: accident rate.

Statistical Procedure	S.No.	Hypothesis Tested	Level of Significance		
			General Sites	Tangent Sites	Winding Sites
One-Way Analysis of Variance	1.	$H_0: \lambda_{tangent} = \lambda_{winding}$	x	.	.
	2.	$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6$	x	x	N.S.
	3.	$H_0: \lambda_2 = \lambda_4 = \lambda_5$	x	x	.
	4.	$H_0: \lambda_1 = \lambda_2 = \lambda_4 = \lambda_5$	.	.	N.S.
T-test	1.	$H_0: \lambda_1 = \lambda_2$ $H_1: \lambda_1 > \lambda_2$	x	x	N.S.
	2.	$H_0: \lambda_2 = \lambda_3$ H_1 $\lambda_2 > \lambda_3$	N.S.	x	N.S.
	3.	$H_0: \lambda_{2,3} = \lambda_4$ $H_1: \lambda_{2,3} > \lambda_4$	N.S.	N.S.	N.S.
	4.	$H_0: \lambda_{2,3} = \lambda_5$ $H_1: \lambda_{2,3} > \lambda_5$	x	x	N.S.
	5.	$H_0: \lambda_4 = \lambda_6$ $H_1: \lambda_4 > \lambda_6$	N.S.	N.S.	x

Notation: λ_i = accident rate under treatment i where

1. No treatment
2. Painted centerline
3. RPM centerline
4. Any centerline + painted edgeline
5. Any centerline + post delineators
6. Any centerline + painted edgeline + post delineator

x - Mean rates are different at significance level 0.05
N.S. - Mean rates are not different at significance level 0.05
. - Not applicable.

Table 27. One-way analysis of variance and t-test results (horizontal curves) dependent variable: accident rate.

Statistical Procedure	S.No.	Hypothesis Tested	Level of Significance
One-Way Analysis of Variance	1.	$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6$	x
	2.	$H_0: \lambda_2 = \lambda_4 = \lambda_5 = \lambda_6$	x
T-test	1.	$H_0: \lambda_1 = \lambda_2$ $H_1: \lambda_1 > \lambda_2$	N.S.
	2.	$H_0: \lambda_2 = \lambda_4$ $H_1: \lambda_2 > \lambda_4$	N.S.
	3.	$H_0: \lambda_2 = \lambda_5$ $H_1: \lambda_2 > \lambda_5$	N.S.
	4.	$H_0: \lambda_4 = \lambda_6$ $H_1: \lambda_4 > \lambda_6$	N.S.

Notation: λ_i: Accident rate under treatment i where
1 = No treatment
2 = Centerline
3 = Guardrail
4 = Centerline + Edgeline
5 = Centerline + Post
6 = Centerline + Edgeline + Post

x : Mean rates are different at significance level 0.05
N.S.: Mean rates are not different at significance level 0.05.

for the lack of delineation treatment by slowing down or driving more carefully at roads with no treatment. This in effect reduces accidents caused solely by the altered driving pattern. But this necessarily causes a deterioration in traffic operational characteristics.

C.4.3.2 Analysis of Variance and Covariance Analysis

One-way analyses of variance and t-tests described in the previous section were designed to assess the effect of only one accident causal factor, the roadway delineation treatment. How this effect is altered by the changing roadway geometric and traffic characteristics was ignored. It is through 2-way and higher order analysis of variance (ANOVA) and covariance analysis, presented here, that these interactions were investigated.

In the analysis of variance (ANOVA) and covariance analysis, the independent variables (the variables whose effect on roadway accidents is being investigated) can be all nonmetric (categorical) or a combination of metric and nonmetric variables. If an independent variable is a categorical variable (or treated as such even though each category may represent some metric value), it is called a factor. If all the variables are factors, the associated analysis is called ANOVA. If the effect of both factors and metric variables are investigated, the analysis is referred to as analysis of covariance. In such analysis, the metric independent variables are called covariates.

The basis of analysis of variance is the decomposition of variation or sums of squares corrected for the mean (SS). To elaborate, let us consider a factorial design comprised of two factors, A and B, as shown in Figure 2. Then, if the number of sample points in each cell is the same (orthogonal factorial design), the total variation in the dependent variable Y can be partitioned into the following independent components

Total SS = SS due to A + SS due to B
+ SS due to AB interaction + SS within

which can be concisely written as

$$SS_Y = SS_A + SS_B + SS_{AB} + SS_{error}$$

		Factor A		
		1	2	3
Factor B	1			
	2			

Figure 2. Example of a factorial design.

If the effect of A and B are additive -- that is, the dependent of Y on one factor is independent of the other factor -- then the interaction term tends to be zero. Various tests made through ANOVA are as follows:

1. The first test is made to determine whether the two factors as a whole have statistically significant effect, which is called the main effect, this test is conducted by determining whether all the observed sums of squares ($SS_A + SS_B + SS_{AB}$) due to factors A and B are likely to have come from a population where no such effects exist. If in fact this is true, the ratio between the following two mean squares are known to have F-distribution:

$$F = \frac{(SS_A + SS_B + SS_{AB})/df_1}{SS_{error}/df_2} = \frac{M_{SA,B,AB}}{MS_{error}}$$

where the degrees of freedom associated with the numerator are

$$(df_1) = (C_A - 1) + (C_B - 1) + (C_A - 1)(C_B - 1) = C_AC_B-1$$

and the degrees of freedom for the denominator are

$$(df_2) = N - C_AC_B$$

where N is the sample size and C_A and C_B are the numbers of categories in the A and B factors (3 and 2, respectively).

2. The second test is conducted to determine whether the interaction effect is significant. If the interaction effect is indeed absent, then the ratio between the following mean squares are known to have the F-distribution.

$$F = \frac{SS_{AB}/df_1}{SS_{error}/df_2} = \frac{MS_{AB}}{MS_{error}}$$

where

$$df_1 = (C_A - 1)\ (C_B - 1)$$

$$df_2 + N - C_A C_B$$

A significant interaction implies that the effect of one factor, say A, is not uniform across different categories of the other factor, factor B.

3. The third test conducted is to determine the effect of each individual factor and is particularly useful if the interaction effect is absent. In conducting this test, the SS due to interaction (SS_{AB}) may or may not be combined with the error term. If not combined the appropriate F-tests for factors A and B are, respectively,

$$F = \frac{SS_A/df_A}{SS_{error}/df_2} = \frac{MS_A}{MS_{error}}$$

$$F = \frac{SS_B/df_B}{SS_{error}/df_2} = \frac{MS_B}{MS_{error}}$$

The appropriate degrees of freedom for the numerator is the number of categories minus 1; that is, $(C_A - 1)$ and $(C_B - 1)$, respectively. For the denominator the degrees of freedom, as usual, are $N - C_A C_B$.

If the number of sample points falling in the cells of a factorial design are unequal, the analysis becomes somewhat complicated. For example, the component sum of squares (SS_A and SS_B) will not add to the total sum of squares because the main effects will not usually be independent of each other and the interaction effects will not be independent of the main effects, as required in the analysis. The problem becomes further complicated if the covariates are also present.

Given such a design, there are several approaches available based on the hierarchy utilized to achieve orthogonality between the component sum of squares corrected to the mean. The choice of a particular hierarchical system depends on the problem at hand, but in each case the component sum of squares are made orthogonal to each other by determining which independent variables are to be "held constant" or which "adjusted for" in each test. An interested reader may consult a reference book on multi-variate analysis. A brief description of choices available in SPSS is presented here.

ANOVA program of SPSS automatically divides the "effects" into six "types," namely

(1) effect of covariates
(2) additive effect of covariates
(3) two-way interaction effect
(4) three-way interaction effects
(5) four-way interaction effects, and
(6) five-way interactions effects.

ANOVA has provision for a maximum of 5 covariates (metric, continuous variables) and 5 factors (nonmetric, categorical variables). In the *classic experimental approach* (default option) each type of effect is assessed separately in the order listed above. The effect within each type are adjusted for the effects of all prior types. Furthermore, within types, each factor main effect is adjusted for all other factors and each covariate effect is adjusted for all other covariates.

In the *hierarchial approach* (option 10 in ANOVA), as in the classic approach, each effect is assessed separately, controlling for all previous types in the order listed earlier. But in addition to separate assessments, the factor main effects and the covariate effects are assessed hierarchically; the factor main effects are adjusted only for the factor main effects already assessed; and similarly, the covariate effects are adjusted only for the covariables already assessed. Hence, under this approach, the variables are prioritized and the main effects of a factor are assessed according to this priority.

In the *regression approach* (option 9) all effects listed above are assessed simultaneously, with each effect being adjusted for all other effects.

The other options available include the order in which blocks of metric covariates and factor main effects are to be assessed. The default causes the covariates to be assessed first. Main effects for the nonmetric factors are then assessed after adjusting for the covariates. Under option 7, covariates and factors are combined in a single block, that is, to process both of them concurrently. With option 8, the block of covariates is assessed after the main effects for nonmetric factors and after adjustment for the latter, but before any interaction effect.

The objective of the analysis of covariance within this study was to assess the effect of certain roadway geometric, traffic, and delineation treatment parameters and how they interacted with each other after the adjustment had been made for the climatic variables. These climatic variables are considered a completely disjoined set of variables from the geometric, traffic, and treatment factors. Hence, climatic variables were chosen as covariates.

Also, the option appropriate for the current analysis was considered to be the default option in SPSS; that is, the *classic experimental approach* where first the effect of covariates the additive effect of factors, and then the interaction effect of factors are considered adjusted for the effect of all prior types in assessing the effect of each type. Within types, furthermore, each factor main effect was adjusted for all other factors and each covariate effect was adjusted for all other covariates. There were two prime reasons for choosing this approach.

1. The primary objective of the analysis of covariance here is to assess the effect of the main factor after adjusting for the climatic variables. Interaction effects are of

secondary importance. (This implies that options 7, 8, and 9 are inappropriate here.)

2. No hierarchy can be established between the factors; that is, between roadway width, shoulder width, traffic volume, delineation treatment, etc. (This implies that option 10 is inappropriate here.)

Although, as noted, it was decided to utilize the default option in the ANOVA program within SPSS, test runs were made with different option combinations to see how the results vary with them. Cross-classification Table 28 was utilized for this test run. The results of this test are given in Table 29.

The results of ANOVA and covariance analysis utilizing various factorial designs are presented in Tables 30 through 53. For ANOVA, the classic experimental approach is used. In covariance analysis, the effect of covariates are adjusted for prior to assessing the effect of factors. The only *covariates* considered in these analyses are climatic variables; namely, the following:

1. average number of precipitation days per year
2. average number of snow days per year
3. average number of foggy days per year

Table 28. Cross classification table for testing various options available within ANOVA and covariance analysis.

a. Low volume

(ADT: 0-2000)

1 ft = 0.3048 m

	TYPE OF SECTION	TANGENT				WINDING			
	ROADWAY WIDTH	16-18		> 18		16-18		> 18	
	SHOULDER WIDTH	< 4	≥ 4	< 4	≥ 4	< 4	≥ 4	< 4	≥ 4
NO CENTERLINE TREATMENT		MEAN RATE (λ) = VARIANCE (S^2) = # OF SITES=		x	x	x	x	x	x
PAINTED CENTERLINE				x	x	x	x	x	x

Table 29. Comparison of results under various options available within SPSS ANOVA subprograms.

Factor Components	No Covariates				5 Covariates						3 Covariates (Climatic Only)			
	Default (Classic)	Option 4 (Classic)	Option 9 (Regression)	Option 9 Option 4	Default (Classic)	Option 4 (Classic)	Option 7	Option 8	Option 9 (Regression)	Option 9 Option 4	Option 4 (Classic)	Option 7	Option 8	Option 9 Option 4
Covariates	-	-	-		.259	.252	-	.292	.201	.196	.371	-	.999	.314
Speed Limit	-	-	-		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	-	-	-	-
Interchange Frequency	-	-	-		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	-	-	-	-
Precipitation	-	-	-		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Snow Days	-	-	-		.033	.032	.044	.044	.042	.041	.076	.113	.113	.067
Fog Days	-	-	-		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Main Effects	.256	.243	.406		.380	.373	-	.334	N.S.	.245	.282	-	.252	.057
Treatment	.029	.028	.130		.156	.153	.156	.125	.308	.301	.046	.049	.029	.034
Site Type	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.	.211	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Roadwidth	N.S.	N.S.	N.S.		.192	.189	.192	N.S.	.286	.250	N.S.	N.S.	N.S.	N.S.
Shoulder Width	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
2-Way Interaction	.154	.142	N.S.		.347	.339	.347	.347	N.S.	.339	.107	.116	.116	.107
Treatment x Site Type	.230	.224	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.221	.226	.226	.221
Treatment x Roadwidth	N.S.	N.S.	N.S.		.309	.305	.309	.309	.310	.305	N.S.	N.S.	N.S.	N.S.
Treatment x Shoulder Width	.091	.087	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.104	.108	.108	.104
Site Type x Roadwidth	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Site Type x Shoulder Width	.014	.013	N.S.		.045	.044	.045	.045	N.S.	.044	.008	.009	.009	.008
Roadwidth x Shoulder Width	.234	.228	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	.240	.246	.246	.240
3-Way Interaction	N.S.	-	N.S.		N.S.	-	N.S.	N.S.	N.S.	-	-	N.S.	N.S.	-
Treatment x Stype x Rwidth	N.S.	-	N.S.		-	-	-	-	-	-	-	N.S.	N.S.	-
Treatment x Stype x Swidth	N.S.	-	N.S.		-	-	-	-	-	-	-	N.S.	N.S.	-
Treatment x Rwidth x Swidth	N.S.	-	N.S.		-	-	-	-	-	-	-	N.S.	N.S.	-
Stype x Rwidth x Swidth	N.S.	-	N.S.		N.S.	-	N.S.	N.S.	N.S.	-	-	N.S.	N.S.	-

N.S. denotes not significant.

Table 30. Accident rate breakdown by roadway alignment and width, shoulder width and delineation treatment for low volume ($\leq$ 2000 ADT) roads.

	Site Type	Tangent				Winding			
	Roadway Width (ft.)	16-18		> 18		16-18		> 18	
	Shoulder Width (ft.)	< 4	≥ 4	< 4	≥ 4	< 4	≥ 4	< 4	≥ 4
No Treatment	Mean =	4.4314	3.7286		3.1965	3.5877	1.9583	7.9017	2.1929
	Variance =	0	0		0	2.8815	1.2540	0	281.3874
	Exposure =	5.1902	7.5095	0	5.3183	85.0124	14.8091	1.1390	8.6645
	Number of Sites =	1	1		1	10	2	0	1
Painted Centerline		0.9962	2.4620	1.4443	2.6706	2.3837	2.4492	2.9462	2.0861
		0.5143	0.1525	0.4494	1.6080	2.2543	1.1283	3.6475	1.3837
		11.0425	31.2748	41.5421	271.8509	117.8778	81.2515	156.8145	117.4466
		1	4	5	33	22	10	19	4

1 ft = 0.3048 m

Table 31. Analysis of variance and covariance analysis results for Table C-30 dependent variable - accident rate.

	Analysis of Covariance					Analysis of Variance				
Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F	Sum of Squares	DF	Mean Square	F	Sig. of F
Covariates	6.801	3	2.267	1.058	.371					
Precipitation Days	.011	1	.011	.005	.999					
Snow Days	6.692	1	6.692	3.123	.076					
Fog Days	.850	1	.850	.397	.999					
Main Effects	10.962	4	2.741	1.279	.282	11.914	4	2.978	1.383	.243
Treatment	8.498	1	8.498	3.966	.046	10.500	1	10.500	4.874	.028
Site Type	.089	1	.089	.042	.999	.002	1	.002	.001	.999
Roadway Width	1.138	1	1.138	.531	.999	.793	1	.793	.368	.999
Shoulder Width	1.522	1	1.522	.710	.999	.609	1	.609	.283	.999
2-Way Interactions	23.026	6	3.838	1.791	.107	21.174	6	3.529	1.638	.142
Treat · Site Type	3.215	1	3.215	1.501	.221	3.194	1	3.194	1.483	.224
Treat · Roadway Width	.086	1	.086	.040	.999	.308	1	.308	.143	.999
Treat · Shoulder Width	5.618	1	5.618	2.622	.104	6.253	1	6.253	2.903	.087
Site Type · Roadway Width	.297	1	.297	.139	.999	.156	1	.156	.072	.999
Site Type · Shoulder Width	15.519	1	15.519	7.242	.008	13.599	1	13.599	6.313	.013
Roadway Width · Shoulder Width	2.963	1	2.963	1.383	.240	3.139	1	3.139	1.457	.228
Residual	233.562	109	2.143			241.263	112	2.154		
Total	274.351	122	2.249			274.351	122	2.249		

Covariate	Beta
Precipitation	.001
Snow	-.045
Fog	-.007

123 cases were processed.
0 cases (0 percent) were missing.

Table 32. Multiple classification analysis results for Table C-30.

Grand Mean = 2.59						
Variable and Category	Unadjusted DEV*N	Unadjusted ETA	Adjusted for Independents DEV*N	Adjusted for Independents BETA	Adjusted for Independents and Covariates DEV*N	Adjusted for Independents and Covariates BETA
Treat						
1 NO TREAT	.78		.83		.77	
2 PAINT CL	-.11		-.12		-.11	
		.20		.21		.20
Site Type						
1 TANGENT	-.07		.01		.04	
2 WINDING	.04		-.00		-.03	
		.04		.00		.02
Roadway Width						
1 16 THRU 18 FT	.06		-.11		-.14	
2 > 18 FT	-.04		.08		.10	
		.03		.06		.08
Shoulder Width						
1 < 4 FT	.11		.09		.14	
2 ≥ 4 FT	-.10		-.08		-.12	
		.07		.05		.09
Multiple R Squared				.043		.065
Multiple R				.208		.254

Table 33. Accident rate breakdown by roadway alignment, shoulder width and delineation treatment for low volume (< 2000 ADT) wide roads (≥ 20 ft.).

		Roadway Width (ft.)	≥ 20			
		Volume (ADT)	0-2000			
		Site Type	Tangent		Winding	
		Shoulder Width (ft.)	< 4	≥ 4	< 4	≥ 4
Centerline Treatment	No Edgeline	Mean = Variance = Exposure = Number of Sites =	1.4642 0.4683 45.0745 4	2.5137 1.7687 291.9958 23	3.0646 3.5582 172.6176 14	2.1777 1.2886 112.5037 9
	Edgeline		2.1217 2.5428 53.7303 4	2.0997 0.8391 398.1448 31	3.3098 2.3295 109.6728 9	2.8731 2.8393 136.4400 11

1 ft = 0.3048 m

Table 34. Analysis of variance and covariance analysis results for Table 33 dependent variable - accident rate.

	Analysis of Covariance					Analysis of Variance				
Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F	Sum of Squares	DF	Mean Square	F	Signif of F
Covariates	28.140	3	9.380	5.680	.002					
Precipitation Days	11.997	1	11.997	7.264	.008					
Snow Days	1.456	1	1.456	.882	.999					
Fog Days	15.039	1	15.039	9.107	.004					
Main Effects	4.648	3	1.549	.938	.999	11.482	3	3.827	2.109	.103
Site Type	3.100	1	3.100	1.877	.171	6.879	1	6.879	3.790	.051
Shoulder Width	.067	1	.067	.041	.999	.579	1	.579	.319	.999
Edgeline	.129	1	.129	.078	.999	.000	1	.000	.000	.999
2-Way Interactions	5.945	3	1.982	1.200	.314	8.009	3	2.670	1.471	.226
Site Type•Shoulder Width	5.133	1	5.133	3.108	.077	5.349	1	5.349	2.947	.085
Site Type•Edgeline	1.119	1	1.119	.678	.999	2.274	1	2.274	1.253	.265
Shoulder Width•Edgeline	.013	1	.013	.008	.999	.106	1	.106	.058	.999
3-Way Interactions	3.756	1	3.756	2.274	.131	2.342	1	2.342	1.290	.258
Site Type•Shoulder Width•Edgeline	3.756	1	3.756	2.274	.131	2.342	1	2.342	1.290	.258
Residual	153.590	93	1.652			174.244	96	1.815		
Total	196.078	103	1.904			196.078	103	1.904		

Covariate	BETA
Precipitation	.013
Snow	.017
Fog	.031

104 cases were processed.
0 cases (0 percent) were missing.

Table 35. Multiple classification analysis results for Table 33 dependent variable: accident rate.

Grand Mean = 2.48						
Variable and Category	Unadjusted		Adjusted for Independents		Adjusted for Independents + Covariates	
	DEV*N	ETA	DEV*N	BETA	DEV*N	BETA
Site Type						
1 Tangent	-.27		-.24		-.16	
2 Winding	.39		.35		.24	
		.24		.21		.14
Shoulder Width						
1 < 4 FT	.33		.13		.05	
2 $\geq$ 4 FT	-.13		-.05		-.02	
		.15		.06		.02
Edgeline						
1 CL BUT NO EL	.05		.00		.04	
2 CL AND EL	-.04		-.00		-.03	
		.03		.00		.03
Multiple R Squared				.059		.167
Multiple R				.242		.409

Table 36. Accident rate breakdown by roadway alignment, traffic volume and delineation treatment for wide roads (≥ 20 ft.) with wide shoulders (≥ 4 ft.).

			Roadway Width (ft.)	≥ 20			
			Shoulder Width (ft)	≥ 4			
			Site Type	Tangent		Winding	
			Traffic Volume (ADT)	0-2000	2000-5000	0-2000	2000-5000
Centerline Treatment	No Edgeline	No Post	Mean =	2.5137	1.7475	2.1777	2.4267
			Variance =	1.8567	0.5862	1.4857	0
			Exposure =	291.9958	335.9010	112.5037	42.0329
			Number of Sites =	11	13	4	2
		Post		1.9720	1.0179	2.0349	0
				0.7829	0.1266	0.1261	
				182.5564	1159.2643	55.5307	
				7	45	2	
	Edgeline	No Post		2.0997	1.8599	2.8731	2.0872
				0.8689	0.6924	3.1794	0.0007
				398.1448	684.4400	136.4400	41.6817
				15	26	5	2
		Post		0.8250	2.3780	0	1.9306
				0	1.5015		0
				24.2430	82.8427		31.0789
				1	3		1

1 ft. = 0.3048 m

Table 37. Analysis of variance and covariance analysis results for Table 36 dependent variable - accident rate.

Source of Variation	Analysis of Covariance					Analysis of Variance				
	Sum of Squares	DF	Mean Square	F	Signif of F	Sum of Squares	DF	Mean Square	F	Signif of F
Covariates	30.902	3	10.301	14.701	.001					
Precipitation	9.488	1	9.488	13.541	.001					
Snow	.000	1	.000	.000	.999					
Fog	.038	1	.038	.055	.999					
Main Effects	10.456	4	2.614	3.731	.007	34.332	4	8.583	11.640	.001
Site Type	.433	1	.433	.619	.999	1.616	1	1.616	2.192	.137
Traffic Volume	5.333	1	5.333	7.612	.007	6.809	1	6.809	9.234	.003
Edgeline	.096	1	.096	.138	.999	.503	1	.503	.682	.999
Post Delineators	2.085	1	2.085	2.975	.083	6.973	1	6.973	9.457	.003
2-Way Interactions	4.428	6	.738	1.053	.395	4.729	6	.788	1.069	.385
Site Type . Traffic Volume	.000	1	.000	.000	.999	.000	1	.000	.000	.999
Site Type . Edgeline	1.292	1	1.292	1.844	.174	.862	1	.862	1.169	.281
Site Type . Post	.080	1	.080	.115	.999	.019	1	.019	.026	.999
Traffic Volume . Edgeline	1.260	1	1.260	1.799	.179	1.502	1	1.502	2.036	.152
Traffic Volume . Post	.012	1	.012	.017	.999	.021	1	.021	.029	.999
Edgeline . Post	1.311	1	1.311	1.871	.170	1.432	1	1.432	1.942	.162
Residual	86.181	123	.701			92.907	126	.737		
Total	131.968	136	.970			131.968	136	.970		

Covariate	Beta
Precipation	.012
Snow	-.000
Fog	.001

154 cases were processed.
16 cases (10. percent) were missing.

Table 38. Multiple classification analysis results for Table 36.

Grand Mean = 1.73						
Variable and Category	Unadjusted DEV*N	Unadjusted ETA	Adjusted for Independents DEV*N	Adjusted for Independents BETA	Adjusted for Independents + Covariates DEV*N	Adjusted for Independents + Covariates BETA
Site Type						
1 Tangent	-.09		-.04		-.02	
2 Winding	.65		.31		.17	
		.24		.12		.06
Traffic Volume						
1 0 to 2000 ADT	.52		.34		.31	
2 2000 to 5000 ADT	-.26		-.17		-.15	
		.38		.25		.22
Edgeline						
0 No EL	-.21		-.06		.03	
1 EL	.32		.09		-.04	
		.26		.07		.03
Post Delineation						
0 No Posts	.35		.24		.17	
1 Posts	-.47		-.32		-.22	
		.42		.28		.19
Multiple R Squared				.260		.313
Multiple R				.510		.560

Table 39. Accident rate - breakdown by degree of curvature, shoulder width and delineation treatment for horizontal curves on low volume (≤ 2000 ADT) narrow roads (≤ 20 ft.).

	Roadway Width (ft.)	≤20			
	Traffic Volume (ADT)	0-2000			
	Degree of Curvature	3-6		>6	
	Shoulder Width (ft.)	< 4	≥ 4	< 4	≥ 4
No Treatment	Mean =	1.8619	1.5189	1.9050	2.9045
	Variance =	0.3744	1.2853	0.0675	23.9618
	Exposure =	3.7597	3.9503	3.1495	2.4100
	Number of Sites =	2	2	2	2
Painted Centerline		0.7352	0.7731	2.3962	3.2506
		0	0.4822	0.0119	31.5207
		1.3602	16.8155	2.9212	2.4611
		1	11	2	2

1 ft = 0.3048 m

Table 40. Analysis of variance and covariance analysis results for Table 39 dependent variable - accident rate.

	Analysis of Covariance					Analysis of Variance				
Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F	Sum of Squares	DF	Mean Square	F	Signif of F
Covariates	13.874	3	4.625	2.014	.165					
Precipitation	7.456	1	7.456	3.248	.094					
Snow	7.303	1	7.303	3.181	.097					
Fog	7.730	1	7.730	3.367	.089					
Main Effects	5.149	3	1.716	.748	.999	12.192	3	4.064	1.690	.211
Deg. of Curv	4.467	1	4.467	1.946	.186	8.940	1	8.940	3.717	.070
Shoulder Width	1.113	1	1.113	.485	.999	.087	1	.087	.036	.999
Treatment	.720	1	.720	.313	.999	1.153	1	1.153	.479	.999
2-Way Interactions	5.004	3	1.668	.727	.999	3.567	3	1.189	.494	.999
Deg. of Curv . Shoulder Width	2.976	1	2.976	1.296	.277	1.107	1	1.107	.460	.999
Deg. of Curv . Treatment	.792	1	.792	.345	.999	1.579	1	1.579	.656	.999
Shoulder Width . Treatment	.338	1	.338	.147	.999	.016	1	.016	.007	.999
3-Way Interactions	.327	1	.327	.142	.999	.062	1	.062	.026	.999
Deg. of Curve . Shoulder Width. Treatment	.327	1	.327	.142	.999	.062	1	.062	.026	.999
Residual	27.548	12	2.296			36.080	15	2.405		
Total	51.901	22	2.359			51.901	22	2.359		

Covariate	Beta
Precipation	-.073
Snow	.292
Fog	-.042

24 Cases were processed.
1 Case (3.3 percent) were missing.

Table 41. Multiple classification analysis results for Table 39 dependent variable - accident rate.

Grand Mean = 1.49						
Variable and Category	Unadjusted		Adjusted for Independents		Adjusted for Independents and Covariates	
	DEV*N	ETA	DEV*N	BETA	DEV*N	BETA
Degree of Curv						
1 3 to 6 Degrees	-.45		-.44		-.33	
1 > 6 Degree	1.07		1.03		.78	
		.46		.45		.34
Shoulder Width						
1 < 4 FT	.38		-.10		-.40	
2 ≥ 4 FT	-.17		.05		.17	
		.17		.05		.18
Treatment						
11 No Treatment	.47		.32		.28	
12 CL	-.26		-.18		-.16	
		.23		.16		.14
Multiple R Squared				.235		.367
Multiple R				.485		.605

1 ft. = 0.3048 m

Table 42. Accident rate breakdown by traffic volume, shoulder width and delineation treatment for 3-6 degree curves on wide roads (≥ 20 ft.).

Centerline Treatment	Edgeline	Post	Roadway Width (ft.)	≥ 20			
			Degree of Curvature	3-6			
			Traffic Volume (ADT)	0-2000		2000-5000	
			Shoulder Width (ft)	< 4	≥ 4	< 4	≥ 4
No	No Edgeline	No Post	Mean =	1.0475	0.9009	0.7857	0.4545
			Variance =	2.6410	1.5212	0.4934	0
			Exposure =	9.5466	21.0890	7.6363	8.8002
			Number of Sites =	3	7	2	3
		Post		2.0748	2.3637	1.6432	1.3248
				2.8743	5.0433	0.5631	0.4696
				27.4720	4.6537	12.7798	20.3807
				9	1	4	6
	Edgeline	No Post		0	1.8753	0.5343	1.5625
				0	1.8359	0	0.5389
				1.5594	17.5972	3.7433	38.3994
				0 *	6	1	12
		Post			0.1626	2.9603	0.8832
					0.1152	0	0.3880
				0	6.1512	6.0804	43.0253
					2	2	14

1 ft = 0.3048 m

* The effective number of sites in each case was less than 0.5.

Table 43. Analysis of variance and covariance analysis results for Table 42 dependent variable - accident rate.

Source of Variation	Analysis of Covariance					Analysis of Variance				
	Sum of Squares	DF	Mean Square	F	Signif of F	Sum of Squares	DF	Mean Square	F	Signif of F
Covariates	7.157	3	2.386	2.041	.117					
Precipitation	1.172	1	1.172	1.002	.322					
Snow	.023	1	.023	.019	.999					
Fog	6.073	1	6.073	5.194	.025					
Main Effects	2.757	4	.689	.590	.999	4.500	4	1.125	.975	.999
Traffic Volume	.679	1	.679	.581	.999	.815	1	.815	.707	.999
Shoulder Width	.785	1	.785	.671	.999	2.478	1	2.478	2.147	.144
Edgeline	1.657	1	1.657	1.417	.237	.614	1	.614	.532	.999
Post Delineators	.378	1	.378	.324	.999	.507	1	.507	.439	.999
2-Way Interactions	10.283	6	1.714	1.466	.205	13.127	6	2.188	1.896	.095
Traf. Vol. Shoulder Width	.379	1	.379	.324	.999	.194	1	.194	.168	.999
Traf. Vol. Edgeline	1.101	1	1.101	.942	.999	.976	1	.976	.846	.999
Traf. Vol. Post	.252	1	.252	.216	.999	.362	1	.362	.314	.999
Shoulder Width . Edgeline	.006	1	.006	.005	.999	.057	1	.057	.049	.999
Shoulder Width . Post	1.882	1	1.882	1.610	.207	2.239	1	2.239	1.941	.165
Edgeline . Post	3.648	1	3.648	3.121	.079	4.653	1	4.653	4.032	.046
Residual	68.977	59	1.169			71.547	62	1.154		
Total	89.174	72	1.239			89.174	72	1.239		

Covariate	Beta
Precipation	.005
Snow	.003
Fog	-.026

76 Cases were Processed.
3 Cases (4.1 percent) Were missing.

Table 44. Multiple classification analysis results for Table 42 dependent variable - accident rate.

Grand Mean = 1.34

Variable and Category	Unadjusted DEV*N	Unadjusted ETA	Adjusted for Independents DEV*N	Adjusted for Independents BETA	Adjusted for Independents + Covariates DEV*N	Adjusted for Independents + Covariates BETA
Traf. Vol.						
1 0 to 2000 ADT	.15		.15		.14	
2 2000 to 5000 ADT	-.09		-.09		-.09	
		.10		.11		.11
Shoulder Width						
1 < 4 FT	.32		.32		.19	
2 ≥ 4 FT	-.14		-.14		-.08	
		.19		.19		.11
Edgeline						
0 No EL	.04		-.11		-.19	
1 EL	-.04		.11		.19	
		.03		.10		.17
Post Delineators						
0 No Posts	-.10		-.09		.09	
1 Posts	.09		.08		-.09	
		.09		.08		.08
Multiple R Squared				.050		.111
Multiple R				.225		.333

Table 45. Accident rate breakdown by degree of curvature, shoulder width and delineation treatment for horizontal curves on low volume (0-2000 ADT) wide roads (≥ 20 ft.).

			Roadway Width (ft.)	≥ 20			
			Traffic Volume (ADT)	0-2000			
			Degree of Curvature	3-6		> 6	
			Shoulder Width (ft.)	< 4	≥ 4	< 4	≥ 4
Centerline Treatment	No Edgeline	No Post	Mean =	1.0475	0.9009	1.5945	1.6691
			Variance =	2.1953	1.4184	1.6280	6.3886
			Exposure =	9.5466	21.0890	10.0342	10.1851
			Number of Sites =	5	11	5	6
		Post		2.0748	2.3637	0.3738	0.6030
				2.7283	2.7150	0.1566	0
				27.4720	4.6537	5.3504	1.6583
				15	3	3	1
	Edgeline	No Post		0	1.8753	1.4518	0.4792
				0	1.6843	1.0039	0.2152
				1.5594	17.5972	6.1990	10.4350
				1	10	3	6
		Post			0.1626		1.5297
					0.0805		0
				0	6.1512	0	1.9612
					3		1

1 ft = 0.3048 m

Table 46. Analysis of variance and covariance analysis results for Table 45 dependent variable - accident rate.

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig. of F	Sum of Squares	DF	Mean Square	F	Sig. of F
Covariates	10.471	3	3.490	1.559	.208					
Precipitation	.062	1	.062	.028	.999					
Snow	.636	1	.636	.284	.999					
Fog	5.607	1	5.607	2.504	.115					
Main Effects	.752	4	.188	.084	.999	4.596	4	1.149	.511	.999
Degree of Curvature	.427	1	.427	.191	.999	1.272	1	1.272	.566	.999
Shoulder Width	.175	1	.175	.078	.999	.868	1	.868	.386	.999
Edgeline	.061	1	.061	.027	.999	.286	1	.286	.127	.999
Post Delineators	.126	1	.126	.056	.999	.225	1	.225	.100	.999
2-Way Interactions	10.759	6	1.792	.801	.999	10.702	6	1.679	.746	.999
Deg. of Curv. · Shoulder	.028	1	.028	.012	.999	.000	1	.000	.000	.999
Deg. of Curv. · Edgeline	.037	1	.037	.016	.999	1.242	1	1.242	.552	.999
Deg. of Curv. · Post	2.759	1	2.759	1.232	.271	4.035	1	4.035	1.794	.182
Shoulder · Edgeline	1.126	1	1.126	.503	.999	.049	1	.049	.022	.999
Shoulder · Post	.565	1	.565	.252	.999	.191	1	.191	.085	.999
Edgeline · Post	5.969	1	5.969	2.665	.104	4.514	1	4.514	2.007	.158
Residual	129.893	58	2.240			137.207	61	2.249		
Total	151.875	71	2.139			151.875	71	2.139		

Covariate	Beta
Precipitation	-.001
Snow	-.014
Fog	-.019

73 cases were processed.
0 cases (0 percent) were missing.

Table 47. Multiple classification analysis results for Table 45 dependent variable - accident rate.

Grand Mean = 1.37						
Variable and Category	Unadjusted		Adjusted for Independents		Adjusted for Independents and Covariates	
	DEV*N	ETA	DEV*N	BETA	DEV*N	BETA
Deg. of Curvature						
1 3 TO 6 DEG	.11		.10		.06	
2 > 6 DEG	-.22		-.19		-.12	
		.11		.10		.06
Shoulder Width						
1 < 4 FT	.19		.14		.07	
2 ≥ 4 FT	-.15		-.11		-.05	
		.12		.09		.04
Edgeline Treatment						
0 NO FL	.10		.05		.02	
1 EL	-.21		-.10		-.05	
		.10		.05		.02
Post Delineators						
0 NO POSTS	-.12		-.05		.04	
1 POSTS	.21		.08		-.07	
		.11		.04		.04
Multiple R Squared				.030		.074
Multiple R				.174		.272

Table 48. Accident rate breakdown by degree of curvature, traffic volume and delineation treatment for horizontal curves on wide roads (≥ 20 ft.) with wide shoulders (≥ 4 ft.).

			Roadway Width (ft.)	≥ 20			
			Shoulder Width (ft.)	≥ 4			
			Degree of Curvature	3-6		> 6	
			Traffic Volume (ADT)	≤ 2000	> 2000	≤ 2000	> 2000
Centerline	No Edgeline	No Post	Mean =	0.9009	0.4545	1.6691	
			Variance =	1.5601	0	8.0816	
			Exposure =	21.0890	8.8002	10.1851	0
			Number of Sites	6	2	3	
		Post		2.3637	1.3248	0.6030	1.9164
				7.1535	0.4822	0	0.9098
				4.6537	20.3807	1.6583	12.0019
				1	6	0	3
	Edgeline	No Post		1.8753	1.5625	0.4792	1.0585
				1.8945	0.5458	0.2701	0.1528
				17.5972	38.3994	10.4350	20.7850
				5	11	3	6
		Post		0.1626	0.8832	1.5297	0.5785
				0.1353	0.3924	0	0.8884
				6.1512	43.0253	1.9612	8.6431
				2	12	1	2

1 ft = 0.3048 m

*The effective number of sites in this case was less than 0.5.

Table 49. Analysis of variance and covariance analysis results for Table 48 dependent variable - accident rate.

Source of Variation	Analysis of Covariance					Analysis of Variance				
	Sum of Squares	DF	Mean Square	F	Signif of F	Sum of Squares	DF	Mean Square	F	Signif of F
Covariates	1.028	3	.343	.326	.999					
Precipitation Days	.033	1	.033	.031	.999					
Snow Days	.104	1	.104	.099	.999					
Fog Days	.451	1	.451	.429	.999					
Main Effects	1.306	4	.326	.310	.999	.883	4	.221	.216	.999
Deg. of Curvature	.111	1	.111	.106	.999	.056	1	.056	.055	.999
Traffic Volume	.021	1	.021	.020	.999	.051	1	.051	.050	.999
Edgeline	.049	1	.049	.047	.999	.482	1	.482	.472	.999
Post Delineators	1.161	1	1.161	1.103	.299	.487	1	.487	.476	.999
2-Way Interactions	10.328	6	1.721	1.635	.157	10.185	6	1.698	1.660	.149
Deg. of Curv. × Traf. Vol.	.137	1	.137	.130	.999	.158	1	.158	.155	.999
Deg. of Curv. × Edgeline	3.131	1	3.131	2.975	.087	2.640	1	2.640	2.582	.110
Deg. of Curv. × Post	.057	1	.057	.054	.999	.064	1	.064	.063	.999
Traf. Vol. × Edgeline	.746	1	.746	.709	.999	.805	1	.805	.787	.999
Traf. Vol. × Post	.190	1	.190	.181	.999	.138	1	.138	.135	.999
Edgeline × Post	5.604	1	5.604	5.325	.024	5.590	1	5.590	5.467	.022
Residual	51.575	49	1.053			53.168	52	1.022		
Total	64.236	62	1.036			64.236	62	1.036		

Covariate	Beta
Precipitation	-.001
Snow	.007
Fog	-.007

66 Cases were Processed.
3 Cases (4.1 percent) were missing

Table 50 Multiple classification analysis results for Table 48 dependent variable - accident rate.

Grand Mean = 1.19						
Variable and Category	Unadjusted		Adjusted for Independents		Adjusted for Independents + Covariates	
	DEV*N	ETA	DEV*N	BETA	DEV*N	BETA
Degree of Curvature						
1 3 to 6 Deg.	.01		.02		.03	
2 > 6 Deg.	-.03		-.05		-.07	
		.02		.03		.04
Traf. Vol.						
1 0 to 2000 ADT	.03		-.05		-.03	
2 2000 to 5000 ADT	-.01		.02		.01	
		.02		.03		.02
Edgeline Treatment						
0 No EL	.10		.12		.04	
1 EL	-.06		-.07		-.02	
		.07		.09		.03
Post Delineators						
0 No Posts	.07		.08		.14	
1 Posts	-.08		-.11		-.18	
		.07		.09		.16
Multiple R Squared				.014		.036
Multiple R				.117		.191

Table 51. Accident rate breakdown by degree of curvature, shoulder width and delineation treatment for horizontal curves on low volume (≤ 2000 ADT) wide roads (≥ 20 ft.).

		Traffic Volume (ADT)	≤ 2000			
		Roadway Width (ft.)	≥ 20			
		Degree of Curvature	3-6		> 6	
		Shoulder Width (ft.)	< 4	≥ 4	< 4	≥ 4
Centerline	No Post	Mean =	1.0475	0.9009	1.5945	1.6691
		Variance =	2.1485	1.4061	1.5954	6.2628
		Exposure	9.5466	21.0890	10.0342	10.1851
		Number of Sites =	6	13	6	6
	Post		2.0748	2.3637	0.3738	0.6031
			2.7106	2.5626	0.1489	0
			27.4720	4.6537	5.3504	1.6583
			16	3	3	1

1 ft = 0.3048 m

Table 52. Analysis of variance and covariance analysis results for Table 51 dependent variable - accident rate.

Source of Variation	Analysis of Covariance					Analysis of Variance				
	Sum of Squares	DF	Mean Square	F	Signif. of F	Sum of Squares	DF	Mean Square	F	Signif. of F
Covariates	10.400	3	3.467	1.331	.276					
Precipitation Days	1.304	1	1.304	.501	.999					
Snow Days	.004	1	.004	.001	.999					
Fog Days	3.866	1	3.866	1.484	.228					
Main Effects	.306	3	.102	.039	.999	4.865	3	1.622	.657	.999
Deg. of Curv.	.044	1	.044	.017	.999	.078	1	.078	.032	.999
Shoulder Width	.159	1	.159	.061	.999	.102	1	.102	.041	.999
Treatment	.018	1	.018	.007	.999	2.776	1	2.776	1.125	.295
2-Way Interactions	8.944	3	2.981	1.145	.342	13.421	3	4.474	1.814	.157
Deg. of Curv. Shoulder Width	.000	1	.000	.000	.999	.052	1	.052	.021	.999
Deg. of Curv. Treatment	7.425	1	7.425	2.851	.095	11.039	1	11.039	4.475	.038
Shoulder Width Treatment	.499	1	.499	.192	.999	.263	1	.263	.106	.999
3-Way Interactions	.142	1	.142	.055	.999	.034	1	.034	.014	.999
Deg. of Curv. Shoulder Width .Treatment	.142	1	.142	.055	.999	.034	1	.034	.014	.999
Residual	111.998	43	2.605			113.471	46	2.467		
Total	131.791	53	2.487			131.791	53	2.487		

Covariate	Beta
Precipitation	-.006
Snow	-.001
Fog	-.023

54 Cases were Processed.
0 Cases (0 percent) were missing.

Table 53. Multiple classification analysis results for Table 51 dependent variable - accident rate.

Grand Mean 1.48						
Variable and Category	Unadjusted DEV*N	Unadjusted ETA	Adjusted For Independents DEV*N	Adjusted For Independents BETA	Adjusted For Independents + Covariates DEV*N	Adjusted For Independents + Covariates BETA
Degree of Curv.						
1 3 to 6 Deg.	.07		.03		.02	
2 > 6 Deg.	-.16		-.06		-.05	
		.07		.03		.02
Shoulder Width						
1 < 4 Ft.	.14		.04		.05	
2 ≥ 4 Ft.	-.20		-.06		-.07	
		.11		.03		.04
Treatment						
12 CL	-.26		-.23		-.02	
15 CL And Post	.34		.30		.03	
		.19		.17		.02
Multiple R Squared				.037		.081
Multiple R				.192		.285

The various *factors* considered are listed in the tables. The various geometric and traffic operational variables considered important and therefore categorized as factors, including roadway delineation treatments, are given below.

1. General Roadway Alignment (Tangent vs. Winding) for General Sites

2. Roadway Width

3. Shoulder Width

4. Traffic Volume

5. Degree of Curvature for Horizontal Curves

6. Roadway Delineation Treatments

Tables 30 through 38 relate to general highway sites; whereas, Tables 39 through 53 relate to the horizontal curve sites. The tables are organized in groups of three. The first table in a group (Tables 30, 33, 36, etc.) provides the factorial design for ANOVA and covariance analysis. In addition, it provides data on mean accident rate, variance of accident rate, total site exposure, and total effective number of sites for each cell. It should be recalled that due to the chosen weighting scheme, the effective number of sites are different from the actual number of highway sites. The effective number of sites are proportional to the total cell exposure.

The second table in the group (Tables 31, 34, 37, etc.) provide the result of ANOVA and covariance analysis. The left half of the data relates to covariance analysis and the right half to analysis of variance. The betas presented at the bottom of the table are the standardized regression coefficients for the covariates.

The third table in the group provides the results of Multiple Classification Analysis (MCA) readily available through STATISTICS 1 of the ANOVA subprogram (Tables 32, 35, 38, etc.). These MCA tables can be viewed as a way of displaying the results of analysis of variance, especially when there are no significant interaction effects. The table is divided into three columns with each column containing two data columns. The left hand data column (DEV*N) provides the category mean, expressed as a deviation from the grand mean. The grand mean, the mean accident rate for sites used in the particular analysis, is given on the left top portion of the table. In the first column no adjustment has been made either for the other factors or covariates. The numbers in the second column indicate the adjusted mean values for each category (again expressed as a deviation from the grand mean) when the other factors are adjusted for. The numbers in the third column provide the mean for each category (and are again expressed as deviation from the grand mean) when adjustment for both the factors and the covariates are made. It is informative to review the data from left to right. As the adjustments are made first for the other factors and then for the covariates, note how the mean accident rate changes.

The right hand data columns within each of the three columns provide ETA and BETA. ETA is the simple regression coefficient between the dependent variable and the factor. BETA in the middle column is the standardized partial regression coefficient when the effect of other factors is controlled for. BETA in the last column is the standardized partial regression coefficient which results by first controlling for the other factors and then controlling for the covariates. The multiple R's at the bottom of the table indicate the overall relationship between the dependent variable and the independent variables (factors as well as covariates).

The results of the analysis of variance and covariance analysis are consolidated in Tables 34 and 35; the former relates to general sites and the latter to horizontal curve sites. The general findings of this analysis are described below.

General Highway Situations

- Climatic variables in general, were found to have an effect on roadway accidents.
- Among the climatic variables considered, number of days of precipitation was found to have the strongest effect.
- All factors considered as a whole were found to have an effect on roadway accidents.
- Among factors, the factors found to have the strongest effect are:
    - centerline treatment
    - post delineators
    - traffic volume.
- Edgeline treatment was found to have no effect on roadway accidents
- Generally, interaction among the independent variables was found to be nonexistent. The only variables with significant interaction were shoulder width and site type (general roadway alignment).

Isolated Horizontal Curves

- The overall effect of independent variables was found to be much less for horizontal curve situations than general sites.
- Among all sources of variation, the only significant variation at .05 was the interaction between the edgeline and post delineator.

Table 54. Comparison of analysis of variance results for general highway situation.

	Significance of F					
	Factorial Design Table C-30		Factorial Design Table C-33		Factorial Design Table C-36	
	Cov. Analysis	ANOVA	Cov. Analysis	ANOVA	Cov. Analysis	ANOVA
Covariates	0.371		0.002		0.001	
Precipitation	N.S.		0.008		0.001	
Snow	0.076		N.S.		N.S.	
Fog	N.S.		0.004		N.S.	
Main Effect	0.282	0.243	N.S.	0.103	0.007	0.001
Centerline	0.046	0.028				
Edgeline			N.S.	N.S.	N.S.	N.S.
Post Delineators					0.083	0.003
Site Type	N.S.	N.S.	0.171	0.051	N.S.	0.137
Traffic Volume					0.007	0.003
Roadway Width	N.S.	N.S.				
Shoulder Width	N.S.	N.S.	N.S.	N.S.		
2-Way Interaction	0.107	0.142	0.314	0.226	0.395	0.385
CL x EL						
CL x POST						
CL x Site Type	0.221	0.224				
CL x Traf. Vol.						
CL x Road Width	N.S.	N.S.				
CL x Shoulder Width	0.104	0.087				
EL x POST					0.170	0.162
EL x Site Type			N.S.	0.265	0.174	0.281
EL x Traf. Vol.					0.179	0.152
EL x Road Width						
EL x Shoulder Width			N.S.	N.S.		
POST x Site Type					N.S.	N.S.
POST x Traf. Vol.					N.S.	N.S.
POST x Road Width						
POST x Shoulder Width						
Site Type x Traf. Vol.					N.S.	N.S.
Site Type x Rd. Width	N.S.	N.S.				
Site Type x Shld. Width	0.008	0.013	0.077	0.085		
Traf. Vol x Rd. Width						
Traf. Vol x Shld. Width						
Rd. Width x Shld. Width	0.240	0.228				

N.S. denotes "not significant" (i.e. significance level .999)

Table 55. Comparison of analysis of variance results for horizontal curves.

	Significance of F									
	Factorial Design Table C-39		Factorial Design Table C-42		Factorial Design Table C-45		Factorial Design Table C-48		Factorial Design Table C-51	
	Cov. Analysis	ANOVA	Cov. Analysis	ANOVA	Cov. Analysis	ANOVA	Cov. Analysis	ANOVA	Cov. Analysis	ANOVA
Covariates	0.165		0.117		0.208		N.S.		0.276	
Precipitation	0.094		0.322		N.S.		N.S.		N.S.	
Snow	0.097		N.S.		N.S.		N.S.		N.S.	
Fog	0.089		0.025		0.115		N.S.		0.228	
Main Effect	N.S.	0.211	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Centerline	N.S.	N.S.								
Edgeline			0.237	N.S.	N.S.	N.S.	N.S.	N.S.		
Post Delineators			N.S.	N.S.	N.S.	N.S.	0.299	N.S.	N.S.	0.295
Traffic Volume			N.S.	N.S.			N.S.	N.S.		
Deg. of Curvature	0.186	0.070			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Roadway Width										
Shoulder Width	N.S.	N.S.	N.S.	0.144	N.S.	N.S.			N.S.	N.S.
2-Way Interaction	N.S.	N.S.	0.205	0.095	N.S.	N.S.	0.157	0.149	0.342	0.157
CL x EL										
CL x POST										
CL x Traf. Vol.										
CL x Deg. of Curv.	N.S.	N.S.								
CL x Rd. Width										
CL x Should. Width	N.S.	N.S.								
EL x POST			0.079	0.046	0.104	0.158	0.024	0.022		
EL x Traf. Vol			N.S.	N.S.			N.S.	N.S.		
EL x Deg. of Curv.					N.S.	N.S.	0.087	0.110		
EL x Rd. Width										
EL x Should. Width			N.S.	N.S.	N.S.	N.S.				
POST x Traf. Vol			N.S.	N.S.			N.S.	N.S.		
POST x Deg. of Curv.					0.271	0.182	N.S.	N.S.	0.095	0.038
POST x Rd. Width										
POST x Should. Width			0.207	0.165	N.S.	N.S.			N.S.	N.S.
Traf.Vol x Deg.of Curv.							N.S.	N.S.		
Traf.Vol x Rd. Width										
Traf.Vol x Shld. Width			N.S.	N.S.						
Deg.of Curv.xRd.Width										
Deg.of Curv.xShld.Width	0.277	N.S.			N.S.	N.S.			N.S.	N.S.
Rd.WidthxShould.Width										

N.S. denotes "not significant" (i.e. significance level .999)

The insensitivity of roadway geometry, traffic volume, roadway delineation treatment, and climatic conditions found for the horizontal curves was unexpected. Additional analysis was conducted to ensure that this was not due to some obvious oversight or some faulty analytical procedure.

First, a breakdown of traffic exposure according to the factorial design tables for horizontal curve sites was obtained. It is given in Table 56. This table indicates how the traffic exposure is distributed among the cells of the factorial design tables (Table 39, 42, 51). Although evidently there are a few cells in the factorial design tables which have little or no exposure, for most of the tables there appears to be acceptable exposure. Nevertheless, to ensure that this is not the reason for the insensitive results, a new factorial design with nearly equal cell exposure was constructed. This design is presented as Table 57. The associated analysis of variance and covariance analysis is given in Table 58. Corresponding multiple classification analysis is presented in Table 59. It is evident from these tables that even a well-balanced design failed to yield any statistically significant results.

In addition, several pairs of roadway delineation treatments for which sites were available with nearly the same exposure, uniformly distributed over the roadway geometric and traffic characteristics, were tested through t-statistics. Appropriate rows of factorial design tables (which represent delineation treatment categories) were utilized for this purpose. The treatments compared were:

- centerline treatment vs. centerline + edgeline treatment
- centerline treatment vs. centerline + post delineator treatment

Table 56. Exposure breakdown for horizontal curves.

Exposure
No. of Actual Sites

Roadway Width (ft)	<20								≥20							
Degree of Curvature	3-6				>6				3-6				>6			
Traffic Volume (ADT)	≤2000		2000-5000		≤2000		2000-5000		≤2000		2000-5000		≤2000		2000-5000	
Should. Width (ft) / Treatments	<4	≥4	<4	≥4	<4	≥4	<4	≥4	<4	≥4	<4	≥4	<4	≥4	<4	≥4
11 No Treatment	3.7597 3	3.9503 2			3.1495 2	2.4100 3										
12 Centerline Treatment	1.3602 1	16.8155 8			2.9212 2	2.4611 2			9.5466 8	21.0890 10	7.6363 2	8.8002 1	10.0342 7	10.1851 7	4.0874 1	
13 Guardrail					0.6573 1				1.8326 1		4.6659 1			3.6881 1		
14 CL + EL		5.0359 2			1.3164 1	1.3164 1			1.5594 2	17.5972 7	3.7433 1	38.3994 8	6.1990 2	10.4350 4		20.785 4
15 CL + POST									27.4720 15	4.6537 3	12.7798 2	20.3807 3	5.3504 3	1.6583 1	8.9427 1	12.0019 2
16 CL + EL + POST										6.1512 3	6.0804 1	43.0253 7		1.9612 1		8.6434 2

1 ft = 0.3048 m

Table 57. Accident rate breakdown by degree of curvature, traffic volume, and shoulder width for horizontal curves on wide roads (≥ 20 ft.).

	Roadway Width (ft)	≥20							
	Degree of Curvature	3-6				>6			
	Traffic Volume (ADT)	0-2000		2000-5000		0-2000		2000-5000	
	Shoulder Width (ft.)	<4	≥4	<4	≥4	<4	≥4	<4	≥4
Centerline Only	Mean Variance =	1.0475	.9009	.7857	.4545	1.5945	1.6691	2.2019	
	Variance =	2.5101	1.4934	.4593	0	1.8457	7.2255	0	
	Exposure =	9.5466	21.0890	7.6363	8.8002	10.0342	10.1851	4.0874	0
	Number of Sites =	3	8	3	3	4	4	1	
Centerline and Edgeline		0	1.8753	.5343	1.5625	1.4518	.4792		1.0585
		0	1.7944	0	.5338	1.2897	.2424		.1462
		1.5594	17.5972	3.7433	38.3994	6.1990	10.4350	0	20.7850
		1	6	1	14	2	4		7
Centerline and Posts		2.0748	2.3637	1.6432	1.3248	.3748	.6030	2.5719	1.9164
		2.8353	4.1329	.5443	.4607	.2152	0	0	.8324
		27.4720	4.6537	12.7798	20.3807	5.3504	1.6583	8.9427	12.0019
		10	2	5	7	2	1	3	4

1 ft = 0.3048 m

Table 58. Analysis of variance and covariance analysis results for Table 57 dependent variable - accident rate.

	ANALYSIS OF COVARIANCE					ANALYSIS OF VARIANCE				
SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
Covariates	8.110	3	2.703	1.987	.123					
Precipitation Days	.006	1	.006	.004	.999					
Snow Days	.271	1	.271	.199	.999					
Fog Days	3.737	1	3.737	2.747	.098					
Main Effects	2.140	5	.428	.315	.999	6.946	5	1.389	1.035	.404
Degree of Curvature	.022	1	.022	.016	.999	.000	1	.000	.000	.999
Traffic Volume	.162	1	.162	.119	.999	.094	1	.094	.070	.999
Shoulder Width	.188	1	.188	.139	.999	.330	1	.330	.246	.999
Treatment	1.943	2	.972	.714	.999	5.435	2	2.718	2.718	.138
2-Way Interaction	14.241	9	1.582	1.163	.332	14.611	9	1.623	1.210	.302
Deg. of Curv • Traf. Vol.	4.398	1	4.398	3.232	.073	5.942	1	5.942	4.428	.037
Deg. of Curv • Shoulder Width	.647	1	.647	.476	.999	.564	1	.564	.420	.999
Deg. of Curv • Treatment	8.013	2	4.006	2.945	.058	8.280	2	4.140	3.085	.050
Traf. Vol. • Shoulder Width	.092	1	.092	.068	.999	.023	1	.023	.017	.999
Traf. Vol. • Treatment	.311	2	.155	.144	.999	.123	2	.061	.046	.999
Shoulder Width • Treatment	1.007	2	.504	.370	.999	.321	2	.161	.120	.999
3-Way Interactions	7.788	7	1.113	.818	.999	7.957	7	1.137	.847	.999
Deg. of Curv • Traf. Vol. •Shoulder Width	.109	1	.109	.080	.999	.020	1	.020	.015	.999
Deg. of Curv • Traf. Vol. •Treatment	2.674	2	1.337	.983	.999	1.760	2	.880	.656	.999
Deg. of Curv • Shoulder Width •Treatment	1.168	2	.584	.429	.999	2.657	2	1.328	.990	.999
Traf. Vol. • Shoulder Width •Treatment	.047	2	.024	.017	.999	.142	2	.071	.053	.999
Residual	92.514	68	1.361			95.278	71	1.342		
Total	124.793	92	1.356			124.793	92	1.356		

Covariate	BETA	
Precipitation	-.000	97 Cases were processed.
Snow	-.008	3 Cases (3.5%) were missing.
Fog	-.016	

Table 59. Multiple classification analysis results for Table 57.

Grand Mean = 1.43	Unadjusted		Adjusted for Independents		Adjusted for Independents + Covariates	
Variable + Category	DEV*N	ETA	DEV*N	BETA	DEV*N	BETA
Degree of Curvature						
1 3 to 6 degrees	.01		.00		.01	
2 > 6 degrees	-.02		-.00		-.02	
		.01		.00		.01
Traffic Volume						
1 0 to 2000 ADT	-.00		.04		.05	
2 2000 to 5000 ADT	.00		-.03		-.04	
		.00		.03		.04
Shoulder Width						
1 < 4 FT	.16		.09		.07	
2 ≥ 4 FT	-.09		-.05		-.04	
		.11		.06		.05
Treatment						
12 CL	-.30		-.32		-.26	
14 CL and EL	-.10		-.06		.04	
15 CL and POST	.34		.31		.16	
		.23		.22		.15
Multiple R Squared				.056		.082
Multiple R				.236		.287

from factorial design Table 57, and

- no treatment vs centerline treatment

from factorial design Table 39.

The results of this t-test are given in Table 60. Again, no significant accident reduction occurred with an increase in the treatment.

The final analysis conducted was to obtain a breakdown of sites and cell exposure by state. This was done for the factorial design on Table 36. These data are presented in Table 61.

It is evident from this table that the distribution of site exposure by state is indeed non-uniform over the cells of the table. For example, all of the exposure for the cells of the bottom row has come from the western states of California, Arizona, Idaho and Washington. A large portion of the exposure for the third cell has come from the State of Arizona, whereas all the exposure for the last cell has come from the State of Washington. For the cells in the first row, the distribution of exposure by state is more uniform. This non-uniformity in distribution by state may be one of the main causes of any incorrect results. However, the cumbersome nature of the site selection process, and the cost and time involved, precluded any possibility of obtaining more uniform distribution of sites.

C.4.3.3 Regression Analysis

The t-test and one-way and higher order analysis of variance described in the previous two sections were primarily designed to test through hypothesis testing whether or not the mean accident rates are

Table 60. t-Test results for a select few delineation treatments with uniform exposure (horizontal curves).

Treatments Compared	Effective Number of Sites	Mean	Standard Deviation	Standard Errors	Test For Homogeneity: F Value	Test For Homogeneity: 2-Tail Probability	Test for Significance: T Value	Test for Significance: Degrees of Freedom	Test for Significance: 1-Tail Prob.
Centerline	28	1.1597	1.286	0.239	2.09	0.042	-0.59	48.16	0.278
Centerline + Edgeline	35	1.3270	0.890	0.150					
Centerline	28	1.1597	1.286	0.239	1.18	0.643	-1.94	53.30	0.029
Centerline + Post	33	1.7696	1.183	0.205					
No Treatment	8	1.9594	1.501	0.521	1.01	1.052	1.16	15.04	0.132
Centerline	15	1.2093	1.505	0.382					

Table 61. Distribution of sites and exposure by state for Table 36.

	Wide Roads (≥20 ft), Wide Shoulders (≥4 ft), With a Centerline (paint or RPM) Present							
	Tangent				Winding			
	0-2000 ADT		2000-5000 ADT		0-2000 ADT		2000-5000 ADT	
	No EL	EL	No EL	EL	No EL	EL	No EL	EL
No POSTS	2.51 (292) CA=6 (68) CT=1 (5) ID=2 (8) LA=5 (69) MD=1 (10) VA=5 (72) WA=2 (59) Total = 22	2.10 (398) CA=4 (99) CT=1 (13) GA=3 (49) LA=1 (28) OH=6 (80) VA=4(115) WA=2 (15) Total = 21	1.75 (336) CA=6 (174) LA=2 (84) MD=2 (77) Total = 10	1.86 (684) CA=6 (153) CT=3 (78) GA=2 (56) LA=4 (167) MD=1 (28) OH=3 (76) VA=2 (38) WA=3 (86) Total = 24	2.18 (113) CA=3 (18) ID=1 (22) LA=3 (34) VA=3 (28) WA=1 (11) Total = 11	2.87 (136) CA=1 (12) CT=1 (20) GA=3 (38) OH=3 (41) VA=2 (26) Total = 10	2.43 (42) VA=1 (42) Total = 1	2.09 (42) CT=1 (29) WA=1 (12) Total = 2
POSTS	1.97 (183) AZ=7(130) ID=4 (52) Total = 11	0.82 (24) CA=1 (16) ID=1 (8) Total = 2	1.02 (1159) AZ=11(997) CA=1 (131) ID=2 (31) Total = 14	2.38 (83) ID=3 (38) WA=2 (44) Total = 5	2.03 (56) CA=1 (23) ID=3 (33) Total = 4	(0) 0	(0) 0	1.93 (31) WA=1 (31) Total = 1

Uppermost number in each cell is accident rate (accidents/MVm); numbers in parenthesis are exposures in MVm; numbers opposite State abbreviations are actual number of sites.

1 ft = .3048 m

significantly different under different roadway delineation and operational characteristics. No attempt was made to quantify these differences except where they were readily available through t-test results. Prediction models for the accident rate from roadway delineation, geometric and traffic characteristics, and climatic parameters were developed through regression analysis as described here.

Regression analysis can be viewed as a technique by which one can develop a relationship between a dependent variable and a set of independent or predictor variables. If there is only one independent variable the procedure is termed simple regression analysis and for more than one independent variable the term used is multiple regression.

Multiple regression can be viewed either as a descriptive tool whereby the linear dependence of variables is summarized, or as an inferential tool whereby relationships in the population are evaluated from the examination of sample data. In either case, the objective of regression analysis is (1) to find the best prediction equation and evaluate its prediction estimate, and (2) to control for other confounding factors in order to evaluate the contribution of a specific variable or set of variables.

The general form of the regression is

$$Y^1 = f(X_1,\ X_2, \ldots\ X_\mu)$$

where Y^1 represents the estimated value of the dependent variable Y and X_1, X_2, ..., X_k denote k independent predictor variables. The functional relationship between the Y and X's is denoted by f.

In the case of multiple linear regression, the above expression takes the form

$$Y^1 = A + B_1X_1 + B_2X_2 + \ldots + B_kX_k$$

where A is the Y intercept and B_i's are the regression coefficients. Another form for regression is the curvilinear or polynominal, denoted by

$$Y^1 = A + B_1X + B_2X^2 + \ldots B_nX^n$$

These are extensions of simple regression expressed as

$$Y^1 + A + BX$$

In regression, the coefficients A and B_i's are selected in such a way that the sum of squared residuals $\Sigma\ (Y - Y^1)^2$, called the "error," is minimized. This least squared criterion implies that any other values of A and B_i would yield a larger $\Sigma\ (Y - Y^1)^2$. It can also be shown that the selection of A and B_i, in the way described also maximizes the correlation between the actual Y and the estimated Y^1. Also, the correlation between the independent variables and the residual values $(Y - Y^1)$ is reduced to zero.

The actual calculation of A and B_i's requires the solution of a set of simultaneous equations derived by differentiating $\Sigma\ (Y - Y^1)^2$ and equating the partial derivatives to zero. The details of the procedure are unimportant here as SPSS, utilized for this study, automatically generates all relevant statistics. Only a brief description of the relevant statistics and the actual procedure utilized is included.

The Meaning of Regression Coefficients B_i

A regression coefficient B_i in a regression equation

$$Y^1 = A + B_1X_1 + \ldots B_iX_i + \ldots + B_kX_k$$

stands for the expected change in Y with a change of one unit in X_i when the other $X_j \neq X_i$ are held constant. In other words B_i is the expected difference in Y between two groups which are different on X_i by one unit but are the same on $X_j \neq X_i$.

For linear regression models it can also be shown that the combined effect of all the independent variables are additive, that is, if all the independent variables are increased by unit amounts, the expected difference in Y would be $(B_1 + B_2 + \ldots + B_k)$.

Standard Error of B_i

Standard error of B_i, in simple terms, denotes the standard deviation of the random variable whose expected value is denoted by B_i. In other words, it provides a measure of uncertainty associated with the estimation of B_i. For large sample sizes it can be assumed to be normally distributed. In the case of smaller samples it is approximated by the t-distribution with (N-k-1) degrees of freedom. N denotes the sample size and k the number of independent variables in the regression. The standard error of a B_i, therefore, is used for developing confidence bands for the individual B_i.

Multiple Correlation R

As in analysis of variance, the total variation or sums of squares in Y can be partitioned into two independent components, one that is "explained" by the regression and another that is "unexplained,"

$$SS_Y = SS\ \text{regression} + SS\ \text{residual}$$

or

$$\Sigma(Y - \bar{Y})^2 = \Sigma(Y^1 - \bar{Y})^2 + \Sigma(Y - Y^1)^2$$

where $\bar{Y}$ is the overall mean.

The square of multiple correlation R^2 then is expressed by

$$R^2 = \frac{SS_Y - SS\ \text{residual}}{SS_Y} \quad \frac{SS\ \text{regression}}{SS_Y}$$

or

$$R^2 = \frac{\text{variation in Y explained by the combined influence of the independent variables}}{\text{total variation in Y}}$$

Standard Error of Estimate of Regression

The standard error of estimate may be interpreted as the standard deviation of the residual, and therefore in a sense predicts the accuracy of the regression in absolute units. This statistic is suitable for developing bounds on the estimated value of the dependent variable Y[1].

Statistical Inference in Regression

Regression, per se, is a descriptive statistic but is, nevertheless, developed from the sample data. Statistical inference procedures such as the estimation of population parameters and hypothesis testing are, therefore, required for the generalization to the population from sample regression statistics. The two hypothesis testing procedures directly relevant to the present study are: (1) the overall test for goodness of fit of the regression equation, and (2) the test for a specific regression coefficient.

The overall test uses statistical inference procedures to test the null hypothesis that the multiple correlation is zero in the population from which the samples are drawn. Any observed multiple correlation is due to sampling fluctuation. The test statistic employed for the overall test is

$$F = \frac{\text{SS regression}/k}{\text{SS residual}/(N-k-1)}$$

$$= \frac{R^2/k}{(1-R^2)/(N-k-1)}$$

where R is the multiple correlation coefficient, N the sample size, and k the number of independent variables in the regression. The F-ratio is distributed as an F-distribution with degrees of freedom k and (N-k-1) and can, therefore, be utilized to test for the significance of R.

For testing the significance of B_i's, the strategy involves the decomposition of the explained sum of squares into components attributable to each independent variable in the regression. Under the standard method each variable is treated as if it had been added to the regression equation in a separate step after all other variables had been entered. The increment in R^2 (or in the explained sum of squares) is taken as the component of variation attributable to that variable due to the addition of a given variable. The F-ratio employed for testing the significance of regression coefficient B_i is given by

$$F = \frac{\text{incremental SS due to } X_i/1}{\text{SS residual}/(N-k-1)}$$

As shown later, this test is also utilized to determine the sequence in which the independent variables enter into the regression in the stepwise method.

The statistics described above are readily available through SPSS and, therefore, did not require any specific efforts during the development of regression models. However, the development of the models required two major decisions on the part of project personnel

(a) specification of inclusion criteria for independent variables, and

(b) selection of candidate independent variables.

A brief discussion of each is included.

Specification of Inclusion Criteria

It was noted earlier that by knowing the candidate independent variables, regression models can be developed by solving a set of linear equations. However, in practice an effort is made to isolate a subset of independent variables that will yield an optimal prediction equation with as few terms as possible. Within SPSS three approaches are available to achieve this.

- Forward Stepwise Inclusion -- Independent variables are entered only if they meet certain statistical criteria. The order of inclusion is determined by the respective contribution of each variable to the explained variance.
- Backward Elimination -- All independent variables are first entered and then eliminated one by one from the regression equation based upon certain specified criteria.
- Stepwise Solution -- Forward inclusion is combined with deletion of variables that no longer meet the pre-established criteria at each successive step.

SPSS also has a provision where stepwise inclusion can be performed in conjunction with a pre-established hierarchy among sets of variables.

In addition, SPSS requires the specification of three parameters to be used in deciding which variables are to be included. The general form of the parameter specification is (n, F, T).

The first parameter, n, is the maximum number of independent variables that will be entered into the equation provided they meet the other criteria. A default value of 80 is provided.

The second parameter, F, relates to the F-ratio computed in a test for significance of a regression coefficient (see discussion under "Statistical Inference in Regression"). For a specified value of F, the procedure ensures that only those independent variables whose associated regression coefficient is significant at the level specified by F will enter into the regression. At each step in the analysis, F-ratios are computed for variables not yet in the equation. The F-ratio for a given variable is the value that would be obtained if that variable were brought in on the very next step.

The third parameter, T, is referred to as tolerance. The tolerance of an independent variable being considered for inclusion is the proportion of the variance of that variable not explained by the independent variables already in the regression equation. The tolerance index has a possible range of 0 to 1. A tolerance of 0 would indicate that a given variable is a perfect linear combination of other independent variables. A tolerance of 1.0 would indicate that the variable is uncorrelated with the other independent variables.

For the regression analysis contained within this report, the following decisions were made.

1. Use stepwise solution. This was chosen because it combines the advantages of both forward inclusion and backward elimination procedures. Thus the independent variables finally appearing in the regression would be those whose associated regression coefficients will be non-zero at the specified level of significance.

2. Set n at its default value. It was considered inappropriate to restrict the number of independent variables in the regression a priori. Any variable meeting other criteria was allowed to enter into the equation.

3. Utilize two values of F, (a) F = 2.71 and (b) F = 1.01. Although the level of significance associated with F obviously depends upon the associated degrees of freedom, for a very large number of degrees of freedom the respective significances are approximately 0.10 and 0.25 for the values of F = 2.71 and F = 1.01. The lower level of significance of 0.25 was included because it was suspected that due to wide dispersion in accident data, the higher level of 1.0 may preclude most of the independent variables from entering the regression equation.

4. Set T = 0.1. This value was chosen somewhat arbitrarily but it is believed that the set value will ensure that the independent variables entering the regression equation will not be too highly correlated.

Selection of Candidate Independent Variables

The selection of candidate independent variables for regression analysis entailed the resolution of the following questions.

1. Should second and higher order polynominal terms or other functions of independent variables be developed as candidates to enter the regression models?

2. Should multiplicative terms be developed as candidates to enter the regression models?

With a clear objective that the developed regression models should reflect the underlying true relationships between the dependent and independent variables to the extent possible, it was imperative that both functions of individual variables and multiplicative terms be developed if indeed necessary. The answer to both questions was a definite yes. The actual procedure that was used to develop these functions and the multiplicative terms, if such terms were indeed required, is given in the following.

The relationships between the accident rate and roadway geometric, traffic, and climatic conditions are not governed by physical laws of nature, and therefore cannot be modeled as such. The approach thus taken was to evaluate the existing data to detect any nonlinear relationships and, if found, to appropriately model them. Scatter diagrams between the accident rate and individual roadway, traffic and climatic parameters were developed. These diagrams were then studied to detect any nonlinear functional relationships.

For continuous variables, least square linear fit was also computed. This linear relationship, along with the standard error of estimates for the residual, and each regression coefficient is also provided with the diagram. Scatter diagrams for categorical variables are also included although no effort was made to develop nonlinear functions for such variables. These diagrams are included only to provide a pictorial view of the distribution of accident rate within the subcategories of a categorical variable.

The diagrams fail to provide any definitive nonlinear functional relationships between the accident rate and individual, independent variables. In view of this finding, no polynominal or other non-linear relationships were considered necessary for the development of the regression models.

Multiplicative terms that are a product of two or more terms, are required in regression analysis if the effects of the independent variables are not additive. The effects are called additive if the relationship between the dependent variable and any given independent variable is the same across all values of the remaining independent variables. A priori, there was no easy method to identify roadway, traffic, and climatic parameters whose effects were not additive.

Hence, the following approach was used to identify multiplicative terms:

- Following the logical sequence of events which are believed to result in various types of accidents, pairs of independent variables were identified which were expected to have strong interaction effects. The product of these variables then became the candidate multiplicative terms.

- A correlation coefficient matrix was developed comprising correlation coefficients between each pair of the independent variables. This matrix indicates how the independent variables correlate to each other for the sites selected for this study. Pairs of variables with strong correlations were expected to have stronger interaction effects and, therefore, were considered candidates for multiplicative terms.

The list of multiplicative terms developed through the above noted methods is included in Tables 62 through 64.

The final task pertaining to the selection of candidate independent variables for regression analysis entailed reviewing each site variable for its appropriateness as an independent variable. This was required for two reasons: (1) multi-collinearity, and (2) categorical variables. A brief description pertaining to each is included.

Multi-collinearity

Multi-collinearity refers to the situation in which some or all of the independent variables are highly intercorrelated. This can cause several problems:

- If at least one of the independent variables is a perfect linear function of one or more other independent variables in the regression equation, the regression coefficient cannot be uniquely determined.

- Estimates of the regression coefficients from sample to sample fluctuate markedly.

- The regression coefficient of an independent variable, although significant when the variable is brought alone in the regression, may lose its significance if other independent variables correlated to this variable are also brought in the regression.

The last point needs elaboration. It can be shown that the regression coefficient of an independent variable which is an element of a set of highly correlated independent variable depends upon how many other independent variables are present in the regression. The larger the number present, the smaller the absolute value of this coefficient. Hence, if enough of these correlated independent variables are present, each and every one of the associated regression coefficients would become statistically insignificant, even though as a group they may explain most of the variance in the dependent variable.

To avoid problems arising from multi-collinearity, several site variables considered unimportant for this study were not explicitly considered. In addition, variables for which the data were poor or unreliable such as unintentional delineation and posted speed limit were also excluded from explicit consideration. The variables thus excluded are listed in Tables 62 through 64.

Categorical Variables

Categorical variables, such as delineation treatment, cause special problems in regression analysis as no hierarchy can be assigned to their subcategories. Dummy variables are utilized to handle these variables.

Table 62. Variable/site inclusion criteria for regression analysis of tangent sites.

Decision	Variable	Abreviated Variable Name/Remarks
Sites discarded from regression analysis	No Treatment	No centerline or any other delineation
	Non-Federal Aid	NFA
	Mountain	-
Variables included in regression analysis	Roadway width	RWIDTH
	Shoulder width	SWIDTH
	Traffic volume	TRAFVOL
	Intersection frequency	INTFREQ
	Days of Precipitation	PRECIP
	Days of snow	SNOW
	Days of fog	FOG
	Delineation treatment	Painted CL (Reference) RPM CL (CLR) Edgeline (EL1) Posts (POSTS1)
	Shoulder type	Good shoulders (Ref.) Poor shoulders (PS)
	Functional classification	Fed. Aid Secondary (Ref.) Fed. Aid Primary (F1)
	Vertical alignment	Rolling (Reference) Flat (G1)
Variables not included in regression analysis	Posted speed limit	Data unreliable
	Driveway frequency	Data unreliable
	No treatment	Not enough sites
	Non-Fed. Aid	Not enough sites
	Pavement type	Not enough sites
	Mountain sites	Not enough sites
	Unintentional delineation	Data unreliable
Categories collapsed	States	All
	Pavement type	PCC and Asphalt-Bituminous
	Shoulder type	PS includes no shoulders and unpaved shoulders

Table 62. Variable/site inclusion criteria for regression analysis of tangent sites (continued).

Decision	Variable	Abbreviated Variable Name/Remarks
Multiplicative terms included	EL1 x TRAFVOL	ACTE1
	EL1 x RWIDTH	ACTE2
	EL1 x SWIDTH	ACTE3
	EL1 x PS	ACTE4
	EL1 x PRECIP	ACTE5
	EL1 x SNOW	ACTE6
	EL1 x FOG	ACTE7
	POSTS1 x TRAFVOL	ACTP1
	POSTS1 x RWIDTH	ACTP2
	POSTS1 x SWIDTH	ACTP3
	POSTS1 x G1	ACTP4
	POSTS1 x PRECIP	ACTP5
	POSTS1 x SNOW	ACTP6
	POSTS1 x FOG	ACTP7
	POSTS1 x EL1	ACTP8
	TRAFVOL x RWIDTH	ACTV1
	TRAFVOL x INTFREQ	ACTV2
	RWIDTH x SWIDTH	ACTW1
	RWIDTH x INTFREQ	ACTW2
	RWIDTH x PS	ACTW3
	SWIDTH x INTFREQ	ACTW4

Table 63. Variable/sites inclusion criteria for regression analysis of winding sites.

Decision	Variable	Abbreviated Variable Name/Remarks
Sites discarded from regression analysis	Flat	-
	Non-Federal Aid	NFA
Variables included in regression analysis	Roadway width	RWIDTH
	Shoulder width	SWIDTH
	Traffic Volume	TRAFVOL
	Intersection frequency	INTFREQ
	Days of precipitation	PRECIP
	Days of snow	SNOW
	Days of fog	FOG
	Delineation treatment	No treatment (Reference) Centerline (CLW) Edgeline (EL1) Post delineators (POSTS1)
	Shoulder type	Good shoulders (Ref.) Poor shoulders (PS)
	Functional classification	Fed. Aid Secondary (Ref.) Fed. Aid Primary (F1)
	Vertical alignment	Rolling (Reference) Mountain (G2)
Variables not included in regression analysis	Posted speed limit	Data unreliable
	Driveway frequency	Data unreliable
	Non-Fed. Aid	Not enough sites
	Pavement type	Not enough sites
	Flat sites	Not enough sites
	Unintentional delineation	Data unreliable
Categories collapsed	States	All
	Centerline treatment	Painted and RPM
	Shoulder type	PS includes no shoulders and unpaved shoulders

Table -63. Variable/site inclusion criteria for regression analysis of winding sites (continued).

Decision	Variable	Abbreviated Variable Name/Remarks
Multiplicative terms included in regression analysis	CLW x TRAFVOL	ACTC1
	CLW x RWIDTH	ACTC2
	CLW x SWIDTH	ACTC3
	CLW x PS	ACTC4
	CLW x G2	ACTC5
	CLW x PRECIP	ACTC6
	CLW x SNOW	ACTC7
	CLW x FOG	ACTC8
	EL1 x TRAFVOL	ACTE1
	EL1 x RWIDTH	ACTE2
	EL1 x SWIDTH	ACTE3
	EL1 x PS	ACTE4
	EL1 x PRECIP	ACTE5
	EL1 x SNOW	ACTE6
	EL1 x FOG	ACTE7
	POSTS1 x TRAFVOL	ACTP1
	POSTS1 x RWIDTH	ACTP2
	POSTS1 x SWIDTH	ACTP3
	POSTS1 x G2	ACTP4
	POSTS1 x PRECIP	ACTP5
	POSTS1 x SNOW	ACTP6
	POSTS1 x FOG	ACTP7
	POSTS1 x EL1	ACTP8
	TRAFVOL x RWIDTH	ACTV1
	TRAFVOL x INTFREQ	ACTV2
	RWIDTH x SWIDTH	ACTW1
	RWIDTH x INTFREQ	ACTW2
	RWIDTH x PS	ACTW3
	SWIDTH x INTFREQ	ACTW4

Table 64. Variable/site inclusion criteria for regression analysis of horizontal curve sites.

Decision	Variable	Abbreviated Variable Name/Remarks
Sites discarded from regression analysis	No treatment	-
Variables included in regression analysis	Roadway width	RWIDTH
	Shoulder width	SWIDTH
	Traffic volume	TRAFVOL
	Degree of Curvature Curvature	DCURV
	Days of precipitation	PRECIP
	Days of snow	SNOW
	Days of fog	FOG
	Average distance to adjacent curves	ADJCNT
	Length of curve (mi.)	LENGTH
	Delineation treatment	Centerline (Reference) Edgeline (EL1) Post delineators (POSTS1)
	Functional classification	Fed. Aid Secondary (Ref.) Fed. Aid Primary (F1)
	Shoulder type	Good shoulders (Ref.) Poor shoulders (PS)
Variables not included in regression analysis	Posted speed limit	Data unreliable
	Advance signing	Data unreliable
	Guardrails	Not enough sites
	Non-Federal Aid	Not enough sites
	Pavement type	Not enough sites
	Unintentional delineation	Data unreliable
Categories collapsed	States	All
	Delineation treatment	Painted and RPM CL Guardrail and non-guardrail
	Pavement type	PCC and Asphalt-Bit.
	Shoulder type	PS includes no shoulders and unpaved shoulders

Table 64. Variable/site inclusion criteria for regression analysis of horizontal curve sites (continued).

Decision	Variable	Abbreviated Variable Name/Remarks
Multiplicative terms included in regression analysis	EL1 x TRAFVOL	ACTE1
	EL1 x RWIDTH	ACTE2
	EL1 x SWIDTH	ACTE3
	EL1 x PS	ACTE4
	EL1 x PRECIP	ACTE5
	EL1 x SNOW	ACTE6
	EL1 x FOG	ACTE7
	EL1 x DCURV	ACTE8
	EL1 x ADJCNT	ACTE9
	POSTS1 x TRAFVOL	ACTP1
	POSTS1 x RWIDTH	ACTP2
	POSTS1 x SWIDTH	ACTP3
	POSTS1 x DCURV	ACTP4
	POSTS1 x PRECIP	ACTP5
	POSTS1 x SNOW	ACTP6
	POSTS1 x FOG	ACTP7
	POSTS1 x EL1	ACTP8
	POSTS1 x ADJCNT	ACTP9
	TRAFVOL x RWIDTH	ACTV1
	TRAFVOL x SWIDTH	ACTV2
	TRAFVOL x PS	ACTV3
	TRAFVOL x DCURV	ACTV4
	TRAFVOL x ADJCNT	ACTV5
	RWIDTH x SWIDTH	ACTW1
	RWIDTH x DCURV	ACTW2
	RWIDTH x PS	ACTW3
	SWDITH x DCURV	ACTW4
	SWIDTH x ADJCNT	ACTW5

A set of dummy variables is created by treating each subcategory of a categorical variable as a separate variable and assigning arbitrary scores (generally 0 and 1) for all cases depending upon their presence or absence in each of the subcategories. For example, the variable "delineation treatment" comprising of "no treatment, centerline, edgeline, and post delineators" can be conceived as four separate dichotomous variables. All cases in a sample can be assigned arbitrary scores of, say, 1 or 0 on all four of these variables. If 1's and 0's are the scores, centerline treatment would be scored 1 on the dummy variable standing for centerline treatment and 0 on other variables. Since the inclusion of all dummy variables created for a categorical variable would render the normal equations unsolvable because k subcategories can be uniquely determined by k - 1 dummy variables, it is necessary to exclude one of the dummies from the equation. Thus, the delineation treatment considered earlier would be uniquely represented by three dummy variables D_1, D_2, and D_3 as shown in the following table.

Delineation Treatment	D_1	D_2	D_3
No Treatment	0	0	0
CL	1	0	0
CL + EL	1	1	0
CL + Post	1	0	1
CL + EL + Post	1	1	1

For this regression, all categorical variables were not included as candidate independent variables. For some categorical variables, the sites were very poorly distributed over the subcategories. For example, within the categorical variable "pavement type," most of the winding sites fell under the subcategory asphaltic. Hence, such categorical variables were excluded from consideration. In some cases, the subcategories were collapsed into a fewer number (to improve the distribution of sites within the subcategories) and then the variable was included. The categorical variables included in the regression analysis as independent variables are listed in Tables 65 through 67. The associated dummy variables for each categorical variable are also included.

Regression Models

The developed regression models are given in Tables 68 through 70. Separate regression models were produced for tangent, winding, and horizontal curve sites. Within each highway type additional models were developed by including only a subcategory of sites in the analysis.

The sites were divided into four categories according to the geographic location of the state. Individual regression models were developed for southwestern, eastern, northwestern and southeastern states including appropriate sites. Sites included in individual regions were:

1. Southwestern States - California and Arizona
2. Eastern States - Connecticut, Maryland, Ohio and Virginia
3. Northwestern States - Washington and Idaho
4. Southeastern States - Georgia and Louisiana

In addition, the highway sites were also divided according to the roadway functional classification. Separate regression models were produced for Federal-Aid Primary and Federal-Aid Secondary roads. These models may be more appropriate if a decision relative to primary roads (or secondary roads) is to be made.

Table 65. Candidate categorical variables with the associated dummy variables for tangent sites.

Categorical Variable	Subcategories	Dummy Variable	Representation
1. Delineation Treatment	Painted Centerline	None	
	RPM Centerline	CLR	0-No RPM Centerline 1-RPM Centerline
	Edgeline	EL 1	0-No Edgelines 1-Edgelines
	Post Delineators	POSTS1	0-No POST 1-POST Delineation
2. Shoulder Type	Good Shoulder (paved or partially paved)	None	
	Poor Shoulders (Unpaved or not at all)	PS	0-good shoulders 1-poor shoulders
3. Highway Classification	Federal Aid Secondary	None	0-Federal Aid Secondary 1-Federal Aid Primary
	Federal Aid Primary	F 1	
4. Vertical Alignment	Rolling	None	0-Rolling 1-Flat
	Flat	G 1	

Table 66. Candidate categorical variables with the associated dummy variables for winding sites.

Categorical Variable	Subcategories	Dummy Variable	Representation
1. Delineation Treatment	No Treatment	None	
	Centerline	CLW	0-No Centerline 1-Centerline
	Edgeline	EL 1	0-No Edgeline 1-Edgeline
	Post Delineators	POSTS1	0-No Post 1-Post Delineation
2. Shoulder Type	Good Shoulders (Paved or Partially paved)	None	
	Poor Shoulders (Unpaved or none at all	PS	0-good shoulders 1-poor shoulders
3. Highway Classification	Federal Aid Secondary	None	
	Federal Aid Primary	F 1	0-Federal Aid Secondary 1-Federal Aid Primary
4. Vertical Alignment	Rolling	None	
	Mountaneous	G 2	0-Rolling 1-Mountaneous

Table 67. Candidate categorical variables with the associated dummy variables for horizontal curves.

Categorical Variable	Subcategories	Dummy Variables	Representation
1. Delineation Treatment	Centerline Treatment	None	
	Edgeline	EL 1	0-No Edgeline 1-Edgeline
	Post Delineators	POSTS1	0-No Post 1-Post Delineation
2. Shoulder Type	Good Shoulders (Paved or Partially Paved)	None	
	Poor Shoulders (Unpaved or none at all)	PS	0-Good Shoulders 1-Poor Shoulders
3. Highway Classification	Federal Aid Secondary	None	
	Federal Aid Primary	F 1	0-Federal Aid Secondary 1-Federal Aid Primary

Table 68. Regression models for tangent sites.

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
All Sites	1.01	1.00	T11	Acc.Rate = 0.87826712 + 0.70798011(PS) + 0.00831004(PRECIP) - 0.006426419(FOG) (0.24646207) (0.15814440) (0.00206641) (0.00335550) - 0.00007993(TRAFVOL) + 0.19818229(INTFREQ) + 0.14642979(G1) (0.00004437) (0.11870107) (0.12592843)	0.672	0.451	0.685
	2.71	2.70	T12	Acc.Rate = 0.73975861 + 0.79374129(PS) + 0.00974700(PRECIP) - 0.00765392(FOG) (0.12075196) (0.13688644) (0.00179722) (0.00332768)	0.655	0.430	0.690
California and Arizona Sites Only	1.01	1.00	T21	Acc.Rate = 1.3682288 + 0.96290825(PS) - 0.55102779(CLR) - 0.44128219(POSTS1) (0.28392245)(0.27804941) (0.19537018) (0.27822532) + 0.16281191(INTFREQ) + 0.22581245 (EL1) (0.14114702) (0.23394880)	0.722	0.521	0.439
	2.71	2.70	T22	Acc.Rate = 1.5444890 + 0.95778152(PS) - 0.52970793(CLR) - 0.46215070(POSTS1) (0.26196188)(0.27248820) (0.17386039) (0.25800008)	0.703	0.494	0.441
Connecticut, Maryland, Ohio and Virginia Sites Only	1.01	1.00	T31	Acc.Rate = 3.0121772 + 0.54592618(PS) - 0.90938006(F1) - 0.10064282(SNOW) (0.47270528)(0.29222825) (0.29461910) 10.04185974	0.620	0.385	0.795
	2.71	2.70	T32	Same as for F = 1.01, 1.00			

Table 68. Regression models for tangent sites (continued).

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Georgia and Louisiana Sites Only	1.01	1.00	T41	Acc.Rate = 2.4955945 - 0.00056841(TRAFVOL) + 1.0651188(G1) + 1.0015464(SNOW) (0.36904201 (0.00012148) (0.35817707) (0.46153270)	0.751	0.564	0.594
	2.71	2.70	T42	Same as for F = 1.01, 1.00.			
Idaho and Washington Sites Only	1.01	1.00	T51	Acc.Rate = 0.83075953 + 0.02885312(FOG) + 1.3523759(PS) + 1.03160640(POSTS1) (0.98625416)(0.01295988) (0.42853720) (0.34623368) – 0.09650686(SNOW) – 0.16125014(SWIDTH) + 0.98060552(EL1) (0.04615826) (0.09597522) (0.35463952) + 0.00024738(TRAFVOL) – 0.50082568(F1) (0.00013955) (0.37320431)	0.770	0.592	0.723
	2.71	2.70	T52	No Variable Entered into the Model.			
Flat Sites Only	1.01	1.00	T61	Acc.Rate = 1.5548854 + 1.1921000(PS) – 0.36093373(CLR) – 0.00011163(TRAFVOL) (0.31571689)(0.24172755) (0.19941278) (0.00005622) – 0.00863907(FOG) + 0.22759985(INTFREQ) (0.00595437) (0.19329529)	0.714	0.510	0.643
	2.71	2.70	T62	Acc.Rate = 1.1335986 + 1.1761586(PS) – 0.33532949(CLR) (0.12123197)(0.16901982) (0.18683859)	0.677	0.458	0.659

Table 68. Regression models for tangent sites (continued).

Highway Sites Included	Enter	Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Rolling Sites Only	1.01	1.00	T71	Acc. Rate = 0.88577372 + 0.01543994(PRECIP) – 0.44620366(F1) (0.28209230)(0.00342411) (0.19594097) – 0.58648157(EL1) + 0.33214844(PS) – 0.02514204(SNOW) (0.22550113) (0.18170457) (0.012129378)	0.711	0.505	0.679
	2.71	2.70	T72	Acc. Rate = 0.90440695 + 0.01347191(PRECIP) – 0.41505993(F1) (0.28219894)(0.00299910) (0.19468086) – 0.54227137(EL1) + 0.34060568(PS) (0.22297021) (0.18205278)	0.704	0.495	0.680
Federal-Aid Primary Sites Only	1.01	1.00	T81	Acc. Rate = 0.49177171 + 0.01448056(PRECIP) + 0.49744488(PS) – 0.01359974(FOG) (0.51789341) (0.00407603) (0.22723154) (0.00572059) + 0.69699323(CLR) – 0.05410533(SWIDTH)+ 0.40652753(POSTS1) + 0.2027273(G1) (0.37609006) (0.03765727) 0.29141212) (0.15020532)	0.708	0.502	0.454
	2.71	2.70	T82	Acc. Rate = 0.84562921 + 0.00750778(PRECIP) + 0.55403550(PS) – 0.00619222(FOG) (0.12543371) (0.00220755) (0.19045008) (0.00331333)	0.644	0.415	0.470
Federal-Aid Secondary Sites Only	1.01	1.00	T91	Acc. Rate = 0.58947735 + 0.00791538(PRECIP) + 0.772654(PS) – 0.00023490(TRAFVOL) (0.46934743) (0.00334143) (0.21953147) (0.00009062) + 0.07726796(SWIDTH) + 0.29030543(INTFREQ) (0.04891401) (0.22574994)	0.601	0.361	0.880
	2.71	2.70	T92	Acc. Rate = 0.95970480 + 0.00984837(PRECIP) _ 0.74636886(PS) – 0.00014624(TRAFVOL) (0.40845913) (0.00284900) (0.21886011) (0.00007685)	0.579	0.335	0.887

Table 69. Regression models for winding sites.

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
All Sites	1.01	1.00	W11	**Rate** = 5.1481252 – 0.52754487(F1) – 0.014111995(PRECIP) (0.81190384)(0.30439030) (0.0058766781) – 0.86628788(CLW) + 0.021437596(SNOW) – 0.48184339(POSTS1) (0.49197286) (0.017591138) (0.41615062)	0.363	0.132	1.280
	2.71	2.70	W12	Rate = 4.8365635 – .57118713(F1) (.68512569)(.25491020) – .01027836(PRECIP) – .89069032(CLW) (.0043681654) (.49159750)	0.335	0.112	1.282
California and Arizona Sites Only	1.01	1.00	W21	**Acc.Rate** = 8.5688178 + 0.01776456(FOG) + 1.0095613(G2) – 1.2683298(PS) (3.0091638) (0.01654096) (0.43861434) (0.49004742) – 0.30951371(RWIDTH) + 1.1043511(ELI) + 0.01432588(PRECIP) (0.13083793) (0.75209953) (0.01247931)	0.879	0.772	0.688
	2.71	2.70	W22	**Acc.Rate** = 1.3407673 + 0.03964895(FOG) + 1.2017954(G2) (0.47402255)(0.00863226) (0.47791579)	0.775	0.601	0.797

Table 69. Regression models for winding sites (continued).

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Connecticut, Maryland, Ohio and Virginia Sites Only	1.01	1.00	W31	Acc.Rate = 12.296344 − 0.05784879(PRECIP) − 2.2493610(F1) + 2.5916294(EL1) (2.1091700)(0.01857135) (0.65662457) (0.60596134) − 0.32899209(SWIDTH) − 0.00048975(TRAFVOL) − 1.8373418(G2) − 0.08885832(SNOW) (0.11573274) (0.00019322) (0.92845111) (0.06132350)	0.712	0.506	1.130
	2.71	2.70	W32	Acc.Rate = 13.368969 − 0.07382586(PRECIP) − 2.4421173(F1) + 2.4861837(EL1) (2.0000956)(0.01513370) (0.65117828) (0.60921929) − 0.24976097(SWIDTH) − 0.00049464(TRAFVOL) − 1.7453220(G2) (0.10329706) (0.00019565) (0.93804565)	0.694	0.482	1.145
Georgia and Louisiana Sites Only	1.01	1.00	W41	Acc.Rate = 10.926686 − 0.23406720(FOG) + 1.6411497(SNOW) − 0.12336439(SWIDTH) (3.4680886) (0.07031494) (1.0591401) (0.11189873)	0.662	0.439	0.919
	2.71	2.70	W42	Acc.Rate = 7.2355292 − 0.15466680(FOG) (1.7834338) (0.05287405)	0.579	0.35	0.940
Idaho and Washington Sites Only	1.01	1.00	W51	Acc.Rate = 9.4052122 + 1.6559179(INTFREQ) − 0.34456795(RWIDTH) − 0.03822925(FOG) (2.8627662) (0.56818944) (0.14026377) (0.01717844) + 0.00042052(TRAFVOL) (0.00036400)	0.673	0.453	0.892
	2.71	2.70	W52	Acc.Rate = 7.8414202 + 1.2869941(INTFREQ) − 0.24904926(RWIDTH) − 0.02630137(FOG) (2.5458685) (0.47430686) (0.11435231) (0.01385649)	0.640	0.410	0.901

Table 69. Regression models for winding sites (continued).

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Rolling Sites Only	1.01	1.00	W61	Acc.Rate = 7.4672413 − 0.83241357(F1) − 0.03905451(FOG) − 0.07828744(SNOW) (1.8661606) (0.361853383) (0.01257198) (0.03305819) − 0.21241737(SWIDTH) − 0.10380263(RWIDTH) (0.10165297) (0.08486897)	0.506	0.256	1.287
	2.71	2.70	W62	Acc.Rate = 5.3259571 − 0.96832959(F1) − 0.03715069(FOG) − 0.07598680(SNOW) (0.65941820)(0.34555222) (0.01251814) (0.03311802) − 0.19868226(SWIDTH) (0.10137814)	0.490	0.240	1.292
Mountain Sites Only	1.01	1.00	W71	Acc.Rate = 4.2181910 − 1.1679956(CLW) − .022202143(PRECIP) (1.2090790) (1.0632439) (.0075867458) + 0.042924701(FOG) + .00052118924(TRAFVOL) − .12893121(SWIDTH) (0.012158784) (.0027363454) (.084656828)	0.623	0.388	0.966
	2.71	2.70	W72	Acc.Rate = 2.2704664 + 0.03483740(SNOW) (0.25391547)(0.01804519)	0.323	0.104	1.094
Federal-Aid Primary Roads Only	1.01	1.00	W81	Acc.Rate = 7.1930087 + 0.02383232(SNOW) − 0.00867001(PRECIP) + 0.05197800(FOG) (2.4912722) (0.01924643) (0.00804795) (0.01984710) − 1.7413132(EL1) − 0.80894714(PS) − 0.20610991(RWIDTH) + 0.65673136(G2) (0.65671776) (0.41480455) (0.10874476) (0.44299543)			
	2.71	2.70	W82	Acc.Rate = 1.8161040 + 0.04859090(SNOW) (0.27529943)(0.01949288)			

Table 69. Regression models for winding sites (continued).

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Federal-Aid Secondary Roads Only	1.01	1.00	W91	Acc.Rate = 6.2446565 − .74064397(CLW) − .016466669(FOG) (1.1008728) (.55290085) (.014328109) − 1.3424477(POSTS1) − .059216195(SNOW) (.91477898) (.036804182) .011149725(PRECIP) − .77013672(G2) − .11943026(SWIDTH) (.0092276299) (.49575794) (.11717536)	0.390	0.152	1.415
	2.71	2.70	W92	Acc.Rate = 3.7426034 − 0.95051046(CLW) (0.50683057)(0.53416098)	0.195	0.038	1.449

Table 70. Regression models for horizontal curves.

Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
All Sites	1.01	1.00	H11	Acc.Rate = 1.6128641 – .21032143(SWIDTH) + 3.3966758(LENGTH) (.43327929)(.049150473) (1.0016904) + .038906616(DCURV) – .017389521(SNOW) (.031449842) (.014831999)	0.440	0.194	1.088
	2.71	2.70	H12	Acc.Rate = 1.7485989 – 0.20640720(SWIDTH) + 2.9656281(LENGTH) (0.26532903)(0.04722734) (0.94238456)	0.414	0.171	1.094
Arizona and California Sites Only	1.01	1.00	H21	Acc.Rate = – 0.84506619 – 0.22353360(SWIDTH) + 6.7698159(LENGTH + 0.20648298 (DCURV) (0.99661286) (0.05955346) (2.3035064) (0.08446692) + 1.1136286(F1) – 0.04807964(FOG) + 0.74731276(PS) (0.38826175) (0.02497399) (0.54697285)	0.836	0.699	0.786
	2.71	2.70	H22	Acc.Rate = – 1.5248842 – 0.25504000(SWIDTH) + 8.0770463(LENGTH) + 0.25410151 (DCURV) (0.96157913)(0.05916304) (2.2954414) (0.08345563) + 1.0046836(F1) (0.39594153)	0.795	0.632	0.821

Table 70. Regression models for horizontal curves (continued).

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Connecticut, Maryland, Ohio, and Virginia Sites Only	1.01	1.00	H31	Acc.Rate = 4.4858490 + 7.1196206(LENGTH) – 0.29176251(SWIDTH) – 0.05792856(SNOW) (1.9224479) (2.5568956) (0.11356577) (0.02866217) + 0.67570323(POSTS1) – 0.11443090(RWIDTH) (0.44016965) (0.09114019)	0.536	0.287	1.006
	2.71	2.70	H32	Acc.Rate = 2.2470391 + 7.1915622(LENGTH) – 0.28839085(SWIDTH) – 0.05407650(SNOW) (0.57109085)(2.5938573) (0.11508441) (0.02864392)	0.479	0.229	1.021
Georgia and Louisiana Sites Only	1.01	1.00	H41	Acc.Rate = 1.5576702 + .62617866(ADJCNT) (.88998738)(.29344285) – 1.4830400(POSTS1) – .14344284(DCURV) (.61074803) (.11581159)	0.753	0.567	0.946
	2.71	2.70	H42	Acc.Rate = 0.69616581 + 0.66534428(ADJCNT) – 1.3104625(POSTS1) (0.57146959) (0.30026579) (0.61203214)	0.695	0.483	0.973
Idaho and Washington Sites Only	1.01	1.00	H51	Acc.Rate = 0.09399091 + 0.19499214(DCURV) + 7.5426553(LENGTH) – 0.22796077(SWIDTH) (0.84027104) (0.07302993) (3.1533976) (0.09924092)	0.500	0.250	1.122
	2.71	2.70	H52	Same as for F = 1.01, 1.00			

70. Regression models for hirozontal curves (continued).

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
Federal-Aid Primary Roads Only	1.01	1.00	H61	Acc.Rate = 3.6312380 – 0.41599368(SWIDTH) + 7.8712210(LENGTH) (1.6654745)(0.07026692) (1.7994058) + 1.4974795(EL1) – 0.10762758(RWIDTH) + 0.62319893(POSTS1) (0.47258997) (0.07564778) (0.35150087) – 0.01054193(FOG) – 0.00018796(TRAFVOL) (0.00853569) (0.00016247)	0.829	0.628	0.720
	2.71	2.70	H62	Acc.Rate = 0.81888985 – 0.41515031(SWIDTH) + 8.3311116(LENGTH) + 1.2835537(EL1) (0.52096949) (0.07139703) (1.6964003) (0.45468558)	0.779	0.607	0.756
Federal-Aid Secondary Roads Only	1.01	1.00	H71	Acc.Rate = 2.3826060 – 0.17358372(SWIDTH) – 0.04467386(SNOW) (0.40134463)(0.07147041) (0.02256072)	0.281	0.079	1.187
	2.71	2.70	H72	Same as for F = 1.01, 1.00.			

For tangent and winding sites, models for flat, rolling and mountain roads were also developed. For tangent sites, individual models for rolling and mountain sites only were developed due to the lack of flat sites.

Associated with each regression model, the distribution of sites within individual predictor variables were computed. These are given in Tables 71 through 83.

C.4.4 Selection of Alternative Dependent Variables

The matching-control analysis presented thus far utilized accident rate as the only dependent variable (where the accident rate was computed by dividing the total number of accidents by the exposure over which these accidents had occurred). It is, however, quite possible that the accident rate based upon a subclass of accidents, such as nighttime only accidents and wet pavement accidents, may have greater dependence on the existing roadway delineation treatments. If such is the case, a dependent variable based upon a subclass of accidents will be more sensitive to the changing delineation treatments and, therefore, a better dependent variable for the analysis.

Similarly, accident severity may be affected differently by different delineation treatments. For example, centerline treatment may reduce head-on collisions but may have little effect on run-off-the-road accidents. On the other hand, edgelines may have a lesser effect on head-on colisions but greatly reduce run-off-the-road accidents. If, in addition, head-on collisions are inherently more severe than run-off-the-road accidents, the benefit derived from centerline treatment will

Table 71. Distribution of site delineation data for tangent sites.

DELINEATION TREATMENT	HIGHWAY SITES INCLUDED / SITE DISTRIBUTION	ALL		AZ, CA		CT, MD OH, VA		GA, LA		ID, WA		FLAT		ROLLING		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
RPM CENTERLINE	ABSENT	115	81.1	33	65.4	39	100.0	23	100.0	30	100.0	44	71.9	70	90.0	41	83.1	68	78.3
	PRESENT	27	18.9	17	34.6	0	0.0	0	0.0	0	0.0	17	28.1	8	10.0	8	16.9	19	21.7
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
EDGELINE	ABSENT	91	64.5	42	83.7	14	35.7	10	43.2	14	48.3	46	75.0	42	54.3	34	69.5	51	57.9
	PRESENT	50	35.5	8	16.3	25	64.3	13	56.8	16	51.7	15	25.0	36	45.7	15	30.5	37	42.1
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
POST DELINEATOR	ABSENT	76	53.7	12	24.3	39	100.0	23	100.0	18	58.8	33	54.2	42	53.2	15	31.1	73	84.0
	PRESENT	65	46.3	38	75.7	0	0.0	0	0.0	12	41.2	28	45.8	36	46.8	34	68.9	14	16.0
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0

NOTE: Number of sites given are "effective number of sites" as defined in Section C.2.2. Hence table numbers do not add.

72. Distribution of traffic volume data for tangent sites.

TRAFFIC VOLUME CATEGORIES \ HIGHWAY SITES INCLUDED / SITE DISTRIBUTION	ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		FLAT		ROLLING		FAP		FAS	
	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
0-500 ADT	1	1.0	0	0.2	0	0.5	0	1.3	1	4.8	1	0.9	1	1.0	0	0.2	2	2.0
500-1000 ADT	9	6.4	1	2.7	3	8.9	2	10.4	5	15.0	4	6.5	5	6.4	1	1.1	12	13.6
1000-1500 ADT	14	9.7	3	6.6	3	7.7	4	16.1	6	17.4	6	9.4	8	10.0	2	5.0	14	16.0
1500-2000 ADT	15	10.3	2	4.3	13	33.7	2	7.7	1	9.5	2	3.4	13	17.1	4	7.2	13	14.6
2000-2500 ADT	11	7.8	2	3.5	3	7.1	3	12.5	7	22.9	3	4.7	8	10.8	4	7.3	7	8.5
2500-3000 ADT	14	9.6	3	5.3	9	23.6	3	11.4	1	4.4	9	14.8	3	4.4	4	8.0	10	11.7
3000-3500 ADT	17	11.7	7	14.7	3	8.6	3	11.9	1	2.9	4	6.0	14	17.3	6	13.0	9	10.1
3500-4000 ADT	7	4.9	1	1.2	2	4.1	5	23.7	3	9.9	5	8.3	1	1.5	1	1.2	9	9.9
4000-4500 ADT	16	11.4	9	17.4	0	0.0	1	5.0	5	16.1	13	21.6	1	1.4	9	17.9	2	2.8
4500-5000 ADT	23	16.3	13	26.4	0	0.0	0	0.0	0	0.0	5	8.5	19	24.0	11	22.3	7	8.4
5000 ADT and UP	15	10.8	9	17.8	2	5.8	0	0.0	0	0.0	10	15.8	5	5.9	8	17.0	2	2.5
TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0

Table 73. Distribution of site roadway data for tangent sites.

ROADWAY VARIABLE	SITE DISTRIBUTION / HIGHWAY SITES INCLUDED	ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		FLAT		ROLLING		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
FUNCTIONAL CLASSIFICATION	FEDERAL AID SECONDARY	60	42.7	7	18.5	28	72.6	20	85.1	17	55.2	31	49.8	28	35.9	49	100.0	0	0.0
	FEDERAL AID PRIMARY	81	57.3	41	81.5	11	27.4	3	14.9	13	44.8	31	50.2	50	64.1	0	0.0	87	100.0
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
SHOULDER TYPE	PAVED	82	58.2	42	83.5	14	35.2	0	0.0	15	49.9	34	55.6	47	60.8	39	80.1	25	28.9
	UNPAVED	59	41.8	8	16.5	25	64.8	23	100.0	15	50.1	27	44.4	31	39.2	10	19.9	62	71.1
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
GENERAL VERTICAL ALIGNMENT	ROLLING	72	50.6	21	42.3	30	77.7	7	32.4	20	68.0	0	0.0	78	100.0	28	56.7	37	42.5
	FLAT	70	49.4	29	57.7	9	22.3	16	67.6	10	32.0	62	100.0	0	0.0	21	43.3	50	57.5
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
ROADWAY WIDTH	0-17 ft.	0	0.1	0	0.0	0	0.7	0	0.0	0	0.0	0	0.3	0	0.0	0	0.2	0	0.0
	17-19 ft.	5	3.4	0	0.0	1	3.4	2	10.4	3	10.5	3	4.9	1	1.9	0	0.0	7	8.0
	19-21 ft.	30	21.0	3	6.9	19	48.6	8	36.8	7	23.0	10	16.5	20	25.4	5	10.9	30	34.6
	21-23 ft.	19	13.5	2	3.2	8	21.2	3	12.9	15	49.8	5	7.9	15	19.0	6	12.8	13	14.5
	23-25 ft.	85	60.1	44	18.3	10	26.1	9	40.0	3	9.3	42	67.5	41	52.9	37	75.2	35	39.9
	25-27 ft.	2	1.7	1	1.6	0	0.0	0	0.0	2	6.6	2	2.6	1	0.8	0	0.0	3	2.9
	27 ft. and up	0	0.1	0	0.0	0	0.0	0	0.0	0	0.8	0	0.2	0	0.0	0	0.8	0	0.2
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0

NOTE: Totals may not match due to round-off error.
1 ft = 0.3048 m

Table 73. Distribution of site roadway data for tangent sites (continued).

HIGHWAY SITES INCLUDED / SITE DISTRIBUTION / ROADWAY VARIABLE		ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		FLAT		ROLLING		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
SHOULDER WIDTH	1-3 ft.	4	3.1	0	0.5	2	4.8	1	4.5	3	10.8	2	2.6	3	3.7	0	0.0	6	-7.3
	3-5 ft.	36	25.6	11	21.9	12	29.6	7	30.6	9	30.1	12	19.8	24	31.2	11	22.4	26	29.9
	5-7 ft.	23	16.4	2	4.6	14	35.5	6	25.2	9	29.3	10	16.7	13	16.1	5	9.3	23	25.9
	7-9 ft.	64	45.3	32	62.7	8	21.1	7	29.6	7	23.2	29	46.6	34	44.1	30	61.4	21	23.7
	9-11 ft.	9	6.3	4	8.4	1	3.0	1	2.4	2	6.6	6	10.0	2	2.7	2	3.1	9	10.6
	11-13 ft.	4	2.7	0	0.8	2	6.0	2	7.6	0	0.0	2	3.2	2	2.2	1	2.7	2	2.6
	13 ft. and up	1	0.6	1	1.1	0	0.0	0	0.0	0	0.0	1	1.2	0	0.0	1	1.1	0	0.0
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
INTERSECTION FREQUENCY (Per Mile)	0	6	4.4	2	3.3	0	0.0	3	13.6	2	5.2	3	5.4	3	3.4	2	3.7	5	5.3
	0-0.3	16	11.0	8	11.4	0	0.0	1	4.8	3	11.1	12	19.4	2	2.7	4	8.2	13	14.7
	0.3-0.6	30	20.9	11	21.4	10	26.2	4	15.3	5	17.3	12	20.2	17	21.7	12	25.3	13	15.1
	0.6-0.9	30	21.2	10	19.7	8	19.6	9	39.0	3	9.1	13	20.3	17	22.1	9	18.1	22	25.4
	0.9-1.2	35	24.9	13	25.1	10	26.8	5	20.5	8	26.3	13	20.3	23	29.4	12	25.0	22	24.9
	1.2-1.5	12	8.2	5	9.6	3	8.4	0	0.0	3	10.8	7	10.7	5	5.9	6	11.4	3	3.9
	1.5-1.8	5	3.9	0	0.8	3	7.2	1	5.2	3	11.0	1	1.5	5	6.2	1	1.7	6	6.7
	More Than 1.8	8	5.5	2	3.7	4	11.2	0	1.7	3	9.1	1	2.2	7	8.6	3	6.5	4	4.1
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0

NOTE: Totals may not match due to round-off error.

Table 74. Distribution of climatic data for tangent sites.

CLIMATIC VARIABLE \ HIGHWAY SITES INCLUDED / SITE DISTRIBUTION		ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		FLAT		ROLLING		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
AVERAGE NUMBER OF DAYS OF PERCIPITATION PER YEAR	0-20	3	2.3	2	4.2	0	0.0	0	0.0	0	0.0	3	4.7	0	0.0	0	0.0	5	5.4
	20-40	52	36.6	34	66.9	0	0.0	0	0.0	0	0.0	27	44.0	23	29.4	27	55.2	10	11.6
	40-60	18	12.6	12	23.1	0	0.0	0	0.0	0	0.0	6	10.5	11	14.7	9	19.1	4	4.0
	60-80	8	5.6	2	3.2	0	0.0	0	0.0	10	32.8	4	6.5	4	4.8	1	1.8	9	10.7
	80-100	19	13.5	1	2.6	0	0.0	14	61.8	8	25.7	13	21.0	5	6.1	4	7.5	19	21.5
	100-120	25	17.5	0	0.0	21	53.0	9	38.2	5	16.4	6	9.9	19	24.9	4	8.5	26	29.5
	120-140	13	8.9	0	0.0	18	47.0	0	0.0	0	0.0	2	3.4	11	14.2	2	3.1	14	16.5
	140-160	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	160-180	4	3.0	0	0.0	0	0.0	0	0.0	8	25.1	0	0.0	5	5.9	2	4.7	1	0.6
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
AVERAGE NUMBER OF DAYS OF SNOW PER YEAR	0	83	59.0	43	85.5	0	0.0	19	84.1	0	0.0	47	76.1	33	42.3	34	68.5	40	46.2
	0-10	50	35.1	6	11.9	34	87.0	4	15.9	25	83.0	11	18.6	40	51.3	13	26.9	40	46.2
	10-20	6	4.5	0	0.0	5	13.0	0	0.0	5	17.0	2	3.5	4	5.5	1	2.1	7	7.6
	20-30	2	1.4	1	2.6	0	0.0	0	0.0	0	0.0	1	1.8	1	1.0	1	2.5	0	0.0
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0
AVERAGE NUMBER OF FOG DAYS PER YEAR	0	2	1.4	1	2.6	0	0.0	0	0.0	0	0.0	2	2.9	0	0.0	1	2.5	0	0.0
	0-10	54	38.1	35	69.6	0	0.0	0	0.0	0	0.0	25	40.5	28	35.7	30	61.0	6	7.4
	10-20	24	17.1	5	10.9	12	29.4	0	0.0	14	46.9	10	16.1	14	18.1	4	7.2	27	30.4
	20-30	15	10.3	0	0.0	15	38.6	3	14.9	2	7.1	1	1.4	15	19.0	3	5.6	14	16.6
	30-40	18	12.6	3	5.8	12	31.9	5	23.3	0	0.0	10	16.9	7	8.4	3	5.8	19	21.7
	40-50	25	17.5	3	5.5	0	0.0	14	61.8	14	46.0	14	22.2	10	12.9	6	12.7	21	23.8
	50 days and up	4	3.0	3	5.5	0	0.0	0	0.0	0	0.0	0	0.0	5	5.9	3	5.2	0	0.0
	TOTAL SITES	141	100.0	50	100.0	39	100.0	23	100.0	30	100.0	62	100.0	78	100.0	49	100.0	87	100.0

Table 75. Distribution of site delineation data for winding sites.

DELINEATION TREATMENT	SITE DISTRIBUTION / HIGHWAY SITES INCLUDED	ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		ROLLING		MOUNTAIN		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
CENTERLINE	ABSENT	7	6.7	1	2.7	6	12.9	0	0.0	1	2.8	7	8.3	1	2.7	1	1.8	8	10.0
	PRESENT	104	93.3	19	97.3	44	87.1	19	100.0	21	97.2	70	91.2	33	97.3	28	98.2	74	90.0
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
EDGELINE	ABSENT	71	64.1	17	83.8	37	75.0	3	16.7	12	54.1	50	64.5	22	63.3	14	48.7	61	74.1
	PRESENT	40	35.9	3	16.2	13	25.0	16	83.3	10	45.9	27	35.5	12	36.7	15	51.3	21	25.9
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
POST DELINEATION	ABSENT	88	79.5	6	41.1	50	100.0	19	100.0	16	72.8	73	95.4	17	48.7	16	55.4	78	95.4
	PRESENT	23	20.5	14	68.9	0	0.0	0	0.0	6	27.2	4	4.6	17	51.3	13	44.6	4	4.6
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0

Table 76. Distribution of traffic volume data for winding sites.

HIGHWAY SITES INCLUDED / SITE DISTRIBUTION / TRAFFIC VOLUME CATEGORIES	ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		ROLLING		MOUNTAIN		FAP		FAS	
	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
0-500 ADT	7	6.3	1	5.2	4	7.5	1	6.7	1	4.9	6	7.2	2	4.6	0	0.8	8	9.9
500-1000 ADT	30	26.7	4	18.5	16	31.0	6	29.3	5	24.5	23	29.3	7	21.8	3	10.7	31	37.2
1000-1500 ADT	23	21.0	4	19.4	11	22.0	6	29.8	3	14.9	17	21.9	7	19.3	6	19.2	18	22.2
1500-2000 ADT	20	18.7	5	26.3	8	15.7	3	16.5	4	18.5	12	15.4	8	25.0	6	22.0	14	16.5
2000-2500 ADT	13	11.5	4	20.8	3	6.6	0	0.0	4	19.6	4	5.4	8	23.3	6	21.8	4	4.7
2500-3000 ADT	7	5.9	2	9.7	0	0.0	0	0.0	4	17.6	4	5.8	2	6.1	4	14.8	4	5.2
3000-3500 ADT	6	5.2	0	0.0	6	12.0	0	0.0	0	0.0	6	7.8	0	0.0	1	5.0	0	0.0
3500-4000 ADT	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
4000-4500 ADT	2	2.2	0	0.0	3	5.2	0	0.0	0	0.0	3	3.4	0	0.0	2	5.6	0	0.0
4500-5000 ADT	3	2.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
5000 ADT and Up	0	0.0	0	0.0	0	0.0	3	17.7	0	0.0	3	3.8	0	0.0	0	0.0	3	4.2
TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0

Table 77. Distribution of site roadway data for winding sites.

HIGHWAY SITES INCLUDED / SITE DISTRIBUTION / ROADWAY VARIABLE		ALL		CA, AZ		CT, MD, OH, VA		GA, LA		ID, WA		ROLLING		MOUNTAIN		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
SHOULDER TYPE	PAVED	22	20.2	7	35.9	7	13.2	3	17.7	4	20.2	12	15.2	10	30.0	11	38.7	6	7.9
	UNPAVED	89	79.8	13	64.1	43	86.8	16	82.3	18	79.8	65	84.8	24	70.0	18	61.1	76	92.1
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
FUNCTIONAL CLASSIFICATION	FEDERAL AID SECONDARY	67	60.4	7	34.3	41	81.8	16	82.2	6	29.1	57	74.5	11	33.0	0	0.0	0	0.0
	FEDERAL AID PRIMARY	44	39.6	13	65.7	9	18.2	3	17.8	16	70.9	20	25.5	23	67.0	29	100.0	82	100.0
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
VERTICAL ALIGNMENT	ROLLING	73	66.0	3	16.9	48	96.6	12	64.0	12	54.4	77	100.0	0	0.0	12	42.4	67	81.4
	MOUNTAIN	38	34.0	17	83.1	2	3.4	7	36.0	10	45.6	0	0.0	34	100.0	17	57.6	15	18.6
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
ROADWAY WIDTH	0-17 ft.	6	5.7	0	0.7	5	9.7	2	9.5	0	0.0	6	7.4	1	2.3	1	1.8	7	8.2
	17-19 ft.	24	21.6	0	2.1	19	37.1	3	16.0	3	13.7	22	28.5	3	8.3	1	1.8	28	34.6
	19-21 ft.	36	32.6	2	11.8	27	53.2	4	21.9	4	19.0	32	42.0	5	14.3	7	23.8	31	38.3
	21-23 ft.	30	27.3	7	37.4	0	0.0	10	52.6	12	55.2	16	20.2	14	41.2	14	49.3	11	12.9
	23-25 ft.	12	11.2	8	40.6	0	0.0	0	0.0	3	12.1	1	0.8	1	31.4	6	19.3	5	5.9
	25-27 ft.	2	1.6	2	7.5	0	0.0	0	0.0	0	0.0	1	1.1	1	2.6	1	4.0	0	0.0
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0

1 ft = 0.3048 m

Table 77. Distribution of site roadway data for winding sites (continued).

ROADWAY VARIABLE	SITE DISTRIBUTION / HIGHWAY SITES INCLUDED	ALL ABSOLUTE	ALL PERCENT	CA, AZ ABSOLUTE	CA, AZ PERCENT	CT, MD, OH, VA ABSOLUTE	CT, MD, OH, VA PERCENT	GA, LA ABSOLUTE	GA, LA PERCENT	ID, WA ABSOLUTE	ID, WA PERCENT	ROLLING ABSOLUTE	ROLLING PERCENT	MOUNTAIN ABSOLUTE	MOUNTAIN PERCENT	FAP ABSOLUTE	FAP PERCENT	FAS ABSOLUTE	FAS PERCENT
SHOULDER WIDTH	0 ft.	6	5.6	5	27.4	0	0.0	0	0.0	0	0.0	1	1.9	5	13.9	3	11.5	2	2.1
	0-1 ft.	13	12.0	5	25.2	4	9.0	1	5.2	2	9.6	6	8.4	6	19.1	4	13.5	9	11.0
	1-3 ft.	45	40.3	7	35.1	19	38.2	7	36.1	12	52.4	33	42.4	12	36.4	10	35.0	36	43.9
	3-5 ft.	33	29.3	2	12.3	16	31.2	10	52.4	6	27.1	25	32.8	8	22.6	9	30.6	23	28.5
	5-7 ft.	11	10.2	0	0.0	11	21.6	1	6.3	0	0.0	11	14.6	1	1.6	1	3.5	12	14.5
	7-9 ft.	3	2.3	0	0.0	0	0.0	0	0.0	2	10.8	0	0.0	2	6.9	2	5.9	0	0.0
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
INTERSECTION FREQUENCY (per mile)	0	12	11.0	5	26.8	0	0.0	3	13.2	4	16.1	4	5.8	7	21.2	5	18.4	5	6.2
	0-0.3	21	18.8	5	24.3	2	3.7	3	15.5	10	45.7	7	9.5	13	36.8	9	32.5	8	9.9
	0.3-0.6	16	14.2	5	23.9	7	13.2	0	1.8	3	14.9	10	12.7	6	17.2	2	7.7	15	18.5
	0.6-0.9	19	17.2	5	25.0	9	18.7	2	8.1	3	11.8	12	15.5	7	20.0	6	22.2	11	13.6
	0.9-1.2	17	15.1	0	0.0	11	22.5	6	32.2	1	3.9	16	21.2	1	3.1	2	7.7	16	19.9
	1.2-1.5	13	12.1	0	0.0	10	21.0	3	17.7	1	2.6	13	17.5	1	1.6	1	3.3	15	17.9
	1.5-1.8	5	4.6	0	0.0	2	4.3	2	11.6	1	5.0	5	6.9	0	0.0	1	2.7	5	5.8
	1.8 and up	8	7.2	0	0.0	8	16.7	0	0.0	0	0.0	8	10.9	0	0.0	2	5.6	7	8.2
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0

1 ft = 0.3048 m

1 mile = 1.609 km

Table 78. Distribution of climatic data for winding sites.

CLIMATIC VARIABLE	SITE DISTRIBUTION	ALL ABSOLUTE	ALL PERCENT	AZ, CA ABSOLUTE	AZ, CA PERCENT	CT, MD, OH, VA ABSOLUTE	CT, MD, OH, VA PERCENT	GA, LA ABSOLUTE	GA, LA PERCENT	ID, WA ABSOLUTE	ID, WA PERCENT	ROLLING ABSOLUTE	ROLLING PERCENT	MOUNTAIN ABSOLUTE	MOUNTAIN PERCENT	FAP ABSOLUTE	FAP PERCENT	FAS ABSOLUTE	FAS PERCENT
AVERAGE NUMBER OF DAYS OF PRECIPITATION PER YEAR	40-60	9	7.9	8	37.5	0	0.0	0	0.0	0	0.0	2	2.4	6	18.6	3	9.3	6	7.1
	60-80	13	11.9	8	41.7	0	0.0	0	0.0	3	14.0	3	4.0	9	27.0	7	23.4	3	4.3
	80-100	9	8.4	3	15.6	0	0.0	0	0.0	5	23.4	1	1.1	8	22.5	6	19.1	1	1.3
	100-120	57	51.2	1	5.3	35	70.7	19	100.0	6	25.6	49	64.1	9	26.3	6	22.2	58	70.3
	120-140	12	11.1	0	0.0	13	25.9	0	0.0	0	0.0	13	16.8	0	0.0	3	8.8	10	12.6
	140-160	1	0.9	0	0.0	0	0.0	0	0.0	1	4.3	0	0.0	1	2.7	1	2.3	0	0.0
	160-180	9	8.5	0	0.0	2	3.4	0	0.0	7	32.7	9	11.5	1	2.3	4	14.8	4	4.5
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
AVERAGE NUMBER OF DAYS OF SNOW PER YEAR	0	6	5.5	4	21.1	0	0.0	1	7.3	0	0.0	2	2.3	4	10.8	1	1.8	7	7.9
	0-10	82	74.1	5	24.7	42	84.1	18	92.7	20	90.9	63	82.0	20	58.9	18	62.7	67	81.6
	10-20	18	16.3	8	38.6	7	14.3	0	0.0	2	9.1	11	14.1	7	20.6	8	27.1	8	9.2
	20-30	3	2.4	2	8.1	1	1.7	0	0.0	0	0.0	1	1.1	2	5.0	1	4.3	1	1.2
	30-40	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	40-50	2	1.6	1	7.5	0	0.0	0	0.0	0	0.0	0	0.0	2	4.7	1	4.0	0	0.0
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0
AVERAGE NUMBER OF DAYS OF FOG PER YEAR	0-10	17	15.5	14	71.4	0	0.0	0	0.0	0	1.5	3	3.5	13	38.7	9	30.2	5	5.8
	10-20	16	16.7	1	3.0	6	12.7	0	0.0	9	39.5	8	10.4	8	23.0	5	18.5	10	12.1
	20-30	32	29.1	1	3.4	22	44.0	9	45.0	3	14.4	32	42.1	1	4.0	5	18.8	29	35.9
	30-40	29	26.3	0	2.3	20	39.8	10	55.0	1	4.3	23	29.9	7	19.4	4	13.7	28	34.6
	40-50	12	11.2	2	11.7	0	0.0	0	0.0	9	40.3	9	11.9	3	9.9	4	14.8	7	8.9
	50-60	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	60-70	2	1.6	1	7.5	0	0.0	0	0.0	0	0.0	0	0.0	2	4.7	1	4.0	0	0.0
	70 and up	2	1.6	0	0.0	2	3.4	0	0.0	0	0.0	2	2.2	0	0.0	0	0.0	2	2.7
	TOTAL SITES	111	100.0	20	100.0	50	100.0	19	100.0	22	100.0	77	100.0	34	100.0	29	100.0	82	100.0

NOTE: Number of sites given are "effective number of sites" as defined in Section C.2.2. Hence table numbers do not add.

Table 79. Distribution of site delineation data for horizontal curves.

HIGHWAY SITES INCLUDED / DELINEATION TREATMENT	SITE DISTRIBUTION	ALL		CA, AZ		CT, MD, OH, VA		GA, LA		ID, WA		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
EDGELINE	ABSENT	71	54.0	22	89.6	30	55.9	3	25.4	12	29.6	10	26.5	65	71.1
	PRESENT	60	46.0	2	10.4	23	44.1	9	74.6	30	70.4	29	73.5	27	28.9
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
POST DELINEATION	ABSENT	76	58.4	1	6.1	43	82.0	8	68.9	26	61.7	15	39.4	65	70.3
	PRESENT	55	41.6	23	93.9	10	18.0	4	31.1	16	38.3	24	60.6	27	29.7
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0

Table 80. Distribution of traffic volume data for horizontal curves.

HIGHWAY SITES INCLUDED / SITE DISTRIBUTION / TRAFFIC VOLUME CATEGORIES	ALL		AZ, CA		CT, MD, OH, VA		GA, LA		ID, WA		FAP		FAS	
	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
0-500 ADT	3	2.3	0	0.5	1	1.5	0	1.3	2	5.9	1	1.3	3	3.0
500-1000 ADT	17	12.9	1	5.6	7	12.6	1	6.8	9	22.6	2	4.8	16	17.9
1000-1500 ADT	20	15.5	2	10.4	9	17.1	3	22.7	6	14.6	4	9.3	18	19.4
1500-2000 ADT	19	14.4	5	19.1	10	18.3	1	8.3	3	6.0	3	7.3	17	18.9
2000-2500 ADT	20	15.2	1	4.9	10	18.5	1	9.7	9	21.3	10	25.5	8	8.8
2500-3000 ADT	10	7.7	1	5.5	3	6.2	1	12.0	4	10.4	5	13.2	4	4.2
3000-3500 ADT	19	14.6	4	16.4	8	14.5	0	0.0	8	19.1	7	16.9	12	13.2
3500-4000 ADT	11	8.0	7	27.3	0	0.0	2	17.7	0	0.0	6	16.2	3	2.9
4000-4500 ADT	6	4.6	2	10.3	3	5.4	0	0.0	0	0.0	0	0.0	7	7.5
4500-5000 ADT	3	2.2	0	0.0	0	0.0	3	21.4	0	0.0	2	5.7	0	0.0
5000 ADT and up	3	2.5	0	0.0	3	6.0	0	0.0	0	0.0	0	0.0	4	4.1
TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0

Table 81. Distribution of site roadway data for horizontal curves.

ROADWAY VARIABLE	SITE DISTRIBUTION / HIGHWAY SITES INCLUDED	ALL ABSOLUTE	ALL PERCENT	CA, AZ ABSOLUTE	CA, AZ PERCENT	CT, MD, OH, VA ABSOLUTE	CT, MD, OH, VA PERCENT	GA, LA ABSOLUTE	GA, LA PERCENT	ID, WA ABSOLUTE	ID, WA PERCENT	FAP ABSOLUTE	FAP PERCENT	FAS ABSOLUTE	FAS PERCENT
SHOULDER TYPE	PAVED	50	38.5	19	81.0	15	27.9	0	0.0	14	33.5	17	44.0	32	35.1
	UNPAVED	81	61.5	5	19.0	38	72.1	12	100.0	28	66.5	22	56.0	60	64.9
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
FUNCTIONAL CLASSIFICATION	FEDERAL AID SECONDARY	81	61.5	12	51.8	41	78.0	7	56.9	19	44.2	0	0.0	92	100.0
	FEDERAL AID PRIMARY	50	38.5	12	48.2	12	22.0	5	43.1	23	55.8	39	100.0	0	0.0
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
ROADWAY WIDTH	0-17 ft.	5	4.1	0	0.0	5	9.7	0	0.0	0	0.0	0	1.0	6	6.0
	17-19 ft.	6	4.6	0	0.0	4	8.3	0	3.2	1	3.0	1	1.5	6	6.5
	19-21 ft.	53	40.3	0	0.0	35	66.4	3	27.6	16	38.0	11	28.1	44	48.0
	21-23 ft.	23	17.2	0	0.5	5	8.9	1	12.0	21	48.9	9	23.9	12	13.0
	23-25 ft.	37	28.5	19	78.5	4	6.7	7	57.1	3	7.9	13	33.9	23	25.1
	25-27 ft.	4	2.8	3	11.2	0	0.0	0	0.0	1	1.2	2	5.9	1	1.0
	27 ft. and up	3	2.5	2	9.7	0	0.0	0	0.0	0	1.0	2	5.8	0	0.4
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
SHOULDER WIDTH	0 ft.	3	2.5	3	10.8	0	0.0	0	0.0	0	0.0	0	0.9	3	3.4
	0-1 ft.	5	3.6	2	10.4	1	2.4	0	0.0	0	0.8	1	1.8	4	4.7
	1-3 ft.	32	24.4	7	30.0	11	21.3	2	12.5	12	29.4	7	18.2	26	28.2
	3-5 ft.	51	38.7	6	23.6	28	52.0	7	60.0	9	21.2	13	33.0	39	42.3
	5-7 ft.	21	16.3	0	0.0	7	14.0	1	9.7	16	37.8	9	23.1	11	12.0
	7-9 ft.	18	14.0	5	22.7	5	10.4	2	17.7	5	10.9	8	21.5	9	9.4
	9-11 ft.	1	0.6	1	2.6	0	0.0	0	0.0	0	0.0	1	1.5	0	0.0
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0

1 ft = 0.3048 m

Table 82. Distribution of site curve data for horizontal curves.

CURVE DATA (HIGHWAY SITES INCLUDED / SITE DISTRIBUTION)		ALL ABSOLUTE	ALL PERCENT	CA, AZ ABSOLUTE	CA, AZ PERCENT	CT, MD, OH, VA ABSOLUTE	CT, MD, OH, VA PERCENT	GA, LA ABSOLUTE	GA, LA PERCENT	ID, WA ABSOLUTE	ID, WA PERCENT	FAP ABSOLUTE	FAP PERCENT	FAS ABSOLUTE	FAS PERCENT
DEGREE OF CURVATURE	0-3 DEG	33	25.0	11	44.5	10	19.4	0	0.0	11	27.1	14	36.5	16	17.8
	3-4.5 DEG	38	29.2	4	18.3	14	26.1	6	52.4	15	35.2	11	29.4	27	29.2
	4.5-6.0 DEG	21	16.3	4	17.4	8	14.3	4	32.9	5	11.7	8	19.9	13	14.0
	6.0-7.5 DEG	16	12.5	2	9.5	10	18.1	1	7.9	3	7.5	2	5.5	15	16.8
	7.5-9.0 DEG	9	6.8	0	0.0	6	11.1	0	0.0	4	8.6	2	6.1	7	7.3
	9.0-11.5 DEG	8	6.3	2	10.3	3	4.8	0	3.2	3	6.4	1	2.6	8	8.5
	11.5-13.0 DEG	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	13 DEG and up	5	3.9	0	0.0	3	6.3	0	3.6	2	3.6	0	0.0	6	6.4
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
AVERAGE DISTANCE TO ADJACENT CURVE (Miles)	0-0.5	23	17.2	3	13.7	16	31.0	1	5.4	1	1.9	3	8.5	21	22.7
	0.5-1.0	58	44.3	10	43.2	23	42.6	5	39.5	21	50.4	18	47.1	39	42.6
	1.0-1.5	24	18.5	2	7.2	10	19.0	1	11.6	13	31.0	7	16.7	18	19.7
	1.5-2.0	7	5.2	3	12.3	2	3.1	0	1.3	2	3.7	3	7.8	3	3.5
	2.0-2.5	8	5.8	0	0.0	2	4.4	3	27.9	2	4.4	2	5.7	5	5.9
	2.5-3.0	3	2.4	0	1.6	0	0.0	1	5.9	2	5.9	1	3.6	2	1.7
	3.0-3.5	5	3.5	3	13.7	0	0.0	0	0.0	1	1.5	2	5.8	2	2.1
	3.5-4.0	1	0.8	0	0.0	0	0.0	1	8.3	0	0.0	0	0.0	1	1.4
	4.0 and up	3	2.2	2	8.3	0	0.0	0	0.0	1	1.2	2	4.9	0	0.5
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
SITE LENGTH (Miles)	0-0.1	47	35.6	0	0.0	34	64.5	3	25.0	10	23.2	7	17.7	43	46.8
	0.1-0.2	42	32.3	4	15.9	14	26.2	4	32.3	24	57.9	16	41.4	25	26.6
	0.2-0.3	23	17.6	8	33.0	4	8.0	4	32.2	6	13.6	7	16.7	17	18.1
	0.3-0.4	16	12.4	10	42.5	1	1.2	1	10.5	2	4.6	7	19.1	8	8.2
	0.4-0.5	2	1.6	2	7.1	0	0.0	0	0.0	0	0.0	2	4.2	0	0.0
	0.5-0.6	0	0.2	0	0.0	0	0.0	0	0.0	0	0.6	0	0.0	0	0.3
	0.6-0.7	0	0.3	0	1.5	0	0.0	0	0.0	0	0.0	0	0.9	0	0.0
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	93	100.0

1 ft = 0.3048 m

1 mile = 1.609 km

Table 83. Distribution of climatic data for horizontal curves.

CLIMATIC VARIABLE	SITE DISTRIBUTION	ALL		CA, AZ		CT, MD, OH, VA		GA, LA		ID, WA		FAP		FAS	
		ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT	ABSOLUTE	PERCENT
AVERAGE NUMBER OF DAYS OF PRECIPITATION PER YEAR	0–20	8	6.1	6	26.7	0	0.0	0	0.0	0	0.0	0	0.0	9	9.9
	20–40	5	3.7	4	16.1	0	0.0	0	0.0	0	0.0	4	9.5	0	0.0
	40–60	6	4.3	5	18.9	0	0.0	0	0.0	0	0.0	2	4.9	4	3.9
	60–80	19	14.7	9	36.7	0	0.0	0	0.0	11	25.5	7	18.1	12	12.5
	80–100	5	3.8	0	1.6	0	0.0	3	23.8	2	4.0	1	2.1	4	4.8
	100–120	54	41.5	0	0.0	31	59.0	9	76.2	15	35.3	17	42.7	37	40.7
	120–140	18	13.8	0	0.0	17	32.5	0	0.0	0	0.0	2	4.6	18	19.5
	140–160	2	1.5	0	0.0	0	0.0	0	0.0	2	5.9	1	2.5	1	0.8
	160–180	12	9.2	0	0.0	4	8.5	0	0.0	10	23.1	5	11.7	7	7.8
	180 and up	2	1.5	0	0.0	0	0.0	0	0.0	3	6.1	2	3.9	0	0.0
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
AVERAGE NUMBER OF DAYS OF SNOW PER YEAR	0	21	15.7	10	41.6	0	0.0	7	61.2	0	0.0	4	9.0	18	19.9
	0–10	78	59.4	5	20.1	41	77.3	5	38.8	31	73.4	23	57.9	56	60.3
	10–20	27	20.9	9	36.7	8	14.2	0	0.0	11	26.6	10	26.4	16	17.9
	20–30	5	4.0	0	1.6	4	8.5	0	0.0	0	0.0	3	6.7	2	2.2
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0
AVERAGE NUMBER OF DAYS OF FOG PER YEAR	0	2	1.8	2	7.8	0	0.0	0	0.0	0	0.0	2	4.6	0	0.0
	0–10	29	21.9	19	80.2	0	0.0	0	0.0	6	14.9	7	19.1	22	23.7
	10–20	22	16.6	1	5.5	7	12.7	0	0.0	17	40.4	6	14.5	16	17.9
	20–30	19	14.8	0	0.0	17	32.6	1	5.4	1	1.8	6	15.4	13	14.5
	30–40	39	29.7	2	6.5	24	46.2	8	70.8	2	5.9	7	18.7	34	36.6
	40–50	15	11.6	0	0.0	0	0.0	3	23.8	16	37.0	9	22.0	5	5.1
	50 and up	5	3.6	0	0.0	4	8.5	0	0.0	0	0.0	2	5.8	2	2.2
	TOTAL SITES	131	100.0	24	100.0	53	100.0	12	100.0	42	100.0	39	100.0	92	100.0

be greater than that derived from edgelines even though the number of accidents reduced (per unit exposure) may be the same for both treatments. In this case, a dependent variable based upon accident severity will be more sensitive to the changes in roadway delineation and, therefore, a better choice for dependent variable. A dependent variable based upon accident severity will be particularly useful in the cost-benefit analysis where benefits are dollar equivalent of reduced accidents.

This section reports on the investigation of these alternative dependent variables.

C.4.4.1 Candidate Choices

Two sets of accident characteristics were utilized to develop candidate choices of alternative dependent variables for further investigation. These can be defined as those based on (a) the accident environment and (b) accident severity. Accident characteristics utilized within each set to develop candidate choices are given below.

Accident Environment

- nighttime accidents
- wet pavement accidents
- non-intersection accidents
- delineation related accidents

Accident Severity

- fatal and injury accidents
- property damage only (PDO) accidents
- severity index.

The candidate choices thus developed are given in Table 84. Each cell of this table represents a candidate dependent variable. A few remarks are in order regarding some of the choices.

Delineation-related accidents were identified by evaluating each accident against a pre-established criterion. This criterion, comprised of accident characteristics, was utilized to identify accidents which could not possibly be related to the existing roadway delineation treatment. All the remaining accidents were classified as delineation related. Details of this classification scheme can be found in Appendix B.

Accidents under snow and icy pavement conditions were not included in the wet pavement accident category as required for some of the candidate dependent variables. This decision was based upon the premise that the cause of such accidents is generally not related to the existing roadway delineation treatment.

On the other hand, in selecting the nighttime accident category, all accidents at dusk, at dawn, or in other adverse visibility conditions were included in the category. The nighttime accidents in effect therefore included all inclement visibility condition accidents.

There were two options available for computing severity index; one based on "accident severity," and the other on "accident type" as described below.

Table 84. Candidate choice of dependent variables.

SEVERITY INDEX RATE	PROPERTY DAMAGE ONLY ACCIDENT RATE	FATAL & INJURY ACCIDENT RATE	ACCIDENT RATE			
				ALL ACCIDENTS	INTERSECTION + NONINTERSECTION	ALL ACCIDENTS
				NIGHTTIME		
				WET PAVEMENT		
				NIGHTTIME + WET PAVEMENT		
				ALL NONINTERSECTION ACCIDENTS	NON-INTERSECTION	
				NIGHTTIME		
				WET PAVEMENT		
				NIGHTTINE + WET PAVEMENT		
				ALL DELINEATION RELATED ACCIDENTS	INTERSECTION + NONINTERSECTION	DELINEATION RELATED ACCIDENTS ONLY
				NIGHTTIME		
				WET PAVEMENT		
				NIGHTTIME + WET PAVEMENT		
				ALL DELINEATION RELATED NONINTERSECTION ACCIDENTS	NON-INTERSECTION	
				NIGHTTIME		
				WET PAVEMENT		
				NIGHTTIME + WET PAVEMENT		

Severity Index Based Upon Accident Severity

Under this method, the severity index is computed by weighting each accident by the average cost of an accident with that severity. The mathematical expression for this computation is:

$$S \cdot I = C_F \times N_F + C_I \times N_I + C_p \times N_p$$

where

$S \cdot I$ = severity index

C_F = average cost of a fatal accident

C_I = average cost of an injury accident

C_p = average cost of a PDO accident

N_F = number of fatal accidents

N_I = number of injury accidents

N_P = number of PDO accidents

The greatest disadvantage of this method lies in the fact that the computed severity index is very sensitive to the number of fatal accidents (due to the high cost associated with such accidents) although fatal accidents are estimated with the least confidence (because of their small number). Only 3 percent of all accidents were fatal accidents for the data collected for this study. The cost of a fatal accident is $234,960. In contrast, the average costs of an injury and PDO accident are $11,200 and $500 respectively. Together they comprise 97 percent of all accidents.

Severity Index Based Upon Accident Type

This method is based upon the premise that "accident severity" has an inherent dependence on "accident type." For example,head-on accidents are inherently more severe than run-off-the-road accidents. The severity index, then, is computed by the formula:

$$S \cdot I = \sum_i C_i \times N_i$$

where

C_i = the average cost of an accident of type i,
N_i = the number of accidents of type i,
i = the index for accident type.

The average cost of an accident of type i is computed by:

$$C_i = C_F \times N_F^i + C_I \times N_I^i + C_p \times N_p^i$$

where C_F, C_I, and C_p are as previously defined

N_F^i = number of type i fatal accidents
N_I^i = number of type i injury accidents
N_P^i = number of type i PDO accidents

Prior to selecting a formula for computing the severity index, the dependence of accident severity on collision type was investigated. The method utilized was a chi-square test of statistical significance with "accident severity" and "accident type" as the two variables. To have as large a data base as possible, all accidents including the before-after site accidents were included in this analysis. Prior to chi-square analysis, the distribution of accidents by severity is contained in Table 85. Table 86 contains the distribution of accidents by the type of collision. The corresponding histograms were also developed and are included as Figures 3 and 4.

Table 85. Distribution of accidents by severity.

Category Label	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj. Freq. (Percent)
Fatal	417	3.0	3.0	3.0
Injury	5,557	39.9	40.0	43.0
Property Damage Only	7,927	56.9	57.0	100.0
Missing	22	.2	Missing	100.0
TOTAL	13,923	100.0	100.0	

Table 86. Distribution of accident by collision type.

Category Label	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj. Freq. (Percent)
Head-On	440	3.2	3.2	3.2
Side-Swipe Opposite Dir.	765	5.5	5.6	8.8
Rear-End	1,327	9.5	9.7	18.6
Side-Swipe Same Direction	592	4.3	4.3	22.9
Run-Off-Road or Over-Turn	6,816	49.0	50.0	72.9
Angle	1,612	11.6	11.8	84.7
All Others	2,086	15.0	15.3	100.0
Missing	285	2.0	Missing	100.0
TOTAL	13,923	100.0	100.0	

ACCIDENT DISTRIBUTION BY SEVERITY

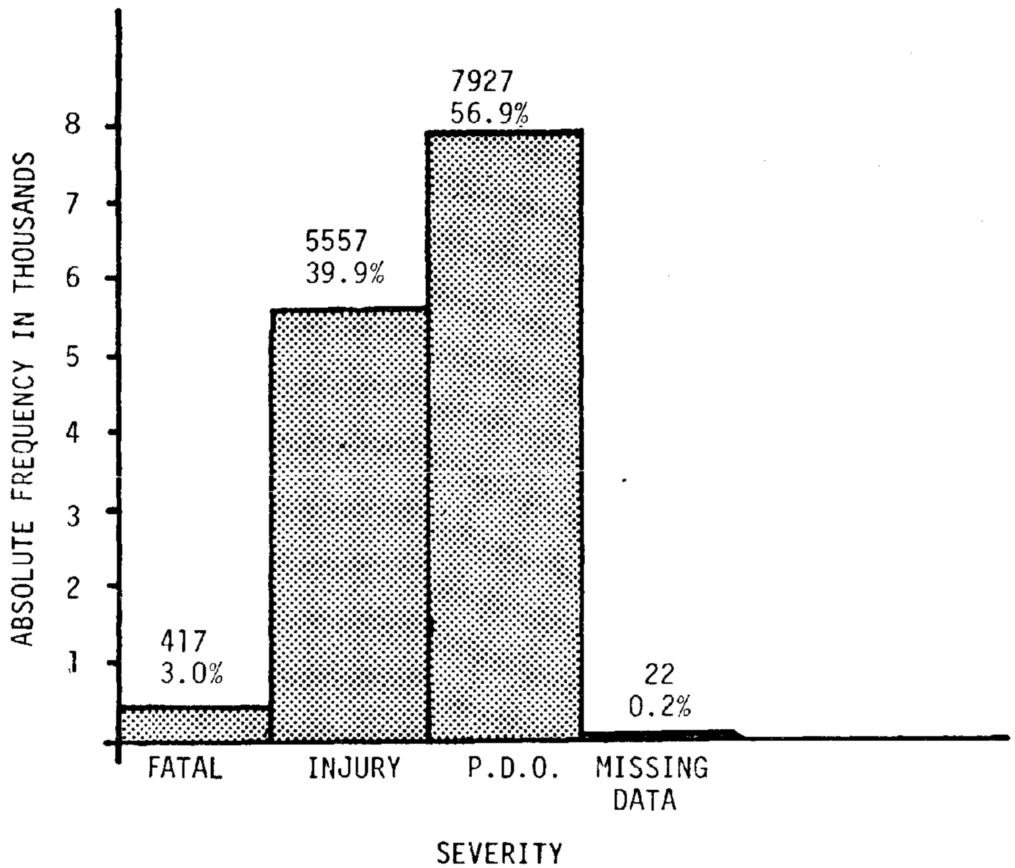

Figure 3. Accident distribution by severity.

ACCIDENT DISTRIBUTION BY COLLISION TYPE

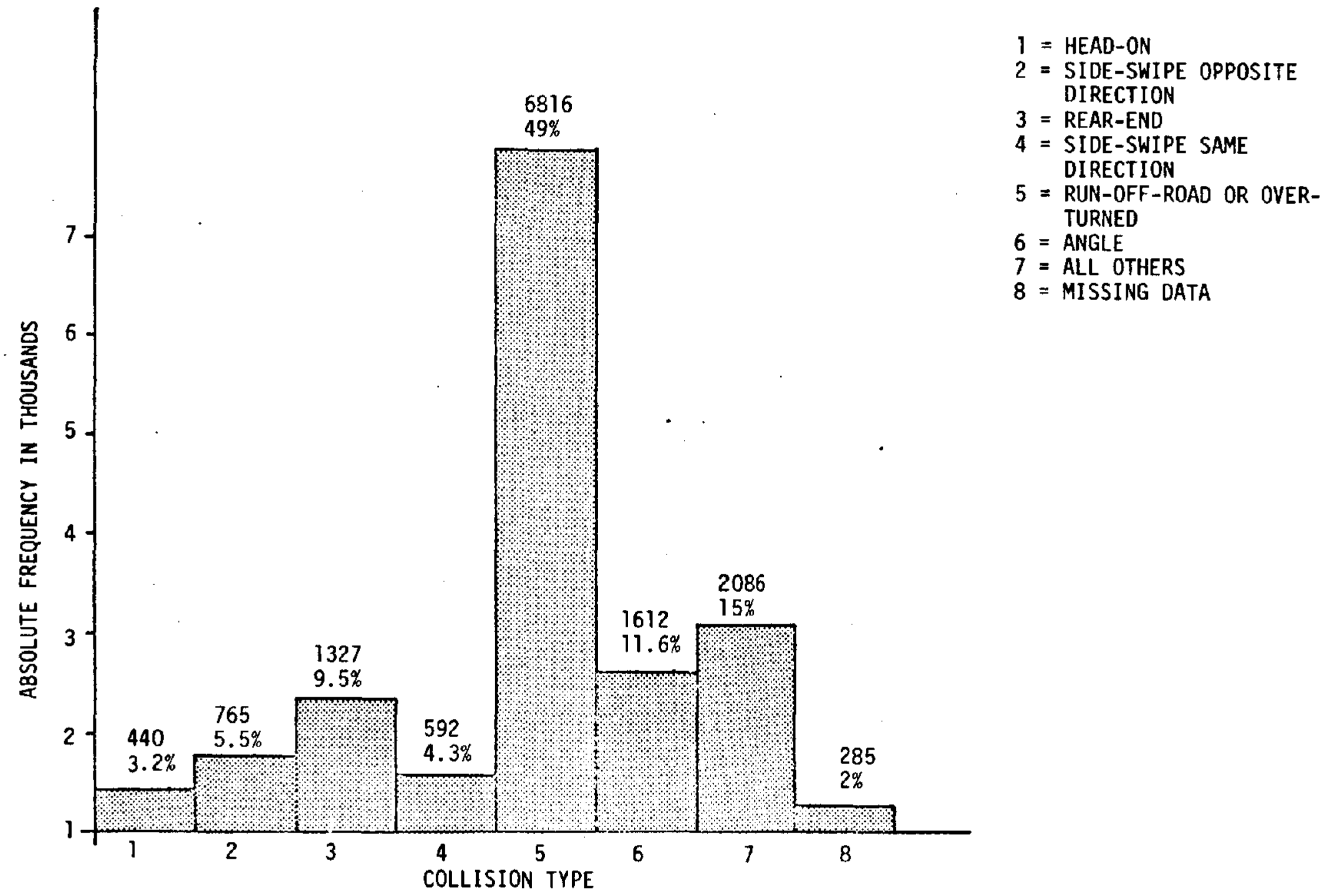

Figure 4. Accident distribution by collision type.

The results of the chi-square analysis are presented in Table -87. These results are also depicted in Figure 5. The computed chi-square value of 768 with 12 degrees of freedom indicates a strong dependence of accident severity on the type of collision.

Note: The data in these tables include *all* the data originally collected for the study. It therefore includes accident data within one mile (1.609 km) on either side of a horizontal curve. When the final data base was established only accidents within 750 feet (228.60 m) of the curve was maintained. Thus, the information contained in the next several tables differs somewhat from the summaries presented previously.

In view of this finding and because of the listed shortcomings of the first method, the second method was chosen to compute the severity index. Additional analysis indicated that both the number of accidents and the average accident cost by collision-type were also more uniform over the various types of collisions. This made the second method even more attractive.

Average cost of an accident by collision type is given in Table C-88. The accident data utilized in the calculations are also included. Accident cost data by severity used in the computation are as follows:

Average cost of a fatal accident (C_F) = \$234,960
Average cost of an injury accident (C_I) = \$ 11,200
Average cost of a PDO accident (C_P) = \$ 500

C.4.4.2 <u>Selection of Alternative Dependent Variables</u>

The 64 candidate choices for dependent variables listed in Table 84 were derived based upon the hypothesis that certain subsets

Table 37. Contingency table (severity by collision type).

SEVERITY / COLLISION TYPE		FATAL	INJURY	PROPERTY DAMAGE ONLY	RAW TOTAL
HEAD-ON	COUNT =	68	236	136	440
	ROW PCT =	15.5	53.6	30.9	3.2
	COL PCT =	16.8	4.3	1.8	
	TOT PCT =	.5	.7	1.0	
SIDE-SWIPE OPP. DIR.		18	269	477	764
		2.4	35.2	62.4	5.6
		4.4	4.9	6.1	
		.1	2.0	3.5	
REAR-END		11	548	767	1326
		.8	41.3	57.8	9.7
		2.7	10.0	9.9	
		.1	4.0	5.6	
SIDE-SWIPE SAME DIR.		4	141	446	591
		.7	23.9	75.5	4.3
		1.0	2.6	5.7	
		.0	1.0	3.3	
ROR OR OVER-TURN		205	3138	3471	6814
		3.0	46.1	50.9	50.0
		50.6	57.5	44.7	
		1.5	23.0	25.5	
ANGLE		45	633	926	1604
		2.8	39.5	57.7	11.8
		11.1	11.6	11.9	
		.3	4.6	6.8	
ALL OTHERS		54	491	1534	2079
		2.6	23.6	73.8	15.3
		13.3	9.0	19.8	
		.4	3.6	11.3	
COLUMN TOTAL		405	5456	7757	13618
		3.0	40.1	57.0	100.0

ROW CHI SQUARE = 768.09658 WITH 12 DEGREES OF FREEDOM. SIGNIFICANCE = 0.
NUMBER OF MISSING OBSERVATIONS = 305.

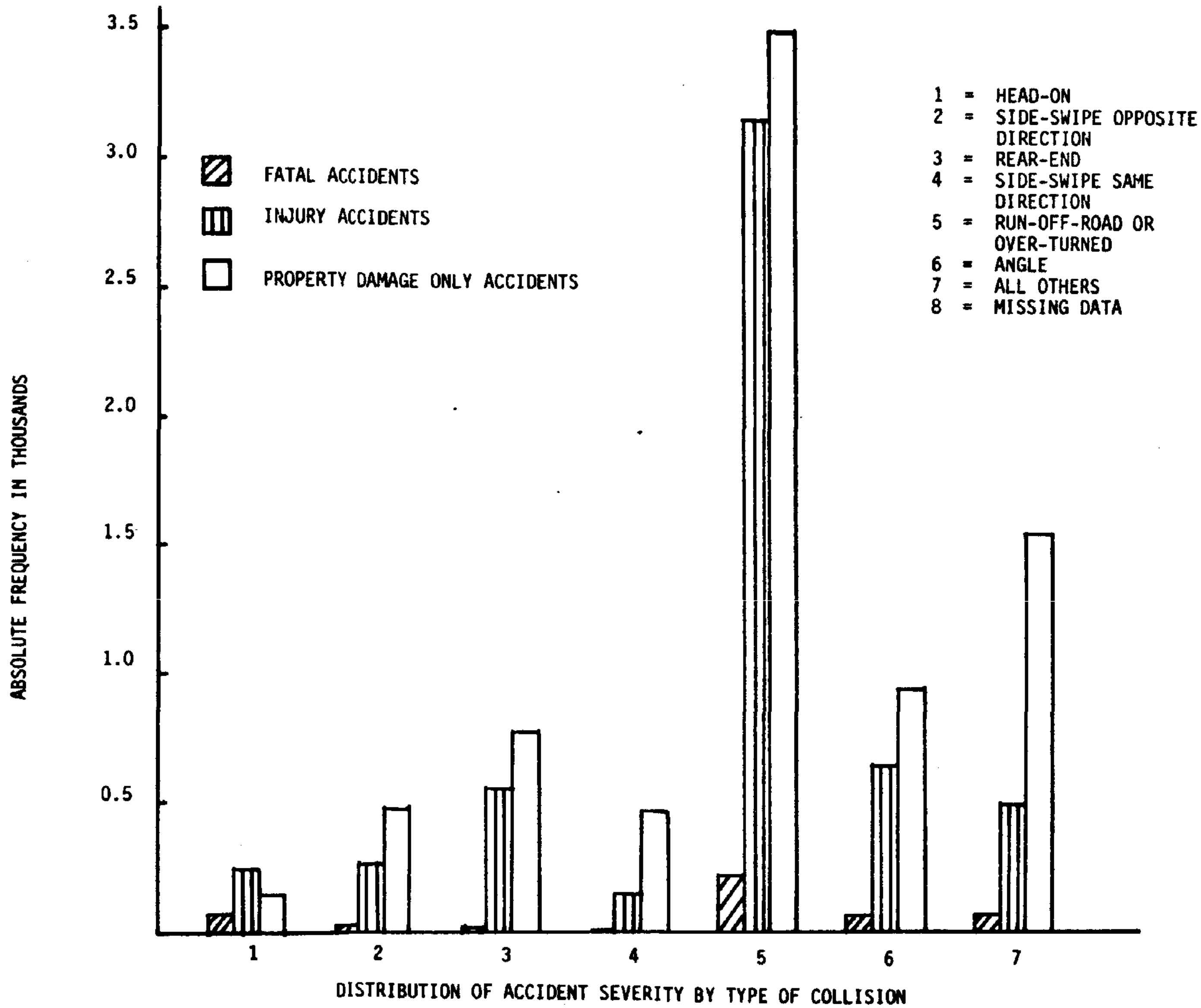

Figure ..5. Distribution of accident severity by type of collision.

Table 88. Accident cost by type of collision.

TYPE OF SEVERITY / TYPE OF COLLISION	NUMBER OF ACCIDENTS				AVERAGE COST
	FATAL	INJURY	PDO	TOTAL	
1. Head - on	68	236	136	440	$42,474
2. Side - swipe opposite direction	18	269	477	764	$ 9,791
3. Rear - end	11	548	767	1326	$ 6,867
4. Side - swipe same direction	4	141	446	591	$ 4,640
5. Run-off road over turn	205	3138	3471	6814	$12,481
6. Angle	45	633	926	1604	$11,300
7. Others	54	491	1534	2079	$ 9,117
TOTAL	405	5456	7757	13618	$11,760

of accidents may be more sensitive to the changing delineation treatment. This section investigates the sensitivity of each candidate choice.

The first analysis conducted was to choose a dependent variable which would best reflect the dependence of accident severity on roadway delineation treatment. The choice was between the severity index (which is based upon the type of collision), and accident subcategories, (e.g., fatal - injury and PDO accidents, based upon accident severity. Fatal accidents were combined with injury accidents because of the small data base available for fatal accidents.

The analysis conducted was by a chi-square test of statistical significance. Through this test, the dependence of "accident severity" and "type of collision" on delineation treatment was investigated. If the type of collision has a stronger dependence, severity index would be the suitable alternative form; otherwise the accident subcategories of fatal-injury and PDO accidents would be the preferred choice.

The results of the chi-square analysis are given in Tables 89 through 92. Separate chi-square tests were conducted for general sites and horizontal curves. The chi-square between delineation treatment and type of collision has a much larger value than between the treatment and accident severity for both general and horizontal curve sites. The severity index, therefore, was the chosen form. Another reason favoring this choice stemmed from the fact that the other choice would have reduced the data base for further analysis by one-half. Nearly 40 percent of all accidents were fatal injury accidents and the remaining 60 percent were property damage.

Table 89. Contingency table for general sites (treatment by severity).

TREATMENT \ SEVERITY		FATAL	INJURY	PROPERTY DAMAGE ONLY	ROW TOTAL
NO TREATMENT	COUNT =	14	158	294	466
	ROW PCT =	3.0	33.9	63.1	
	COL PCT =	4.7	4.0	5.1	
	TOT PCT =	.1	1.6	2.9	4.7
PAINT CL		75	1,146	1,827	3,048
		2.5	37.6	59.9	
		25.3	28.8	31.8	
		.7	1.5	2.0	30.4
RPM CL		11	149	205	365
		3.0	40.8	56.2	
		3.7	3.7	3.6	
		.1	11.4	18.2	3.6
CL AND EL		92	1,339	1,893	3,324
		2.8	40.3	56.9	
		31.1	33.6	33.0	
		.9	13.4	18.9	33.2
CL AND POST		98	1,071	1,345	2,514
		3.9	42.6	53.5	
		33.1	26.9	23.4	
		1.0	10.7	13.4	25.1
CL, EL AND POST		6	118	175	299
		2.0	39.5	58.5	
		2.0	3.0	3.0	
		.1	1.2	1.7	3.0
	COLUMN TOTAL	296	3,981	5,739	10,016
		3.0	39.7	57.3	100.0

Raw Chi Square = 37.45; Degrees of Freedom = 10; Significance = .0000;
Number of Missing Observations = 20

Table 90. Contingency table for horizontal curves (treatment by severity).

TREATMENT \ SEVERITY		FATAL	INJURY	PROPERTY DAMAGE ONLY	ROW TOTAL
NO TREATMENT	COUNT =	1	6	19	26
	ROW PCT =	3.8	23.1	73.1	
	COL PCT =	8.3	2.7	6.1	
	TOT PCT =	.2	1.1	3.5	4.7
CL		4	56	64	124
		3.2	45.2	51.6	
		33.3	25.0	20.4	
		.7	10.2	11.7	22.6
GUARDRAILS		0	11	17	28
		0	39.3	60.7	
		0	4.9	5.4	
		0	2.0	3.1	5.1
CL AND EL		2	67	72	141
		1.4	47.5	51.1	
		16.7	29.9	23.0	
		.4	12.2	13.1	25.7
CL AND POST		3	64	98	165
		1.8	38.8	59.4	
		25.0	28.6	31.3	
		.5	11.7	17.9	30.1
CL, EL AND POST		2	20	43	65
		3.1	30.8	66.2	
		16.7	8.9	13.7	
		.4	3.6	7.8	11.8
	COLUMN TOTAL	12	224	313	549
		3.3	40.8	57.0	100.0

Raw Chi Square = 12.063; Degrees of Freedom = 10; Significance = .2808
Number of Missing Observations = 0

Table 91. Contingency table for general sites (treatment by collision type).

TREATMENT \ COLLISION TYPE		HEAD-ON	SIDE-SWIPE OPP. DIR.	REAR-END	SIDE-SWIPE SAME DIR.	ROR OR OVERTURN	ANGLE	ALL OTHERS	ROW TOTAL
NO TREATMENT	COUNT =	32	52	26	10	248	28	65	461
	ROW PCT =	6.9	11.3	5.6	2.2	53.8	6.1	14.1	
	COL PCT =	10.8	9.5	2.7	2.2	5.1	2.4	4.2	
	TOT PCT =	.3	.5	.3	.1	2.5	.3	.7	4.7
PAINT CL		77	207	282	192	1,418	353	480	3,009
		2.6	6.9	9.4	6.4	47.1	11.7	16.0	
		25.9	37.6	29.0	41.5	29.3	29.7	31.3	
		.8	2.1	2.9	2.0	14.4	3.6	4.9	30.6
RMP CL		16	20	50	19	190	22	41	358
		4.5	5.6	14.0	5.3	53.1	6.1	11.5	
		5.4	3.6	5.1	4.1	3.9	1.9	2.7	
		.2	.2	.5	.2	1.9	.2	.4	3.6
CL AND EL		100	189	363	160	1,518	508	449	3,287
		3.0	5.7	11.0	4.9	46.2	15.5	13.7	
		33.7	34.4	37.3	34.6	31.4	42.7	29.2	
		1.0	1.9	3.7	1.6	15.4	5.2	4.6	33.4
CL AND POST		65	71	211	72	1,348	221	450	2,438
		2.7	2.9	8.7	3.0	55.3	9.1	18.5	
		21.9	12.9	21.7	15.6	27.9	18.6	29.3	
		.7	.7	2.1	.7	13.7	2.2	4.6	24.8
CL, EL AND POST		7	11	41	10	114	57	51	291
		2.4	3.8	14.1	3.4	39.2	19.6	7.5	
		2.4	2.0	4.2	2.2	2.4	4.8	3.3	
		.1	.1	.4	.1	1.2	.6	.5	3.0
COLUMN TOTAL		297	550	973	463	4,836	1,189	1,536	9,844
		3.0	5.6	9.9	4.7	49.1	12.1	15.6	100.0

Raw Chi Square = 318.4; Degrees of Freedom = 30; Significance = 0; Number of Missing Observations = 192

Table 92. Contingency table for horizontal curves (treatment by collision type).

TREATMENT	COLLISION TYPE	HEAD-ON	SIDE-SWIPE OPP. DIR.	REAR-END	SIDE-SWIPE SAME DIR.	ROR OR OVERTURN	ANGLE	ALL OTHERS	ROW TOTAL
NO TREATMENT	COUNT =	2	5	0	0	10	2	7	26
	ROW PCT =	7.7	19.2	0	0	38.5	7.7	26.9	
	COL PCT =	12.5	20.0	0	0	3.3	4.1	9.9	
	TOT PCT =	.4	.9	0	0	1.8	.4	1.3	4.8
CL		4	2	8	4	77	10	19	124
		3.2	1.6	6.5	3.2	62.1	8.1	15.3	
		25.0	8.0	14.8	17.4	25.1	20.4	26.8	
		.7	.4	1.5	.7	14.1	1.8	3.5	22.8
GUARDRAILS		0	0	6	0	8	8	5	27
		0	0	22.2	0	29.6	29.6	18.5	
		0	0	11.1	0	2.6	16.3	7.0	
		0	0	1.1	0	1.5	1.5	.9	5.0
CL AND EL		4	9	13	6	81	15	13	141
		2.8	6.4	9.2	4.3	57.4	10.6	9.2	
		25.0	36.0	24.1	26.1	26.4	30.6	18.3	
		.7	1.7	2.4	1.1	14.9	2.8	2.4	25.9
CL AND POST		4	4	19	8	95	13	19	162
		2.5	2.5	11.7	4.9	58.6	8.0	11.7	
		25.0	16.0	35.2	34.8	30.9	26.5	26.8	
		.7	.7	3.5	1.5	17.4	2.4	3.5	29.7
CL, EL AND POST		2	5	8	5	36	1	8	65
		3.1	7.7	12.3	7.7	55.4	1.5	12.3	
		12.5	20.0	14.8	21.7	11.7	2.0	11.3	
		.4	.9	1.5	.9	6.6	.2	1.5	11.9
	COLUMN	16	25	54	23	307	49	71	545
	TOTAL	2.9	4.6	9.9	4.2	56.3	9.0	13.0	100.0

Raw Chi Square = 66.63; Degrees of Freedom = 30; Significance = .0001; Number of Missing Observations = 4.

Having thus eliminated the two rows pertaining to fatal injury and PDO accidents in Table 84, the choice narrowed between the remaining 32 alternative forms. To reduce this number further, two alternative analytical procedures were available.

The first is based upon regression analysis. Each candidate dependent variable is regressed against the set of categorical delineation treatment variables. The computed R^2, a measure of the proportion of variance of the dependent variable explained by the delineated treatment values, is then used to rank the candidate choices. A higher value of R^2 would be indicative of higher dependence of the test variable on the roadway delineation treatment.

The second procedure is based upon one-way analysis of variance. If one-way analysis of variance is conducted on a candidate dependent variable with delineation treatments as the one-way subcategories, then the computed F-value can be utilized as a measure of the dependence of the candidate variable on delineation treatment. The larger the value of F corresponding to a candidate choice, the greater will be the dependence of this variable on roadway delineation treatment (F is the measure of the difference in mean between the subcategories, and the larger the difference in mean, the greater the dependence of the particular dependent variable on delineation).

Both procedures described above were considered equally suitable and therefore investigated. In the actual analysis an additional variable, number of days of precipitation per year, was also included. In the regression analysis it was included as an independent variable, whereas, in one-way analysis of variance it was included as a covariate.

The reason for including this variable was as follows. There is a wide variation in the site precipitation data due to the wide geographic dispersion of highway sites. Because of the wide variation in state delineation practices, however, sites with a specified delineation treatment often were not uniformly distributed over the country. (An obvious example would be sites with raised pavement markers which were only available in western states.) Because of this, there was a possibility that the dependence of the candidates choice on delineation treatment may enhance partially due to its dependence on the geographical and climatic parameters, particularly the variation in precipitation. The effect of this variable would be particularly great on wet pavement accidents. Explicit inclusion of precipitation as a covariable minimized the resulting error.

The result of regression analysis and one-way analysis of variance were similar. Variation found was well within the bounds of statistical uncertainty. Because of this similarity in results, only the one-way ANOVA results are presented here. The compiled F-value for each of the candidate dependent variables is listed in Table 93. The larger the value of F, the greater the dependence of the variable on changes in delineation treatment. The general conclusions are:

1. Overall, there is a wide variation in the computed F-value for different dependent variable choices.

2. For tangent and horizontal curve sites, the accident rate and severity index computed from all accidents have the largest F-values within their respective accident rate and severity index categories. Between the rate and severity index, the former has greater sensitivity for the horizontal curve sites whereas the latter is more sensitive for tangent sites.

3. For winding sites, wet pavement non-intersection accident rate and severity index have the highest F-value within their respective subcategories of accident rate and severity index.

Table 93. F-value for candidate dependent variables.

		ALL ACCIDENTS								DELINEATION RELATED ACCIDENTS ONLY							
		INTERSECTION + NON-INTERSECTION				NON-INTERSECTION				INTERSECTION + NON-INTERSECTION				NON-INTERSECTION			
		ALL ACCIDENTS	NIGHTTIME	WET PAVEMENT	NIGHTTIME AND WET PAVEMENT	ALL NON-INTERSECTION ACCIDENTS	NIGHTTIME	WET PAVEMENT	NIGHTTIME AND WET PAVEMENT	ALL DELINEATION RELATED ACCIDENTS	NIGHTTIME	WET PAVEMENT	NIGHTTIME AND WET PAVEMENT	ALL DELINEATION RELATED NON-INTERSECTION ACCIDENTS	NIGHTTIME	WET PAVEMENT	NIGHTTIME AND WET PAVEMENT
TANGENT SITES	ACCIDENT RATE	2.585	2.081	2.060	1.232	2.371	1.956	1.707	.011	1.699	1.340	1.590	1.095	1.902	1.305	1.503	0.964
	SEVERITY INDEX RATE	2.989	1.927	1.920	0.992	2.546	1.693	1.668	0.871	1.686	1.032	1.311	0.653	1.781	0.985	1.298	0.586
WINDING SITES	ACCIDENT RATE	1.637	0.922	2.918	1.750	1.914	.932	3.193	2.213	1.860	0.838	2.756	1.315	2.261	0.963	3.051	1.601
	SEVERITY INDEX RATE	2.856	1.144	3.543	2.213	3.236	1.221	3.939	2.725	3.002	0.967	3.299	1.631	3.444	1.097	3.649	1.905
HORIZONTAL CURVES	ACCIDENT RATE	1.985	0.454	1.489	1.273	1.161	0.250	1.464	1.473	1.547	0.115	0.918	1.695	0.692	.094	0.668	1.593
	SEVERITY INDEX RATE	1.700	0.277	1.194	1.355	1.099	0.173	0.967	1.368	1.306	0.075	0.755	1.520	0.789	0.099	0.450	1.331

Prior to making the final selection of alternative dependent variables, the distribution of accidents within various choices was also computed. This was to insure that the chosen alternative dependent variables would have adequate accident statistics available to provide statistically meaningful results. This distribution of accidents is presented in Table 94.

The alternative dependent variables chosen for further analysis are listed below.

1. Accident rate based upon wet pavement non-intersection accidents.
2. Severity index based upon wet pavement non-intersection accidents.
3. Severity index based upon all accidents.

The final choice, although somewhat subjective, responds to the study needs. The analysis described within this section established a need for choosing a dependent variable (or variables) which would bring out the effect of delineation treatment variation on changes in accident severity. The choice, then, obviously lies with the wet non-intersection accident rate and the wet non-intersection severity index. These two variables have the highest associated F-values within their respective categories of accident rate and severity index. Severity index based upon all accidents was chosen because of the large associated accident data base. As will become obvious in the next section, however, the time and resource constraints did not allow for as comprehensive an analysis with these alternative dependent variables as was conducted with accident rate as the dependent variable.

Table C-94. Distribution of accidents under various categories.

ACCIDENT STATISTICS								
HORIZONTAL CURVES		WINDING		TANGENT				
TOTAL NUMBER OF ACCIDENTS	PERCENT	TOTAL NUMBER OF ACCIDENTS	PERCENT	TOTAL NUMBER OF ACCIDENTS	PERCENT			
549	100.0	3,774	100.0	6,262	100.0	ALL ACCIDENTS	INTERSECTION + NON-INTERSECTION	ALL ACCIDENTS
281	51.2	1,674	44.4	2,886	46.1	NIGHTTIME		
94	17.1	752	19.9	782	12.5	WET PAVEMENT		
52	9.5	350	9.3	376	6.0	NIGHTTIME AND WET PAVEMENT		
490	89.3	3,499	92.7	5,260	84.0	ALL NON-INTERSECTION ACCIDENTS	NON INTERSECTION	
253	46.1	1,595	42.3	2,589	41.3	NIGHTTIME		
81	14.8	700	18.5	649	10.4	WET PAVEMENT		
45	8.2	329	8.7	333	5.3	NIGHTTIME AND WET PAVEMENT		
443	80.7	3,098	82.1	4,886	78.0	ALL DELINEATION RELATED ACCIDENTS	INTERSECTION + NON-INTERSECTION	DELINEATION RELATED ACCIDENTS ONLY
226	41.2	1,340	35.5	2,115	33.8	NIGHTTIME		
73	13.3	642	17.0	651	10.4	WET PAVEMENT		
41	7.5	291	7.7	293	4.7	NIGHTTIME AND WET PAVEMENT		
395	71.9	2,865	75.9	4,017	64.1	ALL DELINEATION RELATED NON-INTERSECTION ACCIDENTS	NON INTERSECTION	
204	37.2	1,273	33.7	1,861	29.7	NIGHTTIME		
63	11.5	596	15.8	535	8.5	WET PAVEMENT		
36	6.6	272	7.2	257	4.1	NIGHTTIME AND WET PAVEMENT		

C.4.5 Analysis with Selected Alternative Dependent Variables

This analysis, as with accident rate as the dependent variable, can be categorized as follows:

- one-way analysis of variance and t-test
- two-way and higher order analysis of variance and co-variance analysis
- regression analysis.

Within each category the statistical analysis was identical to the one utilized with accident rate as the dependent variable, only the dependent variables were different. The alternative dependent variables chosen were:

1. wet non-intersection accident rate
2. wet non-intersection severity index
3. all accident severity index.

Due to time and resource constaints the analysis was generally restricted to the winding sites (because of the stronger dependence of accident severity on delineation treatment for such sites). The exception was one-way analysis of variance and t-test, with all accident severity index as the dependent variable, which was conducted for all site categories: general sites, tangent sites, winding sites, and horizontal curves. A brief discussion of each analysis follows.

C.4.5.1 One-Way Analysis of Variance and t-Test

The results of this analysis are presented in Tables 95 through 116. One-way ANOVA and t-tests with wet non-intersection

Table 95. One-way analysis of variance for winding sites dependent variable: wet non-intersection accident rate.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treat.	8.5529	.7615	.4683	2.2437	11
2 Paint Cl	25.3858	.4654	.4144	9.1940	55
3 RPM Cl	1.2738	.7971	.2194	.0288	2
4 Cl and El	22.8381	.5631	.3389	4.5429	41
5 Cl and Post	5.0953	.2291	.1836	.7162	22
6 Cl, El and Post	.5459	.1931	.0000	.0000	2
TOTAL	63.6919	.4789	.3863	19.7009	133

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	2.9752	5	.5950
Within Groups	16.7256	127	.1317
Total	19.7009	132	
F = 4.5183	Sig. = .0008		

*N denotes the effective number of sites which is different from the actual number of sites (refer to Section C.2).

Table 96. One-way analysis of variance for winding sites dependent variable: wet non-intersection accident rate.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treat	8.5812	.7615	.4682	2.2511	11
2 Paint Cl	25.4699	.4654	.4144	9.2245	55
4 Cl and El	22.9138	.5631	.3389	4.5580	41
5 Cl and Post	5.1122	.2291	.1836	.7186	22
Total	62.0771	.4812	.3887	19.3424	129

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	2.5903	3	.8634
Within Groups	16.7522	125	.1340
Total	19.3424	128	
F = 6.4426	Sig. = .0004		

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2).

Table 97. t-Test results for difference in mean wet non-intersection accident rate (winding sites) dependent variable - wet non-intersection accident rate.

Treatments Compared	Effective Number of Sites	Mean	Standard Deviation	Standard Error	Test for Homogenicity of Variance		Test for Significance		
					F-Value	2-Tail Prob.	T-Value	Degrees of Freedom	1-Tail Prob.
1. No Treatment	14	0.7615	0.464	0.123	1.26	0.522	2.23	17.75	0.019
2. Painted CL	68	0.4654	0.414	0.050					
2. Painted CL	61	0.4654	0.414	0.053	0	1.000	-6.27	60.21	0.000
3. RPM CL	1	0.7971	0	0					
2. & 3. CL	54	0.4749	0.413	0.056	1.48	0.203	-1.14	90.42	0.259
4. CL & EL	39	0.5631	0.339	0.054					
2. & 3. CL	55	0.4749	0.413	0.055	5.05	0.000	3.63	74.87	0.000
5. CL & Post	22	0.2291	0.184	0.039					
4. CL & EL	29	0.5631	0.340	0.062	-	-	5.95	28.91	0.000
6. CL & EL & Post	2	0.1931	0.000	0.000					

Table 98. Confidence bounds for mean wet non-intersection accident rate difference for winding sites dependent variable: wet non-intersection accident rate.

(**Number of such accidents per <u>total</u> million-vehicle-mile, not per just the wet million-vehicle-mile)**

Highway Situation	Treatment Combination	Mean No. Sites	Mean	Std. Error of the Mean	Pooled Std. Error	Deg. of Free-Dom	Mean Diff.	Confidence Bands							
								P=60		P=90		P=95		P=99	
								Dev. From Mean	Band	Dev. From Mean	Band	Dev. From Mean	Band	Dev. From Mean	Band
Winding Sites	1. No Treat.	14	.7615	.123	.133	18	.2961	±.115	.181	±.231	.065	±.279	.017	±.383	.087
	2. Paint CL	68	.4654	.050					.411		.527		.575		.679
	2. & 3. CL	55	.4549	.055	.067	75	.2458	±.0567	.1891	±.1118	.134	±.1337	.1121	±.1746	.0712
	5. CL + Post	22	.2291	.039					.3025		.3576		.3795		.4204
	4. CL + EL	29	.5631	.062	.062	29	.3700	±.0529	.3171	±.1053	.2647	±.1268	.2432	±.1709	.1991
	5. CL + EL + Post	2	.1931	.000					.4229		.4753		.4968		.5409

Table 99. One-way analysis of variance for winding sites dependent variable: wet non-intersection severity index.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treat.	107.4304	9.5652	6.5022	432.5634	11
2 Paint CL	301.7584	5.5323	5.0902	1387.3583	55
3 RPM CL	17.8726	11.1831	3.6726	8.0680	2
4 CL and EL	277.1376	6.8332	4.2618	718.4733	41
5 CL and Post	60.1585	2.7049	2.1593	99.0315	22
6 CL, EL and Post	5.8495	2.0685	0	0	3
TOTAL	770.2069	5.7910	4.8856	3150.6602	133

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	505.1657	5	101.0331
Within Groups	2645.4945	127	20.8307
Total	3150.6602	132	
F = 4.8502	Sig. = .0004		

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2)

Table 100. One-way analysis of variance for winding sites dependent variable: wet non-intersection severity index.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treat.	107.7863	9.5652	6.5011	433.9966	11
2 Paint CL	302.7582	5.5323	5.0901	1391.9549	55
4 CL and EL	278.0558	6.8332	4.2616	720.8538	41
5 CL and Post	60.3578	2.7049	2.1591	99.3596	22
TOTAL	748.9581	5.8059	4.8950	3067.0412	129

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	420.8763	3	140.2921
Within Groups	2646.1649	125	21.1693
Total	3067.0412	128	
F = 6.6271	Sig. = .0003		

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2)

Table 101. t-Test results for difference in mean wet non-intersection severity index (winding sites) dependent variable: wet non-intersection severity index.

Treatments Compared	Effective Number Of Sites	Mean	Standard Deviation	Standard Error	Test for Homogeneity Of Variance		Test for Significance		
					F-Value	2-Tail Prob.	T-Value	Degrees Of Freedom	1-Tail Prob.
1. No treatment	14	9.5652	6.437	1.710	1.61	0.210	2.22	16.71	0.020
2. Painted CL	68	5.5323	5.080	0.612					
2. Painted CL	61	5.5323	5.085	0.650	0	1.000	-8.69	60.21	0.000
3. RPM CL	1	11.1831	0	0					
2 & 3. CL	54	5.6932	5.120	0.693	1.44	0.237	-1.17	90.08	0.122
4. CL+EL	39	6.8332	4.263	0.679					
2 & 3. CL	55	5.6932	5.119	0.685	5.62	0.000	3.62	75.62	0.000
5. CL + Post	22	2.7049	2.160	0.459					
4. CL+EL	29	6.8332	4.281	0.783	--	--	6.09	28.91	0.000
6. CL+EL+Post	2	2.0685	0.000	0.000					

Table 102. Confidence bounds for mean wet non-intersection severity index (winding sites)
dependent variable: wet non-intersection severity index.

Highway Situation	Treatment Combination	Effective No. Of Sites	Mean	Standard Error Of The Mean	Pooled Standard Error	Degrees Of Freedom	Mean Difference	Confidence Bands P = 60 Dev. From Mean	Confidence Bands P = 60 Band	Confidence Bands P = 90 Dev. From Mean	Confidence Bands P = 90 Band	Confidence Bands P = 95 Dev. From Mean	Confidence Bands P = 95 Band	Confidence Bands P = 99 Dev. From Mean	Confidence Bands P = 99 Band
Winding Sites	1. No Treat	14	9.5652	1.710	1.816	17	4.0329	±1.567	2.4659	±3.160	0.8729	±3.832	0.2009	±5.263	-1.2301
	2. Paint CL	68	5.5323	0.612					5.5999		7.1929		7.8649		9.2959
	2&3. CL	55	5.6932	0.685	0.824	76	2.9883	±0.6979	2.2904	±1.3744	1.6139	±1.6439	1.3444	±2.1473	0.841
	5. CL + Post	22	2.7049	0.459					3.6862		4.6627		4.6322		5.1356
	4. CL + EL	29	6.8332	0.783	0.783	29	4.7647	±0.6687	4.096	±1.3303	3.4344	±1.6012	3.1635	±2.1579	2.6068
	6. CL+EL+Post	2	2.0685	0.000					5.4334		6.095		6.3659		6.9226

(Units = thousands of dollars per total mil.-veh.-mi; not just per the wet mil.-veh.-mil.)

Table 103. One-way analysis of variance (general sites) dependent variable: all accidents severity index.

Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 Tangent	3741.2293	18.3192	10.2073	21173.7044	204
2 Winding	2451.1350	31.5154	18.5706	26477.6122	78
TOTAL	6192.3643	21.9587	14.2997	57459.6503	282

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	9808.3337	1	9808.3337
Within Groups	47651.3166	280	170.1833
Total	57459.6503	281	
F = 57.6339	Sig. = .0000		

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2)

Table 104. One-way analysis of variance (general sites)
dependent variable: all accident severity index.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treat.	326.8702	43.4288	29.8055	5797.9879	8
2 Paint CL	1839.4752	26.5970	15.2122	15773.2617	69
3 RPM CL	232.2323	22.7005	14.3928	1912.0722	10
4 CL and EL	2054.1645	24.3628	13.3831	14922.5105	84
5 CL and Post	1562.0205	15.5128	8.8732	7849.2048	101
6 CL, EL and Post	177.6017	17.6299	12.3399	1381.7172	10
TOTAL	6192.3643	21.9587	14.2997	57459.6503	282

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	9822.8959	5	1964.5792
Within Groups	47636.7544	276	172.5969
Total	57459.6503	281	
F = 11.3825	Sig. = .0000		

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2)

Table 105. One-way analyis of variance (general sites) dependent variable: all accidents severity index.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
2 Paint Cl	1671.7945	26.5970	15.2234	14335.4216	63
4 Cl and El	1866.9134	24.3628	13.3912	13562.2222	77
5 Cl and Post	1419.6317	15.5128	8.8777	7133.6964	92
Total	4958.3395	21.4647	13.2817	40572.5294	231

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	5541.1893	2	2770.5946
Within Groups	35031.3402	228	153.6462
Total	40572.5294	230	
F = 18.0323	Sig. = .000		

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2).

Table 106. One-way analysis of variance (tangent sites) dependent variable - all accidents severity index.

Treatment Categories	Sum	Mean	Std Dev	Sum of Sq	N*
1 No Treat	31.9830	45.7250	0	0	1
2 Paint CL	668.3493	24.5828	12.4325	4047.7255	27
3 RPM CL	130.3484	19.2196	8.4946	417.2183	7
4 CL and EL	956.9572	21.6447	9.4374	3848.6263	44
5 CL and Post	839.5754	13.1234	5.7269	2065.4134	64
6 CL,EL and Post	102.3529	16.6608	13.7537	972.9415	6
Total	2729.5661	18.3192	10.2166	15448.1376	149

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	4096.2125	5	819.2425
Within Groups	11351.9251	143	79.3841
Total	15448.1376	148	
F = 10.3200 SIG. = 0			

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2).

Table 107. One-way analysis of variance (tangent sites) dependent variable - all accidents severity index.

Treatment Categories	Sum	Mean	Std Dev	Sum of Sq	N*
2 Paint CL	617.1270	24.5828	12.4522	3737.5076	25
4 CL and EL	883.6159	21.6447	9.4464	3553.6674	41
5 CL and Post	775.2303	13.1234	5.7307	1907.1200	59
Total	2275.9732	18.2078	9.9303	12227.8341	125

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	3029.5390	2	1514.7695
Within Groups	9198.2951	122	75.3959
Total	12227.8341	124	
F = 20.0909 SIG. = .0000			

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2).

Table 108. One-way analysis of variance (winding sites) dependent variable: all accident severity index.

Treatment Categories		Sum	Mean	Std. Dev.	Sum of Sq.	N*
1	No Treat	483.9987	43.0936	30.1199	9281.9221	11
2	Paint Cl	1579.0770	28.9501	17.7790	16925.1660	55
3	RPM Cl	91.6115	57.3225	17.5155	183.5160	2
4	Cl and El	1269.7548	31.3076	18.6615	13775.8534	41
5	Cl and Post	703.2920	31.6220	9.5909	1953.8191	22
6	Cl, El and Post	63.8079	22.5644	0	0	3
	Total	4191.5419	31.5154	18.5206	45277.8089	133

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	3157.5322	5	631.5064
Within Groups	42120.2767	127	331.6557
Total	45277.8089	132	
F = 1.9041	Sig. = .0981		

*N denotes the effective number of sites which is different from the actual number of sites (refer to Section C.2).

Table 109. One-way analysis of variance (winding sites) dependent variable: all accident severity index.

Treatment Categories	Sum	Mean	Std. Dev.	Sum of Sq.	N*
1 No Treat	485.6023	43.0936	30.1150	9312.6751	11
2 Paint Cl	1584.3088	28.9501	17.7785	16981.2427	55
4 Cl and El	1273.9618	31.3076	18.6607	13821.4957	41
5 Cl and Post	705.6221	31.6220	9.5901	1960.2925	22
Total	4049.4950	31.3914	18.5292	43946.4734	129

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	1870.7673	3	623.5891
Within Groups	42075.7061	125	336.6056
Total	43946.4734	128	
F = 1.8526	Sig. = .1411		

*N denotes the effective number of sites which is different from the actual number of sites (refer to Section C.2).

Table 110. One-way analysis of variance (horizontal curves) dependent variable: all accidents severity index.

Treatment Categories	Sum	Mean	Std Dev	Sum of Sq	N*
11 No Treat	123.0556	26.0097	18.8423	1324.6763	5
12 CL	538.4707	14.2660	15.8664	9250.3058	38
13 Guardrails	102.0269	26.3886	21.6792	1347.1280	4
14 CL and EL	596.9006	15.7363	11.4473	4839.5019	38
15 CL and Post	680.9427	20.4833	14.5638	6839.0105	33
16 CL,EL and Post	265.8383	11.3208	11.7466	3102.1501	23
Total	2307.2348	16.3634	14.3611	28873.9414	141

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	2171.1689	5	434.2338
Within Groups	26702.7725	135	197.7983
Total	28873.9414	140	
F = 2.1953 SIG. = .0583			

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2).

Table 111. One-way analysis of variance (horizontal curves) dependent variable: all accidents severity index.

Treatment Categories	Sum	Mean	Std Dev	Sum of Sq	N*
12 CL	516.4989	14.2660	15.8756	8872.8549	36
14 CL and EL	572.5446	15.7363	11.4539	4642.0302	36
15 CL and Post	653.1574	20.4833	14.5734	6559.9504	32
16 CL,EL and Post	254.9910	11.3208	11.7577	2975.5695	23
Total	1997.1919	15.7259	13.8834	24286.3653	127

	Sum of Squares	Degrees of Freedom	Mean Square
Between Groups	1235.9603	3	411.9868
Within Groups	23050.4050	123	187.4017
Total	24286.3653	126	
F = 2.1984 SIG. = .0916			

*N denotes the effective number of sites which is different from the actual number of sites (refer Section C.2).

Table 112. t-Test results for difference in mean all accidents severity index (general sites). Dependent variable - all accidents severity index.

TREATMENT COMPARED	EFFECTIVE NUMBER OF SITES	MEAN	STANDARD DEVIATION	STANDARD ERROR	TEST FOR HOMOGENEITY OF VARIANCE		TEST FOR SIGNIFICANCE		
					F-VALUE	2-TAIL PROBABILITY	T-VALUE	DEGREES OF FREEDOM	1-TAIL PROBABILITY
1. NO TREATMENT	13	43.4288	28.866	7.930	3.62	0.000	2.09	13.00	0.028
2. PAINTED CL	121	26.5970	15.164	1.374					
2. PAINTED CL	100	26.5970	15.178	1.516	1.15	0.814	0.98	18.84	0.170
3. RPM CL	14	22.7005	14.157	3.678					
2 and 3. CL	96	26.0949	15.061	1.537	1.27	0.239	0.85	189.94	0.197
4. CL AND EL	101	24.3628	13.369	1.324					
2 and 3. CL	70	26.0949	15.090	1.802	2.89	0.000	5.20	105.77	0.00
5. CL AND POST	88	15.5128	8.879	0.942					
4. CL AND EL	82	24.3628	13.385	1.477	1.17	0.858	1.60	11.44	0.069
6. CL, EL AND POST	9	17.6299	12.358	3.944					

Table 113. t-Test results for difference in mean all accidents severity index (tangent sites) dependent variable - all accidents severity index.

TREATMENTS COMPARED	EFFECTIVE NUMBER OF SITES	MEAN	STANDARD DEVIATION	STANDARD ERROR	TEST FOR HOMOGENEITY OF VARIANCE		TEST FOR SIGNIFICANCE		
					F-VALUE	2-TAIL PROBABILITY	T-VALUE	DEGREES OF FREEDOM	1-TAIL PROBABILITY
1. NO TREATMENT	1	45.7250	0	0	0	1.000	12.21	49.70	0.000
2. PAINTED CL	50	24.5828	12.324	1.731					
2. PAINTED CL	41	24.5828	12.351	1.915	2.24	0.197	1.68	21.27	0.054
3. RPM CL	10	19.2196	8.251	2.561					
2 and 3. CL	45	23.5120	11.795	1.755	1.57	0.107	0.87	82.84	0.193
4. CL AND EL	58	21.6447	9.410	1.227					
2 and 3. CL	28	23.5120	11.795	2.241	4.29	0.000	4.37	33.95	0.000
5. CL AND POST	52	13.1234	5.736	0.789					
4. CL AND EL	52	21.6447	9.420	1.298	2.07	0.146	0.96	7.19	0.367
6. CL, EL AND POST	7	16.6608	13.544	5.006					

Table 114. t-Test results for difference in mean all accidents severity index (winding sites).

TREATMENTS COMPARED	EFFECTIVE NUMBER OF SITES	MEAN	STANDARD DEVIATION	STANDARD ERROR	TEST FOR HOMOGENEITY OF VARIANCE		TEST FOR SIGNIFICANCE		
					F-VALUE	2-TAIL PROBABILITY	T-VALUE	DEGREES OF FREEDOM	1-TAIL PROBABILITY
1. NO TREATMENT	14	43.0936	29.819	7.921	2.82	0.005	1.72	15.15	0.052
2. PAINTED CL	68	28.9501	17.745	2.139					
2. PAINTED CL	61	28.9501	17.761	2.270	0	1.000	-12.50	60.21	0.000
3. RPM CL	1	57.3225	0	0					
2 and 3. CL	54	20.7578	18.251	2.471	1.05	0.867	-0.40	81.83	0.345
4. CL AND EL	39	31.3076	18.668	2.973					
2 and 3. CL	55	29.7578	18.247	2.441	3.62	0.002	- 0.59	69.86	0.280
4. CL AND POST	22	31.6220	9.592	2.039					
4. CL AND EL	29	31.3076	18.746	3.427	--	--	2.55	28.91	0.008
6. CL, EL AND POST	2	22.5644	0.000	0.000					

Table 115. t-Test results for difference in mean all accidents severity index (horizontal curves).

TREATMENTS COMPARED	EFFECTIVE NUMBER OF SITES	MEAN	STANDARD DEVIATION	STANDARD ERROR	TEST FOR HOMOGENEITY OF VARIANCE		TEST FOR SIGNIFICANCE		
					F-VALUE	2-TAIL PROBABILITY	T-VALUE	DEGREES OF FREEDOM	1-TAIL PROBABILITY
11. NO TREATMENT	6	26.0097	18.119	6.951	1.31	0.534	1.61	6.94	0.075
12. CL	54	14.2660	15.801	2.146					
12. CL	41	14.2660	15.847	2.463	1.92	0.040	-0.48	73.47	0.314
14. CL AND EL	41	15.7363	11.434	1.773					
12. CL	43	14.2660	15.840	2.414	1.19	0.598	-1.84	78.86	0.035
15. CL AND POST	37	20.4833	14.536	2.360					
14. CL AND EL	28	15.7363	11.500	2.157	1.06	0.870	1.24	34.51	0.111
16. CL, EL AND POST	17	11.3208	11.835	2.822					

Table 116. Confidence bands for all accidents severity index differences for general sites.

HIGHWAY SITUATION	TREATMENT COMBINATION	EFFECTIVE NO. OF SITES	MEAN	STANDARD ERROR OF THE MEAN	POOLED STANDARD ERROR	DEGREES OF FREEDOM	MEAN DIFFERENCE	CONFIDENCE BANDS P=60 DEV. FROM MEAN	P=60 BAND	P=90 DEV. FROM MEAN	P=90 BAND	P=95 DEV. FROM MEAN	P=95 BAND	P=99 DEV. FROM MEAN	P=99 BAND
GENERAL SITES	1. NO TREATMENT	13	43.4288	7.93	8.048	13	16.8318	±7.002	9.8298	±14.253	2.5788	±17.384	- .5522	±24.240	-7.4082
	2. PAINT CL	121	26.5970	1.374					23.8338		31.0848		34.2158		41.0718
	2 and 3. CL	70	26.0949	1.802	2.033	106	10.5821	±1.718	8.8641	± 3.371	7.2111	± 4.025	6.5571	± 5.320	5.2621
	5. CL AND POST	88	15.5128	.942					12.3001		13.9531		14.6071		15.9021
TANGENT SITES	1. NO TREATMENT	1	45.725	0	1.731	50	21.1422	±1.471	19.6712	± 2.905	18.2372	± 3.479	17.6632	± 4.642	16.5002
	2. PAINT CL	50	24.5828	1.731					22.6132		24.0472		24.6212		25.7842
	2 and 3. CL	28	23.512	2.241	2.376	34	10.3886	±2.027	8.3616	± 4.020	6.3686	± 4.833	5.5556	± 6.491	3.8976
	5. CL AND POST	52	13.1234	.789					12.4156		14.4086		15.2216		16.8796
WINDING SITES	4. CL AND EL	29	31.3076	3.427	3.427	29	8.7432	±2.927	5.8162	± 5.822	2.9212	± 7.008	1.7352	± 9.445	- .7018
	6. CL, EL AND POST	2	22.5644	0.00					11.6702		14.5652		15.7512		18.1882
WINDING SITE SIGNIFICANCE AT α = .0525 (1-TAIL)	1. NO TREATMENT	14	43.0936	7.921	8.205	15	14.1435	±7.106	7.0375	±14.383	- .2395	±17.485	-3.3415	±24.180	-10.0365
	2. PAINT CL	68	28.9501	2.139					21.2495		28.5265		31.6285		38.3235

(Units = Thousands of dollars per million vehicle mile ($1,000/MVkm)).

accident rate as the dependent variable were only conducted for winding sites. Tables 95 and 96 present one-way ANOVA results. Table 96 was obtained by deleting a few treatment categories (from Table 95) for which only a small number of effective sites were available. The t-test results are presented in Table 97. Confidence limits for mean difference are presented in Table 98. These limits were only obtained for treatment pairs which had different means at 0.05 level of statistical significance.

Tables 99 through 102 are similar to Tables 95 through 98 except that the dependent variable is wet non-intersection accident severity index.

Tables 103 through 116 relate to all accident severity index as the independent variable. For independent variable, a separate analysis for each of the following sites was conducted: (a) general sites, (b) tanget sites, (c) winding sites, and (d) horizontal curves. Tables 103 through 111 present the results of one-way ANOVA. t-Test results are presented in Tables 112 through 115. Confidence bands for statistically significant differences in the mean (at 0.05 level of significance) are computed in Table 116.

C.4.5.2 Analysis of Variance and Covariance Analysis

The results of this analysis are presented in Tables 117 through 125. The procedure followed was identical to that utilized with accident rate as the dependent variable. Because of the lack of statistical significance of results generally found with accident rate as the dependent variable, this analysis was restricted to winding sites only. Furthermore, only one dependent variable, wet non-intersection accident rate was tested. Tables 117, 120, and 123 present the

Table 117. Wet non-intersection accident rate breakdown by roadway width, shoulder width, and delineation treatment for low volume winding roads
dependent variable - wet non-intersection rate.

SITE TYPE		WINDING			
TRAFFIC VOLUME (ADT)		0 - 2000			
ROADWAY WIDTH (ft.)		16 - 18		> 18	
SHOULDER WIDTH (ft.)		< 4	≥ 4	< 4	≥ 4
NO CL	MEAN =	.8234	.6077	0	.1154
	VARIANCE =	.2264	.0942	0	1.2193
	EXPOSURE =	85.0124	14.8091	1.1390	8.6645
	NUMBER OF SITES =	11	2	0*	1
PAINT CL	MEAN =	.4329	.6031	.5994	.2980
	VARIANCE =	.1544	.2563	.2496	.0946
	EXPOSURE =	177.8778	81.2515	156.8145	117.4466
	NUMBER OF SITES =	22	10	20	15

1 ft. = 0.3048 m

*The effective number of sites was less than 0.5.

Table 118. Analysis of variance and covariance analysis results for Table 117
dependent variable.- wet non-intersection accident rate.

	Analysis of Covariance					Analysis of Variance				
SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
COVARIATES	.396	3	.132	.692	.999					
PRECIPITATION	.012	1	.012	.065	.999					
SNOW	.368	1	.368	1.928	.166					
FOG	.057	1	.057	.301	.999					
MAIN EFFECTS	1.110	3	.370	1.941	.130	1.029	3	.343	1.784	.157
TREATMENT	.336	1	.336	1.763	.186	.470	1	.470	2.442	.119
ROADWIDTH	.014	1	.014	.072	.999	.027	1	.027	.141	.999
SHOULDER WIDTH	.461	1	.461	2.417	.121	.253	1	.253	1.314	.254
2-WAY INTERACTIONS	1.367	3	.456	2.388	.075	1.182	3	.394	2.048	.113
TREAT ROADWIDTH	.155	1	.155	.812	.999	.084	1	.084	.437	.999
TREAT SHOULDER WIDTH	.107	1	.107	.558	.999	.139	1	.139	.725	.999
ROADWIDTH SHOULDER WIDTH	.875	1	.875	4.585	.034	.783	1	.783	4.072	.045
3-WAY INTERACTIONS	.097	1	.097	.511	.999	.073	1	.073	.377	.999
TREAT ROADWIDTH SHOULDER SHOULDER WIDTH	.097	1	.097	.511	.999	.073	1	.073	.377	.999
REDIDUAL	13.162	69	.191			13.849	72	.192		
TOTAL	16.132	79	.204			16.132	79	.204		

COVARIATE	BETA
PRECIP	.001
SNOW	-.014
FOG	-.003

80 cases were processed
0 cases (0 pct) were missing

Table 119. Multiple classification analysis results for Table 117.

Grand Mean = .52

Variable + Category	Unadjusted DEV*N	Unadjusted BETA	Adjusted For Independents DEV*N	Adjusted For Independents BETA	Adjusted For Independents + Covariates DEV*N	Adjusted For Independents + Covariates BETA
Treatment						
1 No Treat	.21		.18		.16	
2 Paint CL	-.04		-.04		-.03	
		.21		.18		.16
Road Width						
1 16 thru 18 ft	.05		.02		.01	
2 > 18 ft	-.06		-.02		-.02	
		.13		.04		.03
Shoulder Width						
1 < 4 ft	.05		.04		.06	
2 > 4 ft	-.10		-.08		-.11	
		.16		.13		.18
Multiple R Squared				.064		.093
Multiple R				.253		.306

1 ft = 0.3048 m

Table 120. Wet non-intersection accident rate breakdown by shoulder width, and delineation treatment for low volume, wide winding roads dependent variable - wet non-intersection rate.

	Site Type	Winding	
	Traffic Volume (ADT)	0-2000	
	Roadway Width (ft)	≥20	
	Shoulder Width (ft)	<4	≥4
CL	Mean =	.6257	.3111
	Variance =	.2315	.0975
	Exposure =	172.6176	112.5037
	Number of Sites =	16	10
CL + EL		.6109	.6523
		.1427	.1169
		109.6728	136.4400
		10	12

1 ft = 0.3048 m

Table C-121. Analysis of variance and covariance analysis for Table 120 dependent variable - wet non-intersection accident rate.

	Analysis of Covariance					Analysis of Variance				
Source of Variation	Sum Of Squares	DF	Mean Square	F	Signif. Of F	Sum Of Squares	DF	Mean Square	F	Signif. Of F
Covariates	.386	3	.129	.800	.999	.460	2	.230	1.438	.247
Precip	.241	1	.241	1.495	.227	.251	1	.251	1.569	.215
Snow	.033	1	.033	.208	.999	.282	1	.282	1.766	.188
Fog	.157	1	.157	.973	.999					
Main Effects	.392	2	.196	1.218	.306	.368	1	.368	2.302	.133
Swidth	.288	1	.288	1.789	.186	.368	1	.368	2.302	.133
Eltreat	.179	1	.179	1.110	.299	6.869	43	.160		
2-Way Interactions	.478	1	.478	2.971	.089	7.696	46	.167		
Swidth Eltreat	.478	1	.478	2.971	.089					
Residual	6.439	40	.161							
Total	7.696	46	.167							

Covariate	Beta
Precip	.003
Snow	-.003
Fog	.005

48 cases were processed.
0 cases (0 PCT) were missing.

Table 122. Multiple classification analysis results for Table 120.

GRAND MEAN = .56						
VARIABLE & CATEGORY	UNADJUSTED DEV*N	ETA	ADJUSTED FOR INDEPENDENTS DEV*N	BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV*N	BETA
SWIDTH						
1 < 4 FT	.06		.07		.08	
2 ≥ 4 FT	-.06		-.08		-.09	
		.15		.18		.20
ELTREAT						
1 CL BUT NO EL	-.06		-.07		-.06	
2 CL AND EL	.07		.08		.07	
		.16		.19		.16
MULTIPLE R SQUARED				.060		.101
MULTIPLE R				.244		.318

1 ft = 0.3048 m

Table 123. Wet non-intersection rate by traffic volume and delineation treatment for wide winding roads with wide shoulders. Dependent variable: Wet non-intersection rate. Common delineation treatment: Centerline

SITE TYPE		WINDING			
		ROADWAY WIDTH ≥ 20 ft.			
		SHOULDER WIDTH ≥ 4 ft.			
TRAFFIC VOLUME (ADT)		0 - 2000		2000 - 5000	
		NO EL	EL	NO EL	EL
NO POSTS	MEAN =	.3111	.6523	.3807	.6718
	VARIANCE =	.1009	.1202	0	.0003
	EXPOSURE =	112.5037	136.4400	42.0329	41.6817
	NUMBER OF SITES =	8	9	3	3
POSTS	MEAN =	.3241			.1931
	VARIANCE =	.0766			0
	EXPOSURE =	55.5307	0	0	31.0789
	NUMBER OF SITES =	4			2

1 ft = 0.3048 m

Table 124. Analysis of variance and covariance analysis results for Table 123
dependent variable: wet non-intersection accident rate.

	ANALYSIS OF COVARIANCE					ANALYSIS OF VARIANCE				
SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFI-CANCE OF F	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIFI-CANCE OF F
COVARIATES	.421	3	.140	1.465	.252	.670	3	.223	2.504	.082
PRECIPITATION	.364	1	.364	3.805	.062	.021	1	.021	.232	.999
SNOW	.076	1	.076	.790	.999	.422	1	.422	4.734	.038
FOG	.060	1	.060	.630	.999	.145	1	.145	1.621	.213
MAIN EFFECTS	.379	3	.126	1.321	.294	2.140	24	.089		
TRAFFIC VOLUME	.003	1	.003	.035	.999					
EL TREATMENT	.277	1	.277	2.892	.100	2.810	27	.104		
POST TREATMENT	.056	1	.056	.581	.999					
RESIDUAL	2.010	21	.096							
TOTAL	2.810	27	.104							

COVARIATE	BETA
PRECIPITATION	.005
SNOW	-.011
FOG	-.006

31 Cases were processed.
2 Cases (7.4 Pct.) were missing.

Table 125. Multiple Classification Analysis Results for Table 123.

GRAND MEAN = .46						
VARIABLE & CATEGORY	UNADJUSTED DEV*N	UNADJUSTED ETA	ADJUSTED FOR INDEPENDENTS DEV*N	ADJUSTED FOR INDEPENDENTS BETA	ADJUSTED FOR INDEPENDENTS + COVARIATES DEV*N	ADJUSTED FOR INDEPENDENTS + COVARIATES BETA
TRAFVOL						
1 0 to 2000 ADT	.01		.02		.01	
2 2000 TO 5000 ADT	-.02		-.04		-.02	
		.04		.09		.04
ELTREAT						
0 NO EL	-.13		-.12		-.10	
1 EL	.13		.12		.10	
		.42		.40		.34
PIREAT						
0 NO POSTS	.05		.04		.04	
1 POSTS	-.18		-.14		-.16	
		.30		.23		.26
MULTIPLE R SQUARED				.238		.285
MULTIPLE R				.488		.534

factorial designs. The corresponding analysis of variance and covariance analysis results are listed in Tables 118, 121 and 124. The corresponding multiple classification analysis results are included in Tables 119, 122, and 125.

C.4.5.3 Regression Analysis

The results of this analysis are presented in Tables 126 through 128. Regression models for various subclasses of winding sites were developed only for wet non-intersection accident rate dependent variables. These are contained in Table 126. The subclasses are similar to those utilized in the case of accident rate. For the other two dependent variables, wet non-intersection severity index and all accidents severity index, only models corresponding to all winding sites were developed. These are presented in Tables 127 and 128, respectively.

C.5 BEFORE-AFTER ANALYSIS

Before-after analysis, for the purposes of this study, refers to the accident analysis of those test sites for which there was some major change (upgrading) in the delineation treatment. The premise in before-after analysis is that if, after taking out the effect of a trend with time, there is a significant difference in the accident rate between the "before" and "after" period, this difference was caused by the test delineation treatment. For the purposes of detecting time trends, a "matching-control site associated to a before-after site" will be defined as a site which is identical to the before-after site except that its delineation has remained unchanged. In this study, such matching-control sites were to be selected from the matching-control sites used in the matching-control analysis (described in Section C.4).

Table 126. Regression models for winding sites with wet non-intersection accident rate as dependent variable.

Highway Sites Included	F To Enter	F To Remote	Model No.	Regression Model	Multiple R	Multiple R^2	Standard Error Of Regression
All Winding Sites	1.01	1.00	W311	Wet non-intersection accident rate = 0.95816672-0.21545931 (POSTS1) (0.12939581) (0.09953076) -0.39579441 (CLW)-0.13927680 (G2) (0.13486860) (0.08453551)	0.458	0.210	0.352
	2.71	2.70	W312	Wet non-intersection accident rate = 0.95816672-0.21545931 (POSTS1) (0.12939581) (0.09953076) -0.39579441 (CLW)-0.13927680 (G2) (0.13486860) (0.08453551)	0.458	0.210	0.352
Rolling Winding Sites	1.01	1.00	W321	Wet non-intersection accident rate = 1.3414868-0.38349328 (CLW) (0.19461261) (0.15255816) -0.02348671 (SNOW)-0.00723476 (FOG) (0.00883942) (0.00376245) -0.3533958 (POSTS1) (0.21162918)	-	-	-
	2.71	2.70	W322	Wet non-intersection accident rate = 1.1163161-0.42317933 (CLW) (0.15718858) (0.15490722) -0.02193922 (SNOW) (0.00893960)	0.398	0.159	0.385
Mountain Winding Sites	1.01	1.00	W331	Wet non-intersection accident rate = 0.12890815 + 0.00846682 (FOG) (0.06189061) (0.00210779)	0.579	0.335	0.225
	2.71	2.70	W332	Same as for F = 1.01	-	-	-

Table 126. Regression models for winding sites with wet non-intersection accident rate as dependent variable (continued).

Highway Sites Included	F To Enter	F To Remove	Model No.	Regression Model	Multiple R	Multiple R^2	Standard Error Of Regression
Federal-Aid Primary Winding Sites	1.01	1.00	W341	Wet non-intersection accident rate = 0.19848882 + 0.00191001 (PRECIP) (0.16660350) (0.0017766) +0.22262834 (INTFREQ)-0.00013172 (TRAFVOL) (0.07184656) (0.00005892) +0.00516565 (FOG) (0.00362680)	0.683	0.466	0.230
	2.71	2.70	W342	Wet non-intersection accident rate = 0.13452916+0.00365938 (PRECIP) (0.16370477) (0.00130979) +0.21645892 (INTFREQ)-0.00012317 (TRAFVOL) (0.07317638) (0.00005980)	0.649	0.421	0.235
Federal-Aid Secondary Winding Sites	1.01	1.00	W351	Wet non-intersection accident rate = 1.3495858 - 0.41545553 (CLW) (0.20297078) (0.14153850) -0.29617116(G2) - 0.01863195 (SNOW) (0.13097805) (0.00916763) -0.55263248(POSTS1) - 0.00556690 (FOG) (0.23920997) (0.00355768) -0.14982238 (INTFREQ) + 0.00007034 (TRAFVOL) (0.08500382) (0.00004525)	0.537	0.289	0.380
	2.71	2.70	W352	Wet non-intersection accident rate = 1.1265465 - 0.41113320 (CLW) (0.14717829) (0.14352859) -0.24937556 (G2) -0.02229370 (SNOW) (0.11979184) (0.00903979) -0.36252366 (POSTS1) (0.21924626)	0.478	0.229	0.388

Table 127. Regression models for winding sites with wet non-intersection severity index as dependent variable.

Highway Sites Included	F to Enter	F to Remove	Model #	Regression Model	Multiple R	Multiple R^2	Standard Error of Regression
All Winding Sites	1.01	1.00	W2 11	Wet Non-intersection Severity Index = 12.119630 - 2.8530076 (Posts) -5.4289398 (CLW) -1.3696409 (G2) (1.6439529) (1.2645222) (1.7134838) (1.0740101)	0.455	0.207	4.480
	2.71	2.70	W2 12	Wet Non-intersection Severity Index = 11.931037 - 3.7251436 (Posts) -5.5349866 (CLW) (1.6420281) (1.0667109) (1.7164199)	0.441	0.195	4.492

Table 128. Regression models for winding sites with all accidents severity index as dependent variable.

HIGHWAY SITES INCLUDED	F TO RETURN	F TO REMOVE	MODEL #	REGRESSION MODEL	MULTIPLE R	MULTIPLE R^2	STANDARD ERROR OF REGRESSION
ALL WINDING SITES	1.01	1.00	W111	All Accidents Severity Index = 76.246026 - 16.44]697 (CLW) (10.620640) (6.5118262) -0.25319131 (PRECIP) - 13.735685 (POSTS1) + 0.24757451 (SNOW) (0.07606576) (5.4896669((0.22591271)	0.392	0.153	17.008
	2.71	2.70	W112	All Accidents Severity Index = 76.860280 - 16.171735 (CLW) (10.615794) (6.5132384) - 0.24656707 (PRECIP) - 12.362039 (POSTS1) (0.0758939) (5.3496672)	0.379	0.144	17.024

As stated in the introduction to this appendix, the analysis of the matching-control sites was emphasized over the analysis of the before-after sites. Difficulties had been encountered in locating suitable before-after sites with the result that a full spectrum of "before-after" delineation and site types was not found. In addition, a truly satisfactory matching-control site could not always be identified from the available data base for each before-after site. This meant that the accounting for time trends would either be impossible in some cases or not as good as one would like in other cases for a truly rigorous analysis. Besides, the pairing of before-after and matching-control sites was not a part of the site selection design or field inspection, but merely an after-the-fact effort to the data collection. Therefore, the before-after analysis was neither as extensive nor as sophisticated as the matching-control analysis. Only relatively simple analyses were warranted. The details of these analyses are presented here.

The before-after analysis proceeded in three steps. First, a final selection of before-after sites had to be made from the available data base, and associated matching-control sites had to be identified where possible. Second, the analysis approach and specific statistical tests had to be devised and tailored to the available data. Lastly, the analysis had to be carried out and the results evaluated.

C.5.1 Selection and Organization of Sites for the Before-After Analysis

As was stated in Appendix B, by the time the data tape was ready for analysis, the flag that indicated whether a site was a before-after site or a matching-control site was no longer completely valid. Too many exceptions and special cases could not be flagged in a simple way on the tape itself. Therefore, some special coding and hand analysis had to be done.

In the case of the before-after study, a visual search through the data base was conducted by hand to accomplish the following tasks:

- select final list of before-after sites
- identify associated matching-control sites where possible
- define in each case the specific delineation installation to be tested and the before-after time periods to be analyzed.

The visual search, although tedious, was not as tedious as the programming to fully automate these tasks on the computer would have been. This is particularly true of the second of these tasks, which was largely subjective. Some computer sorting was utilized to an extent, however, in the first and third tasks.

Considerations in the actual selection of the final before-after sites were as follows. First, the "before-after" change in delineation had to be a change between two of the major delineation categories defined in the matching-control analysis (no treatment, painted centerline, raised pavement marker centerline, centerline plus edgeline, centerline plus posts, centerline plus edgelines plus posts, guardrails). Second, at least one full year of accident data had to be available for a period in which it was definitely known that the "before-after" delineation was not present; and one full year of accident data for which it was definitely known that the "before-after" delineation was present. (See also definition of time period dates below.) Lastly, within the designated "before" and "after" periods, no other delineation change would be allowed. Within these guidelines, 151 out of the 514 sites on tape qualified for some sort of before-after analysis. This is in contrast to the 423 sites selected for the matching-control analysis out of the 514 on tape. Obviously some sites qualified for both types of analysis, though certainly not for the same time periods.

Considerations that went into the identification of associated matching-control sites from those available on the tape were as follows:

- The associated matching-control site should have, as nearly as possible, the identical delineation as its paired before-after site did in the latter's "before" period.
- The associated matching control site should have nearly the same climatic and geometrical configuration as did its paired before-after site.
- The matching-control site and the associated before-after site should have the same approximate level of traffic volume in the analysis periods.
- The matching-control site and the before-after site should be selected from the same state (Arizona, California,...)

Using the above considerations as guidelines for the subjective hand search, it was possible to identify matching-control sites for 49 of the 151 before-after sites. Of these 49 pairings, 18 later proved unusable, usually because no accidents occurred in the matching-control site. It should be emphasized that the pairing of matching-control sites to before-after sites was accomplished by searching through computer printouts of the data tape contents, and not by actual inspection of the sites in the field. Also, the above guidelines were not always strictly adhered to, although they were closely followed.

The selection of the "before" and "after" period dates for a given before-after site or before-after/matching-control site pair was conducted under the following ground rules.

- If the month of the "before-after" delineation installation was known, then the "before" period would have to terminate in the preceeding month, and the "after" period could start only in the following month. Thus even if the exact day of installation was known, the entire month was eliminated from analysis.
- If only the year of the "before-after" delineation installation was known, then neither the "before" period nor the "after" period could contain any part of that year -- the entire year had to be eliminated from analysis to insure that there would be no possible bias.
- The "before" analysis period must equal the "after" analysis period in length of time.
- The analysis periods must be an integral number of years so as to minimize any seasonal bias.
- The analysis periods for a site pair would have to apply equally to both the before-after site and its associated matching-control site.
- Within all of the above rules, the largest possible time periods were to be selected.

Using the above rules, appropriate analysis periods were selected, in some cases by hand, in others by computer. It should be mentioned that these analysis-time-period rules were strictly adhered to. Tables 129 and 130 present the breakdown of before-after sites selected.

C.5.2 Analysis Approach

The types of statistical tests employed in the before-after analysis naturally divided themselves into (1) those for use with

Table 129. Breakdown of sites for computerized before-after analysis (number of sites).

BA	ED	Tangent			Winding			Horizontal Curve		
		AU	NU	NA	AU	NU	NA	AU	NU	NA
RPM	CL	2	-	6	-	-	3			
	CL + EL	-	-	2	-	-	-			
	CL + Post	-	-	2	-	-	1			
	CL + EL + Post	-	-	-	-	-	-			
EL	Paint CL	7	3	3	1	1	4	3	7	40
	RPM CL	4	-	5	-	-	6	-	-	-
	Paint CL + Post	9	1	-	4	-	7	-	3	10
	RPM CL + Post	-	-	1	-	-	-	-	-	1
	Paint CL +Guardrail	-	-	-	-	-	-	-	-	1

Key: BA = Test "before-after" delineation

ED = Existing Delineation

AU = Sites for which matching-control sites were available and useable.

NU = Sites for which matching-control sites were available but not useable

NA = Sites for which matching-control sites were not available

Total: 137

Table 130. Breakdown of sites for non-computerized before-after analysis (number of sites).

BA	ED	Tangent			Winding			Horizontal Curve		
		AU	NU	NA	AU	NU	NA	AU	NU	NA
Paint CL	No Treat	-	1	-	-	-	-	1	1	3
RPM	CL + Post	-	-	-	-	-	-	-	-	1
RPM	CL + EL + Post	-	-	-	-	-	-	-	-	1
EL	Paint CL	-	-	-	-	-	-	-	-	1
EL	Paint CL + Post	-	-	-	-	-	1	-	-	-
Post	Paint CL	-	-	-	-	-	1	-	-	-
Paint CL + EL*	No Treat	-	-	-	-	-	1	-	-	2
EL + Post*	Paint CL	-	-	-	-	-	-	-	-	1
Post + Guardrail*	Paint CL	-	-	-	-	-	-	-	1	-

*Simultaneous Installation (Key same as in Table 129)

Total: 16 breakdowns involving 14 sites

before-after sites that did not have associated matching-control sites. The latter tests, of course, were applied to the first set of sites as well. The purpose of all of the tests was to detect significant differences in either the number of accidents or the accident rate between the "before" and "after" periods. If there was a significant difference, assuming little or no other time trend, then the clear inference was that the test delineation treatment caused the difference. The tests will now be described. For ease of reference they will be numbered using Roman numerals and letters.

C.5.2.1 Analysis of Before-After Sites for which Matching-Control Sites are Available

Three different kinds of tests were employed for the analysis of before-after sites for which matching-control sites were available. These were x^2 analysis, t-tests with SPSS, and "Poisson analysis". In discussing these tests, the following notation will be adopted.

- b = number of accidents occurring during the "before" period in the before-after site(s)
- a = number of accidents occurring during the "after" period in the before-after site(s)
- B = number of accidents occurring during the "before" period in the associated matching-control site(s)
- A = number of accidents occurring during the "after" period in the associated matching-control site(s).

Test Series I. x^2 Analysis

The chi-square tests in this series can be applied to individual before-after/matching-control site pairs or to groups of pairs with the same test delineation. The tests all find their justification in the following theorem.

Theorem: If $n_1, n_2, \ldots, n_r$ and $e_1, e_2, \ldots, e_r$ represent the observed and expected frequencies, respectively, for the r possible outcomes of an experiment that is performed m times, then as m becomes infinite, the distribution of the random variable

$$\sum_{i=1}^{r} \frac{(n_i = e_i)^2}{e_i}$$

will approach a chi-square distribution with r-1 degrees of freedom (see page 228 of Reference 1).

Test Ia. This test is based on the premise that the expected frequencies in the before-after sites should be directly proportional to those in their associated matching-control sites if indeed the test "before-after" delineation has no effect. In other words, the trend seen in the matching-control site is taken to be an absolute standard expected of the time trend when there is no change in delineation. Thus the possibility of a random fluctuation associated with the matching-control site is ignored. Under the null hypothesis that the test delineation has no effect, we then would expect

$$E(b) = \left(\frac{a + b}{A + B}\right) B$$

and

$$E(a) = \left(\frac{a + b}{A + B}\right) A$$

Thus using the theorem quoted above we construct the chi-square variable

$$\chi^2 = \frac{\left[b - \left(\frac{a + b}{A + B}\right) B \right]^2}{\left(\frac{a + b}{A + B}\right) B} + \frac{\left[a - \left(\frac{a + b}{A + B}\right) \right]^2}{\frac{a + b}{A + B} \; A}$$

degrees of freedom = 1

After some algebra, the above reduces to

$$\chi^2 = \frac{\left(a - b \cdot \frac{A}{B}\right)^2}{\frac{A}{B} \cdot (a + b)} \quad ; \qquad \text{degrees of freedom} = 1$$

Given a desired significance level, the critical value for a chi-square variable with one degree of freedom can be determined from a chi-square table. Then, if the computed χ^2 exceeds this critical value, the deviation of the observed "before" and "after" frequencies from those expected would be deemed "significant." In such a case the null hypothesis is rejected, which in turn means that the test delineation would be deemed to have a significant effect on the number of accidents.

<u>Test Ib</u>. This test is identical to Ia. save that Yates' continuity correction is applied; namely, we have

$$\chi^2 = \frac{\left[\left| b - \left(\frac{a + b}{A + B}\right) B \right| - 0.5\right]^2}{\left(\frac{a + b}{A + B}\right) B} + \frac{\left[\left| a - \left(\frac{a + b}{A + B}\right) A \right| - 0.5\right]^2}{\left(\frac{a + b}{A + B}\right) A}$$

degrees of freedom = 1

Now we are really only interested in the case where

$$a < E(a) = \left(\frac{a + b}{A + B}\right) A$$

$$b > E(b) = \left(\frac{a + b}{A + B}\right) B$$

This enables us to determine the proper sign for the quantities in absolute value bars. Then, after much algebra, the Yates' corrected expression for this case is

$$\chi^2 = \frac{\left(a - b \cdot \frac{A}{B} + \frac{A + B}{2B}\right)^2}{\frac{A}{B} \cdot (a + b)} \quad ; \qquad \text{degrees of freedom} = 1$$

<u>Test Ic</u>. This test is based on applying the chi-square theorem to the following contingency table.

Table 131. Contingency table for before-after analysis

	Before-after site	Matching-Control site	
Before Period	b	B	b + B
After Period	a	A	a + a
	a + b	A + B	n=a+b+A+B

Assuming that the expected table frequencies are equal to the products of the marginals, we have

$$\chi^2 = \frac{\left[b - \frac{(a + b)\ (b + B)}{n}\right]^2}{\frac{(a + b)(b + B)}{n}} + \frac{\left[B - \frac{(A + B)(b + B)}{n}\right]^2}{\frac{(A + B)(b + B)}{n}}$$

$$+ \frac{\left[a - \frac{(a + b)(a + A)}{n}\right]^2}{\frac{(a + b)(a + A)}{n}} + \frac{\left[A - \frac{(A + B)(a + A)}{n}\right]^2}{\frac{(A + B)(a + A)}{n}}$$

degrees of freedom = 3

This expression reduces to

$$\chi^2 = \frac{(aB - AB)^2\ (a + b + A + B}{(b + B)\ (a + b)\ (a + A)\ (A + B)}\ ;$$

degrees of freedom = 3.

The benefit of this χ^2 test over the two preceding tests is that random fluctuations associated with the matching-control sites are included. The null hypothesis here is that the row categories of Table 131 are independent of the column categories; in other words, the comparision of the number of "before" accidents to the number of "after" accidents is independent of whether the site is a before-after site or a matching-control site. Thus again, if the computed χ^2 exceeds the value in a chi-square table of the desired significance and appropriate degrees of freedom, then the null hypothesis is rejected - before-to-after comparison is not independent of whether the site is before-after or matching-control.

Some additional remarks are appropriate to tests associated with Table 131. First, the number of degrees of freedom to the x^2 expression has been given as 3, under the assumption that the expected table frequencies are exactly equal to the products of the marginals. If one wishes to account for the fact that the products of the marginals are really only estimates of the individual table cell frequencies, then the number of degrees of freedom must be reduced to

$$(2-1) \times (2-1) = 1$$ (see page 235 of Reference 1)

Second, often more exact methods such as Fisher's exact test are preferred in the analysis of small contingency tables. However, in this study the quality of the data did not warrant further investigation beyond the rudimentary levels described here.

Final Remarks to Series I Tests in General: (1) In each of the above tests it has been assumed that the quanitites A, B, and a + b are all non-zero. If any are zero, then the matching-control site paired to a before-after site is not usable in the x^2 analysis, as the formulas given above become undefined. (Thus 18 of the originally paired 49 matching-control sites were not usable.)

(2) The computed x^2 values using the above expressions do not differentiate between cases where a is significantly smaller than E(a) vs. a being significantly larger than E(a), and similarly for b. In other words, the direction of the trend is not included. This must be kept in mind in the construction of the null and alternative hypotheses to be tested, and in the selection of the appropriate significance level.

For example, in testing

$H_0 : \; a = E(a)$ and $b = E(b)$
$H_1 : \; a < E(a)$ and $b > E(b)$

with test Ia, the 95% confidence level would correspond to the .10 entry in the chi-square table (Table 132). However, for

$H_0 : \; a = E(a)$ and $b = E(b)$
$H_1 : \; a \neq E(a)$ and $b \neq E(b)$

(i.e., "$a < E(a)$ and $b > E(b)$" *or* "$a > E(a)$ and $b < E(b)$")

then the .05 entry would be appropriate.

Table 132. Portion of a chi-square table (page 392 of Reference 1).

Degrees of Freedom	p = 0.10	0.05	0.02	0.01
1	2.706	3.841	5.412	6.635
2	4.605	5.991	7.824	9.210
3	6.251	7.815	9.837	11.341

<u>Test Series II. t-Tests with SPSS</u>

<u>Test IIa.</u> For a given before-after/matching-control site pair construct

$$z = (\hat{\lambda}_\beta - \hat{\lambda}_\alpha) - (\hat{\lambda}_B - \hat{\lambda}_A)$$

where

$\hat{\lambda}_b$ = computed before accident rate for the before-after site

$\hat{\lambda}_a$ = computed after accident rate for the before-after site

$\hat{\lambda}_B$ = computed before accident rate for the associated matching control site

$\hat{\lambda}_A$ = computed after accident rate for the associated matching control site

The idea, then, is to test to see whether or not the statistic $\bar{z}$ is significantly different from zero for a set of before-after/matching-control site pairs that have the same test delineation.

In order to perform this test with SPSS, the hypotheses had to be formulated as:

$$H_o: \overline{(\hat{\lambda}_b - \hat{\lambda}_a)} = \overline{(\hat{\lambda}_B - \hat{\lambda}_A)}$$

$$H_1: \overline{(\hat{\lambda}_b - \hat{\lambda}_a)} > \overline{(\hat{\lambda}_B - \hat{\lambda}_A)}$$

where, of course, the bar denotes the sample mean (of the difference in estimated (observed) rates). The "correlated t-test" had to be used.

To compute t for paired samples, the paired difference variable $D = X_1 - X_2$ is formed, where X_1 is the measurement before treatment and X_2 the measurement after. D is normally distributed with mean δ. The sample mean and variance ($\bar{d}$ and $s_{\bar{d}}^2$) are computed, and then

$$t = \frac{\bar{d} - \delta}{s_{\bar{d}}}$$

df = n-1 where n is the number of pairs, and

$$s_{\bar{d}} = \sqrt{\left(s_1^2 + s_2^2 - \frac{2\Sigma x_1 x_2}{n-1}\right) \Big/ n}$$

$(\Sigma X_{1i} X_{2i})/(n-1)$ is the covariance between X_1 and X_2.

If pairing were not used, the denominator in the t calculation would be $\sqrt{(s_1^2 + s_2^2)/n}$, with 2n-2 degrees of freedom; therefore, the improvement to t made by pairing, which has to compensate for the reduced degrees of freedom, is dependent on the covariance of X_1 and X_2. Since the covariance is proportional to the correlation coefficient, this is sometimes called a correlated t. The correlation between X_1 and X_2 must be positive for pairing to be effective. (See pages 270-271 in Reference 3.)

Test IIb. Construct the expected number of after accidents as follows:

$$a^* = \frac{A}{B} \cdot b$$

Then use the correlated t-test to test

H_0: $a = a^*$

H_1: $a > a^*$

using SPSS.

General remarks concerning Test Series II: Weighting with SPSS

In accordance with the general weighting discussion in section C-2-2 of this appendix, the following weighting for the ith site was used:

$$wt_i = \frac{(\phi_b + \phi_a)_i}{\sum_{i=1}^{k} (\phi_b + \phi_a)_i} \cdot k$$

where

ϕ_b = before period exposure

ϕ_a = after period exposure

$(\phi_b + \phi_a)_i$ = sum of before and after period exposures of the ith site

k = number of before-after sites in the group of sites to be analyzed.

Test III. Comparison to the Possion Distribution

Let a* be defined as above. Then, in accordance with the original modeling in the first part of this appendix, assume that the "after" number of accidents are Poisson distributed with mean and variance a*. Then if the probability P ["after"< a ; a*] is sufficiently small, the observed a can be deemed significantly less than the expected a*.

Specifically, let a level of significance α be specified. Then given a*, find the biggest interger a_p such that

$$\sum_{n=0}^{a_p} \frac{e^{-a^*} \cdot (a^*)^n}{n!} \leq \alpha$$

Note that if $e^{-a^*} > \alpha$, then no a_p will work, in that case we will define $a_p = -1$. Likewise if $a^* = 0$, define $a_p = -9$ say. So finally, if

$$a < a_p$$

then the result is deemed significant at the α level. In this study α = .05 was chosen.

C.5.2.2 Analysis of Before-After Sites for which Matching-Control Sites are not Available

If associated matching-control sites are not available, only some relatively simple comparisons can be made with the before-after site data. In this study two tests were defined, here labeled IV and V.

Test IV. Simple t-Test of Before-and-After Accident Rate.

This test is almost identical to IIa., except that $\hat{\lambda}_B$ and $\hat{\lambda}_A$ are not available. Using the SPSS paired t-test, the average value of $\hat{\lambda}_b$ is compared against the average value of $\hat{\lambda}_a$ for a set of sites that have the same test delineation.

Test V. Rudimentary Interval Comparison

This last test is a very crude comparison tool designed for hand analysis of test delineations for which just one or a small number of sites were available. Suppose we have a particular before-after site. Let ϕ_b and ϕ_a be the exposures in the before and after periods, respectively. Focus, for the moment, on the before period, say. Now in accordance with the original Poisson model, we have

$$\hat{\lambda}_b = \frac{b}{\phi_b}$$

and

$$\text{Var } \hat{\lambda}_b = \frac{\hat{\lambda}_b}{\phi_b}$$

Then with the idea of mimicing the $\pm 2\sigma$ levels of a normal distribution, which encompass 95% of the distribution, we define the interval

$$I_b = \left(\hat{\lambda}_b - 2\sqrt{\frac{\hat{\lambda}_b}{\phi_b}} \, , \ \hat{\lambda}_b + 2\sqrt{\frac{\hat{\lambda}_b}{\phi_b}} \right)$$

A similar interval for I_a is defined. Then if I_b and I_a do not overlap, and if $I_a < I_b$, then the reduction in number of accidents is deemed "significant." The confidence level for this test is assumed to be "somewhere around 95%." It would have been possible to define the intervals I_b and I_a using the exact Poisson model, and hence have exact confidence levels. However, for the purposes of easy hand analysis and in light of the quality of the data, the added effort using the exact Poisson formulation was not worth while.

C.5.3 Before-After Analysis Results

After a careful inspection of the breakdowns for various categories of before-after sites (Table 129), the following organization of calculations to be made was developed.

Calculation Matrix

I. Before-After Sites With Matching-Control Sites -- Test Delineation = Edgelines
   A. Tangent Sites
      1. those with painted centerline only in before period
      2. those with RPM centerline only in before period
      3. those with any centerline only in before period
      4. those with centerline and posts in before period
      5. all
   B. Winding Sites - all
   C. Horizontal Curves - those with painted centerline only in before period

II. Before-After Sites With no Matching-Control Sites -- Test Delineation = Raised Pavement Marker Centerline (RPM)
   A. Tangent sites - all
   B. Winding sites - all

III. Before-After Analysis With no Matching-Control Sites Considered -- Test Delineation = Edgelines

A. Tangent Sites
   1. those with painted centerline only in before period
   2. those with RPM centerline only in before period
   3. those with any centerline only in before period
   4. those with centerline and posts in before period
   5. all

B. Winding Sites
   1. those with painted centerline only in before period
   2. those with RPM centerline only in before period
   3. those with any centerline only in before period
   4. those with centerline and posts in before period
   5. all

C. Horizontal Curves
   1. those with painted centerline only in before period
   2. those with centerline and posts or guardrails in before period
   3. all

IV. Individual Hand Analysis on the Non-Computer Sites.

The hand analysis on the non-computerized sites results in no significant results whatsoever. The remaining calculations in the above matrix outline were performed on the computer. The results of these calculations are given in Tables 133 through 143.

An inspection of the results involving matching-control sites (Tables 133 through 135) reveals the following. The only significant result appears to be for the installation of edgelines to tangent sites with centerlines and posts. The chi-square tests were significant as was the Poisson analysis ($a = 105 < a_p = 125$). The t-tests for this grouping, however, are somewhat dubious since the pairing correlation

Table 133. Before-after/matching control site pair analysis results not obtained with SPSS --test delineation = edgelines.

GROUPINGS OF SITES	NUMBER OF SITES	CHI-SQUARE TESTS		T-TESTS		POISSON ANALYSIS	
		Ia	Ic	Z (IIa)	a* (IIb)	a	a_p
TANGENT SITES							
PAINT CL	7	W	.324	-.281	81.26	92	66
RPM CL	4	W	.525	-.546	41.86	52	31
CL	11	W	.702	-.349	124.29	144	105
CL and POST	9	6.647	3.423	.677	145.56	105	125
ALL	20	.930	.470	.201	271.10	249	243
WINDING SITES							
ALL	5	W	.706	-.256	92.00	110	76
HORIZONTAL CURVES							
PAINT CL	3	.400	.202	1.388	6.00	4	1

W denotes that the trend in the before/after frequency comparison was in the wrong direction (i.e., a > E(a) and b < E(b)).

Table 134. Before-after/matching control test IIa results with SPSS - test delineation = edgelines.

		VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
TANGENT SITES	PAINT CL	ZBA	6	-.4503	1.145	.433	-.1826	1.607	.607	.197	.673	-.30	6	.774
		ZMC		-.2676	1.375	.520								
	RPM CL	ZBA	4	-.3978	1.388	.694	-.3551	1.849	.924	-.055	.945	-.38	3	.726
		ZMC		-.0427	1.148	.574								
	CL	ZBA	11	-.4310	1.169	.352	-.2458	1.607	.485	.112	.744	-.51	10	.623
		ZMC		-.1853	1.241	.374								
	CL & POST	ZBA	9	.7369	.618	.206	.5757	.885	.245	-.101	.795	1.95	8	.087
		ZMC		.1612	.574	.191								
	ALL	ZBA	20	.2044	1.071	.239	.2012	1.305	.292	.158	.506	.69	19	.499
		ZMC		.0032	.934	.209								
WINDING SITES ALL		ZBA	5	-.4360	.462	.207	.1879	2.137	.956	-.066	.916	.20	4	.854
		ZMC		-.6239	2.056	.920								
HORIZONTAL CURVES - ALL		ZBA	2	1.1315	3.190	1.842	1.5694	4.305	2.485	-.719	.489	.63	2	.592
		ZMC		-.4378	1.396	.806								

ZBA = $\overline{(\hat{\lambda}_b - \hat{\lambda}_a)}$ ZMC = $\overline{(\hat{\lambda}_B - \hat{\lambda}_A)}$

Table 135. Before-after/matching control test IIb results with SPSS - test delineation = edgelines.

		VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
TANGENT SITES	PAINT CL	A	6	16.9491	12.528	4.735	1.9872	3.351	1.266	.971	.000	1.57	6	.168
		ASTAR		15.0120	13.710	5.182								
	RPM CL	A	4	13.3435	11.206	5.603	-6.8469	14.143	7.072	.885	.117	-.97	3	.404
		ASTAR		20.1904	23.032	11.516								
	CL	A	11	15.6614	11.626	3.505	-1.2456	9.329	2.813	.843	.001	-.44	10	.667
		ASTAR		16.9070	16.714	5.040								
	CL & POST	A	9	19.2818	10.252	3.417	-14.3836	27.839	9.280	.500	.170	-1.55	8	.160
		ASTAR		33.6654	31.516	10.505								
	ALL	A	20	17.6312	10.766	2.407	-8.3938	21.854	4.887	.595	.006	-1.72	19	.102
		ASTAR		26.0250	26.474	5.920								
WINDING SITES ALL		A	5	22.3447	5.366	2.400	2.1240	7.750	3.466	.741	.152	.61	4	.573
		ASTAR		20.2207	10.834	4.845								
HORIZONTAL CURVES PAINT CL		A	2	1.4952	.612	.354	-.3695	2.947	1.701	-.961	.178	-.22	2	.848
		ASTAR		1.8647	2.353	1.359								

Table 136. Installation of RPMs to tangent sites - basic results.

TEST DELINEATION = RPM				TANGENT SITES				
NUMBER OF SITES	NUMBER OF ACCIDENTS		EXPOSURE (Mi./Veh. Mi.)		ACCIDENT RATE		I_b	I_a
	a	b	a	b	a	b		
12	120	107	140.2	173.2	.856	.618	(.699, 1.012)	(.498, .737)

Table 137. Installation of RPMs to tangent sites - SPSS results.

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
BEFORE RATE	11	.7957	.764	.220	.1269	.485	.140	.803	.002	.91	11	.384
AFTER RATE		.6688	.781	.225								

Table 138. Installation of RPMs to winding sites - basic results.

TEST DELINEATION = RPM					WINDING SITES			
NUMBER OF SITES	NUMBER OF ACCIDENTS		EXPOSURE (Mi./Veh. Mi.)		ACCIDENT RATE			
	b	a	b	a	b	a	I_b	I_a
4	29	22	7.560	8.791	3.836	2.503	(2.411, 5.261)	(1.435, 3.570)

Table 139. Installation of RPMs to winding sites - SPSS results.

VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
BEFORE RATE		3.6939	3.706	1.853								
	3				1.1084	1.926	.963	.918	.082	1.15	3	.333
AFTER RATE		2.5855	2.154	1.077								

140. Installation of edgelines - basic results involving no matching control sites.

SITE GROUP	NUMBER OF SITES	NUMBER OF ACCIDENTS		EXPOSURE*		ACCIDENT RATE		I_b	I_a
		b	a	b	a	b	a		
TANGENT SITES									
PAINT CL	13	109	147	52.31	55.22	2.084	2.662	(1.684, 2.484)	(2.223, 3.101)
RPM CL	9	81	93	54.27	55.58	1.492	1.673	(1.161, 1.824)	(1.326, 2.020)
CL	22	190	240	106.59	110.80	1.783	2.166	(1.524, 2.041)	(1.886, 2.446)
CL & POST	11	161	109	78.63	82.60	2.043	1.320	(1.725, 2.370)	(1.067, 1.572)
ALL	33	351	349	185.22	193.40	1.895	1.805	(1.693, 2.097)	(1.611, 1.998)
WINDING SITES									
PAINT CL	6	144	165	30.07	33.27	4.789	4.960	(3.991, 5.583)	(4.187, 5.732)
RPM CL	6	91	83	21.15	24.53	4.302	3.383	(3.400, 5.204)	(2.640, 4.126)
CL	12	235	248	51.22	57.80	4.588	4.291	(3.989, 5.187)	(3.746, 4.835)
CL & POST	11	164	166	57.86	62.06	2.835	2.675	(2.392, 3.277)	(2.259, 3.090)
ALL	23	399	414	109.08	119.87	3.658	3.454	(3.292, 4.024)	(3.114, 3.743)
HORIZONTAL CURVES									
PAINT CL	50	38	53	55.30	57.68	0.687	0.919	(.464, .910)	(.666, 1.171)
CL & POST OR GUARD-RAILS	15	25	20	15.49	18.28	1.614	1.094	(.968, 2.259)	(.605, 1.583)
ALL	65	63	73	70.79	75.96	0.890	0.961	(.666, 1.114)	(.736, 1.186)

*Million-vehicle-miles for general sites (tangent, winding); Million-vehicle for horizontal curves.

Table 141. Installation of edgelines to tangent sites - SPSS results involving no matching-control sites (Test IV).

TANGENT SITES	VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
PAINT CL	BEFORE RATE	12	2.0655	1.276	.354	-.6094	1.015	.281	.736	.004	-2.17	12	.051
	AFTER RATE		2.6750	1.471	.408								
RPM CL	BEFORE RATE	8	1.4783	1.098	.366	-.2182	1.030	.343	.676	.045	-.64	8	.543
	AFTER RATE		1.6966	1.381	.460								
CL	BEFORE RATE	22	1.7688	1.199	.256	-.4118	1.016	.217	.731	.000	-1.90	21	.071
	AFTER RATE		2.1806	1.478	.315								
CL & POST	BEFORE RATE	11	2.0420	.726	.219	.7182	.573	.173	.621	.041	4.16	10	.002
	AFTER RATE		1.3238	.519	.215								
ALL	BEFORE RATE	33	1.8851	1.021	.178	.0694	1.018	.177	.607	.000	.39	32	.698
	AFTER RATE		1.8157	1.236	.215								

Table 142. Installation of edgelines to winding sites - SPSS results involving no matching-control sites (Test IV).

WINDING SITES	VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
PAINT CL	BEFORE RATE	6	4.8288	3.628	1.481	-.1012	1.207	.493	.970	.001	-.21	5	.845
	AFTER RATE		4.9301	2.692	1.099								
RPM CL	BEFORE RATE	5	4.4333	1.796	.733	1.0909	1.406	.574	.675	.142	1.90	5	.116
	AFTER RATE		3.3424	.744	.304								
CL	BEFORE RATE	11	4.6631	2.868	.828	.3983	1.378	.398	.886	.000	1.00	11	.338
	AFTER RATE		4.2647	2.170	.626								
CL & POST	BEFORE RATE	10	2.8217	.417	.126	.1267	.713	.215	.243	.472	.59	10	.569
	AFTER RATE		2.6950	.689	.208								
ALL	BEFORE RATE	32	3.6986	2.158	.376	.2560	1.060	.185	.874	.000	1.39	32	.175
	AFTER RATE		3.4425	1.128	.301								

Table 143. Installation of edgelines to horizontal curves - SPSS results involving no matching-control sites (Test IV).

HORIZONTAL CURVES	VARIABLE	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR	(DIFFERENCE) MEAN	STANDARD DEVIATION	STANDARD ERROR	CORR.	2-TAIL PROB.	T VALUE	DEGREES OF FREEDOM	2-TAIL PROB.
PAINT CL	BEFORE RATE	50	.6976	1.458	.206	-.2232	1.595	.226	.160	.269	-.99	49	.327
	AFTER RATE		.9208	.920	.130								
CL & POSTS OR GUARDRAILS	BEFORE RATE	14	1.6054	1.771	.457	.4530	1.519	.392	.707	.003	1.15	14	.267
	AFTER RATE		1.1524	2.112	.545								
ALL	BEFORE RATE	65	.9065	1.569	.195	-.0676	1.592	.197	.389	.001	-.34	64	.733
	AFTER RATE		.9741	1.277	.158								

was negative (-.101) in Table 134, and the significance was not great enough (.160) in Table 135. A close inspection revealed that site Az 95 was the primary cause for the observed trends and significance in this grouping. Hence, the results involving matching-control sites was somewhat dubious.

An inspection of the results involving no matching control sites (Tables 136 through 143) reveals the following. The installation of raised pavement marker (RPM) centerlines gave no significant results (Tables 136 through 139). For edgelines, a very significant result was obtained for tangent sites with centerlines and posts (see Table 141 entry). A visual inspection of the sites involved with this particular result revealed that several other sites in the grouping besides Az 95 exhibited this same beneficial trend. Therefore, this result will indeed be accepted as significant and is the one lone result obtained from the before-after study. Accordingly, confidence bounds at various levels have been developed as shown in Table 144 for use in the benefit-cost model along the fashion used in the matching-control study.

Table 144. Confidence bounds for the installation of edgelines to tangent sites with centerines and posts already present.

HIGHWAY SITUATION	TREATMENT COMBINATION	EFFECTIVE NO. OF SITES	MEAN	MEAN DIFFERENCE	STANDARD ERROR OF MEAN DIFFERENCE	CONFIDENCE BANDS							
						P=.60		P=.90		P=.95		P=.99	
						DEVIATION FROM MEAN	BAND	DEVIATION FROM MEAN	BAND	DEVIATION FROM MEAN	BAND	DEVIATION FROM MEAN	BAND
TANGENT	B: CL & POST A: CL, EL & POST	11	2.04 1.32	.72	.173 (ν=10)*	±.152	.568 .872	±.313	.407 1.033	±3.85	.335 1.105	±.548	.172 1.268

Numbers are accident rates in number accidents per million-vehicle-mile.
*Degrees of freedom (ν)

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