Safety Evaluation of the Safety Edge Treatment

Final Work Plan

For
University of North Carolina
Highway Safety Research Center

Federal Highway Administration
Office of Safety Research and Development

MRI Project No. 110164.1.004

May 31, 2006

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University of North Carolina
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Chapel Hill, North Carolina 27599

Federal Highway Administration
Office of Safety Research and Development
Turner-Fairbank Highway Research Center
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McLean, Virginia 22101

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Preface

The work reported herein was performed under Subcontract 5-55614, Task Order 4, between the University of North Carolina—Chapel Hill (UNC-CH) and Midwest Research Institute (MRI), as part of the prime contract, "Development, Operation, and Maintenance of Highway Safety Information System (HSIS.70), between UNC-CH and the FHWH. The work was performed in MRI's Applied Engineering Division, directed by Mr. Roger Starnes. This work plan was prepared by Mr. Jerry L. Graham, Mr. Douglas W. Harwood, Ms. Karin M. Bauer, and Ms. Karen R. Richard.

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Contents

Preface.......... ii

Section 1. Background.......... 1

Section 2. Evaluation Objectives and Scope.......... 2

Section 3. Recommended Safety Edge Evaluation Approaches.......... 3
- 3.1 Target Crashes to Be Evaluated.......... 3
- 3.2 Independent Variables.......... 5
- 3.3 EB-Based Before-After Evaluation.......... 6
- 3.4 Cross-Sectional Comparison of After Data.......... 9

Section 4. Data Collection Plan.......... 12
- 4.1 Participating States.......... 12
- 4.2 Before-Period Database.......... 12
- 4.3 Reference Site Data for SPF Development.......... 19
- 4.4 After-Period Data Collection and Sequencing of Preliminary and Final Analyses.......... 19

Section 5. Anticipated Results.......... 21

Section 6. Level of Effort and Costs to Conduct Evaluation.......... 22

Appendices

Appendix A—Locations and Characteristics of Candidate-Treated Sites
Appendix B—Fields Used to Filter Drop-Off-Related Crash Data
Appendix C—Pavement Edge Drop-Off Data Collection Methodology

Figures

Figure 1. Safety Edge Detail.......... 1
Figure 2. Example Indiana Accident Data Plotted With Microsoft Streets and Trips.......... 16

Tables

Table 1. Available Site and Treatment Layout.......... 6
Table 2. Accident Data.......... 15
Table 3. Estimated Level of Effort.......... 23

Section 1. Background

Two-lane rural highways often have unpaved shoulders immediately adjacent to the traveled way. Other two-lane highways, and many multilane rural highways, have narrow paved shoulders with widths of 1 to 4 feet. If roadway maintenance forces do not keep material against the pavement edge, a pavement-shoulder drop-off may form. The drop-off height can vary from less than 1 inch to 6 inches or more, even though maintenance performance standards usually require maintenance when the drop-off exceeds 1 ½ to 2 inches.

When a vehicle leaves the traveled way and encounters a pavement-shoulder drop-off, it may be difficult for the driver to return safely to the traveled way. As the driver attempts to steer back onto the roadway, the side of the tire may scrub along the drop-off, resisting the driver's attempts to steer and make a smooth reentry to the roadway. This resistance often leads to driver over-correction with a greater steering angle than desired to remount the drop-off. When the tire does remount the drop-off, the increased tire angle may "slingshot" the vehicle across the road, resulting in a collision with other traffic or loss of control and overturning on the roadway or roadside.

The safety edge is a treatment that is intended to minimize drop-off-related crashes. With this treatment, the pavement edge is formed at a sloped angle of less than 45 degrees to lessen the resistance of the tire to remounting the drop-off. (See Figure 1.) The lessened resistance should allow a more controlled reentry onto the traveled way.

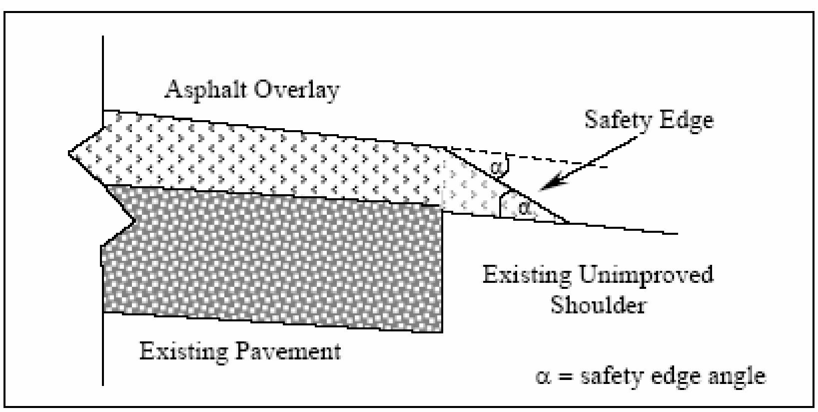


Figure 1. Safety Edge Detail

Selected highway agencies have begun to use the safety edge treatment as part of pavement resurfacing projects. However, there has been no formal evaluation of the effectiveness of this treatment in reducing drop-off-related crashes on rural highways. Such an evaluation is needed to determine whether this treatment should receive more widespread use.

Section 2.
Evaluation Objectives and Scope

The objective of the proposed evaluation is to quantify the safety effectiveness of the Safety edge treatment. Safety effectiveness measures for this treatment will be determined for both two-lane and multilane rural roads. An evaluation will be performed to determine whether provision of the safety edge treatment as part of a pavement resurfacing project reduces crashes in comparison to pavement resurfacing without the safety edge treatment. Two-lane rural roads, with no paved shoulder and with a paved shoulder no wider than 4 feet, will be studied. Multilane rural roads with narrow paved shoulders no wider than 4 feet will also be studied.

The evaluation results will be presented in terms of the percentage reduction in the frequency of specific target crash types that can be expected from provision of the safety edge treatment.

The safety effectiveness measures will be used in an economic analysis to define the types of roadways and traffic volume levels for which provision of the safety edge would be cost-effective.

Section 3.
Recommended Safety Edge Evaluation Approaches

Two statistical approaches are proposed to evaluate the safety effectiveness of the safety edge treatment: (1) a before-after comparison of the effect of pavement resurfacing with and without the safety edge treatment and (2) a cross-sectional comparison of the effect of pavement resurfacing with and without the safety edge treatment, based on after-period data only. These two evaluation approaches will be applied concurrently because it cannot be anticipated which approach will work best. The target crashes to be analyzed and the independent variables used in both analyses will be identical and are discussed next. The two recommended evaluation approaches are then discussed individually.

Three state highway agencies have identified resurfacing projects involving safety edge treatments that are suitable for evaluation. These three states, which have agreed to participate in the evaluation, are Georgia, Indiana, and New York. All of the treated sites in these three states involve implementation of the safety edge treatment in conjunction with pavement resurfacing or sites repaved without the safety edge treatment. The sites in Georgia include both rural two-lane highways and rural multilane highways. All of the treated sites in Indiana and New York are on rural two-lane highways. Data were collected at two sites in Colorado in March, 2006. Other participating states and sites should be sought as the work proceeds.

3.1 Target Crashes to Be Evaluated

The dependent variable for the evaluation will be the frequency of specific target accident types. The evaluation will include all accidents that occur within the limits of the roadway segments of interest during the study period, but the analysis will be limited to collision types that are most likely to be affected by provision of the safety edge.

The selection of the target crash types to be evaluated has been guided by two recent studies of accidents related to pavement/shoulder edge drop-offs by Council and Hallmark. These studies identified five scenarios (crash sequences) under which over-steering may occur resulting in a crash related to a pavement/shoulder edge drop-off. This analysis plan assumes that only these types of crashes and no other would be affected by provision of the safety edge.

The five types of crashes used to identify potential drop-off-related crashes are:

1. Head-on collision with an oncoming vehicle
2. Sideswipe collision with an oncoming vehicle
3. Run-off-road crash on the opposite side of the road
4. Overturning within the traveled way or on the opposite side of the road

5. Same-direction sideswipe collisions on multilane roads

Of course head-on crashes may involve a vehicle that crossed the centerline without first running off the road; such head-on accidents should not be classified as drop-off-related and should not be treated as target crashes. Criteria for identifying target crashes should exclude all intersection or intersection-related crashes, and specify that all drop-off-related crashes must show evidence of a vehicle leaving the road.

It is recommended that target crashes should be further defined into categories which include:

- Category A: Run-off-road right, cross centerline/median, hit vehicle traveling in the opposite direction (head-on or sideswipe)
- Category B: Run-off-road right, sideswipe with vehicle is same direction (multilane roads)
- Category C: Run-off-road right, rollover (could be in road or roadside)
- Category D: Run-off-road right, then run-off-road left
- Category E: Single vehicle run-off-road right

Selection of the crash types was based on descriptors in the crash database furnished by the participating states that have been identified to date. The data fields used include sequence of events, location of first harmful event, type of collision, driver, and roadway contributing circumstances. The specific fields used to filter before crashes for each participating state are described in Appendix A.

The target crash types described above represent ***potential*** drop-off-related crashes, defined as precisely as possible without obtaining and reviewing individual hard-copy police crash forms. Past research by Council that included a detailed analysis of hard copy reports indicated that a larger percentage of potential accidents were judged as probable or possible drop-off crashes when the officer had noted a shoulder defect. Therefore if the agency's crash form has a item for "low shoulder" or "shoulder defect" this item will also be used to chose potential drop-off crashes.

Only nonintersection accidents will be considered as target accidents because provision of the safety edge is unlikely to affect intersection or intersection-related accidents. Thus the target accidents will include only accidents that do not occur at an intersection and are not related to the presence or operation of an intersection.

Accident severity levels that will be considered in the evaluation are:

- Fatal, injury, and property-damage-only (PDO) accidents (i.e., all accident severity levels combined)
- Fatal, injury, and tow-away PDO accidents (in states where a tow-away indicator is available)

- Fatal and injury accidents

The highest priority in assessment of the safety edge will be the evaluation of its effect on fatal and injury accidents because these categories include the most severe accidents among the target accident types of interest. Accidents of all severity levels (i.e., also including PDO accidents) will also be considered because the larger accident sample size with PDO accidents included makes it easier to detect statistically significant improvement effects. However, because of variations in accident reporting thresholds and practices among jurisdictions for PDO accidents, it is desirable, when possible, to consider only PDO accidents that are sufficiently severe that at least one of the involved vehicles is towed from the accident scene. PDO tow-away accidents are more likely to be reported than other PDO accidents. PDO tow-away accidents can be distinguished from other PDO accidents in data from only one of the three participating states that have been identified to date (Indiana).

3.2 Independent Variables

The independent variables in a safety evaluation are those variables whose effects on accidents are to be determined or controlled for in the analysis. For the evaluation the primary independent variable will be the edge treatment (i.e. with safety edge, without safety edge). Other variables will be the road type (two-lane, multilane) and the shoulder type and width (no paved shoulder, narrow paved shoulder 1 to 4 feet wide).

There is also a need in all safety evaluations of roadway segments to account for the effects of traffic volume (AADT) and segment length. It is anticipated that the safety effects of lane width and roadside design should also be accounted for. These effects may also be accounted for by using a terrain variable or by matching sites in the same district or region of an agency.

Field measurements of drop-off heights will also be made before and after treatment implementation to verify that the safety edge treatment is effective in minimizing pavement/shoulder edge drop-offs.

Three states—Georgia, Indiana, and New York—initially agreed to participate in the study. The breakdown of the number and type of treated sites is summarized in Table 1. A fourth state, Colorado, agreed to participate in March, 2006, and provided data for two sites. However, due to their recent participation and limited number of sites, Colorado’s information has been excluded from any summaries of collected data.

The table shows that the three participating states have identified 27 sites that have been resurfaced with the safety edge treatment for a total length of 214.6 miles of road. The participating states have also identified 25 sites that have been resurfaced without the safety edge treatment for a total length of 231.7 miles of road. Repaved sites without the safety edge were chosen to be similar to safety edge sites in location and AADT, when possible.

Table 1. Available Site and Treatment Layout

Before treatment	After treatment	Number of sites (total length in mi)			
		Georgia	Indiana	New York	Total
Two-lane rural highways					
No paved shoulder	Resurfaced with safety edge	6 (45.2)	5 (57.3)	0 (0.0)	11 (102.5)
	Resurfaced without safety edge	8 (92.9)	5 (58.1)	0 (0.0)	13 (151.0)
Narrow paved shoulder	Resurfaced with safety edge	7 (53.3)	3 (25.4)	4 (10.3)	14 (89.0)
	Resurfaced without safety edge	3 (27.2)	3 (21.3)	3 (15.2)	10 (67.8)
Multilane rural highways					
Narrow paved shoulder	Resurfaced with safety edge	2 (23.1)	0 (0.0)	0 (0.0)	2 (23.1)
	Resurfaced without safety edge	2 (12.9)	0 (0.0)	0 (0.0)	2 (12.9)
Total*		28 (254.6)	16 (162.1)	7 (25.5)	52 (446.3)

* Data were collected for one test site and one control site in Colorado in March, 2006, and is not shown here.

3.3 EB-Based Before-After Evaluation

The first recommended evaluation approach is a before-after comparison using the Empirical Bayes (EB) approach. The following discussion addresses the proposed evaluation plan, including issues related to the specific nature of the safety edge treatment.

In current practice, the safety edge treatment is always being used in conjunction with pavement resurfacing. Therefore, the safety effects of the pavement resurfacing and installation of the safety edge treatment will be confounded, at least for some time, following resurfacing. Previous research has indicated that pavement resurfacing by itself may have an effect on safety, increasing crashes because of increased speeds. This effect was found in one study to be statistically significant, but was found to persist for only 12 to 30 months after resurfacing (Hauer, Terry, and Griffith, 1994). However, a more recent, larger study in NCHRP Project 17-9(2) found inconsistent results; increases in crash frequency with resurfacing were found in some states, but decreases in crash frequency with resurfacing were found in others. It is anticipated that the safety effect of resurfacing and that of the safety edge, taken separately, on the target crashes will be small. The challenge in the statistical evaluation will be to separate the effect of the two treatments in light of other trends over time (e.g., traffic volume changes.) An analysis approach based on an empirical Bayes (EB) before-after comparison is proposed. These results from the literature, although inconsistent, indicate that the evaluation plan must anticipate the possibility of a pavement resurfacing effect on safety and must anticipate the need to separate that resurfacing effect from the safety edge effect on safety. This will be addressed in two ways. First, resurfaced sites both with and without the safety edge treatment will be considered. Differences in safety between resurfaced sites with and without the safety edge treatment may represent an effect of the safety edge treatment. Second, the period after evaluation should be sufficiently long as to extend beyond the duration of any short-term resurfacing effect. A study period after resurfacing of at least three years is recommended, with annual interim evaluations to monitor time trends.

A number of two-lane and multilane rural highway sites will be considered and treated as follows:

- Treated sites resurfaced with safety edge (Treatment A)
- Treated sites resurfaced without safety edge (Treatment B)
- Reference sites not resurfaced

Data from comparable reference sites are needed to develop safety performance functions (SPFs). These SPFs will then be used to estimate relevant crash frequencies at the treated sites had these sites not been resurfaced.

The treatment effectiveness will be estimated separately for resurfacing projects with safety edge (Treatment A) and resurfacing projects without safety edge (Treatment B) based on the available crash data. In each case, the significance of the before-after change in crash frequencies will be assessed using the EB method as follows:

1. Obtain data for the observed crash frequency at each treated site during both the before and after periods.
2. Develop SPFs that model crash frequencies as a function of site parameters (i.e., traffic volumes and site characteristics). These are determined by a negative binomial (NB) regression analysis using data for a reference group of untreated sites; in this case, sites that are not resurfaced.
3. Estimate the predicted crash frequency at each treated site during the before period using the SPF developed for that type of site.
4. Compute a weighted-average of the predicted and observed crash frequencies at each treated site for the before period. This crash frequency is referred to as the EB-adjusted expected crash frequency.
5. Using the EB-adjusted expected crash frequency at each site during the before period, make an estimate of the expected crash frequency at each treated site during the after period had the treatment not been implemented. This step of the analysis accounts for changes in traffic volumes between the before and after periods and for differences in before- and after-period lengths and other annual factors in the crash data.
6. Compare the observed after crash frequencies at the treated sites to the expected after crash frequencies at the treated sites had the site not been resurfaced. The

difference between the observed and expected crash frequencies is an estimate of the safety effectiveness of the treatment. Remember that these calculations will be performed separately for Treatment A and Treatment B.

As indicated in Table 1, three SPFs will need to be developed for the target crashes in each state:

- SPF for two-lane rural highways with no paved shoulder
- SPF for two-lane rural highways with narrow paved shoulders
- SPF for multilane rural highways with narrow paved shoulders

These SPFs will be functions predicting target crash frequencies on a per-mile per-year basis as a function of traffic volume and highway geometrics. Where possible, each site will be subdivided into sections that are homogeneous with respect to roadway geometrics. Based on previous experience, a minimum section length of 3 miles will be considered for analysis.

Alternatively, it may be possible to develop a combined SPF for two-lane rural highways either with no paved shoulder or with narrow paved shoulders in each state. In this case, shoulder width will be included in the regression model.

The above approach to developing SPFs assumes that the reference sites provide a sufficient number of target crashes to develop statistical models with acceptable confidence. Should this not be the case, then SPFs could be developed for total and fatal and injury crashes and proportions of target crashes (see Section 3.1) of these crashes could be applied to the appropriate SPFs. Proportions of target crashes could be estimated from the data obtained from all the sites (Treatment A, Treatment B, and Reference) for each state.

The EB before-after evaluation will produce an estimate of the effectiveness of (1) resurfacing with a safety edge (Treatment A), and (2) resurfacing only (Treatment B), separately for each target crash type in each state. In each case, the mean and standard error of the percent change in target crash frequency and its statistical significance will be calculated.

Next, from each pair of estimated percent change (Treatment A and Treatment B), the effect of the safety edge provision alone will need to be isolated. Assuming that within each highway type and for each state sections resurfaced without safety edge were comparable to sections resurfaced with safety edge in their crash history and site geometrics before resurfacing, then the effect of the safety edge can be estimated as the difference between the two measures of effectiveness (i.e., Treatment B – Treatment A).

The comparability before resurfacing of the two types of treated sites is key to the interpreting the comparison of the two estimated treatment effects as an effect of the safety edge treatment. The comparability of sites will be established through use of the before-period data. The following steps are proposed.

1. Physical comparison—the sites will be compared with respect to their roadway geometrics and traffic volumes.
2. Crash trend comparisons—the sites will be compared on their yearly total crash and target crash distributions.
3. Formal crash frequency comparisons—for each section and total crash and target crash type, an EB-adjusted expected crash frequency will be calculated over the entire before period (Step 4, above). The use of the appropriate SPF will adjust these expected crash frequencies for all variations in traffic volumes and geometrics as long as these parameters are included in the SPF. It is assumed that if a particular site geometric parameter is not included in the SPF, then it was not significant during the development of that SPF. The mean EB-adjusted expected crash counts in the two groups can then be compared and tested for statistical significance using for example a two-sample test for comparison of two Poisson means. Additionally, the distributions of target crash types between the two groups of sites could be compared using statistical procedures developed in Module 4 of *SafetyAnalyst*.

In addition, it will be desirable to confirm from field measurements that drop-offs of any specified height are less likely to be found after resurfacing on the Treatment A sites than the Treatment B sites. This examination of field-measured drop-off heights is necessary to confirm the existence of a cause-and-effect chain leading from reduced drop-off frequency and height to reduced target crashes. It is also possible that drop-offs on roadways with the safety edge treatment are less likely to cause crashes because the safety edge treatment enables vehicle to recover safely.

3.4 Cross-Sectional Comparison of After Data

As discussed above, it is anticipated that the treatment effectiveness being sought will be relatively small. The EB-based before-after comparison approach is theoretically the strongest approach to evaluations of this type. However, because of the confounding of the pavement resurfacing effect and the safety edge treatment effect, it cannot be assured that this approach will necessarily be successful. Therefore, it is recommended that an alternative cross-sectional comparison approach also be considered.

This approach may also be more cost effective when there are less than four safety edge sites available for evaluation in a state. The EB- based before-after evaluation discussed in Section 3.3 would require data collection on a set of reference sites to establish SPFs for various roadway-shoulder type combinations. The amount of work required to develop the SPFs would not increase the likelihood of a significant finding in a state with a small number of sites.

A cross-sectional evaluation of the after data at the treated sites is proposed to directly compare the crash data between the two types of treatment—resurfacing with safety edge and resurfacing without safety edge. Assuming that all roadway factors except resurfacing were held constant, then one could hypothesize that the differences in either after-crash frequencies or after-crash distributions between Treatment A and Treatment B sites are simply due to the provision of the safety edge. This comparison will be made using data for the after-period only, but only after establishing in a separate analysis that there are also no substantial differences between the sites in each state in the before period. This comparison of before-period data would be similar to that described for the before-period data shown in the discussion of the EB-based before-after comparison section above; the comparability of the treated sites before resurfacing is a key factor in this approach. Thus, the same approach and its conclusions apply here.

The comparability before resurfacing of the two types of treated sites is key to interpreting the comparison of the two estimated treatment effects as an effect of the safety edge treatment. The comparability of sites will be established through use of the before-period data. The following steps are proposed.

1. Physical comparison—the sites will be compared with respect to their roadway geometrics and traffic volumes.
2. Crash trend comparisons—the sites will be compared on their yearly total crash and target crash distributions.
3. Formal crash frequency comparisons—the mean crash counts in the two groups can then be compared and tested for statistical significance using for example a two-sample test for comparison of two Poisson means. Additionally, the distributions of target crash types between the two groups of sites could be compared using statistical procedures developed in Module 4 of *SafetyAnalyst*.

Once it is established that the treated sites are comparable in the before period, an analysis of variance (ANOVA) can be used to predict the after crash frequency of the sites resurfaced with the safety edge, and those resurfaced without the safety edge. The ANOVA will be conducted on the log-transformed after crash frequencies. State would be considered a blocking factor in the ANOVA to account for state differences, and resurfacing, with or without safety edge, would be the main factor of interest in the analysis. The effect of additional factors, or covariates, such as lane width and shoulder width can be studied in this ANOVA approach to quantify the relationship between these factors and a given target crash type, should such a relationship be significant. The safety edge treatment effect and its standard error will be calculated, adjusted for state differences, if any, and other covariates, if necessary, for each target crash type.

In addition to evaluating mean crash counts, a comparison of the after target crash proportions (of total crashes) between Treatment A and Treatment B sites in each state will be performed. The target crash proportions to evaluate will include both potential drop-off related crash proportions as well as crash severity proportions. These comparisons can be accomplished by calculating a simple confidence interval for the difference between the two independent proportions at a preselected significance level (e.g., 5 percent, 10 percent)

A comparison will also be made between the drop-off frequencies and heights on the sites resurfaced with and without the safety edge treatment, to document any differences. The safety edge treatment may reduce the frequency and height of drop-offs, but should also reduce the risk to motorists of any drop-offs that do develop. Comparison of drop-off frequencies and heights in the after study period should help to clarify this issue.

Section 4.
Data Collection Plan

The evaluation of safety edge will require roadway geometrics, traffic volume data, accident data, and construction cost and implementation data for rural two-lane and multilane study sites. These data will be obtained in two phases: the “before implementation” period, and the “after implementation” period. When possible, data have been obtained from agency databases; otherwise, data were prepared by manual means.

4.1 Participating States

The three states that have agreed to implement the safety edge treatment and to participate in the study are Georgia, Indiana, and New York. Sites for this study have been selected by the three states which had volunteered to implement the safety edge as part of their normal resurfacing project plans. Some initially selected sites were excluded from the study if shoulder widths were greater than 4 feet, or if they were found to be extremely nonhomogenous with the other sites

It may be desirable to include additional states in the evaluation if additional states willing to participate are identified. This would increase the number of sites available for analysis. A fourth state, Colorado, agreed to participate in March, 2006, and provided data for two sites. However, due to their recent participation and limited number of sites, Colorado’s information has been excluded from summarized tables appearing in this section.

4.2 Before-Period Database

A substantial amount of before-period data have been collected and assembled into a database for consideration in the analysis phase of this study. The before-period data that have already been collected include the 52 sites in Georgia, Indiana, and New York shown in Table 1. For the purpose of this report, subject data have been separated into five different files, although all site-related information could theoretically be assembled in one comprehensive file. Information regarding data availability, data collection, and contents, as well as the data elements used to link them, will be given for the following datasets:

- Site list
- Accidents
- Field drop-off measurements
- Traffic volumes
- Roadway characteristics

Descriptions of the individual agency's files will be provided within each of the sections describing these files. Additionally, all files and supporting documentation are available in the form of SAS data files for use in subsequent analyses.

4.2.1 Sites

These files contain the master list of comparison and test locations that were selected for inclusion in our study. Sites for which data were subsequently collected, have been assigned a unique site ID (e.g., T99 or C99), which can be used to link site information between files. Additionally, this file contains data elements for its location on the agency's highway system, the project construction dates, and, in some cases, basic roadway characteristics.

Each row in this file contains information on the contiguous section of roadway that has been selected for resurfacing by an agency, so that one record equals one resurfacing project or safety edge project. However, an exception to this rule exists for Georgia, where multiple records exist for projects that cross county lines. Further, each section of roadway for a state's project may not be a homogeneous section of roadway (i.e., a section of roadway with analogous characteristics). Therefore, this file in conjunction with the Roadway Characteristics file will be used to determine the actual analysis units (sites) that are evaluated. Summary information on the number and type of sites for which data have been collected is shown in Table 1.

The actual project data have been stored in three files (GAprojects.sas7bdat, INprojects.sas7bdat, and NYprojects.sas7bdat), as the format of the route identifier data differs between agencies as described next. A separate file was also compiled for the Colorado sites (COprojects.sas7bdat).

New York

New York maintains electronic records of their data with a linear referencing system that uses a combination of control section numbers and county/route/milepost information. Location reference variables that appear in New York's data can contain up to 13 characters of information. The first four characters contain the route number. The second four characters contain the region/county numbers and the county order number, which represents the order of the counties in one of eleven regions. The last four or five characters have the control segment number followed by the mileage (expressed in tenths or hundredths of a mile) into the control segment. For ease in linking files, all files have been created with the following variables: route number, county number, county order, control segment number, and milepost.

Indiana

Indiana has provided two documents describing their use of reference posts and their county log mile system, Indiana Statewide References Posts, and Indiana User Guide to Reference Post System for use in this study. The first document provides the reference post, corresponding continuous log milepost, and cross-road description for each interstate, state route, US route, and toll road in each county in the state. The second document is simply a user's guide to the first document. For purposes of this study, only the milepost values generated from the reference post and offset values are used in the state files created. Therefore, only the route number and milepost variables are needed to link information between files.

Georgia

Georgia maintains electronic records of their data with a linear referencing system that utilizes county, route number, and milepost. In this system, the milepost is set to zero when a route crosses a county line. Therefore, the county number, route number, and milepost variables are all needed to link information between files.

Colorado

For the two Colorado sites, electronic records were provided with a linear referencing system that relies on route number and milepost only. Consequently, these two variables are all that are needed to link information between files.

4.2.2 Accidents

Sample accident data were requested from each of the participating agencies to determine suitability as well as the prevalence of drop-off-related accidents for modeling requirement consideration. The preliminary review of the initial data indicated that the accident records contained enough summary information to determine potential drop-off-related accidents, by the methodology described in a recent study by Council et al. (2005), and that drop-off-related accidents are a relatively small proportion of total accidents. As a result, a minimum of five years of before-accident data were requested. However, due to a recent data systems conversion, Indiana was only able to provide two years of before data. Table 2 summarizes the data availability of each agency and the breakdown of total and potential drop-off-related accidents for each agency.

Table 2. Accident Data

State[b]	Accident data period: First yr.	Last yr.	Total No. of yrs.	Number of sites (miles)	Total No. of accidents	Total No. of drop-off-related accs[a]
Georgia	1999	2003	5	254.6	6,145	676
Indiana	2003	2004	2	162.1	1,257	93
New York	1999	2003	5	25.5	360	50

[a] This methodology is described in Appendix B.
[b] Accident data are also available for Colorado but have not been sorted.

Accident records were provided by the participating agencies from their electronic accident record databases. The amount of information for each accident as well as the format in which they are stored varied between agencies. For Georgia, information regarding an accident is contained in one master file, with one record for each accident. Conversely, for New York and Indiana, information regarding an accident can be included in one of three related files. The first file contains basic event information such as location, date, time, and severity, and is organized by having one row equal to one accident. The second file contains vehicle information, with one record for each vehicle involved in the accident. The last file contains individual information, with one record for each driver/passenger in each vehicle involved in the accident. For New York, this is called the “factors” file as it contains a row for each contributing factor for each driver in each vehicle involved in the accident.

In addition to the accident information provided from the agencies, a study site number has been added to the files for linking the accidents to the sites. Alternatively, the agency’s location referencing system variables may be used to link accidents to study locations, should the actual analysis units differ from the project units. However, there is one exception to this linking capability. Indiana was only able to provide reference-point information, as well as latitude and longitude information, for some of the accidents. Approximately 20 percent of the accidents had no reference point or coordinate information, but contained a verbal description of the accident. Efforts to better locate these accidents may be necessary during the execution of this work plan. Consequently, alternative algorithms or software programs may need to be utilized to separate accidents into different analysis units and/or assign location information. For example, Microsoft Streets and Trips may be used to plot the accidents and separate them into the appropriate analysis units, or to assign location reference information. Figure 2 illustrates an example of plotted Indiana accidents.

Accident data definitions and information for linking related accident files have been provided by New York DOT for use in this study in the form of a data dictionary. While Georgia and Indiana could not provide a data dictionary for their data, one has been created from the data found in the records received by performing frequencies of data and copying relevant definitions from correspondence. Consequently, all enumerated levels for a data field normally found in their files may not be shown in these data dictionaries. For Colorado, a data dictionary was created from a detailed accident summary report provided for the sites. Therefore, all of the enumerated levels for most of the data fields are identified.

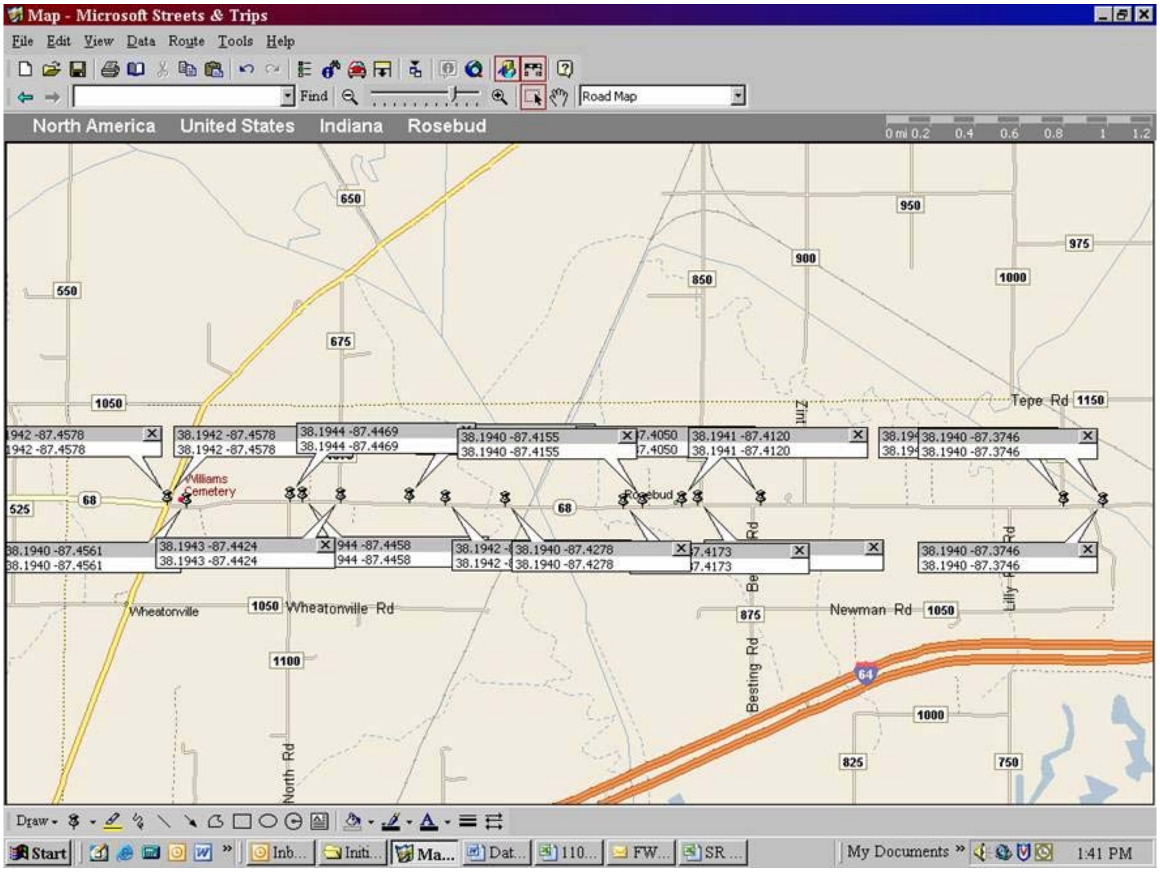


Figure 2. Example Indiana Accident Data
Plotted With Microsoft Streets and Trips

The final accident data that have been collected, as well as the data dictionaries, are stored in the following files:

1. GAaccs.sas7bdat
2. NYaccs.sas7bdat
3. NYvehs.sas7bdat
4. NYfactor.sas7bdat
5. INaccs.sas7bdat
6. INvehs.sas7bdat
7. INindividual.sas7bdat
8. GAAccDataDict.doc
9. NYAccDataDict.doc
10. INAccDataDict.doc
11. COAccs.sas7bdat
12. COAccDataDict.doc

4.2.3 Field Drop-Off Measurements

Field visits were conducted to collect pavement drop-off measurements, as well as additional geometric design variables, for each of the treated sites. Additionally, late adjustments to the project site lists by the agencies prohibited this supplemental data collection at some sites.

The methodology for collecting these data, and the type of data collected, are documented in Appendix C. Collected field data were entered into a Microsoft Access database created for use in this study. This data has been subsequently reviewed for accuracy and converted into three agency files. All field data and corresponding documentation have been saved and stored:

1. NYfield.sas7bdat
2. Infield.sas7bdat
3. GAfield.sas7bdat
4. SafetyEdge.mdb
5. FieldDataDictionary.doc
6. COfield.sas7bdat

4.2.4 Traffic Volumes

Traffic volume (AADT) data for all study locations have been obtained through various published sources from each of the participating agencies, so no field traffic counts were required in preparing this data. When possible, separate AADT values for each year of the "before" study period were obtained. When separate AADT values are not obtained, it is expected that values can be interpolated for the missing between years for the actual analysis. However, there were slight variations in the values obtained, as described next.

Traffic volume data for New York sites were manually prepared from the NYSDOT 2003 Traffic Volume Report provided to the research team. This report details how sites are counted and provides up to three previous non-consecutive years of AADT data (and is included on the data disk). For Georgia and Indiana, traffic volume data are available through their agency websites, www.dot.state.ga.us/DOT/plan-prog/transportation_data/traffic_counts/index.shtml and www.state.in.us/dot/div/traffic/count/index.html, respectively. Indiana provides up to three non-consecutive years of county flow (AADT) maps on their website. Data from these maps have been manually entered and quality checked in a data file for use in this study. Conversely, Georgia provides electronic data files of AADT for all state routes in any county for every year. More information regarding how the AADT values are calculated or estimated can be found on the websites.

All of the traffic volume files that have been prepared for this study contain the unique project ID, route location information, and the boundary points for which the data apply, for ease in linking to other site files. However, the roadway units in these files are often shorter in length than the project file. Consequently, multiple rows (records) in this table will apply to a single project. Additionally, for Georgia, there is one record for each year of ADT. The final traffic volume data that have been collected are stored as: NYaadt.sas7bdat, INaadt.sas7bdat, GAaadt.sas7bdat, and COaadt.sas7bdat.

4.2.5 Roadway Characteristics

Roadway geometric design data were collected for each treated site. The source of geometric data, as well as the amount of information, varied by agency, and is addressed next.

Georgia provided roadway inventory data from their electronic Road Characteristics (RC) file. Data from this central computer file are coded and entered from information provided by each of the seven district offices. Each district follows guidelines in the Systems Inventory and Data Collection Coding and Procedures Manual (included on disk) for completing the roadway characteristics data file, which Georgia has also provided for our use in this study. The RC files present a snapshot of the current conditions and will be requested again in the after period to assure that there were no changes to roadway geometrics other than the resurfacing.

Geometric data were manually prepared from various sources for New York and Indiana. For New York, data were entered from a single published report, the 2004 Highway Sufficiency Ratings for New York State. Conversely, for Indiana, geometric data were prepared from a combination of sources: highway agency project memoranda, construction or as-built plans, and field data. Data dictionaries have been created for each of these files (and are available with the roadway characteristics files). These files will also be created for the after period in New York and Indiana.

All of the roadway characteristics files that have been prepared for use in this study contain the unique project ID, route information, and termini points for which the geometrics apply, for ease in linking to other site files. Since the roadway units in these files are often shorter in length than the project file, they have a many-to-one relationship with the project file.

The final roadway characteristics data that have been collected, as well as the data dictionaries, are stored in the following eight files:

1. NYroads.sas7bdat
2. GAroads.sas7bdat
3. INroads.sas7bdat
4. NYRoadDataDict.doc
5. GARoadDataDict.doc

6. INRoadDataDict.doc
7. CORoadways.sas7bdat
8. CORoadDataDict.doc

4.3 Reference Site Data for SPF Development

Reference sites that have not been resurfaced will be selected in each participating state. The total length of reference site selected will be approximately the same as the length of treated sites in a state, and road-shoulder-type categories will be matched in the same manner. For example, if treated sites were only on two-lane rural roads in a state, then reference sites will also be chosen from two-lane rural roads. In states where four-lane treated sites are available, the total length of four-lane reference sites will be equivalent to the total length of two-lane reference sites. Reference sites will be chosen from the same highway districts as the treated sites. Input from district engineers will be sought to ensure that the reference sites match treated sites in that area.

The reference sites will be chosen in the first year of the evaluation. Five years of crash data will be requested. The date of the previous resurfacing for each reference site will be determined to ensure that the site was not resurfaced during the five-year study period. Road characteristics and traffic volumes will be compared to the treated sites to ensure that similar roadway sections are chosen.

For the first-year interim report, the reference site crash data will be analyzed to develop SPFs for targeted crash types for each road-shoulder-type combination in each state. Additional sites will be added if necessary to develop statistically reliable SPFs.

4.4 After-Period Data Collection and Sequencing of Preliminary and Final Analyses

The cost and date of resurfacing for each treated site will be collected in the after period. Some of these dates and resurfacing costs have already been collected and are available.

Approximately one year after resurfacing, field data will be collected in an identical manner to the before-period field data collection that has already been completed including field measurements of any drop-offs that are present. (See field data collection methodology in Appendix C.) Drop-off will be measured on safety edge sites in the same manner as for non-safety edge sites. While we do not necessarily expect a large number of drop-offs to have developed during the first year after resurfacing, the field data will confirm this, will indicate where drop-offs are more common without the safety edge than with it. If drop-offs are present on safety edge treated sites they may still be safer than other drop-offs due to the shaped of the drop-off. Field data collection will also document that each site is still in the same road-shoulder-type category. AADT, road characteristics and crash data will also be collected as soon as available. When Year 1 crash data are available, we will perform both the before-after EB and cross-sectional analyses using the before-period data and the Year 1 crash data for the after period. While it is unlikely that one year of after-period data will produce reliable results, the interim analysis should assure us that there is not an increase in any type of crash, and will reveal how the safety edge treatments affect the formation of drop-offs in the first year after resurfacing. A Year 1 interim report presenting these analysis results will be submitted.

In Years 2 and 3, we will again collect field, crash, road characteristic, and ADT data, including field measurement of drop-offs. In Years 2 and 3, we will redo both the EB and cross-sectional analyses using all available data. We expect that at least three years of data will be necessary to obtain reliable results, and it is possible that additional years and/or treated sites will be needed.

An interim report will be submitted at the end of Year 2, and the study final report will be submitted at the end of Year 3.

Section 5.
Anticipated Results

The anticipated result from execution of this work plan is an AMF for installation of the safety edge on two-lane rural highways with no paved shoulder, on two-lane rural highways with narrow paved shoulders, and on multilane rural highways with narrow paved shoulders.

The AMFs will be presented in tables. These tables will be supplemented by graphs and charts, as appropriate, to illustrate the AMFs. It is expected that the AMFs will vary with AADT and may also vary with the width of the paved shoulder. It is possible that the AMFs may be influenced by lane width or roadside design.

In addition, the study will document the frequency and height of drop-offs based on field measurements at sites with and without the safety edge for up to three years after resurfacing.

It is to be expected that the safety edge will have the greatest impact on two-lane highways with no paved shoulders. However, most of these roadways have low AADT and are therefore not expected to have a high frequency of potential drop-off-related crashes.

For this reason the safety evaluation will probably require five years of before-period crash data and three to five years of after-period crash data to provide statistically reliable conclusions. However, it is recommended that the crash data be analyzed for each year of the after period to look for trends or spikes in the number of a certain type of crash such as motorcycle crashes. An assessment can be made, based on the initial results, whether to extend the after period beyond three years.

These interim results may provide enough data that some additional agencies would implement the safety edge in resurfacing projects. Early adoption of the safety edge may be most critical for local city and county agencies.

Section 6.
Level of Effort and Costs to Conduct Evaluation

The safety edge evaluation is expected to take three years after the date of resurfacing of all treated sites. Each year during the evaluation, the treated sites will be visited to measure drop-offs and to determine that no other changes have been made to the site. During the first year of the evaluation, a number of reference sites will be chosen in each state to allow development of SPFs for the various road-shoulder types found in the treated sites. Crash and ADT data will be collected also. While we do not expect there to be sufficient drop-off-related crashes to make a statistically sound analysis after one or two years, the yearly analysis will allow us to determine that no unexpected crash patterns, such as an increase in motorcycle crashes, are occurring on the safety edge sites.

In Year 1, reference sites will be selected and SPFs developed for each state and site type. Field drop-off measurements will be made at the treated sites, and crash and ADT data will be collected. A preliminary analysis will be performed, and an interim report will be submitted at the end of Year 1.

Field and office data will also be collected in Year 2 of the analysis. Again field visits will be made to treated sites to measure drop-offs and verify that the roadway has not been changed. A second interim report will be submitted at the end of Year 2.

Year 3 will be the last year of the analysis and again field and office data will be collected. At the end of Year 3, a final analysis of the treated sites using the two analysis approaches described above will be conducted. A final report will be written summarizing the results of the analysis.

Table 3 presents the estimated level of effort for each activity as part of the evaluation. The estimated total cost of the evaluation for Georgia, Indiana, and New York, including both labor and travel, is:

Year 1 Cost	$129,000
Year 2 Cost	88,000
Year 3 Cost	122,000
Total Cost	$339,000

The estimated level of effort and cost would increase if additional states, sites, or years of after-period data were added to the planned evaluation.

Colorado has joined the study, and data was collected at two Colorado sites in March, 2006. North Carolina is expected to resurface four sites with the safety edge in the near future. If the sample sizes in these states remain limited, these sites will be included in the cross-sectional analysis but not the EB analysis.

Table 3. Estimated Level of Effort

Activity	Senior Traffic Engineer (hrs)	Statistician/Analyst (hrs)	Assistant Engineer/Technician (hrs)	Total (hrs)
Year 1				
Project management	100			100
Reference site selection	120	60	240	420
Field data collection	20		200	220
Office data retrieval	40	48	80	168
Interim analysis	40	60	20	120
Interim report	40	40		80
Total	360	208	540	1108
Year 2				
Project management	100			100
Field data collection	20		200	220
Office data retrieval	40	48	80	168
Interim analysis	40	60	20	120
Interim report	40	40		80
Total	240	148	300	688
Year 3				
Project management	100			100
Field data collection	20		200	220
Office data retrieval	40	48	80	168
Final analysis	80	120	40	240
Final report	80	80		160
Total	320	248	320	888
Combined total	920	604	1160	2684

Appendix A

Locations and Characteristics of Candidate Treated Sites

This appendix provides a listing of the resurfacing projects, with and without the safety edge treatment, for each of the participating agencies. Information regarding the project location (route, county, and boundary points) and current roadway geometrics are given for each project. In total, there are 29 projects in Georgia (see Table A-1), 16 projects in Indiana (see Table A-2), and seven projects in New York (see Table A-3). Resurfacing at all of these sites was completed in 2005. Data on Colorado sites collected in March, 2006, are not included in this table.

Table A-1. Candidate Treated Sites in Georgia

Proj. No.	Route	County Name	Beginning Route Name	End Route Name	BMP	EMP	Length (mi)	Edge Trt.[1]	Road Type	Shoulder Type	Paved Shldr. Width (ft)	Lane Width (ft)	Rdside Design Rating
T01	SR 211	Barrow	0.01 mi N of SR 316	0.10 mi S of SR 11	0.00	9.72	9.72	A	Two-lane	Unpaved	0	12	3.5
T02	SR 60	Hall	Fraiser Cir.	0.02 mi N of Lodge Dr.	16.60	20.50	3.90	A	Two-lane	Paved	2	12	4.0
T03	SR 115	Habersham	0.45 mi N of Chattahoochee River	0.27 mi S of SR 17	0.45	4.98	4.53	A	Two-lane	Paved	2	12	3.5
T04	SR 197	Habersham	0.01 mi S of SR 15/SR 365	SR 17/US 441 BUS	0.23	3.65	3.42	A	Two-lane	Unpaved	0	12	4.0
T05	SR 17	White	Habersham Co. Line	SR 75	0.00	4.25	4.25	A	Two-lane	Paved	2	11	3.5
T06	SR 98	Banks	SR 15	RR crossing	0.00	6.24	6.24	A	Two-lane	Unpaved	0	11	3.5
T07	SR 15AL	Jackson	SR 11 in Jefferson	SR 15/US 441	12.23	23.63	11.40	A	Two-lane	Unpaved	0	12	3.0
T08	SR 17	Elbert	SR 172 in Bowman	Hart Co. Line	23.60	25.77	2.17	A	Two-lane	Paved	2	12	3.5
		Hart	Elbert Co. Line	SR 17 Royston Bypass	0.00	3.97	3.97	A	Two-lane	Paved	2	12	3.5
T09	SR 119	Liberty	SR 25/US 17	SR 196	0.00	15.69	15.69	A	Two-lane	Paved	4	12	3.0
T10	SR 30	Toombs	0.06 mi W of SR 4	Tattnall Co. Line	7.28	17.04	9.76	A	Two-lane	Paved	4	12	3.0
		Tattnall	Toombs Co. Line	0.34 mi E of Ohoopee River Br.	0.00	0.72	0.72	A	Two-lane	Paved	4	12	3.0
T11	SR 126	Dodge	S of Delaware Ave.	Laurens Co Line	4.39	8.12	3.73	A	Two-lane	Paved	4	12	1.5
		Laurens	Dodge Co. Line	SR 117	0.00	4.54	4.54	A	Two-lane	Paved	4	12	3.0

Table A-1. Candidate Treated Sites in Georgia (Continued)

Proj. No.	Route	County Name	Beginning Route Name	End Route Name	BMP	EMP	Length (mi)	Edge Trt.[1]	Road Type	Shoulder Type	Paved Shldr. Width (ft)	Lane Width (ft)	Rdside Design Rating
T12	SR 11	Bibb	SR 87, Martin Luther King, Jr.	Jones Co. Line	12.51	16.74	4.23	A	Multilane	Paved	2	12	3.0
		Jones	Bibb Co. Line	0.10 mi S of Sterwart Ave.	0.00	9.67	9.67	A	Multilane	Paved	2	12	3.0
T13	SR 100	Troup	SR 14/US 29	Coweta Co. Line	3.82	7.36	3.54	A	Two-lane	Unpaved	0	12	2.5
		Coweta	Troup Co. Line	Heard Co. Line	0.00	0.43	0.43	A	Two-lane	Unpaved	0	12	3.0
		Heard	Coweta Co. Line	0.23 mi E of SR 1/US 27	0.00	5.74	5.74	A	Two-lane	Unpaved	0	12	4.0
T14	SR 1	Haralson	Carroll Co. Line	SR 1 BUS	0.00	9.24	9.24	A	Multilane	Paved	4	12	4.0
T15	SR 151	Walker	SR 136	Catoosa Co. Line	10.12	14.83	4.71	A	Two-lane	Unpaved	0	12	3.0
C01	SR 81	Walton	SR 20	Barrow Co. Line	10.73	19.97	9.24	B	Two-lane	Paved	2	12	3.0
C02	SR 183	Dawson	SR 53	SR 52	0.00	10.42	10.42	B	Two-lane	Unpaved	0	11	3.5
C03	SR 2	Rabun	Hill Camp Ln. (0.10 mi W Charlie Mtn. Rd.)	South Carolina State Line	8.82	24.45	15.63	B	Two-lane	Unpaved	0	12	3.5
C04	SR 51	Hall	Cornelia Hwy/Main St. in Lula	County Line Rd./Banks Co. Line	1.12	1.52	0.40	B	Two-lane	Unpaved	0	12	2.5
		Banks	County Line Rd./Hall Co. Line	SR 15/US 441	0.00	10.58	10.58	B	Two-lane	Unpaved	0	12	2.5
C05	SR 12	McDuffie	Warren Co. Line	SR 10	0.00	5.90	5.90	B	Multilane	Paved	4	12	3.0
C06	SR 24	Bulloch	0.2 mi W Clito Rd.	Screven Co. Line	6.50	14.76	8.26	B	Two-lane	Paved	3	12	2.0

Table A-1. Candidate Treated Sites in Georgia (Continued)

Proj. No.	Route	County Name	Beginning Route Name	End Route Name	BMP	EMP	Length (mi)	Edge Trt.[1]	Road Type	Shoulder Type	Paved Shldr. Width (ft)	Lane Width (ft)	Rdside Design Rating
C07	SR 101	Carroll	SR 8	Paulding Co. Line	0.61	6.39	5.78	B	Two-lane	Unpaved	0	12	3.5
		Paulding	Carroll Co. Line	SR 120	0.00	3.16	3.16	B	Two-lane	Unpaved	0	12	4.0
C08	SR 6	Paulding	0.05 mi E Polk Co. Line	Pumpkinvine Creek Br.	0.05	7.06	7.01	B	Multilane	Paved	4	12	4.0
C09	SR 120	Paulding	SR 101	SR 6	3.46	13.11	9.65	B	Two-lane	Paved	4	12	3.5
CN1	SR 328	Stephens	SR 17	Franklin Co. Line	0.00	3.64	3.64	B	Two-lane	Unpaved	0		
		Franklin	Stephens Co. Line	SR 59	0.00	6.14	6.14	B	Two-lane	Unpaved	0		
CN2	SR 171	Emanuel	US 80	Johnson Co. Line	4.26	10.40	6.14	B	Two-lane	Unpaved	0	12	
		Johnson	Emanuel Co. Line	Jefferson Co. Line	0.00	13.40	13.40	B	Two-lane	Unpaved	0	12	
		Jefferson	Johnson Co. Line	SR 78	0.00	1.95	1.95	B	Two-lane	Unpaved	0	12	
CN3	SR 129	Evans	Old SR 250 (CR204)	0.99 mi N of CR 58/Perkins Mill Rd.	0.00	5.51	5.51	B	Two-lane	Unpaved	0	12	
CN4	SR 76	Cook	SR 37	Berrien Co. Line	10.30	15.66	5.36	B	Two-lane	Unpaved	0	12	
		Berrien	Cook Co. Line	SR 11/SR 125	0.00	4.82	4.82	B	Two-lane	Unpaved	0	12	

[1] A = Resurfaced with safety edge
B = Resurfaced without safety edge

Table A-1. Candidate Treated Sites in Georgia (Continued)

Proj. No.	Route	County Name	Beginning Route Name	End Route Name	BMP	EMP	Length (mi)	Edge Trt[1]	Road Type	Shoulder Type	Paved Shldr Width (ft)	Lane Width (ft)	Rdside Design Rating
T01	SR 67	Rensselaer	Clum Rd.	Kim Ct.	10.00	13.30	3.30	A	Two-lane	Paved	3	10	3.0
T02	SR 18	Orleans	Townline Rd. CR 67	Kuckville	7.90	10.30	2.40	A	Two-lane	Paved	4	11	3.5
T03	SR 9	Columbia	SR 9J (Jct.)	CR 46	6.20	6.50	0.30	A	Two-lane	Paved	3	12	3.0
T04	SR 354	Erie	Bowen Rd	Two Rod Rd.	8.58	12.87	4.29	A	Two-lane	Paved	4	11	3.0
C02	SR 9	Columbia	0.3 mi from SR 9J (Jct.)	CR 46	6.50	8.20	1.70	B	Two-lane	Paved		12	3.0
C03	SR 9H	Columbia	Ghent CL	Town of Kinderhook	7.60	13.20	5.60	B	Two-lane	Paved		12	
C04	SR 18	Orleans	Orleans CL	MP 1078	0.00	7.90	7.90	B	Two-lane	Paved	4	9	1.5

[1] A = Resurfaced with safety edge
B = Resurfaced without safety edge

Table A-2. Candidate Treated Sites in Indiana

Proj. No.	Route	County Name	Beginning Route Name	End Route Name	BMP	EMP	Length (mi)	Edge Trt.[1]	Road Type	Shoulder Type	Paved Shldr. Width (ft)	Lane Width (ft)	Rdside Design Rating
T01	SR 18	Benton White	E Jct. US 52	US 231	12.15	26.65	14.50	A	Two-lane	Unpaved	0	13	2.5
T02	US 136	Fountain	US 41	Fount/Mont CL	16.98	25.33	8.35	A	Two-lane	Unpaved	0	12	2.5
T04	SR 11	Jackson	US 50	I-65	38.17	43.30	5.08	A	Two-lane	Paved	3	12	3.0
T06	SR 62	Warrick Spencer	SR 61	US 231	44.00	58.02	14.02	A	Two-lane	Paved	2	12	3.0
T07	US 231	Jasper	SR 114	SR 14	251.83	258.14	6.31	A	Two-lane	Paved	2		
T09	SR 39	Washington Jackson	SR 56	SR 250	0.00	15.59	14.91	A	Two-lane	Unpaved	0	10	3.0
T10	SR 68	Gibson	SR 65	SR 57	12.82	26.82	13.00	A	Two-lane	Unpaved	0	11	2.0
T11	SR 17	Cass	Northern Ave. (Logansport)	SR 16	1.42	7.96	6.54	A	Two-lane	Unpaved	0	10	3.0
C01	SR 42	Morgan Putnam	US 231	Little Point	33.00	46.65	13.69	B	Two-lane	Unpaved	0	10	
C02	SR 65	Vanderburgh	SR 66	I-64	0.00	10.95	10.95	B	Two-lane	Unpaved	0	11	3.0
C03	SR 37	Crawford	SR 62	SR 64	29.56	38.46	8.90	B	Two-lane	Unpaved	0	11	
C04	SR 44	Fayette	Rush/Fayette CL	SR 121	63.00	71.51	8.51	B	Two-lane	Paved	2		
C05	SR 64	Dubois	SR 161	US 231	41.89	46.27	4.38	B	Two-lane	Paved	1	12	2.5
C06	US 136	Hendricks	SR 39	W of Brownsburg	59.02	67.37	8.37	B	Two-lane	Paved	2	12	2.0
C08	SR 160	Washington Scott	SR 60	US 31	0.00	18.24	18.19	B	Two-lane	Unpaved	0	10	2.5
C09	SR 58	Jackson	SR 135	Jackson/Barth CL	105.00	111.45	6.40	B	Two-lane	Unpaved	0	10	5.5

[1] A = Resurfaced with safety edge
B = Resurfaced without safety edge

Table A-3. Candidate Treated Sites in New York

Proj. No.	Route	County Name	Beginning Route Name	End Route Name	BMP	EMP	Length (mi)	Edge Trt[1]	Road Type	Shoulder Type	Paved Shldr Width (ft)	Lane Width (ft)	Rdside Design Rating
T01	SR 67	Rensselaer	Clum Rd.	Kim Ct.	10.00	13.30	3.30	A	Two-lane	Paved	3	10	3.0
T02	SR 18	Orleans	Townline Rd. CR 67	Kuckville	7.90	10.30	2.40	A	Two-lane	Paved	4	11	3.5
T03	SR 9	Columbia	SR 9J (Jct.)	CR 46	6.20	6.50	0.30	A	Two-lane	Paved	3	12	3.0
T04	SR 354	Erie	Bowen Rd	Two Rod Rd.	8.58	12.87	4.29	A	Two-lane	Paved	4	11	3.0
C02	SR 9	Columbia	0.3 mi from SR 9J (Jct.)	CR 46	6.50	8.20	1.70	B	Two-lane	Paved		12	3.0
C03	SR 9H	Columbia	Ghent CL	Town of Kinderhook	7.60	13.20	5.60	B	Two-lane	Paved		12	
C04	SR 18	Orleans	Orleans CL	MP 1078	0.00	7.90	7.90	B	Two-lane	Paved	4	9	1.5

[1] A = Resurfaced with safety edge
B = Resurfaced without safety edge

Appendix B

Fields Used to Filter Drop-Off-Related Crashes

To quantify the number of edge drop-off-related accidents, the methodology used by Council et al. (2005) was adapted to the specific accident characteristics reported from each of the participating agencies. Their study separated accidents of interest into five categories. However, since multiple vehicle edge drop-off-related accidents may occur for collision types other than “Head-On” and “Sideswipe,” a sixth category has been added for these accidents.

- Category A—Run-off-road right, cross centerline/median, hit vehicle in opposite direction (head-on or sideswipe).
- Category B—Run-off-road right, sideswipe vehicle in same direction.
- Category C—Run-off-road right, rollover.
- Category D—Run-off road right, then run-off-road left.
- Category E—Single vehicle run-off-road right.
- Category F—Multiple vehicle run-off-road right.

The crashes were also separated into tiers based on weather the reporting officer noted a shoulder defect at the crash site. Tier 1 crashes had a shoulder defect noted and tier 2 crashes did not.

All accidents from the participating agencies were screened for inclusion into one of the above categories (summarized in Table 2) with the exception of Colorado data. Only New York had a shoulder defect item on their crash form and none of the crashes had shoulder defects noted. For Georgia and New York, only accidents that occurred on the test locations were included. Conversely, Indiana’s data included all accidents that occurred within a county for a route, as the location reference data were missing for approximately 20 percent of the accidents. Intersection-related or at-intersection accidents were excluded from the analysis but varied between agencies due to differences in accident descriptors. New York non-reportable accidents and non-injury accidents, with less than $1,000 in property damage to any vehicle, were also excluded, as non-reportable accidents were not available for all years.

Accident descriptors found in the data were used to indicate that the set of selection criteria for a category definition were met. Generally, descriptors that provided information regarding the type of collision (head-on, sideswipe same-direction, sideswipe opposite-direction, etc.), sequence of events (ran off road, crossed centerline/median, etc.), location of the first harmful event, driver contributing circumstances (overcorrecting/over-steering), or roadway contributing factors (defective shoulder) were used in the selection criteria. One of these descriptors had to contain an indication that the vehicle ran off the road before selecting a particular category. Differences in accident reporting between agencies led to individualized selection criteria for each agency. The descriptors used for each agency and the differences between them are described next.

The initial cut of the data was made by determining if an accident descriptor indicated that a vehicle ran off the road. For Indiana, the first selection criteria were solely determined by the Primary Factor field equaling one of three enumeration levels: ran-off-road right, ran-off-road left, or overcorrecting/over-steering. Conversely, Georgia and New York considered only accidents in which a roadside object was involved (Georgia—Harmful Event field, New York—Accident Type field), or the location of impact (Georgia) or the location of first harmful event (New York) was off the roadway. New York also considered accidents where the Second Event field for Vehicle 1 and Vehicle 2 involved a roadside object, as well as a Contribution Factor field containing information on a defective shoulder.

Criteria were then developed to assign each of these accidents to one of the categories of edge drop-off-related accidents. To do this, an indicator variable was created to classify the accident as a multiple-vehicle or single-vehicle accident for all agencies. From this classification, only multiple-vehicle accidents were considered for Categories A, B, and F. The remaining categories considered only single-vehicle accidents.

Categories A, B, and F were subsequently determined by the type of Collision field. Category A included the enumeration levels equal to head-on or opposite-direction sideswipe. Similarly, Category B included sideswipe same-direction. However, New York also had to consider the direction of travel for each vehicle, as its Collision field did not distinguish between same and opposite direction for sideswipes. All other multiple-vehicle accidents were placed in Category F. Criteria for single-vehicle categories were similarly created. Accidents were identified as Category C if the Harmful Event, Collision With, or Accident Type field had an enumeration level of overturn/rollover for Georgia, Indiana, and New York, respectively. Category D accidents could not be identified for any agency, as fields for the sequence of events were not available in the data. All other single-vehicle accidents were classified as Category E.

Appendix C

Pavement Edge Drop-Off Data Collection Methodology

Field Data Collection Form

A sample data collection form is shown in Figure C-1.

Definition of Segments and Sections

Roadway segments are selected from each participating state's resurfacing program. Only roadways with an unpaved shoulder or a paved shoulder with a width of less than 4 ft are sampled.

Each segment will generally have three to four sections, but segment length and roadway conditions may call for more or less. Data collectors are then instructed to collect data for sections 2 to 4 miles apart, as appropriate, to obtain an appropriate number of sections to represent the segment, as allowed by safety and segment length. Once the number of sections and section spacing appropriate for the section are determined, the collector will determine the appropriate distance, in whole miles, from the segment start to the first section for data collection. To remove bias from the collection process, a random, single-digit whole number is selected. It is then divided by 10 and added to the distance previously decided upon by the collector. For example, it is determined that the first section should start 2 miles into the segment, and 5 is the random number. The first section then starts 2.5 miles (2.0 + 5.0/10.0 = 2.5) into the section. The random number is shown on the data sheet. Sections within the segments are spaced evenly, if possible, and at whole-mile increments so that the starting location of each 0.1-mile section is determined before arriving at the section. In the interest of safety, or if the section does not adequately represent the section, the section may be moved as needed. Subsequent sections start at their previously determined locations. Data are not collected for a section if:

- Recent maintenance has occurred
- There is insufficient sight distance to collect data safely
- Weather does not permit data to be reasonably collected safely or accurately

Field Characteristics

Data are collected in the field for 0.1-mile intervals. Pavement edge drop-off height was measured every 52 feet within the 0.1-mile interval.

Pavement Edge Drop-off Data Collection

County & State: ______________________ **Date:** ________________

Site: ______________ **Milepost:** ___________ **(Page ___ of ___)**

Weather Condition: sunny partly cloudy overcast

Main St. (include gov and local names): ____________________________________

Begin cross-street: ____

End cross-street: ____

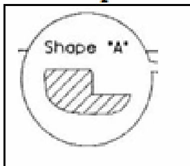
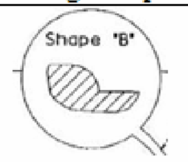
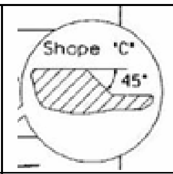
Speed Limit: ___________ **Orientation:** N / S E / W

Pavement Type: Asphalt Concrete

Shoulder Type:

asphalt	concrete	gravel	earth	mixed / varies
N / S / E / W	N / S / E / W	N / S / E / W	N / S / E / W	N / S / E / W

Circle pavement edge shape:

				
Sharp break-off or concrete	overlay, may be more jagged	Wedge in place	Squashed Wedge	Other (draw)
N / E S / W	N / E S / W	N / E S / W	N / E S / W	N / E S / W

random start point (mi)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9

	Grade (%)	Width (ft)
N or E Shoulder		
S or W Shoulder		
N or E Lane		
S or W Lane		
Road Grade (if sig)		up / down

Horizontal Curve left right none

Vertical crest sag none

Initial Grade _______ up down

Final Grade _______ up down

Roadside Rating _______

Additional Comments:

Dist from Start Pt	N / E	S / W
0 (ft)		
52 (ft)		
104 (ft)		
156 (ft)		
208 (ft)		
260 (ft)		
312 (ft)		
364 (ft)		
416 (ft)		
468 (ft)		
520 (ft)		

Figure C-1. Sample Data Collection Form

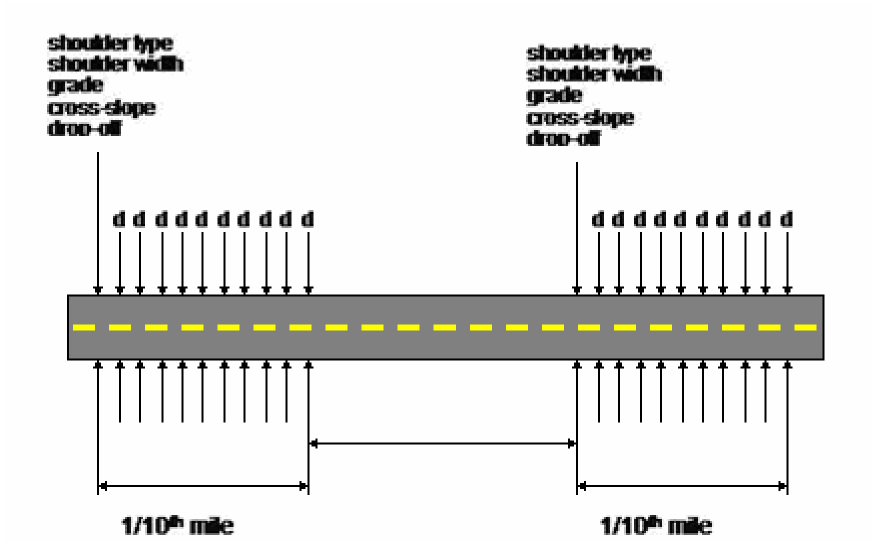


Figure C-2. Data Collection Intervals

The data collector will regularly collect one 0.1-mile interval each 2 to 4 miles, based on the total segment length. Drop-off data will be collected in the 0.1-mile interval at 52-ft spacing on both sides of the roadway. Other road characteristics are collected at the beginning of the interval since they are not expected to change significantly throughout the length of the segment. Characteristics that are recorded at the beginning include:

- Speed limit
- Pavement type
- Shoulder type
- Shoulder grade
- Shoulder width
- Lane cross-slope
- Lane width
- Pavement edge drop-off shape
- Grade
- Pavement edge drop-off

Shoulder Type

Shoulder type is expected to be paved, gravel, or earth. In some cases, a mixture of material is found along the shoulder as shown. When a mixture of material is found, the width of pavement beyond the lane edge-line will be recorded and the other materials noted.

Drop-Off Shape

Drop-off shapes are shown in the data collection form. Shapes A, B, and C were defined in other literature. Most shapes correspond to A, B, or C. Shape A typically corresponds to concrete pavement edge shape. The likely cause is settling of the concrete pavement. It also occurs when asphalt pavement breaks. Shape B is the most common shape for asphalt pavement. It is the shape that occurs from typical overlay. Shape C corresponds to the safety wedge. It is recorded when the edge shape is approximately 45 degrees and appears to be intentionally shaped. Drop-off appears to be more pronounced when erosion is apparent but does not appear to affect drop-off shape itself.

Lane Width and Pavement Width

Pavement width is measured; then lane width and the amount of paved shoulder are recorded as well. Most shoulders on rural roadways are not paved. However, some extension of the pavement beyond the painted edge-line may exist. There was some discussion among the research team as to whether small amounts of pavement (2- to 4-inches) beyond the pavement edge-marking functions as part of the lane or shoulder. It was determined that material that is 4 inches or less beyond the pavement edge-marking will be considered to be part of the lane. Material with a width that is greater than 4 inches will be considered paved shoulder. Lane width will be measured from the edge of the lane, as defined above, to the painted centerline of the roadway. In the event that no centerlines are present, the lane width will be calculated as half of the total paved roadway.

Drop-Off Height

Drop-off height is collected to the nearest 0.125-inch since most measuring tools measure in 0.125-inch increments. Additionally, measurement tools marked with 0.125-in measurements have been found to be easier to read consistently than those marked with 0.1-inch increments. It is assumed that a tire could still catch on just a few inches of drop-off, even if shoulder material is at grade beyond that distance. Therefore, drop-off is collected approximately 4 inches from the edge of pavement for Shape A, or 4 inches from the base of the pavement for Shapes B and C (Figure C-3).

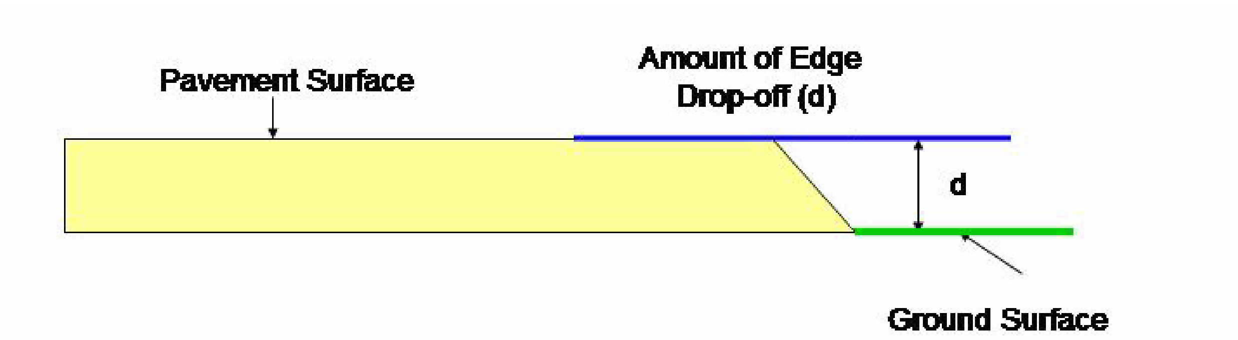


**Figure C-3. Measurement of Pavement Edge Drop-Off
Tangent to Pavement Surface**

Drop-off is collected by placing a level across the top of the pavement surface so that it overhangs the shoulder. A ruler is then used to measure the vertical distance between the shoulder and the level at the appropriate location as discussed above. Drop-off is measured from the ground to the base of the level as shown in Figure C-4.

Figure C-4. Measurement of Drop-Off

Pavement edge drop-off is not collected at driveways or minor intersections if they coincide with a data collection point. If a driveway or intersection is located at a data collection point along a segment, data collectors record that information and move to the next data collection point.

Photos

Photos are taken at regular intervals along the route. Photos labeled with specific locations will not be released to the public to prevent possible litigation against the DOT. Photos will be used as a permanent record and reference. Photos can be used for reporting or illustration if the specific location is not identified.