A Realistic Test of Hauer's Promising Site Identification Method

A Realistic Test of Hauer's Promising Site Identification Method

Final Report
Prepared for the:

Southeastern Transportation Center
Dr. Stephen H. Richards, Center Director
University of Tennessee at Knoxville

As part of the project "Accidents on Secondary Highways and Countermeasures"
Conducted during STC Year 9

Written by:

Kimberly A. Krull
Research Assistant, Department of Civil Engineering
North Carolina State University
Raleigh, NC 27695-7908
Telephone: 919-515-6456, Fax: 919-515-7908
E-mail: kkrull@eos.ncsu.edu

Joseph E. Hummer, Ph.D., P.E.
Associate Professor
Department of Civil Engineering
North Carolina State University
Raleigh, NC 26795-7908
Telephone: 919-515-7733, Fax: 919-515-7908
E-mail: hummer@eos.ncsu.edu

Jason A. Crouch
Research Associate, Transportation Center
The University of Tennessee, Knoxville
Knoxville, TN 37996-4133
Telephone: 423-974-0161, Fax: 423-974-3889
E-mail: jacrouch@utk.edu

Arun Chatterjee, Ph.D., P.E.
Professor
Department of Civil and Environmental Engineering
The University of Tennessee, Knoxville
Knoxville, TN 37996-2010
Telephone: 423-974-7714, Fax: 423-974-2669
E-mail: arun@utk.edu

July 5, 2000

ABSTRACT

The prevailing methods of identifying hazardous locations use the collision history of a system to find the locations where more collisions have occurred. Problems with these prevailing methods include the tremendous burden on agencies to maintain a full and accurate collision data set, the inability to assess the safety of new or changed sites, and the fact that cost-effective countermeasures may not be available for high-collision sites. In 1996, Dr. Ezra Hauer suggested the use of five criteria to find "promising sites" with potential for productive countermeasure installation to address these problems. The objective of this research was to apply Hauer's ideas in a realistic test using an existing data set. Collision files from 1990 to 1997 for Buncombe County, North Carolina were used to apply the method. The county was selected because of the quality of its collision data, the amount of collision data easily retrievable, cooperative officials, and the proximity to the investigating universities.

Our application showed that an accurate, complete, and recent roadway inventory is pivotal to the implementation of Hauer's method. The method is data intensive to set up the first year, but isn't intensive to maintain in subsequent years. After the initial year, the majority of the effort is monitoring for changes in the system. Collision data for at least five years are desirable to begin. The addition of an intersection database would strengthen the application of the method. Once established, Hauer's method would likely be an efficient safety management system for a medium to large jurisdiction.

ACKNOWLEDGEMENTS

The data for this paper were extracted from FHWA's Highway Safety Information System (HSIS) which is maintained by the Highway Safety Research Center (HSRC) at the University of North Carolina at Chapel Hill. The authors appreciate FHWA's and HSRC's support in providing these data.

This project was completed with the cooperation and assistance of Mr. Kenneth Putnam, Division Traffic Engineer, Division 13, North Carolina Department of Transportation.

The authors thank the US Department of Transportation, the Southeastern Transportation Center, North Carolina State University, and the University of Tennessee at Knoxville for providing the financial support to make this work possible.

The opinions, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the view of the FHWA, HSRC, or any of the project sponsors.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

BACKGROUND

In 1998 motor vehicle collisions killed over 41,000 people and injured 3.2 million (NHTSA, 1998). The collision causes include the driver, the vehicle, and the roadway. If traffic engineers could identify and correct roadways that are hazardous, collisions could be significantly reduced. Many different procedures to identify hazardous locations exist. The prevailing methods of identification use the collision history of a system to sort out the locations where the most collisions are occurring. However, once sites are identified by collision frequency as being hazardous locations, the amount of funding available constrains traffic engineers. There may not be enough funding to provide the necessary alterations to make all locations safe. In addition, the prevailing methods include the tremendous burden on agencies to maintain a full and accurate collision data set. An ideal method would be able to sort out sites that are in need of remedial action and are capable of being cost-effectively improved without employing all the resources of a department.

In *Transportation Research Record 1542*, Dr. Ezra Hauer addresses these economic concerns. He reviews the historical and conceptual development of procedures for the identification of hazardous locations. Based on this review, he suggests ways to improve the identification stage of safety management. Dr. Hauer suggests that hazardous location identification consider the concepts of funding constraints by identifying hazardous locations that have some promise of being improved in a cost-effective way. He also suggests evaluating locations by multiple criteria.

Two pivotal ideas emerge from Hauer's paper. First, the object of the identification stage should be to select sites that have a good chance of being in need of remedial action and are amenable to improvements in a cost-effective way. Second, a site does not need to be unduly hazardous for there to be an opportunity to reduce the amount of collisions at the location cheaply. From these two pivotal ideas, the phrase, 'sites with promise' emerges.

Hauer is critical of statistical methods that only identify one aspect of statistical criteria, i.e., collision frequency or rate. He suggests identifying locations by five criteria and a subset of hazardous locations with promise will arise from these five ranked lists. These criteria include collision frequency of a particular type (F), scaled deviation after construction or reconstruction ($\Delta F/\sigma_F$), size of increase in frequency, scaled deviation in rate after construction or reconstruction ($\Delta R/\sigma_R$), and collision rate (R). With the first criterion, Hauer emphasizes that sites should be identified by target frequency, not just overall frequency. Target frequency would relate types of collisions to cost effective measures. For example, the target frequency of night collision could relate to the cost-effective countermeasure of installing illumination on a roadway. In this respect, hazardous sites with promise, not just hazardous sites, are identified.

OBJECTIVE

The objective of this research was to apply the ideas presented by Hauer in a realistic test using an existing data set. Specifically the objectives include:

- Develop and apply a method by which Hauer's concepts can be applied,
- Identify problems encountered when applying this method,
- Identify possible solutions to problems encountered when applying this method, and
- Evaluate the feasibility of applying this method at the city level, county level, region level, and/or state level.

Achieving these four objectives will provide engineers with insight on how to apply Hauer's concepts in their jurisdictions.

SITE SELECTION

Collision files from Buncombe County, North Carolina were selected as the data set to apply Hauer's procedure. Buncombe County is located in the Blue Ridge Mountains of western North Carolina. The land area is over 650 square miles with a population of 194,000 people. The majority of the people are concentrated in the medium-sized city of Asheville. The terrain is mountainous and rolling. The North Carolina Department of Transportation helped to identify Buncombe County as the test site. The county was selected because of the quality of its collision data, the amount of collision data easily retrievable, cooperative officials, and the proximity to the investigating teams. Medium-sized cities such as Asheville historically are a good source of quality collision data.

The FHWA's Highway Safety Information System (HSIS) database maintains collision data for the state of North Carolina. The Highway Safety Information System is a multi-state relational database that contains collision, roadway inventory, and traffic volume data for a select group of states. The states are selected based on the quality of data available and their ability to merge data from various files. Currently, collisions from eight states are included in the database.

The HSIS database contained collision files from 1990 to 1997 for Buncombe County. HSIS uses data already collected by the State of North Carolina for the management of the highway system. Therefore, not all of the collisions that occurred in Buncombe County in the eight-year range are included in the collision files. Only collisions occurring on the state maintained roadway system are included in the file. The state road system in North Carolina includes all roadways except for some city streets.

DATA COLLECTION AND MANAGEMENT

The research team requested collision and roadway inventory database information from the accident and roadlog files from 1990 to 1997 for Buncombe County from HSIS. The collision files contain information on the vehicle and environmental factors involved in a collision. The roadway inventory database file contains information on the roadway cross-section, types of roadway, and other roadway characteristics. HSIS determines segments based on field inventory and construction plans. The database has each route described by segments based on similar roadway characteristics. When any feature of the route changes (e.g. the shoulder widens, another lane is added, the pavement surface changes) a new segment starts. The segments are referenced by milepost. Table 1 lists the requested accident and roadlog file variables.

Table 1: Requested Variables from the Accident and Roadlog Files

Accident File Variables Requested	Roadlog File Variables Requested
Accident type	AADT
Hour	Year of AADT
Light condition	Beginning milepost (segment)
Accident location type	Ending milepost (segment)
Means of involvement	Functional class
Milepost	Left shoulder type
Road character	Left shoulder width
Road configuration	Number of lanes total
Type of road surface	Right shoulder type
Surface condition	Right shoulder width
Direction from reference	Route number
Distance from reference	Route type
Reference road	Section length in miles
Road on	Surface type
Mileposted route number	
Nearby intersection road	
Traffic control type	
Weather condition	

Many of the collision file variables and roadway inventory variables were not used in this analysis. Without complete foresight as to which variables would be used in the analysis, extraneous variables were requested. Discarding variables once it is determined that they are not needed is easier than obtaining variables later when it is determined that they are needed.

The research team received the data in Microsoft Excel form as nine files: one collision file for each year from 1990 to 1997 and one file containing the 1994 Roadway Inventory Information for Buncombe County. The inventory information was not completely current as of 1994, but was the most current information available as of 1994. The eight collision files together contained 17,000+ rows of data. Each row represents one collision. Each column displays information for one collision variable. The roadway inventory file contains 785 rows of data. Each row represents one roadway segment.

Each column displays information for one roadway inventory variable. The 785 segments are from 166 different roadways and represent 532 miles of road. The average segment is 2/3 of a mile long, but segments range in length from .01 miles to 7.59 miles.

The research team imported the data into Microsoft Access as two data tables: one table containing all the collision files and one table containing all of the roadway inventory information. Microsoft Access software is a relational database software program. The program made it possible to relate the information contained in the roadway inventory files to the collision files. Collisions were referenced to the roadway file segments they occurred on. In order to link the collision files to the appropriate roadway segment, the research team assigned each segment an alphanumeric designation. The numeric portion is the route number and the alphabetic portion is an arbitrary letter designation given to each segment. HSIS is able to provide the collision data already linked to the roadway data. However, the research team did not take advantage of this ability of the database to more accurately simulate an analyst using a typical collision database.

The research team attempted to aggregate the collisions occurring at an intersection separately from collisions occurring in the mid-block. Intersections are of particular importance in collision analysis because a high proportion of collisions occur there and the set of effective countermeasures for intersections differs from the set for road segments. Additionally, collisions occurring on all legs of an intersection need to be grouped together to estimate the hazard of the intersection. If collisions are only attributed to the roadway segments, the set of collisions at an intersection could be distributed between multiple segments and the true hazard of the intersection would not be revealed.

The current road inventory in the HSIS database for North Carolina does not identify intersections. The HSIS guidebook notes that, "The major gaps in the inventory information include intersection/interchange inventory information.... In addition, there is no current computerized intersection inventory information available. Inventory information does exist on a separate file related to traffic signals. At this point it is not readily merged with the location file, but it is possible that the merging will be made possible within the next two years."

The research team attempted to use the collision data, roadway inventory, and graphical maps to identify all intersections in the county, assign a number to the intersections, then associate all collisions occurring at these intersections with the location number. Several collision variables indicate the presence of an intersection including the variables 'traffic control type', 'location type', and 'reference distance'. The variable 'reference distance' indicates the distance that the collision occurred from the nearest intersecting roadway. The variable 'traffic control type' indicates the type of traffic control device, if any, at the location of the collision. The variable 'location' reports the type of location where the collision occurred. The research team tried to use these three variables to locate all intersections in the data set.

Collisions that occurred on the approach (within 100 or 200 feet) of an intersection are typically considered intersection collisions (ITE, 198). Logically, it would seem that sorting out all collisions whose reference distance was under .03 miles (approximately 150 ft.) could identify all intersections. From this set of collisions, the combinations of the routes the collisions occurred on and the roads the routes were referenced to could define a subset of intersection locations. The intersections should appear in the data set in two forms: occurring on the major route and referenced to the minor road, and occurring on the minor route and referenced to the major road. After all intersections are identified, the intersections could be numbered and collisions that occurred on any approach of this intersection could be attributed to the intersection as a location. However, the application of this procedure to the data set created many problems.

Many of the reference roads did not appear in the roadway inventory. This could occur for a number of reasons. First, the database maintained by HSIS only includes collisions occurring in the state road system. Second, the reference road may have been coded with the incorrect route number. Out of 8,138 collisions occurring within .03 miles of a reference road, only 2,868 (35%) of the collisions were referenced to roads that were included in the roadway inventory. These collisions indicate 225 possible intersections. Of these 225 possible intersections, 52 are roads intersecting with themselves (i.e. Route A referenced to Route A). Of the remaining 173 possible intersections, some of the identified combinations of route and reference road occurred at multiple mileposts. This would indicate that the roads intersect at multiple places. The maps show that this is not the case. Beyond these flaws, the location type and traffic control for collisions reported at these possible intersections differ greatly. Some intersections appear to have stop signs, yield signs, no control, and traffic signals all at the same intersection. This is highly improbable.

In addition to the problems with incongruent data, numbering the multiple intersections at highway interchanges generates further problems. At interchanges upwards of eight intersections are possible as each on-ramp and off-ramp meet with the roadways. Would these ramp terminals be considered intersections? Does the whole interchange represent one intersection or multiple intersections? The conclusion drawn from the attempt to number intersections was to only reference collisions to the segments where they occurred. The laborious task of identifying intersections was outside the scope of this project. Eventually HSIS may make the intersection inventory information available in a computerized form. Municipalities could number their own intersections with ease for data collection and coding.

APPLYING EACH OF THE FIVE CRITERIA

After the data were in a form that could be manipulated, the five criteria identified by Hauer were applied: collision frequency (F), scaled deviation after construction or reconstruction $(\Delta F/\sigma_F)$, size of increase in frequency, scaled deviation in rate after construction or reconstruction $(\Delta R/\sigma_R)$, and collision rate (R). The collision frequency criterion was applied as multiple target collision frequencies.

Criteria A: Expected Target Collision Frequency

Jurisdictions may have money in their budgets to apply a certain countermeasure such as installing illumination. In order to find the most cost-effective location to apply a countermeasure the countermeasures or target improvements have to be related to a type of collision, collision characteristic, or road condition that is recorded in the collision files. The researchers applied three target improvements to this data set for demonstration.

Installing Illumination

Installing illumination to roadways is sometimes a cost-effective collision reduction measure to reduce collisions that occur during nighttime conditions (Ogden, 1996). The roadway inventory database does not contain lighting information. Therefore, the collision information determined the lighting conditions of the segments.

There are five choices that the investigating officer can select from to describe the light condition on the collision report: daylight, dawn, dusk, night with street lighting, night without street lighting. The last two conditions were used to determine if street lighting exists on each roadway segment. By collectively viewing the light conditions of all collisions occurring at a location, the light condition was discerned. The reason for identifying night collisions was to locate segments with promise if street lighting was installed. Therefore, segments that already had street lighting need not be considered. However, some segments reported some of the collisions coded as night with street lighting and some coded as night without street lighting on the same segment. Segments with more than two collisions recorded as 'dark-street lit' were considered to already have illumination and the segments were removed from the analysis. This criterion allowed for the possibility of two coding errors. Possibly, some segments are long enough to have a portion of them lit and a portion of them unlit. The researchers did not identify any reasonable remedy to this problem.

Once the unlit segments were identified, the frequency of night collisions on the segments were calculated. Collisions reported as occurring at dawn, dusk, or night without street lighting were considered night collisions. Twenty-six collisions did not have a light condition reported. For those collisions, the hour variable was used to identify night collisions. Collisions occurring from outside of 800 to 1600 hours were considered night collisions. This time range was based on the hour variable distribution of collisions that reported the light condition.

Five collisions occurring during a targeted condition and ten total collisions at a segment were set as the threshold values, below which countermeasures aren't cost effective. Segments with less than five night collisions were removed from the analysis. The resulting night frequencies were compared in a ratio with overall frequencies. The total collision frequency, segment length, collision frequency per mile, night collision frequency, and the ratio of night to total collisions are presented by route segment in the Appendix as Table A1. For comparison, the lit segments are included and labeled in this table. The segments were then sorted in ascending order of night to total ratio. The results are presented in the Appendix as Table A2. If lighting improvements were being funding, the safety engineer would select sites for detailed safety analysis from the top of this list as the segments at the top have the most 'promise'. Hauer does not explicitly state in the research record to rank the segments by target frequency over total frequency. He does indicate to rank by expected collision frequency. Above some threshold, night collisions to total is a good way to find segments where the lack of lighting was a contributing factor to the collision.

Grooved Concrete

Many collisions are attributed to environmental factors such as weather conditions. One of the most common of these factors is a wet roadway. Wet surfaces reduce the available friction. Adding grooves to the pavement is a cost-effective measure to reduce collisions where wet pavement is a contributing cause of the collision (Ogden, 1996). The added grooves increase the available friction.

The first step to apply grooved pavement as a target reduction measure is to identify collisions that occurred when the pavement was wet. The variable 'surface condition' reports the road condition at the time of the collision. The investigating officer identifies the surface as dry, wet, muddy, snowy, icy, or other. For this analysis, collisions that are reported as wet, snowy, and icy conditions were considered slick pavement collisions. The distribution of the variables among the collision file is represented in Table 2.

Table 2: Distribution of Surface Condition Variable

Surface Condition Reported	Total Collisions Reported with condition
Not stated	39
Dry	12168
Wet	3980
Muddy	262
Snowy	809
Icy	13

Using the slick pavement criteria, the amount of slick pavement collisions at each segment was found. Again, for statistical significance segments with less than five slick pavement collisions or less than ten total collisions were removed from the analysis. For the remaining segments a ratio of slick pavement collisions to total collision frequency was calculated. The ratios are sorted in order of route segment and presented in the Appendix as Table A3.

Whether the road surface is grooved or not is not reported in the roadway inventory file, but is reported in the collision files. The roadway inventory file reports the type of pavement in the variable 'surface type'. However, this variable only reports the type of pavement material. Therefore, in order to determine if a segment of roadway is grooved or not, the determination must be made from the judgement of the reporting police officer in the collision report. This is reported in the variable 'type of road surface'. The investigating officer reports the road surface as concrete, grooved concrete, smooth asphalt, coarse asphalt, gravel, sand, soil, or other. Similar to the light condition, this is a very crude method of determining if a roadway surface is grooved. However, the information is not included in the roadway inventory file. Hauer's first criterion depends on complete collision and inventory data. In most states, a complete set of data is not available.

All segments that had three or more collisions that reported the road surface as grooved concrete were considered to have grooved concrete. This allowed for two coding errors. The ratios from Table A3 are sorted in decreasing order in Table A4 in the Appendix. Segments where grooved concrete may already exist are highlighted. The remaining segments have the potential to be made skidproof, whether by adding a friction overlay to asphalt pavements or by grooving concrete pavements, as a target improvement.

Increasing Shoulder Width

Wide shoulders have many safety benefits including providing a pull-off area for breakdowns, space for bicyclists and pedestrians, and increased sight distance. Wide shoulders also provide a recovery area for errant vehicles. Increasing the width of shoulders on roads is a cost-effective measure of decreasing run off the road collisions (Ogden. 1996). Run off the road collisions are a result of errant vehicles leaving the roadway. Identifying run off the road collisions was the first step to applying this target reduction. Collisions are reported in the database by the first harmful event. There are 24 choices for first harmful event. Three of these relate to run off the road collisions—ran off road right, ran off road left, and ran off road straight. Only ran off the road right and ran off the road left were considered since ran off the road straight collisions are not directly correlated to shoulder width.

The research team calculated the frequency of run off the road collisions for each segment. No distinction was made between run off the road left and run off the road right. Segments with less than five run off the road collisions or less than ten total collisions were removed from the analysis. The ratio of run off the road to total collisions was calculated for the remaining segments. The results are presented by route segment in the Appendix as Table A5.

Increasing the width of existing road shoulders has been found to decrease related collisions for both paved and unpaved shoulders (Zegeer 1995). Therefore, the roadway variable that reports shoulder width was used instead of shoulder type. The widths of shoulders were considered regardless if they were paved or unpaved. Roadway segments with curbs were removed from the analysis. Existing shoulders of four feet or more were considered sufficient. Segments with less than four feet of shoulder, paved or unpaved, are presented in the Appendix as Table A6 with the ratio of run off the road collisions to total collisions and the width of right and left shoulder. The table is organized in decreasing order of collision ratio.

Criteria B and E: Scaled Deviation in Frequency and Scaled Deviation in Rate after Reconstruction or Construction

Hauer's proposed method considers deficiencies after a segment of road has been improved. He states, "When a site is opened to traffic or rebuilt or when its traffic control has changed, begin monitoring its scaled deviation $\Delta F/\sigma_F$. When it can be precisely estimated, decide whether the site appears normal or the scaled deviation is large enough to warrant detailed analysis. Once a site is classified as normal, no yearly monitoring is needed. If it appears deviant and the estimate of $\Delta F/\sigma_F$ is sufficiently precise, a diagnostic study may be warranted." In Hauer's formulation, ΔF is the difference between the collision frequency for a site and the mean frequency for its comparison group while σ_F is the standard deviation about the mean frequency of the comparison group.

The research team received a list of highway improvements for the years 1992-1997 in Buncombe County from Division 13 of the North Carolina Department of Transportation. The list of improvements included projects such as repaving, widening, improving markings, upgrading signs, and installing signals. Hauer's method uses comparison sites to monitor the scaled frequency and scaled rate after reconstruction or construction. The research team attempted to identify groups of similar sites together for comparison. An ideal comparison group would have at least thirty sites in it. For the purposes of our study, a similar site was defined to have the same number of travel lanes, speed limit, and similar AADT. Similar sites could be defined in a variety of ways; however, the more similarities between the group, the more effective the comparison. If intersection information had been available, intersections would also be grouped by traffic control device. An improved site would be compared in its new configuration with similar segments.

A problem arose in that the roadway inventory information and the accident files are referenced by mileposts of their respective roads. The NCDOT improvement data listed the projects by location only without any milepost information. For example, a repaving project would be referenced as shown in Table 3. Milepost information must be associated with each project in order to correlate the projects with the collision and the roadway inventory information.

Table 3: Excerpt from Road Improvement Information

Project Number	Map No.	Route	Description	Length (miles)	Width (ft)
7.8421130	12	SR 1647	SR 1649 to SR 1645	1.20	18
7.9411130	1	US 19&23	NB-NC197 to Madison Co. Line	2.28	32

The research team obtained a road inventory list that catalogues information about events along each route (i.e. intersecting roadways, city limits, etc.) in the county by milepost information from the NCDOT. An excerpt from the inventory is presented Table 4. This excerpt gives all the significant features of SR 3081 in Buncombe County. Each number in the 'Item' description lists a route intersecting with SR 3081. When 'Common' is listed, SR 3081 runs concurrent with the route listed as common. Street names are denoted below the route number to which they apply. For example, Chestnut is the name associated with county route 2256. City and county lines are also noted, as well as bridges, railroads (RRD), and overhead signs. All features are listed with their milepost location and length on the route.

Table 4: Excerpt from Buncombe County, North Carolina Road Inventory

Item	Milepost	Distance
Begin Route 40003081		
50002256	0.00	0.12
Chestnut		
City Begin 1010 Biltmore Forest		
50005963	0.12	0.00
Hendersonville		
20000025	0.12	0.03
90001010	0.15	0.02
Common 50010816		
Rock Hill		
City End 1010 Biltmore Forest		
RRD 720624D	0.17	0.06
40003108	0.23	0.09
40003107	0.32	0.23
21000025	0.60	0.00
Common None		
End Route 40003081		

This file proved useful in assigning milepost numbers to the improvement projects. However, not all of the routes mentioned in the road improvement projects could be found in the road inventory list. The reason for this is not clear. Of the 249 road widening/paving improvements, only 57 (23%) could be identified and correlated to the road inventory file from HSIS. Out of 32 signal installation improvements, 24 were located in the inventory. This task was time consuming. An additional complication was that some improvements encapsulated only a portion of the section. The improvements would not span the entire length of the section defined in the roadway inventory.

Following identification of as many of the improvement sites as possible, the next step involved searching through the accident file for any collisions occurring in the years following an improvement to a segment. If a signal was installed in 1993, collisions from 1994-1997 were considered in the analysis. A query of the collision database generated collisions that met the location and date criteria. The results of this step are presented in the Appendix as Table A7 and A8.

After assigning the collisions to each improved segment, the safety engineer would need to identify what comparison group each reconstructed segment should be measured against. For this report, the process is described by using the reconstruction at Route 40002776 from milepost 0 to 1.68. In 1996, the site was listed in the repaving/widening improvements. This segment is a portion of section A. However, section A spans to milepost 2.2. This improvement only involved up to milepost 1.68. Therefore, only the collisions occurring in the first 1.68 miles of the section are considered for this analysis.

First, the engineer must determine the comparison group this section is going to be contrasted with. Section A is a two-lane section of 55 mph roadway with an AADT in 1993 of 2156. AADT values between 1000 and 4000 were considered similar enough for this analysis. Thirty-six sections in the roadway inventory had similar characteristics to this section. These comparisons sections range from 0.3 to 5.5 miles in length.

Since section A was improved in 1996, 1997 is the year that was examined. During 1997, there were nine collisions in the 1.68-mile segment of section A. Collisions occurring in each of the comparison sections were tabulated for 1997. Since the segments varied greatly in length, the collisions were normalized per mile. For instance at the improved section, the nine collisions over the 1.68-mile segment were normalized to 5.4 collisions per mile. An average normalized collisions per mile was calculated from the comparison group to be 3.5 collisions per mile with a standard deviation of 2.9. Although the segment being examined has a greater collision frequency per mile than the comparison group, it is within one standard deviation of the mean of the comparison group and may not need to be recommended for a detailed safety analysis. However, the engineer may want to monitor the scaled deviation in frequency for the next few years.

A similar comparison can be achieved with the scaled deviation in collision rate. Using the same comparison group, the calculated mean collision rate is 528 collisions per 100 million vehicle miles with a standard deviation of 481. The collision rate at section A in 1997 was 832. Once again, although the rate is greater than the mean rate of the comparison group, it is within one standard deviation and may not need to be recommended for a detailed safety analysis.

One problem with the application of these two criteria is that they are both volume-dependent. The AADT's used for the calculations were the values listed in the roadway inventory. As explained in subsequent sections, these AADT's may be out of date and may need to be updated through field data collection or interpolation. Sections within the same group may have AADT's from a variety of different years. Sections with AADT's from 1990 may be combined in a group and considered to be similar to sections with AADT's from 1996. Engineers could help alleviate some concerns by collecting the volume data for sites in the same group in the same year.

Criteria C: Rate

Hauer suggests ranking sites based on collision rate. Once an estimate of a segment's collision rate is sufficiently precise, its rate will not need to be calculated every year. Any deterioration of the segment will be identified by another criteria. The research team separated the segments into spots or sections for the rate calculation. Segments less than or equal to 0.2 miles are considered spots (ITE 1994). All others are sections. Chapter

11 of the ITE *Manual for Traffic Engineering Studies* (ITE 1994) describes a standard rate calculation.

$$\text{RSEC}= \frac{100{,}000{,}000 * A}{365 * T * V * L}$$

Where: RSEC=collision rate for the section (collisions per 100 million vehicle miles)

A=number of reported collisions

T=time frame of analysis, years

V=AADT (Average Annual Daily Traffic)

L=length of section, miles

And,

$$\text{RSP}= \frac{1{,}000{,}000 * A}{365 * T * V}$$

Where: RSP=collision rate for the spot (collisions per million entering vehicle)

The accepted period used for a rate calculation was three years (ITE 1994). In the roadway inventory, the AADT was only reported for one year. The variable 'Year of AADT' reports the year the AADT was collected. For this rate calculation, the AADT was assumed to remain constant for the three-year period. The rate was calculated by using the frequency of collisions for the AADT year and those for one year prior to and one year after the AADT year. For example, if the AADT was taken in 1993, 1992-1994 would be the time frame of analysis.

Most segments in the roadway inventory reported AADT from 1993. However, some segments have AADT reported from as early as 1978. In this effort, AADT information from before 1992 was not used for analysis. The information was gathered five years before the end of the collision data set. Using AADT values from prior years would increase the volatility of the rates computed. The dispersion of the AADT years is provided in Table 5. The total number of segments and total mileage for each year of AADT is calculated.

The 1996 AADT maps produced by the State of North Carolina provided a graphical source from which to update the AADT data. However, locating each route on the map was time consuming. Additionally, not all sections had AADT information on the map. The research team narrowed the set of segments needing AADT down to fifteen segments for demonstration purposes. From this set of fifteen segments, only five had AADT information on the 1996 map. The AADT of the remaining segments had to be projected. The AADT was projected into 1996 from its reported AADT with the simple interest formula and a 2% annual growth rate.

Table 5: Distribution of AADT

AADT Year	Segments	Miles
1978	116	62.09
1979	55	37.93
1980	4	3.74
1981	2	1.23
1982	8	2.67
1983	3	0.11
1984	3	2.0
1985	2	0.74
1986	2	0.81
1987	2	0.5
1988	1	0.2
1989	2	1.3
1990	3	1.6
1991	16	6.65
1992	13	7.83
1993	552	402.55
No year	1	0.27
Total	785	532.22

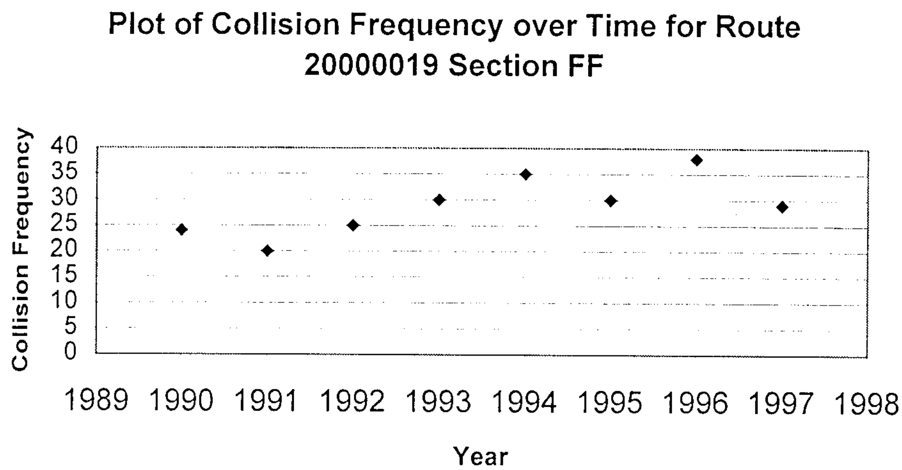
With the updated AADT, the rates were calculated for both spots and sections. The collision rates for sections are presented in the appendix in decreasing order in Table A9. The source of the AADT (1992, 1993, 1996 map, 1996 projected) is indicated. The collision rates for spots are presented in the appendix in decreasing order in Table A10. The source of AADT is also indicated.

Criteria D: Change in Frequency

Dr. Hauer proposes an intricate time series method for calculating change in frequency in another paper in Transportation Research Record 1542 (TRB 1996b). However, the method is not feasible for wide-scale application in North Carolina at this time. This is due to the cumbersome mathematics, lack of software, and lack of needed input data. Instead, other methods were applied. The first is a simple plot of collision frequency versus time for each segment. Software such as Microsoft Excel or a similar program handles this task with ease. The traffic safety engineer would review each segments plot. Sites that show (through the slope of a trend line) a large jump in frequency, or a steady, continual increase in frequency could be sorted out for further analysis. A sample plot is displayed in Figure 1 for illustrative purposes.

The plotting method is a relatively simple method to execute. In the above example, the traffic engineer would be alerted that collisions on the segment were steadily increasing. She may want to submit the segment for further investigation to determine why the collisions were increasing. The major drawback of this method is that it is time consuming to plot and review every segment in the network. In this data set, there were 785 segments. Plotting and reviewing each segment may take an engineer a few days. This is an inefficient method.

Figure 1: Plot of Collision Frequency over Time for Route 20000019 Section FF



The second method is the application of a statistical distribution to each segment. The Poisson distribution is a common distribution used in collision data to distinguish between significant factors that are changing collision frequencies and those changes occurring through fluctuations in annual frequency (Ogden, 1996). The Poisson distribution best describes random processes like collisions. Collisions are considered random processes because they take place throughout continuous intervals of time. Johnson (1994) states that, to apply the distribution three assumptions are made:

1. The probability of collisions during a time interval T is the product of the mean number of collisions per unit time and T
2. The probability of more than one collision during a small time interval ΔT is negligible; collisions are spaced out over T
3. The probability of a collision during a time interval does not depend on what happened prior to that time; collisions are considered independent events

The probabilities for a Poisson Distribution are:

$$p(x;u) = \frac{e^{-\mu}\mu^{x}}{x!} \qquad \mu = np$$

This represents the probability that x collisions occur in n years given that the mean collision rate and the variance are μ. Figure 2 demonstrates the method.

Figure 2: Sample Poisson Probability Calculation for Route 2000019 Section FF

Route 2000019; section FF has the following collision history:

Year	Collisions
1990	24
1991	20
1992	25
1993	30
1994	35
1995	30
1996	43

The mean of these 7 years is 29.5 collisions per year. In 1997, there were 34 collisions total.

P = (24+20+25+30+35+30+43)/7 = 29.5 collisions/year
$\mu = np = 1*29.5 = 29.5$

The probability that the 34 collisions in 1997 were due to chance variations is
= 1-(P(0, 29.5) + P(1, 29.5) +P(2, 29.5) + ...+ P(34, 29.5))
= 1-(1.43E-13 + 4.25E-12 + 6.28E-11 +...+ 0.0571 + 0.0497)
= 1- 0.819302
= 0.18070

The research team calculated the probability that the frequency of collisions in 1997 was due to chance variations for each segment. Segments with less than 10 collisions total in the 8-year period from 1990 to 1996 and segments with zero collisions for 1997 were excluded from the calculations. Table A11 in the appendix presents the segments in order of increasing probability. This number is the probability that the frequency was due to fluctuations over time. The traffic engineer would sort out segments with low Poisson probabilities for further investigation. These are the segments where the increase in frequency is most likely attributed to something other than fluctuations over time.

The two methods (plots and the Poisson distribution) illustrated here used the eight years of data that were available. If more data are available, they will solidify the results. Other methods to detect a change in frequency not illustrated here include finding the highest absolute jumps or finding the highest percentage jumps. Scanning the data manually or using computer software such as Microsoft Access to automatically sort these segments out could be practical methods for either of these criteria.

CREATING AN ANNUAL SYSTEM

Hauer's proposed method does not require that every criterion would have to be applied every year. The basis of the program is to initially understand what the system contains, and then monitor for changes. In the first year of applying the method, the frequency and rate of each segment would be calculated. If there were enough collision data to decide if the estimates of the frequency and rate are sufficiently precise, the engineer would decide what cost-effective improvements could be performed to segments with unacceptable frequencies and rates. On this basis, a safety improvement investment work program would be devised. Segments with unacceptable frequency and rate would not need to be repeatedly identified. If there weren't enough collision data to sufficiently estimate the frequency and rate for a segment, the engineer would continue to monitor the segment until enough history had been accumulated to make the estimates.

Only when a segment is opened to traffic, when it is rebuilt, or when its traffic control has changed would the scaled deviation in rate and frequency need to be computed. The practicing engineer would compile a list of all construction or reconstruction projects throughout the year. The set of those projects would be the only segments that would need to be monitored. As discussed above, the scaled deviation is based on a comparison group of locations with similar traffic and geometric characteristics. Each segment would be compared to the existing corresponding group that had been determined in the initial year of the Hauer system. Groups would not have to be reformed once the system was established. When enough history had been accumulated, the engineer would make the comparison and decide whether the segment was normal or if a deficiency existed. If a deficiency existed, the engineer would need to study the segment more in depth. The engineer could strengthen the comparative value of the groups by collecting the AADT for the whole group in the same year. Although the AADT may only be collected every five years or so and will likely have changed from when it was collected to when it was used for comparison, if all the AADT's in the group were from the same time period in a city or small area, the engineer could assume that they had changed similarly.

All segments would need the change in frequency criteria monitored yearly to detect deterioration. However, this monitoring could simply involve annually adding a single data point to an existing description of the collision history. In the case of the plotting method, a new point would be added to the plots annually and the revised plots would be reviewed.

Only when a segment is opened to traffic, when it is rebuilt, or when its traffic control has changed would the scaled deviation in rate and frequency need to be computed. The practicing engineer would compile a list of all construction or reconstruction projects throughout the year. The set of those projects would be the only segments that would need to be monitored. As discussed above, the scaled deviation is based on a comparison group of locations with similar traffic and geometric characteristics. Each segment would be compared to the existing corresponding group that had been determined in the initial year of the Hauer system. Groups would not have to be reformed once the system was established. When enough history had been accumulated, the engineer would make the comparison and decide whether the segment was normal or if a deficiency existed. If a deficiency existed, the engineer would need to study the segment more in depth. The engineer could strengthen the comparative value of the groups by collecting the AADT for the whole group in the same year. Although the AADT may only be collected every five years or so and will likely have changed from when it was collected to when it was used for comparison, if all the AADT's in the group were from the same time period in a city or small area, the engineer could assume that they had changed similarly.

All segments would need the change in frequency criteria monitored yearly to detect deterioration. However, this monitoring could simply involve annually adding a single data point to an existing description of the collision history. In the case of the plotting method, a new point would be added to the plots annually and the revised plots would be reviewed.

CONCLUSIONS

The HSIS database was useful in the application of Hauer's method. The HSIS database (and others like it) is an excellent source of collision data for the traffic safety engineer. The database is easily accessible, the variables are formatted, the roadway information is easily related to crash files, the computerized files are easily linked for analysis, and the database has undergone a large amount of error checking to ensure the quality. Foresight of the detailed application of the data would help to refine the request for data from UNC. This will assist UNC to produce to a useful and complete set of HSIS data.

The roadway inventory is pivotal to the application of Hauer's method. Inventory information is needed to form comparison groups and to find sites where countermeasures of choice can be installed. To be helpful, the roadway inventory should be accurate, complete, and recent. Most of the roadway inventory from Buncombe County was useful. However, the Buncombe County roadway inventory would benefit from updated AADT information. In addition, reporting as many AADT years as available would strengthen the inventory. The addition of an intersection database would also strengthen the inventory. The exclusion of intersection information is the largest drawback to application of the inventory database now. As more information is added to the database, it will become even more useful.

The Hauer method is excellent for the states included in the HSIS database. However, only eight of 50 states are currently included in the database. The method is still valid for the other 42 states if their data are contained in a database similar to the HSIS database. Roadway inventory and collision files must be accurate, searchable, and linkable. Collision data for at least five years will help to make the method a helpful tool to identify hazardous locations.

The usefulness of Hauer's method is also a function of the jurisdiction size. Smaller jurisdictions will not have good expected values to base their comparisons on. Additionally, rural collisions often go unreported. Conversely with larger jurisdictions, although the database will be more complete, errors will be harder to spot. Intersections will also be harder to discern without the aid of an intersection database. The method seems best suited an intermediate level such as county or mid-sized city.

Popular software such as the programs in Microsoft Office will greatly aid in the application of the method. The software is user-friendly and has all the abilities needed to apply this method.

Hauer's suggestion to sort out segments by target frequencies emerges as an excellent way to manage collision data. An engineer may select countermeasures that are more meaningful to their jurisdiction or more easily applied. For example, public opinion may call for more crosswalks or a traffic engineer may have surplus in the lighting budget. This aspect of the method addresses the economic constraints of hazardous location remediation. It is also simple to apply.

Hauer's suggestion to sort out segments by collision rate is best applied where updated and complete AADT information is available. Unfortunately, AADT may not be available regularly on most roadways.

Hauer's suggestion to monitor the change in frequency can be executed by any of the methods illustrated. This is the only criterion that would need to be updated for all roadways on an annual basis. A simple plot or Poisson calculation will suffice for most agencies until large data sets and software are available to implement Hauer's sophisticated time series method.

Future research in this area should concentrate on developing that time series software. Further research into additional cost-effective countermeasures paired with collision types or conditions, that could be applied to the target frequency identification, would also be beneficial.

Collision data are important tools of the traffic safety engineer. The data help the engineer to identify locations that may be hazardous. A good management system aids in the location. Hauer's method appears to be an efficient management system the traffic safety engineer can practice.

References

Eno Foundation (1968), "Roadside Hazards," The Eno Foundation for Highway Traffic Control, Saugatuck, Connecticut.

Hauer, Ezra (1996a), "Identification of Sites with Promise," Transportation Research Record 1542, Transportation Research Board, Washington, DC.

Hauer, Ezra (1996b), "Detection of Safety Deterioration in a Series of Collision Counts," Transportation Research Record 1542, TRB, Washington, DC.

Hummer, J.E (1994). "Chapter 11: Traffic Collision Studies" *ITE Manual of Transportation Engineering Studies*.

Johnson, R.A. (1994), *Miller and Freund's Probability and Statistics for Engineers.* Prentice Hall, Inc., New Jersey.

National Cooperative Highway Research Program Report 132 (1987), "System-Wide Safety Improvements: An Approach to Safety Consistency," TRB, Washington, DC.

NHTSA (1998), "Traffic Safety Facts 1998: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System." Report DOT HS 808 983. National Center for Statistics and Analysis, USDOT, Washington, DC.

Organisation of Economic Co-operation and Development (1976), Hazardous Road Locations: Identification and Counter Measures.

Ogden, K.W. (1996) "Safer Roads: A Guide to Road Safety Engineering," Institute of Transport Studies, Cambridge, U.K.

Spring, G.S. and J.E. Hummer (1995) "Identifying Hazardous Locations Using Geographical Information Systems," Final Report, Southeastern Transportation Center Project No. 23385-021.

Appendix

Table A1: Ratio of Night to Total Collisions Organized by Route Segment
(Highlight denotes street lit segments)

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
10000026	A	78	0.8	98	29	0.372
10000026	B	50	0.54	93	16	0.320
10000026	C	54	0.29	186	13	0.241
10000026	D	289	4.62	63	96	0.332
10000026	E	34	0.04	850	9	0.265
10000026	F	66	2.79	24	18	0.273
10000026	G	11	0.32	34	Less than 5	N/A
10000040	A	67	0.76	88	25	0.373
10000040	AA	69	2.11	33	23	0.333
10000040	BB	29	0.92	32	11	0.379
10000040	C	16	0.23	70	6	0.375
10000040	CC	18	0.66	27	Less than 5	N/A
10000040	D	79	1.3	61	33	0.418
10000040	DD	27	0.93	29	9	0.333
10000040	E	115	2.71	42	43	0.374
10000040	EE	20	0.77	26	5	0.250
10000040	F	11	0.46	24	Less than 5	N/A
10000040	FF	29	0.52	56	14	0.483
10000040	G	61	1.54	40	24	0.393
10000040	H	36	0.51	71	11	0.306
10000040	I	268	1.58	170	65	0.243
10000040	II	13	0.64	20	5	0.385
10000040	J	72	0.71	101	23	0.319
10000040	JJ	12	0.71	17	5	0.417
10000040	K	12	0.06	200	Less than 5	N/A
10000040	L	22	0.12	183	12	0.545
10000040	M	21	0.17	124	6	0.286
10000040	N	97	2.65	37	34	0.351
10000040	O	33	0.54	61	12	0.364
10000040	Q	16	0.16	100	6	0.375
10000040	R	61	0.97	63	17	0.279
10000040	T	32	1.35	24	13	0.406
10000040	U	20	0.17	118	6	0.300

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
10000040	V	26	1.02	25	8	0.308
10000040	W	39	0.42	93	10	0.256
10000040	X	21	0.65	32	11	0.524
10000040	Y	59	1.02	58	13	0.220
10000040	Z	136	3.11	44	44	0.324
10000240	A	104	0.53	196	25	0.240
10000240	B	33	0.31	106	5	0.152
10000240	C	34	0.21	162	Less than 5	N/A
10000240	D	21	0.82	26	7	0.333
10000240	E	33	0.44	75	11	0.333
10000240	F	321	0.81	396	80	0.249
10000240	G	159	0.42	379	36	0.226
10000240	H	23	0.08	288	Less than 5	N/A
10000240	I	36	0.16	225	9	0.250
10000240	J	111	0.09	1233	23	0.207
10000240	K	22	0.31	71	6	0.273
10000240	L	108	0.62	174	23	0.213
10000240	M	39	0.23	170	12	0.308
10000240	N	53	0.18	294	12	0.226
10000240	O	17	0.19	89	7	0.412
10000240	Q	142	1.54	92	40	0.282
10000240	R	16	0.32	50	Less than 5	N/A
10000240	T	16	0.99	16	7	0.438
20000019	A	34	0.74	46	11	0.324
20000019	AA	11	0.09	122	Less than 5	N/A
20000019	BB	62	1.66	37	19	0.306
20000019	C	10	0.23	43	Less than 5	N/A
20000019	D	74	1.42	52	19	0.257
20000019	E	10	0.22	45	Less than 5	N/A
20000019	EE	29	1.21	24	13	0.448
20000019	F	102	1.67	61	23	0.225
20000019	FF	241	3.08	78	68	0.282

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
20000019	GG	21	0.84	25	Less than 5	N/A
20000019	H	85	0.16	531	22	0.259
20000019	I	310	1.38	225	55	0.177
20000019	J	153	1.27	120	26	0.170
20000019	JJ	23	0.86	27	6	0.261
20000019	K	98	0.27	363	15	0.153
20000019	KK	10	0.52	19	5	0.500
20000019	L	13	0.17	76	Less than 5	N/A
20000019	LL	27	1.4	19	Less than 5	N/A
20000019	O	30	0.18	167	Less than 5	N/A
20000019	OO	31	1.36	23	13	0.419
20000019	P	54	0.9	60	12	0.222
20000019	PP	14	0.5	28	5	0.357
20000019	Q	13	0.05	260	Less than 5	N/A
20000019	R	92	0.57	161	33	0.359
20000019	S	23	0.12	192	10	0.435
20000019	T	147	0.62	237	79	0.537
20000019	U	80	0.27	296	16	0.200
20000019	V	36	0.21	171	13	0.361
20000019	W	27	0.18	150	Less than 5	N/A
20000019	X	16	0.32	50	10	0.625
20000019	Y	19	0.92	21	Less than 5	N/A
20000019	Z	26	0.15	173	7	0.269
20000025	A	201	1.07	188	42	0.209
20000025	B	96	1.03	93	19	0.198
20000025	C	63	1.87	34	18	0.286
20000025	CC	85	0.19	447	17	0.200
20000025	DD	55	0.11	500	16	0.291
20000025	EE	10	0.06	167	Less than 5	N/A
20000025	FF	153	0.21	729	38	0.248
20000025	G	28	1	28	Less than 5	N/A
20000025	H	66	0.75	88	10	0.152
20000025	HH	156	0.49	318	27	0.173

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
20000025	I	68	0.98	69	18	0.265
20000025	II	80	0.23	348	19	0.238
20000025	J	37	0.15	247	5	0.135
20000025	JJ	329	0.63	522	51	0.155
20000025	KK	18	0.09	200	Less than 5	N/A
20000025	L	17	0.27	63	Less than 5	N/A
20000025	LL	118	0.37	319	17	0.144
20000025	M	41	0.17	241	6	0.146
20000025	MM	10	0.53	19	Less than 5	N/A
20000025	NN	15	0.16	94	Less than 5	N/A
20000025	OO	50	0.89	56	9	0.180
20000025	P	10	0.19	53	Less than 5	N/A
20000025	Q	122	0.62	197	15	0.123
20000025	RR	11	0.08	138	Less than 5	N/A
20000025	S	63	0.41	154	8	0.127
20000025	UU	46	1.75	26	15	0.326
20000025	V	16	0.25	64	Less than 5	N/A
20000025	VV	34	3.04	11	14	0.412
20000025	Y	27	0.18	150	Less than 5	N/A
20000025	Z	14	0.08	175	5	0.357
20000070	B	40	0.14	286	6	0.150
20000070	CC	28	0.16	175	6	0.214
20000070	G	19	0.2	95	Less than 5	N/A
20000070	H	97	0.14	693	22	0.227
20000070	I	34	0.33	103	7	0.206
20000070	J	307	0.37	830	77	0.251
20000070	K	146	0.3	487	37	0.253
20000070	L	15	0.34	44	Less than 5	N/A
20000070	M	51	0.31	165	12	0.235
20000070	N	257	1.22	211	61	0.237
20000070	O	109	0.18	606	24	0.220
20000070	P	28	0.44	64	Less than 5	N/A
20000074	F	38	1.08	35	14	0.368

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
20000074	I	18	0.23	78	Less than 5	N/A
20000074	J	17	0.09	189	Less than 5	N/A
20000074	K	81	0.71	114	10	0.123
20000074	M	37	0.55	67	Less than 5	N/A
20000074	N	288	5.18	56	81	0.281
20000074	P	34	2.35	14	13	0.382
20000074	Q	11	2.22	5	5	0.455
21000025	A	19	0.14	136	5	0.263
21000025	B	113	1.18	96	17	0.150
21000025	F	56	1.47	38	14	0.250
21000025	I	25	0.38	66	7	0.280
21000025	J	26	0.28	93	9	0.346
21000025	K	56	0.95	59	11	0.196
21000025	L	13	0.13	100	Less than 5	N/A
29000019	F	41	0.92	45	11	0.268
29000019	G	126	1.8	70	20	0.159
29000019	J	11	0.78	14	Less than 5	N/A
29000019	O	25	0.25	100	9	0.360
29000019	P	12	0.2	60	Less than 5	N/A
30000009	A	18	4.9	4	10	0.556
30000009	B	53	7.59	7	30	0.566
30000009	C	12	1.1	11	Less than 5	N/A
30000009	G	11	0.08	138	Less than 5	N/A
30000009	I	38	0.38	100	8	0.211
30000009	J	14	0.14	100	Less than 5	N/A
30000009	K	16	0.28	57	Less than 5	N/A
30000009	L	10	0.14	71	Less than 5	N/A
30000009	Q	12	0.35	34	5	0.417
30000063	A	180	1.36	132	37	0.206
30000063	B	115	0.87	132	23	0.200
30000063	C	261	1.78	147	59	0.226
30000063	D	155	2.51	62	51	0.329
30000063	E	175	2.74	64	46	0.263

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
30000063	F	38	1.88	20	10	0.263
30000063	G	45	3.91	12	17	0.378
30000081	D	49	0.96	51	19	0.388
30000081	E	56	0.37	151	25	0.446
30000081	H	32	1	32	18	0.563
30000081	I	54	0.16	338	20	0.370
30000112	A	10	0.25	40	Less than 5	N/A
30000112	E	51	1.01	50	13	0.255
30000112	F	25	0.36	69	7	0.280
30000112	G	102	1.72	59	28	0.275
30000146	B	31	1.35	23	8	0.258
30000146	C	34	0.17	200	12	0.353
30000146	D	21	0.11	191	Less than 5	N/A
30000146	E	77	1.08	71	10	0.130
30000151	A	14	4.37	3	6	0.429
30000151	B	33	2.23	15	11	0.333
30000151	D	69	1.34	51	19	0.275
30000151	F	161	3.19	50	51	0.317
30000191	A	95	2.65	36	29	0.305
30000191	B	83	2.84	29	30	0.361
30000191	D	85	0.9	94	20	0.235
30000191	F	92	0.53	174	15	0.163
30000191	G	20	0.21	95	Less than 5	N/A
30000191	H	59	0.14	421	17	0.288
30000191	I	15	0.28	54	5	0.333
30000191	J	54	1.01	53	Less than 5	N/A
30000191	K	41	0.22	186	9	0.220
30000191	L	16	0.13	123	Less than 5	N/A
30000191	M	34	0.17	200	8	0.235
30000191	P	20	0.13	154	5	0.250
30000191	Q	28	0.23	122	Less than 5	N/A
30000191	R	12	0.3	40	5	0.417
30000191	S	33	0.6	55	5	0.152

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
30000197	A	11	0.13	85	Less than 5	N/A
30000197	B	136	5.9	23	47	0.346
30000197	C	11	3.03	4	5	0.455
30000251	C	50	3.76	13	16	0.320
30000251	E	36	3.41	11	12	0.333
30000251	H	20	3.45	6	5	0.250
30000280	B	32	0.71	45	7	0.219
30000280	F	223	1.67	134	57	0.256
30000694	A	18	4	5	13	0.722
40001001	B	12	1.35	9	5	0.417
40001002	A	56	2.9	19	23	0.411
40001002	B	57	2.4	24	13	0.228
40001003	A	45	0.69	65	9	0.200
40001003	C	14	0.19	74	Less than 5	N/A
40001003	E	17	0.9	19	5	0.294
40001003	F	65	1.7	38	17	0.262
40001003	G	15	0.69	22	7	0.467
40001003	H	20	2.3	9	5	0.250
40001003	Q	17	2.22	8	10	0.588
40001004	A	27	0.5	54	11	0.407
40001004	C	68	5.49	12	20	0.294
40001004	D	21	2.71	8	7	0.333
40001123	A	10	0.7	14	5	0.500
40001130	A	22	1.74	13	8	0.364
40001130	B	13	0.83	16	5	0.385
40001130	C	12	0.6	20	Less than 5	N/A
40001130	D	16	0.22	73	5	0.313
40001130	E	14	0.79	18	5	0.357
40001220	A	17	3.1	5	6	0.353
40001220	K	15	1.9	8	6	0.400
40001220	M	28	1.28	22	10	0.357
40001220	N	21	0.48	44	14	0.667
40001220	O	11	0.3	37	Less than 5	N/A

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
40001720	D	10	0.8	13	Less than 5	N/A
40001727	A	12	0.3	40	Less than 5	N/A
40001727	B	24	0.7	34	5	0.208
40001727	G	40	2.35	17	13	0.325
40001740	A	35	0.81	43	6	0.171
40001740	B	12	0.29	41	7	0.583
40001740	C	17	1.7	10	5	0.294
40001742	A	18	2	9	10	0.556
40001756	A	19	0.4	48	9	0.474
40001756	E	11	1.18	9	Less than 5	N/A
40001756	F	26	2.3	11	11	0.423
40002002	A	31	0.4	78	8	0.258
40002002	B	12	0.18	67	Less than 5	N/A
40002002	D	23	0.76	30	8	0.348
40002002	E	18	0.65	28	5	0.278
40002002	G	18	1.28	14	9	0.500
40002002	H	19	1.73	11	7	0.368
40002002	I	27	0.6	45	6	0.222
40002109	A	15	4.1	4	7	0.467
40002130	A	10	0.7	14	Less than 5	N/A
40002148	B	16	1.52	11	6	0.375
40002173	A	48	3.6	13	20	0.417
40002173	B	16	1.4	11	8	0.500
40002207	D	14	0.29	48	Less than 5	N/A
40002207	F	49	2.59	19	12	0.245
40002230	B	12	0.45	27	Less than 5	N/A
40002230	I	10	2.68	4	5	0.500
40002403	A	12	0.72	17	7	0.583
40002403	C	33	1.23	27	14	0.424
40002416	A	36	1.15	31	11	0.306
40002416	B	34	1.55	22	8	0.235
40002416	C	21	1.25	17	7	0.333
40002435	A	29	0.5	58	Less than 5	N/A

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
40002435	B	26	0.3	87	7	0.269
40002435	C	100	1.8	56	20	0.200
40002776	A	68	2.2	31	35	0.515
40002776	B	36	3.34	11	15	0.417
40002776	E	17	3.81	4	8	0.471
40002806	A	66	3.26	20	31	0.470
40002806	B	31	2.82	11	16	0.516
40003075	A	16	1.13	14	8	0.500
40003116	C	25	0.51	49	5	0.200
40003116	D	33	0.2	165	6	0.182
40003116	E	41	1.63	25	12	0.293
40003116	F	15	0.2	75	5	0.333
40003116	G	25	1	25	8	0.320
40003116	H	26	0.8	33	5	0.192
40003121	B	20	1.1	18	9	0.450
40003121	C	17	1.05	16	5	0.294
40003121	E	16	2.12	8	Less than 5	N/A
40003136	D	98	4.9	20	45	0.459
40003136	E	17	1.09	16	9	0.529
40003412	A	33	1.35	24	13	0.394
40003412	E	32	1.4	23	7	0.219
40003437	F	30	2.72	11	13	0.433
40003446	B	28	0.62	45	7	0.250
40003446	C	24	0.45	53	5	0.208
40003446	D	24	0.97	25	6	0.250
40003452	D	16	1.29	12	5	0.313
40003486	D	32	1.3	25	11	0.344
40003495	A	29	1.6	18	13	0.448
40003495	E	71	0.93	76	23	0.324
40003495	F	36	1.01	36	8	0.222
40003501	A	10	1.32	8	5	0.500
40003548	B	13	0.33	39	Less than 5	N/A

Table A1 Continued

State Route Number	Route Segment	Total Collision Frequency	Segment Length (miles)	Total Collision Frequency (Expressed as Collisions/Mile)	Night Collision Frequency	Ratio of Night to Total Collisions
40003548	H	10	0.06	167	Less than 5	N/A
40003548	I	55	0.51	108	13	0.236
40003548	J	39	0.34	115	Less than 5	N/A
40003548	K	71	0.1	710	20	0.282
40003556	A	18	0.23	78	Less than 5	N/A
40003556	D	10	0.56	18	Less than 5	N/A
40003556	E	20	0.04	500	Less than 5	N/A
40003556	H	29	0.53	55	7	0.241
40003556	I	19	0.26	73	Less than 5	N/A

Table A2: Ratio of Night to Total Collisions in Descending Order of Ratio
(Highlight denotes street lit segments)

State Route Number	Route Segment	Ratio of Night to Total Collisions
40001238	B	0.727
30000694	A	0.722
40001220	N	0.667
20000019	X	0.625
40001003	Q	0.588
40001740	B	0.583
40002403	A	0.583
30000009	B	0.566
30000081	H	0.563
30000009	A	0.556
40001742	A	0.556
40001263	C	0.550
10000040	L	0.545
40001332	E	0.545
20000019	T	0.537
40003136	E	0.529
10000040	X	0.524
40002806	B	0.516
40002776	A	0.515
20000019	KK	0.500
40001123	A	0.500
40001315	A	0.500
40002002	G	0.500
40002173	B	0.500
40002230	I	0.500
40003075	A	0.500
40003501	A	0.500
10000040	FF	0.483
40001403	A	0.475
40001756	A	0.474
40001401	A	0.471
40002776	E	0.471
40002806	A	0.470
40001003	G	0.467
40001319	D	0.467
40002109	A	0.467

State Route Number	Route Segment	Ratio of Night to Total Collisions
40003136	D	0.459
20000074	Q	0.455
30000197	C	0.455
40003121	B	0.450
20000019	EE	0.448
40003495	A	0.448
30000081	E	0.446
10000240	T	0.438
20000019	S	0.435
40003437	F	0.433
30000151	A	0.429
40001319	A	0.429
40002403	C	0.424
40001756	F	0.423
20000019	OO	0.419
10000040	D	0.418
10000040	JJ	0.417
30000009	Q	0.417
30000191	R	0.417
40001001	B	0.417
40002173	A	0.417
40002776	B	0.417
10000240	O	0.412
20000025	VV	0.412
40001002	A	0.411
40001004	A	0.407
10000040	T	0.406
40001220	K	0.400
40003412	A	0.394
10000040	G	0.393
30000081	D	0.388
10000040	II	0.385
40001130	B	0.385
20000074	P	0.382
40001641	A	0.381
10000040	BB	0.379

Table A2 Continued

State Route Number	Route Segment	Ratio of Night to Total Collisions
30000063	G	0.378
10000040	C	0.375
10000040	Q	0.375
40001224	F	0.375
40001332	G	0.375
40002148	B	0.375
10000040	E	0.374
10000040	A	0.373
10000026	A	0.372
30000081	I	0.370
20000074	F	0.368
40002002	H	0.368
10000040	O	0.364
40001130	A	0.364
30000191	B	0.361
20000019	V	0.361
29000019	O	0.360
20000019	R	0.359
20000019	PP	0.357
20000025	Z	0.357
40001130	E	0.357
40001220	M	0.357
30000146	C	0.353
40001220	A	0.353
10000040	N	0.351
40001338	F	0.348
40002002	D	0.348
21000025	J	0.346
30000197	B	0.346
40001620	A	0.345
40003486	D	0.344
40001338	E	0.343
40001332	D	0.341
10000040	AA	0.333
10000040	DD	0.333
10000240	D	0.333

State Route Number	Route Segment	Ratio of Night to Total Collisions
10000240	E	0.333
30000151	B	0.333
30000191	I	0.333
30000251	E	0.333
40001004	D	0.333
40001224	I	0.333
40002416	C	0.333
40003116	F	0.333
10000026	D	0.332
30000063	D	0.329
20000025	UU	0.326
40001727	G	0.325
40003495	E	0.324
10000040	Z	0.324
20000019	A	0.324
40001319	C	0.322
10000026	B	0.320
30000251	C	0.320
40003116	G	0.320
10000040	J	0.319
30000151	F	0.317
40001130	D	0.313
40003452	D	0.313
10000040	V	0.308
10000240	M	0.308
20000019	BB	0.306
10000040	H	0.306
40002416	A	0.306
30000191	A	0.305
10000040	U	0.300
40001338	D	0.300
40001003	E	0.294
40001004	C	0.294
40001740	C	0.294
40003121	C	0.294
40003116	E	0.293

Table A2 Continued

State Route Number	Route Segment	Ratio of Night to Total Collisions
20000025	DD	0.291
30000191	H	0.288
10000040	M	0.286
20000025	C	0.286
20000019	FF	0.282
10000240	Q	0.282
40003548	K	0.282
20000074	N	0.281
21000025	I	0.280
30000112	F	0.280
10000040	R	0.279
40002002	E	0.278
30000151	D	0.275
30000112	G	0.275
10000026	F	0.273
10000240	K	0.273
20000019	Z	0.269
40002435	B	0.269
29000019	F	0.268
10000026	E	0.265
20000025	I	0.265
21000025	A	0.263
30000063	F	0.263
30000063	E	0.263
40001003	F	0.262
20000019	JJ	0.261
20000019	H	0.259
30000146	B	0.258
40002002	A	0.258
20000019	D	0.257
10000040	W	0.256
30000280	F	0.256
30000112	E	0.255
20000070	K	0.253
20000070	J	0.251
10000040	EE	0.250

State Route Number	Route Segment	Ratio of Night to Total Collisions
10000240	I	0.250
21000025	F	0.250
30000191	P	0.250
30000251	H	0.250
40001003	H	0.250
40001224	D	0.250
40001338	B	0.250
40003446	B	0.250
40003446	D	0.250
10000240	F	0.249
20000025	FF	0.248
40002207	F	0.245
10000040	I	0.243
40003556	H	0.241
10000026	C	0.241
10000240	A	0.240
20000025	II	0.238
20000070	N	0.237
40003548	I	0.236
20000070	M	0.235
30000191	D	0.235
30000191	M	0.235
40002416	B	0.235
40001002	B	0.228
20000070	H	0.227
10000240	G	0.226
10000240	N	0.226
30000063	C	0.226
40001332	A	0.226
20000019	F	0.225
20000019	P	0.222
40002002	I	0.222
40003495	F	0.222
10000040	Y	0.220
20000070	O	0.220
30000191	K	0.220

Table A2 Continued

State Route Number	Route Segment	Ratio of Night to Total Collisions
30000280	B	0.219
40003412	E	0.219
20000070	CC	0.214
10000240	L	0.213
30000009	I	0.211
20000025	A	0.209
40001332	C	0.208
40001727	B	0.208
40003446	C	0.208
10000240	J	0.207
20000070	I	0.206
30000063	A	0.206
20000019	U	0.200
20000025	CC	0.200
30000063	B	0.200
40001003	A	0.200
40002435	C	0.200
40003116	C	0.200
20000025	B	0.198
21000025	K	0.196
40003116	H	0.192
40001332	B	0.184
40003116	D	0.182
20000025	OO	0.180
20000019	I	0.177
20000025	HH	0.173
40001740	A	0.171
20000019	J	0.170
30000191	F	0.163
29000019	G	0.159
20000025	JJ	0.155
20000019	K	0.153
10000240	B	0.152
20000025	H	0.152
30000191	S	0.152
21000025	B	0.150

State Route Number	Route Segment	Ratio of Night to Total Collisions
20000070	B	0.150
20000025	M	0.146
20000025	LL	0.144
20000025	J	0.135
30000146	E	0.130
20000025	S	0.127
20000074	K	0.123
20000025	Q	0.123

Table A3: Ratio of Slick to Total Collisions Organized by Route Segment

State Route Number	Route Segment	Ratio of Slick to Total Collisions
10000026	A	0.346
10000026	B	0.280
10000026	C	0.259
10000026	D	0.332
10000026	F	0.348
10000040	A	0.448
10000040	AA	0.522
10000040	BB	0.690
10000040	C	0.438
10000040	CC	0.278
10000040	D	0.658
10000040	DD	0.259
10000040	E	0.296
10000040	EE	0.400
10000040	FF	0.621
10000040	G	0.344
10000040	H	0.306
10000040	I	0.250
10000040	II	0.692
10000040	J	0.486
10000040	L	0.500
10000040	M	0.381
10000040	N	0.340
10000040	O	0.152
10000040	R	0.311
10000040	T	0.438
10000040	U	0.550
10000040	V	0.654
10000040	W	0.641
10000040	X	0.571
10000040	Y	0.559
10000040	Z	0.574
10000240	A	0.558
10000240	B	0.576
10000240	C	0.294
10000240	D	0.333
10000240	E	0.273
10000240	F	0.374
10000240	G	0.277
10000240	I	0.278
10000240	J	0.189
10000240	L	0.352
10000240	M	0.385
10000240	N	0.302

State Route Number	Route Segment	Ratio of Slick to Total Collisions
10000240	O	0.412
10000240	Q	0.268
10000240	R	0.313
10000240	T	0.313
20000019	A	0.353
20000019	BB	0.290
20000019	C	0.800
20000019	D	0.162
20000019	E	0.600
20000019	EE	0.310
20000019	F	0.343
20000019	FF	0.315
20000019	H	0.282
20000019	I	0.242
20000019	J	0.255
20000019	JJ	0.391
20000019	K	0.235
20000019	LL	0.259
20000019	O	0.400
20000019	OO	0.548
20000019	P	0.278
20000019	PP	0.500
20000019	Q	0.370
20000019	R	0.217
20000019	S	0.304
20000019	T	0.211
20000019	U	0.238
20000019	V	0.417
20000019	X	0.500
20000019	Y	0.368
20000019	Z	0.385
20000025	A	0.209
20000025	B	0.156
20000025	C	0.159
20000025	CC	0.200
20000025	DD	0.255
20000025	FF	0.301
20000025	G	0.179
20000025	H	0.258
20000025	HH	0.186
20000025	I	0.324
20000025	II	0.175
20000025	J	0.243
20000025	JJ	0.198

Table A3 Continued

State Route Number	Route Segment	Ratio of Slick to Total Collisions
20000025	KK	0.278
20000025	L	0.412
20000025	LL	0.178
20000025	M	0.293
20000025	OO	0.240
20000025	P	0.500
20000025	Q	0.295
20000025	S	0.349
20000025	UU	0.283
20000025	Y	0.185
20000070	B	0.200
20000070	H	0.196
20000070	I	0.265
20000070	J	0.241
20000070	K	0.233
20000070	M	0.314
20000070	N	0.300
20000070	O	0.248
20000070	P	0.214
20000074	F	0.316
20000074	I	0.389
20000074	J	0.529
20000074	K	0.272
20000074	M	0.351
20000074	N	0.347
20000074	P	0.235
20000074	Q	0.545
21000025	A	0.316
21000025	B	0.319
21000025	F	0.250
21000025	J	0.423
21000025	K	0.196
29000019	F	0.171
29000019	G	0.270
29000019	P	0.750
30000009	A	0.333
30000009	B	0.377
30000009	I	0.237
30000009	J	0.429
30000063	A	0.233
30000063	B	0.252
30000063	C	0.241
30000063	D	0.284
30000063	E	0.303

State Route Number	Route Segment	Ratio of Slick to Total Collisions
30000063	F	0.316
30000063	G	0.244
30000081	D	0.388
30000081	E	0.268
30000081	H	0.313
30000081	I	0.222
30000112	E	0.431
30000112	F	0.360
30000112	G	0.265
30000146	B	0.516
30000146	C	0.265
30000146	D	0.333
30000146	E	0.286
30000151	B	0.152
30000151	D	0.275
30000151	F	0.317
30000191	A	0.316
30000191	B	0.361
30000191	D	0.294
30000191	F	0.196
30000191	G	0.300
30000191	H	0.220
30000191	J	0.407
30000191	K	0.317
30000191	M	0.235
30000191	Q	0.393
30000191	R	0.583
30000191	S	0.303
30000197	B	0.272
30000251	C	0.300
30000251	E	0.333
30000280	F	0.229
30000694	A	0.389
40001002	A	0.286
40001002	B	0.281
40001003	A	0.422
40001003	E	0.294
40001003	F	0.231
40001003	G	0.667
40001003	Q	0.529
40001004	A	0.333
40001004	C	0.279
40001004	D	0.238
40001130	B	0.385

Table A3 Continued

State Route Number	Route Segment	Ratio of Slick to Total Collisions
40001130	C	0.500
40001220	A	0.294
40001220	M	0.214
40001220	N	0.333
40001224	D	0.188
40001315	A	0.308
40001319	A	0.367
40001319	C	0.237
40001319	D	0.167
40001332	A	0.161
40001332	B	0.184
40001332	C	0.292
40001332	D	0.244
40001332	E	0.409
40001332	F	0.462
40001332	G	0.469
40001338	B	0.325
40001338	C	0.455
40001338	D	0.367
40001338	E	0.200
40001338	F	0.217
40001401	A	0.529
40001403	A	0.425
40001620	A	0.328
40001641	A	0.238
40001720	B	0.455
40001720	D	0.600
40001727	G	0.300
40001740	A	0.200
40001740	B	0.417
40001742	A	0.278
40001756	F	0.308
40002002	A	0.290
40002002	B	0.417
40002002	D	0.217
40002002	E	0.333
40002002	I	0.407
40002109	A	0.467
40002173	A	0.333
40002207	F	0.388
40002403	C	0.242
40002416	A	0.361
40002416	B	0.147
40002435	B	0.231

State Route Number	Route Segment	Ratio of Slick to Total Collisions
40002435	C	0.260
40002776	A	0.324
40002776	B	0.167
40002776	E	0.471
40002806	A	0.379
40002806	B	0.290
40003075	A	0.313
40003116	C	0.280
40003116	D	0.364
40003116	E	0.171
40003116	F	0.333
40003116	G	0.200
40003116	H	0.346
40003121	B	0.300
40003121	C	0.588
40003121	E	0.313
40003136	D	0.327
40003136	E	0.294
40003412	A	0.333
40003412	E	0.281
40003437	F	0.200
40003446	B	0.393
40003446	C	0.375
40003446	D	0.208
40003452	D	0.313
40003486	D	0.438
40003495	A	0.310
40003495	E	0.296
40003495	F	0.222
40003548	I	0.345
40003548	J	0.205
40003548	K	0.183
40003556	E	0.300
40003556	H	0.414

Table A4: Ratio of Slick to Total Collisions in Decreasing Order by Ratio
(Highlighting Denotes Grooved Surface)

State Route Number	Route Segment	Ratio of Slick to Total Collisions
20000019	C	0.800
29000019	P	0.750
10000040	II	0.692
10000040	BB	0.690
40001003	G	0.667
10000040	D	0.658
10000040	V	0.654
10000040	W	0.641
10000040	FF	0.621
20000019	E	0.600
40001720	D	0.600
40003121	C	0.588
30000191	R	0.583
10000240	B	0.576
10000040	Z	0.574
10000040	X	0.571
10000040	Y	0.559
10000240	A	0.558
10000040	U	0.550
20000019	OO	0.548
20000074	Q	0.545
20000074	J	0.529
40001003	Q	0.529
40001401	A	0.529
10000040	AA	0.522
30000146	B	0.516
10000040	L	0.500
20000019	PP	0.500
20000019	X	0.500
20000025	P	0.500
40001130	C	0.500
10000040	J	0.486
40002776	E	0.471
40001332	G	0.469
40002109	A	0.467
40001332	F	0.462
40001338	C	0.455
40001720	B	0.455
10000040	A	0.448
10000040	C	0.438
10000040	T	0.438
40003486	D	0.438
30000112	E	0.431
30000009	J	0.429

State Route Number	Route Segment	Ratio of Slick to Total Collisions
40001403	A	0.425
21000025	J	0.423
40001003	A	0.422
20000019	V	0.417
40001740	B	0.417
40002002	B	0.417
40003556	H	0.414
10000240	O	0.412
20000025	L	0.412
40001332	E	0.409
30000191	J	0.407
40002002	I	0.407
10000040	EE	0.400
20000019	O	0.400
30000191	Q	0.393
40003446	B	0.393
20000019	JJ	0.391
20000074	I	0.389
30000694	A	0.389
30000081	D	0.388
40002207	F	0.388
10000240	M	0.385
20000019	Z	0.385
40001130	B	0.385
10000040	M	0.381
40002806	A	0.379
30000009	B	0.377
40003446	C	0.375
10000240	F	0.374
20000019	Q	0.370
20000019	Y	0.368
40001319	A	0.367
40001338	D	0.367
40003116	D	0.364
30000191	B	0.361
40002416	A	0.361
30000112	F	0.360
20000019	A	0.353
10000240	L	0.352
20000074	M	0.351
20000025	S	0.349
10000026	F	0.348
20000074	N	0.347
10000026	A	0.346

Table A4 Continued

State Route Number	Route Segment	Ratio of Slick to Total Collisions
40003116	H	0.346
40003548	I	0.345
10000040	G	0.344
20000019	F	0.343
10000040	N	0.340
10000240	D	0.333
30000009	A	0.333
30000146	D	0.333
30000251	E	0.333
40001004	A	0.333
40001220	N	0.333
40002002	E	0.333
40002173	A	0.333
40003116	F	0.333
40003412	A	0.333
10000026	D	0.332
40001620	A	0.328
40003136	D	0.327
40001338	B	0.325
20000025	I	0.324
40002776	A	0.324
21000025	B	0.319
30000191	K	0.317
30000151	F	0.317
20000074	F	0.316
21000025	A	0.316
30000063	F	0.316
30000191	A	0.316
20000019	FF	0.315
20000070	M	0.314
10000240	R	0.313
10000240	T	0.313
30000081	H	0.313
40003075	A	0.313
40003121	E	0.313
40003452	D	0.313
10000040	R	0.311
20000019	EE	0.310
40003495	A	0.310
40001315	A	0.308
40001756	F	0.308
10000040	H	0.306
20000019	S	0.304
30000191	S	0.303
30000063	E	0.303
10000240	N	0.302
20000025	FF	0.301
30000191	G	0.300
30000251	C	0.300
40001727	G	0.300
40003121	B	0.300
40003556	E	0.300
20000070	N	0.300
40003495	E	0.296
10000040	E	0.296
20000025	Q	0.295
10000240	C	0.294
30000191	D	0.294
40001003	E	0.294
40001220	A	0.294
40003136	E	0.294
20000025	M	0.293
40001332	C	0.292
20000019	BB	0.290
40002002	A	0.290
40002806	B	0.290
30000146	E	0.286
40001002	A	0.286
30000063	D	0.284
20000025	UU	0.283
20000019	H	0.282
40003412	E	0.281
40001002	B	0.281
10000026	B	0.280
40003116	C	0.280
40001004	C	0.279
10000040	CC	0.278
10000240	I	0.278
20000019	P	0.278
20000025	KK	0.278
40001742	A	0.278
10000240	G	0.277
30000151	D	0.275
10000240	E	0.273
30000197	B	0.272
20000074	K	0.272
29000019	G	0.270
30000081	E	0.268

Table A4 Continued

State Route Number	Route Segment	Ratio of Slick to Total Collisions
10000240	Q	0.268
20000070	I	0.265
30000112	G	0.265
30000146	C	0.265
40002435	C	0.260
10000026	C	0.259
10000040	DD	0.259
20000019	LL	0.259
20000025	H	0.258
20000019	J	0.255
20000025	DD	0.255
30000063	B	0.252
10000040	I	0.250
21000025	F	0.250
20000070	O	0.248
30000063	G	0.244
40001332	D	0.244
20000025	J	0.243
40002403	C	0.242
20000019	I	0.242
30000063	C	0.241
20000070	J	0.241
20000025	OO	0.240
40001004	D	0.238
40001641	A	0.238
20000019	U	0.238
40001319	C	0.237
30000009	I	0.237
20000074	P	0.235
30000191	M	0.235
20000019	K	0.235
30000063	A	0.233
20000070	K	0.233
40001003	F	0.231
40002435	B	0.231
30000280	F	0.229
30000081	I	0.222
40003495	F	0.222
30000191	H	0.220
20000019	R	0.217
40001338	F	0.217
40002002	D	0.217
20000070	P	0.214
40001220	M	0.214

State Route Number	Route Segment	Ratio of Slick to Total Collisions
20000019	T	0.211
20000025	A	0.209
40003446	D	0.208
40003548	J	0.205
20000025	CC	0.200
20000070	B	0.200
40001338	E	0.200
40001740	A	0.200
40003116	G	0.200
40003437	F	0.200
20000025	JJ	0.198
21000025	K	0.196
20000070	H	0.196
30000191	F	0.196
10000240	J	0.189
40001224	D	0.188
20000025	HH	0.186
20000025	Y	0.185
40001332	B	0.184
40003548	K	0.183
20000025	G	0.179
20000025	LL	0.178
20000025	II	0.175
29000019	F	0.171
40003116	E	0.171
40001319	D	0.167
40002776	B	0.167
20000019	D	0.162
40001332	A	0.161
20000025	C	0.159
20000025	B	0.156
10000040	O	0.152
30000151	B	0.152
40002416	B	0.147

Table A5: Route Segments With the Ratio of Run Off the Road to Total Collisions Organized by Route

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
10000026	A	78	37	0.474
10000026	B	50	16	0.320
10000026	C	54	10	0.185
10000026	D	289	108	0.374
10000026	E	34	Less than 5	N/A
10000026	F	66	29	0.439
10000026	G	11	Less than 5	N/A
10000040	A	67	22	0.328
10000040	AA	69	21	0.304
10000040	BB	29	18	0.621
10000040	C	16	6	0.375
10000040	CC	18	9	0.500
10000040	D	79	41	0.519
10000040	DD	27	Less than 5	N/A
10000040	E	115	48	0.417
10000040	EE	20	8	0.400
10000040	F	11	5	0.455
10000040	FF	29	12	0.414
10000040	G	61	33	0.541
10000040	H	36	12	0.333
10000040	I	268	51	0.190
10000040	II	13	Less than 5	N/A
10000040	J	72	26	0.361
10000040	JJ	12	Less than 5	N/A
10000040	K	12	Less than 5	N/A
10000040	L	22	13	0.591
10000040	M	21	9	0.429
10000040	N	97	50	0.515
10000040	O	33	11	0.333
10000040	Q	16	Less than 5	N/A
10000040	R	61	16	0.262
10000040	T	32	13	0.406
10000040	U	20	5	0.250
10000040	V	26	6	0.231
10000040	W	39	11	0.282
10000040	X	21	8	0.381

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
10000040	Y	59	25	0.424
10000040	Z	136	58	0.426
10000240	A	104	40	0.385
10000240	B	33	6	0.182
10000240	C	34	6	0.176
10000240	D	21	8	0.381
10000240	E	33	6	0.182
10000240	F	321	67	0.209
10000240	G	159	13	0.082
10000240	H	23	Less than 5	N/A
10000240	I	36	Less than 5	N/A
10000240	J	111	6	0.054
10000240	K	22	Less than 5	N/A
10000240	L	108	10	0.093
10000240	M	39	7	0.179
10000240	N	53	12	0.226
10000240	O	17	Less than 5	N/A
10000240	Q	142	24	0.169
10000240	R	16	Less than 5	N/A
10000240	T	16	Less than 5	N/A
20000019	A	34	Less than 5	N/A
20000019	AA	11	5	0.455
20000019	BB	62	18	0.290
20000019	C	10	Less than 5	N/A
20000019	D	74	12	0.162
20000019	E	10	Less than 5	N/A
20000019	EE	29	7	0.241
20000019	F	102	19	0.186
20000019	FF	241	75	0.311
20000019	GG	21	6	0.286
20000019	H	85	Less than 5	N/A
20000019	I	310	19	0.061
20000019	J	153	5	0.033
20000019	JJ	23	11	0.478
20000019	K	98	Less than 5	N/A
20000019	KK	10	9	0.900
20000019	L	13	Less than 5	N/A

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
20000019	LL	27	9	0.333
20000019	O	30	Less than 5	N/A
20000019	OO	31	16	0.516
20000019	P	54	5	0.093
20000019	PP	14	5	0.357
20000019	Q	13	Less than 5	N/A
20000019	R	92	Less than 5	N/A
20000019	S	23	Less than 5	N/A
20000019	T	147	Less than 5	N/A
20000019	U	80	5	0.063
20000019	V	36	10	0.278
20000019	W	27	Less than 5	N/A
20000019	X	16	8	0.500
20000019	Y	19	Less than 5	N/A
20000019	Z	26	5	0.192
20000025	A	201	7	0.035
20000025	B	96	Less than 5	N/A
20000025	C	63	5	0.079
20000025	CC	85	Less than 5	N/A
20000025	DD	55	Less than 5	N/A
20000025	EE	10	Less than 5	N/A
20000025	FF	153	Less than 5	N/A
20000025	G	28	Less than 5	N/A
20000025	H	66	Less than 5	N/A
20000025	HH	156	5	0.032
20000025	I	68	12	0.176
20000025	II	80	Less than 5	N/A
20000025	J	37	Less than 5	N/A
20000025	JJ	329	19	0.058
20000025	KK	18	Less than 5	N/A
20000025	L	17	Less than 5	N/A
20000025	LL	118	Less than 5	N/A
20000025	M	41	Less than 5	N/A
20000025	MM	10	Less than 5	N/A
20000025	NN	15	Stop 2	N/A
20000025	OO	50	5	0.100
20000025	P	10	Stop 2	N/A

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
20000025	Q	122	7	0.057
20000025	RR	11	Stop 2	N/A
20000025	S	63	5	0.079
20000025	UU	46	Less than 5	N/A
20000025	V	16	Stop 2	N/A
20000025	VV	34	6	0.176
20000025	Y	27	Less than 5	N/A
20000025	Z	14	Stop 2	N/A
20000070	B	40	Stop 2	N/A
20000070	CC	28	Stop 2	N/A
20000070	G	19	Stop 2	N/A
20000070	H	97	Less than 5	N/A
20000070	I	34	Stop 2	N/A
20000070	J	307	9	0.029
20000070	K	146	Less than 5	N/A
20000070	L	15	Stop 2	N/A
20000070	M	51	7	0.137
20000070	N	257	13	0.051
20000070	O	109	Less than 5	N/A
20000070	P	28	Less than 5	N/A
20000074	F	38	9	0.237
20000074	I	18	Less than 5	N/A
20000074	J	17	Less than 5	N/A
20000074	K	81	6	0.074
20000074	M	37	7	0.189
20000074	N	288	72	0.250
20000074	P	34	21	0.618
20000074	Q	11	5	0.455
21000025	A	19	Less than 5	N/A
21000025	B	113	16	0.142
21000025	F	56	7	0.125
21000025	I	25	8	0.320
21000025	J	26	6	0.231
21000025	K	56	5	0.089
21000025	L	13	Less than 5	N/A
29000019	F	41	Less than 5	N/A
29000019	G	126	9	0.071

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
29000019	J	11	Less than 5	N/A
29000019	O	25	Stop 2	N/A
29000019	P	12	Less than 5	N/A
30000009	A	18	13	0.722
30000009	B	53	36	0.679
30000009	C	12	9	0.750
30000009	G	11	Stop 2	N/A
30000009	I	38	Stop 2	N/A
30000009	J	14	Stop 2	N/A
30000009	K	16	Less than 5	N/A
30000009	L	10	Less than 5	N/A
30000009	Q	12	Less than 5	N/A
30000063	A	180	14	0.078
30000063	B	115	9	0.078
30000063	C	261	18	0.069
30000063	D	155	35	0.226
30000063	E	175	45	0.257
30000063	F	38	9	0.237
30000063	G	45	20	0.444
30000081	D	49	24	0.490
30000081	E	56	27	0.482
30000081	H	32	18	0.563
30000081	I	54	11	0.204
30000112	A	10	Less than 5	N/A
30000112	E	51	5	0.098
30000112	F	25	Less than 5	N/A
30000112	G	102	17	0.167
30000146	B	31	8	0.258
30000146	C	34	Less than 5	N/A
30000146	D	21	Less than 5	N/A
30000146	E	77	5	0.065
30000151	A	14	12	0.857
30000151	B	33	15	0.455
30000151	D	69	22	0.319
30000151	F	161	59	0.366
30000191	A	95	31	0.326

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
30000191	B	83	31	0.373
30000191	D	85	16	0.188
30000191	F	92	Less than 5	N/A
30000191	G	20	Less than 5	N/A
30000191	H	59	Less than 5	N/A
30000191	I	15	Less than 5	N/A
30000191	J	54	Less than 5	N/A
30000191	K	41	Less than 5	N/A
30000191	L	16	Less than 5	N/A
30000191	M	34	Less than 5	N/A
30000191	P	20	Less than 5	N/A
30000191	Q	28	5	0.179
30000191	R	12	Less than 5	N/A
30000191	S	33	10	0.303
30000197	A	11	Less than 5	N/A
30000197	B	136	54	0.397
30000197	C	11	7	0.636
30000251	C	50	15	0.300
30000251	E	36	19	0.528
30000251	H	20	13	0.650
30000280	B	32	Less than 5	N/A
30000280	F	223	Less than 5	N/A
30000694	A	18	15	0.833
40001001	B	12	8	0.667
40001002	A	56	34	0.607
40001002	B	57	20	0.351
40001003	A	45	7	0.156
40001003	C	14	Less than 5	N/A
40001003	E	17	5	0.294
40001003	F	65	28	0.431
40001003	G	15	12	0.800
40001003	H	20	11	0.550
40001003	Q	17	14	0.824
40001004	A	27	14	0.519
40001004	C	68	27	0.397
40001004	D	21	11	0.524

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
40001123	A	10	9	0.900
40001130	A	22	12	0.545
40001130	B	13	6	0.462
40001130	C	12	Less than 5	N/A
40001130	D	16	Less than 5	N/A
40001130	E	14	10	0.714
40001220	A	17	10	0.588
40001220	K	15	7	0.467
40001220	M	28	8	0.286
40001220	N	21	12	0.571
40001220	O	11	Less than 5	N/A
40001224	D	48	9	0.188
40001224	F	16	11	0.688
40001224	G	11	Less than 5	N/A
40001224	H	16	7	0.438
40001224	I	15	8	0.533
40001238	B	11	6	0.545
40001263	A	12	Less than 5	N/A
40001263	C	20	10	0.500
40001315	A	26	7	0.269
40001319	A	49	17	0.347
40001319	C	59	9	0.153
40001319	D	30	10	0.333
40001332	A	31	Less than 5	N/A
40001332	B	49	Less than 5	N/A
40001332	C	24	Less than 5	N/A
40001332	D	41	5	0.122
40001332	E	22	Less than 5	N/A
40001332	F	13	Less than 5	N/A
40001332	G	32	9	0.281
40001338	A	14	Less than 5	N/A
40001338	B	40	13	0.325
40001338	C	22	10	0.455
40001338	D	30	5	0.167
40001338	E	35	17	0.486
40001338	F	23	15	0.652

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
40001401	A	17	11	0.647
40001403	A	40	26	0.650
40001620	A	58	22	0.379
40001641	A	21	12	0.571
40001684	A	10	5	0.500
40001684	D	16	Less than 5	N/A
40001720	B	11	7	0.636
40001720	D	10	Less than 5	N/A
40001727	A	12	Less than 5	N/A
40001727	B	24	6	0.250
40001727	G	40	13	0.325
40001740	A	35	Less than 5	N/A
40001740	B	12	10	0.833
40001740	C	17	9	0.529
40001742	A	18	13	0.722
40001756	A	19	9	0.474
40001756	E	11	5	0.455
40001756	F	26	19	0.731
40002002	A	31	6	0.194
40002002	B	12	5	0.417
40002002	D	23	5	0.217
40002002	E	18	6	0.333
40002002	G	18	12	0.667
40002002	H	19	12	0.632
40002002	I	27	15	0.556
40002109	A	15	14	0.933
40002130	A	10	Less than 5	N/A
40002148	B	16	11	0.688
40002173	A	48	34	0.708
40002173	B	16	13	0.813
40002207	D	14	Less than 5	N/A
40002207	F	49	21	0.429
40002230	B	12	7	0.583
40002230	I	10	7	0.700
40002403	A	12	Less than 5	N/A
40002403	C	33	15	0.455

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
40002416	A	36	14	0.389
40002416	B	34	13	0.382
40002416	C	21	14	0.667
40002435	A	29	Less than 5	N/A
40002435	B	26	Less than 5	N/A
40002435	C	100	33	0.330
40002776	A	68	44	0.647
40002776	B	36	22	0.611
40002776	E	17	12	0.706
40002806	A	66	40	0.606
40002806	B	31	15	0.484
40003075	A	16	13	0.813
40003116	C	25	Less than 5	N/A
40003116	D	33	7	0.212
40003116	E	41	10	0.244
40003116	F	15	Less than 5	N/A
40003116	G	25	15	0.600
40003116	H	26	Less than 5	N/A
40003121	B	20	9	0.450
40003121	C	17	15	0.882
40003121	E	16	7	0.438
40003136	D	98	54	0.551
40003136	E	17	11	0.647
40003412	A	33	15	0.455
40003412	E	32	10	0.313
40003437	F	30	20	0.667
40003446	B	28	16	0.571
40003446	C	24	9	0.375
40003446	D	24	10	0.417
40003452	D	16	10	0.625
40003486	D	32	22	0.688
40003495	A	29	17	0.586
40003495	E	71	30	0.423
40003495	F	36	Less than 5	N/A
40003501	A	10	7	0.700
40003548	B	13	Less than 5	N/A

Table A5 Continued

State Route Number	Segment	Total Collision Frequency	ROR Collision Frequency	Ratio of ROR to Total Collisions
40003548	H	10	Less than 5	N/A
40003548	I	55	8	0.145
40003548	J	39	Less than 5	N/A
40003548	K	71	Less than 5	N/A
40003556	A	18	Less than 5	N/A
40003556	D	10	Less than 5	N/A
40003556	E	20	Less than 5	N/A
40003556	H	29	7	0.241
40003556	I	19	Less than 5	N/A

Table A6: Ratio of Run off Road to Total Collisions with Shoulder Width

Ratio of ROR to Total Collisions	State Route Number	Route Section	Left Shoulder Width (feet)	Right Shoulder Width (feet)
0.933	40002109	A	3	3
0.900	40001123	A	2	2
0.857	30000151	A	3	3
0.833	30000694	A	2	2
0.813	40003075	A	2	2
0.722	40001742	A	3	3
0.688	40001224	F	2	2
0.688	40003486	D	3	3
0.667	40001001	B	2	2
0.667	40003437	F	3	3
0.652	40001338	F	3	3
0.650	40001403	A	3	3
0.650	30000251	H	3	3
0.647	40001401	A	3	3
0.636	40001720	B	1	1
0.632	40002002	H	3	3
0.621	10000040	BB	2	10
0.606	40002806	A	2	2
0.588	40001220	A	1	1
0.583	40002230	B	2	3
0.571	40001641	A	3	3
0.563	30000081	H	3	3
0.556	40002002	I	3	3
0.545	40001238	B	3	3
0.528	30000251	E	3	3
0.524	40001004	D	3	3
0.519	40001004	A	3	3
0.500	40001684	A	1	1
0.500	40001263	C	2	2
0.500	10000040	CC	2	10
0.490	30000081	D	2	4
0.486	40001338	E	2	2
0.484	40002806	B	2	2

Table A6 Continued

Ratio of ROR to Total Collisions	State Route Number	Route Section	Left Shoulder Width (feet)	Right Shoulder Width (feet)
0.467	40001220	K	3	3
0.455	20000074	Q	2	2
0.455	40002403	C	3	3
0.455	40001338	C	3	3
0.438	40003121	E	2	2
0.426	10000040	Z	2	10
0.423	40003495	E	2	2
0.397	40001004	C	3	3
0.379	40001620	A	2	2
0.347	40001319	A	3	3
0.325	40001338	B	3	3
0.320	21000025	I	2	2
0.313	40003412	E	3	3
0.304	10000040	AA	2	10
0.281	40001332	G	1	1
0.269	40001315	A	2	2
0.241	40003556	H	3	3
0.237	20000074	F	3	3
0.231	21000025	J	3	6
0.204	30000081	I	6	2
0.188	40001224	D	2	2
0.179	30000191	Q	1	1
0.167	40001338	D	2	2
0.153	40001319	C	3	3
0.125	21000025	F	2	2
0.100	20000025	OO	1	3
0.089	21000025	K	3	6

Table A7: Signal Installations and Subsequent Collisions

Signal Installations				Number of Collisions in Years After Improvement				
Year	Road	Route Number	Milepost	1993	1994	1995	1996	1997
1992	SR 3556	40003556	2.4	0	2	2	2	1
1992	NC 280	30000280	2.47	9	10	7	12	6
1992	NC 280	30000280	2.7	2	1	3	1	0
1992	US 19-23	20000019	11.08	2	1	1	0	1
1992	US 19-23	20000019	11.7	13	10	5	3	3
1992	US 19-23	20000019	20.73	6	2	5	5	5
1993	US 25	20000025	6.49		6	5	0	0
1993	US 70	20000070	19.79		0	0	0	0
1993	US 25	20000025	7.48		3	3	2	2
1993	NC 112	30000112	1.56		4	2	3	4
1993	US 25	20000025	4.28		0	0	0	0
1994	US 74	20000074	19.4			0	0	0
1994	US 25A	21000025	3.01			0	0	0
1994	SR 3556	40003556	0.79			0	0	0
1994	US 25A	21000025	1.77				0	0
1995	SR 2435	40002435	2.86				2	0
1995	NC 191	30000191	8.86				1	2
1995	NC 280	30000280	0.64				5	5
1995	US 25	20000025	1.21				5	1
1995	NC 191	30000191	5.69				0	0
1995	1-240	10000240	3.12				17	23
1996	NC 191	30000191	5.24					0
1996	US 70	20000070	26.68					0
1996	SR 1781	40001781	1.45					0
1996	SR 3284	40003284	0.35					0

Table A8: Repaving and Widening Improvements and Subsequent Collisions

REPAVING / WIDENING IMPROVEMENTS						Number of Accidents in Yrs. After Improvement				
Year	Road		Begin MP	End MP	Length	1993	1994	1995	1996	1997
1992	NC 191	30000191	9.56	9.77	0.21	6	5	2	1	1
1992	NC 81	30000081	0	0.48	0.48	2	1	2	1	1
1992	SR 1720	40001720	0.64	0.95	0.31	1	4	0	1	2
1992	SR 1725	40001725	0	0.7	0.7	0	0	1	0	0
1992	SR 3238	40003238	0	0.22	0.22	0	0	0	0	0
1992	SR 3452	40003452	3.16	4.18	1.02	0	0	2	0	2
1992	US 19	20000019	23.81	27.31	3.5	5	9	14	11	12
1992	US 19	20000019	24.97	27.31	2.34	4	7	9	8	6
1992	US 25A	21000025	6.9	7.05	0.15	4	2	1	1	3
1993	I-240	10000240	0.84	0.9	0.06		2	0	1	1
1993	NC 112	30000112	0	3.64	3.64		32	19	24	27
1993	NC 191	30000191	0	6.72	6.72		28	25	30	21
1993	NC 191	30000191	7.55	8.97	1.42		26	25	19	12
1993	SR 1130	40001130	4.16	4.18	0.02		0	0	2	1
1993	SR 1740	40001740	0	0.81	0.81		5	7	9	2
1993	US 25	20000025	8.22	8.88	0.66		13	9	4	4
1993	US 25	20000025	11.69	13.49	1.8		156	141	107	114
1993	US 25A	21000025	6.34	7.98	1.64		11	18	11	13
1993	US 70	20000070	18.59	18.84	0.25		20	18	16	16
1993	US 70	20000070	18.84	19.79	0.95		30	24	25	31
1994	SR 1401	40001401	0	2.22	2.22			2	1	4
1994	SR 3116	40003116	3.07	4.87	1.8			6	10	9
1994	US 19-23	20000019	10.04	11.7	1.66			32	6	7
1994	US 25	20000025	8.88	9.15	0.27			11	10	8
1994	US 25	20000025	9.15	9.95	0.8			24	24	23
1994	US 25	20000025	10.46	10.83	0.37			2	2	5
1994	US 25A	21000025	8.42	8.47	0.05			1	1	1
1994	US 70	20000070	15.34	18.59	3.25			147	115	113
1995	NC 63	30000063	4.8	15.2	10.4				37	41
1995	NC 9	30000009	15.21	15.36	0.15				0	3
1995	SR 1002	40001002	0.55	2.88	2.33				2	3
1995	SR 1004	40001004	0.6	8.8	8.2				19	10
1995	SR 1224	40001224	2.68	4.15	1.47				10	9
1995	SR 3214	40003214	0	1.48	1.48				0	0
1995	SR 3501	40003501	0	1.3	1.3				0	3
1995	SR 3556	40003556	0	1.55	1.55				7	8
1995	US 19-23	20000019	6.11	7.39	1.28				1	3
1995	US 25	20000025	14.95	15.37	0.42				5	3
1995	US 25	20000025	15.37	16	0.63				1	1
1995	US 70	20000070	27.95	29.36	1.41				4	6
1996	NC 151	30000151	0	4.32	4.32					2
1996	SR 1003	40001003	4.51	7.11	2.6					4
1996	SR 1107	40001107	0	1	1					2
1996	SR 1108	40001108	0	1	1					0
1996	SR 1109	40001109	0	0.3	0.3					0
1996	SR 1116	40001116	0	0.4	0.4					0
1996	SR 1117	40001117	0	0.5	0.5					1
1996	SR 1118	40001118	0	0.2	0.2					0
1996	SR 1119	40001119	0	0.7	0.7					1
1996	SR 1120	40001120	0	1.48	1.48					1
1996	SR 1130	40001130	0	4.16	4.16					8
1996	SR 1220	40001220	3.1	5.4	2.3					0
1996	SR 1220	40001220	7.1	9.4	2.3					0
1996	SR 1349	40001349	0	0.8	0.8					1
1996	SR 2776	40002776	0	1.68	1.68					9
1996	SR 3486	40003486	4.67	5.06	0.39					0
1996	SR 3521	40003521	0	0.57	0.57					1

Table A9: Collision Rates for Sections in Decreasing Order

Route	Section	Rate (Accidents per 100 million vehicle miles)	Year of AADT
40003495	E	3657	1996 (Projected)
40002403	C	3465	1996 (Projected)
40003495	F	2868	1996 (Projected)
30000009	I	2445	1993
40001220	M	2262	1993
40001003	Q	2057	1992
40001315	A	1985	1996 (Projected)
29000019	O	1512	1996 (Projected)
40001004	A	1484	1993
20000070	J	1250	1993
20000025	FF	1228	1993
20000025	JJ	1173	1993
20000074	K	926	1993
30000280	F	917	1996 (AADT Map)
30000191	F	832	1993
40002806	A	832	1993
40003116	H	761	1996 (Projected)
20000070	K	756	1993
40003548	I	748	1993
40001338	B	739	1993
30000191	K	697	1993
20000025	II	692	1993
20000019	K	687	1993
30000151	D	682	1993
20000025	LL	672	1993
40002207	F	670	1993
40001319	A	664	1996 (AADT Map)
40003446	D	617	1996 (Projected)
40003116	G	609	1996 (Projected)
20000025	HH	597	1993
40001338	F	538	1993
30000063	E	515	1993
40003486	D	514	1993
30000081	E	497	1993
40001332	D	493	1993
40002776	A	481	1993
20000070	N	472	1993
20000074	N	452	1993
30000191	Q	432	1993
40001332	A	422	1993
20000074	M	418	1993
30000063	C	411	1993
40003116	E	411	1996 (Projected)
40003556	A	403	1993
40001003	A	401	1993

Table A9 Continued

Route	Section	Rate (Accidents per 100 million vehicle miles)	Year of AADT
20000025	Q	392	1993
40002435	C	388	1993
30000063	G	381	1993
30000063	B	375	1993
10000240	F	369	1993
30000694	A	360	1993
20000025	A	357	1993
40001727	G	357	1993
40003412	A	356	1993
40002002	A	351	1993
21000025	B	351	1993
40001003	F	350	1993
20000025	UU	349	1993
21000025	J	345	1993
20000019	I	335	1993
20000019	U	334	1993
20000019	R	327	1993
40002173	A	324	1993
20000025	S	320	1993
40003548	J	314	1993
40001403	A	307	1993
30000081	D	307	1993
30000191	D	302	1993
29000019	G	298	1993
30000009	B	297	1993
30000151	F	293	1993
30000112	F	291	1993
30000063	A	289	1993
30000191	I	289	1993
30000112	E	275	1993
29000019	F	273	1993
20000070	M	268	1993
30000191	A	266	1993
40001130	A	252	1996 (Projected)
30000251	E	238	1993
30000197	B	237	1993
30000146	B	231	1993
20000074	I	231	1993
20000019	V	229	1993
30000191	S	229	1993
40003136	D	228	1993
40003437	F	228	1993
20000019	T	226	1993
20000019	J	226	1993
30000112	G	221	1993

Table A9 Continued

Route	Section	Rate (Accidents per 100 million vehicle miles)	Year of AADT
40001003	E	221	1993
40002416	B	221	1993
40001004	C	218	1993
20000025	H	215	1993
40001224	D	211	1993
10000240	A	210	1993
20000074	P	207	1993
40001338	E	205	1993
30000063	F	204	1993
30000146	E	202	1993
30000063	D	196	1993
20000025	B	195	1993
20000025	VV	187	1993
20000025	OO	186	1993
10000240	G	176	1993
40001002	B	172	1996 (AADT Map)
30000191	J	168	1993
40003412	E	167	1993
10000240	L	166	1996 (AADT Map)
10000240	C	161	1993
20000070	I	156	1993
20000019	F	154	1993
20000019	P	153	1993
40002776	B	152	1993
20000019	D	150	1993
21000025	K	148	1993
20000019	FF	142	1993
30000191	B	139	1993
10000040	A	135	1993
10000040	FF	124	1993
20000074	F	123	1993
10000026	C	120	1993
10000240	B	117	1993
10000240	M	116	1993
20000025	I	108	1993
10000040	J	101	1993
10000040	I	96	1993
21000025	F	89	1993
10000026	A	82	1993
10000040	W	72	1993
10000040	R	70	1993
10000040	D	68	1993
10000240	Q	65	1993
10000240	E	65	1993
30000251	C	64	1993
10000040	Y	64	1993

Table A9 Continued

Route	Section	Rate (Accidents per 100 million vehicle miles)	Year of AADT
10000040	H	63	1993
10000040	DD	62	1993
20000025	C	60	1993
40001620	A	57	1993
20000025	G	56	1993
10000040	E	52	1993
10000040	BB	52	1993
10000026	B	50	1993
10000040	AA	50	1993
10000040	G	47	1993
10000040	Z	42	1993
20000019	BB	40	1993
10000026	D	38	1993
10000040	T	36	1993
20000019	OO	36	1993
20000019	EE	29	1993
10000040	N	29	1993
10000040	V	21	1993
10000026	F	21	1993

Table A10: Collision Rates for Spots in Decreasing Order

State Route Number	Spot	Rate (Accidents per million entering vehicles)	Year of AADT
20000025	CC	3.95	1993
40001332	B	2.95	1993
20000070	H	2.87	1993
40003548	K	2.87	1993
40001338	D	2.76	1993
30000081	I	2.24	1993
20000019	H	2.05	1993
20000025	DD	1.76	1993
30000146	C	1.63	1993
20000070	O	1.41	1993
30000191	M	1.35	1993
40001332	C	1.22	1993
20000025	Y	1.20	1993
30000191	P	1.17	1993
40003116	D	1.12	1996 (AADT Map)
20000070	CC	1.10	1993
30000191	H	1.03	1993
20000025	M	1.00	1993
20000070	B	0.88	1993
20000070	G	0.65	1993
20000025	J	0.62	1993
30000146	D	0.57	1993
10000240	J	0.54	1993
20000019	S	0.53	1993
10000240	N	0.52	1993
20000074	J	0.48	1993
20000019	W	0.33	1993
10000240	I	0.20	1993

Table A11: Poisson Probabilities

State Route Number	Route Segment	Poisson Probability
10000026	D	0.00001
30000081	E	0.00010
30000151	F	0.00012
20000019	LL	0.00034
40003495	F	0.00035
10000040	M	0.00110
40001332	D	0.00162
10000240	H	0.00249
20000070	P	0.00278
20000019	Y	0.00305
10000026	E	0.00381
10000026	B	0.00400
40003116	C	0.00500
40001319	D	0.00511
40002416	C	0.00651
10000040	I	0.00655
20000019	Z	0.00682
30000081	I	0.00883
10000040	D	0.01111
30000191	S	0.01113
21000025	F	0.01254
40002435	A	0.01530
40001727	B	0.01628
40003446	C	0.01628
20000025	UU	0.01648
40001756	A	0.01656
40003121	C	0.01656
10000040	Y	0.02021
30000112	F	0.02109
30000251	H	0.02229
40001332	B	0.02735
10000040	X	0.02921
40001220	N	0.02921
40003486	D	0.02959
10000240	R	0.03053
30000191	L	0.03053
40002148	B	0.03053

State Route Number	Route Segment	Poisson Probability
40002435	C	0.03063
30000146	E	0.03256
10000040	AA	0.03418
20000025	C	0.03532
20000025	S	0.03532
40002403	C	0.03591
40001130	A	0.03742
40001401	A	0.04068
40003556	E	0.04202
20000070	N	0.04873
20000070	J	0.04899
40002002	G	0.05265
10000026	C	0.05557
40001332	F	0.05700
40001332	C	0.05789
10000240	I	0.06010
10000240	L	0.06432
20000025	Q	0.06632
40002002	H	0.06646
10000040	Z	0.06757
20000070	O	0.06983
40001332	A	0.07094
40001003	H	0.08209
40001263	C	0.08209
21000025	J	0.08392
40001315	A	0.08392
40001756	F	0.08392
10000040	CC	0.08770
40003548	B	0.08827
40001003	A	0.08835
10000026	A	0.08916
10000240	M	0.09259
20000025	NN	0.09534
20000070	L	0.09534
40002109	A	0.09534
30000009	K	0.09587
10000240	E	0.09633

Table A11 Continued

State Route Number	Route Segment	Poisson Probability
40001319	C	0.09852
20000025	Y	0.09900
40001641	A	0.09949
10000026	F	0.10189
40001727	G	0.10528
20000025	II	0.10633
20000019	A	0.11067
10000040	A	0.11192
40001220	M	0.11541
20000025	V	0.11806
40002776	A	0.12251
20000025	B	0.12626
10000240	F	0.12629
40003556	H	0.13309
30000251	E	0.14251
40001740	C	0.14288
40003437	F	0.15197
21000025	B	0.15307
10000240	Q	0.15506
40001002	B	0.15532
40003446	D	0.16133
20000025	JJ	0.16903
10000040	J	0.17018
29000019	P	0.17345
40001130	C	0.17345
40002002	B	0.17345
40002230	B	0.17345
30000063	F	0.17821
20000019	FF	0.18070
10000040	Q	0.18474
29000019	O	0.18474
40003116	G	0.18474
20000019	F	0.18823
30000112	G	0.18823
30000081	H	0.19296
21000025	A	0.19775
21000025	L	0.20928

State Route Number	Route Segment	Poisson Probability
10000040	V	0.20929
40002435	B	0.20929
10000040	N	0.21521
40001338	B	0.21724
40001403	A	0.21724
20000025	A	0.21885
40003136	D	0.22798
40002403	A	0.23400
40003116	E	0.23782
30000151	A	0.24655
30000063	E	0.25710
10000240	D	0.25780
40001338	E	0.26097
20000070	K	0.26928
40001003	G	0.28472
40001224	I	0.28472
40003116	F	0.28472
40002776	B	0.28492
20000019	EE	0.28811
40001620	A	0.28972
20000070	M	0.29620
20000025	HH	0.29720
20000019	X	0.32332
20000025	Z	0.32332
40001684	D	0.32332
40003075	A	0.32332
30000146	C	0.32974
30000009	I	0.33405
30000009	B	0.33771
20000019	OO	0.34328
40002002	A	0.34328
40002806	B	0.34328
10000040	R	0.34786
20000025	FF	0.35283
10000040	W	0.35899
10000240	O	0.36193
40001003	E	0.36193

Table A11 Continued

State Route Number	Route Segment	Poisson Probability
40002776	E	0.36193
20000019	BB	0.36764
20000019	H	0.36972
20000025	DD	0.38001
40001224	D	0.39370
40003495	E	0.39378
10000040	O	0.39905
30000151	B	0.39905
40003116	D	0.39905
20000025	KK	0.40017
30000009	A	0.40017
21000025	K	0.40129
29000019	G	0.40571
40003116	H	0.41650
40002207	F	0.41663
10000026	G	0.41799
20000074	Q	0.41799
29000019	J	0.41799
30000197	C	0.41799
40001238	B	0.41799
30000146	B	0.41909
20000070	G	0.43774
40003556	I	0.43774
30000280	F	0.43923
20000019	W	0.44788
40002002	I	0.44788
30000280	B	0.45387
30000009	C	0.46579
30000191	R	0.46579
40001263	A	0.46579
40001727	A	0.46579
10000040	EE	0.47437
10000040	U	0.47437
30000191	G	0.47437
10000040	E	0.47489
20000070	CC	0.47870
30000146	D	0.48478

State Route Number	Route Segment	Poisson Probability
40001004	C	0.48670
10000040	F	0.49633
20000019	AA	0.49633
40001756	E	0.49633
40001742	A	0.49818
10000040	FF	0.50882
40001004	D	0.50987
40003121	E	0.53055
20000074	F	0.53409
20000019	O	0.53813
40001338	D	0.53813
10000040	L	0.54406
10000240	K	0.54406
40001338	C	0.54406
30000197	B	0.54596
40001130	E	0.55395
40001338	A	0.55395
10000040	BB	0.55951
40003548	J	0.55951
20000019	JJ	0.57681
40001338	F	0.57681
40002002	D	0.57681
40001332	G	0.59393
40003412	E	0.59393
40001224	G	0.59399
30000081	D	0.59906
20000019	D	0.59933
20000025	M	0.60813
10000240	B	0.62027
20000025	OO	0.62049
30000251	C	0.62049
10000240	T	0.63128
40001130	D	0.63128
40001224	F	0.63128
40002173	B	0.63128
40003452	D	0.63128
40001003	C	0.63723

Table A11 Continued

State Route Number	Route Segment	Poisson Probability
21000025	I	0.63770
30000112	E	0.64126
10000240	C	0.64551
20000025	VV	0.64551
20000070	I	0.64551
20000019	I	0.65552
40001220	A	0.66584
40003136	E	0.66584
10000240	A	0.67518
10000040	II	0.69156
10000040	DD	0.69216
10000040	H	0.69256
20000019	V	0.69256
40002416	A	0.69256
40003548	K	0.69257
40002002	E	0.69773
30000191	J	0.69929
10000040	C	0.71270
20000025	J	0.71435
30000191	Q	0.71698
40003495	A	0.74021
40002806	A	0.75136
30000191	P	0.75392
40003121	B	0.75392
30000191	D	0.76801
20000070	B	0.77282
20000019	GG	0.77847
30000191	H	0.78117
30000191	K	0.79007
40001332	E	0.80085
10000040	G	0.80876
30000063	A	0.83254
30000191	M	0.83430
40002416	B	0.83430
30000191	F	0.84497
40001740	A	0.84913
40003548	I	0.85151

State Route Number	Route Segment	Poisson Probability
40001003	F	0.85570
30000063	B	0.88154
20000025	I	0.88431
40001004	A	0.88510
30000063	C	0.89206
40001319	A	0.89297
40003446	B	0.89738
30000063	D	0.90055
20000025	LL	0.90092
10000240	G	0.91997
20000025	CC	0.93239
10000040	T	0.93523
40003412	A	0.94237
40001002	A	0.94357
30000063	G	0.94411
20000074	M	0.96412
30000191	A	0.96944
20000070	H	0.97411
10000240	N	0.97613
10000240	J	0.98046
30000151	D	0.98436
30000191	B	0.98756
40002173	A	0.99064
20000019	U	0.99508
20000074	K	0.99905
20000019	K	0.99933
20000019	T	0.99999
20000074	N	~1