To the Graduate Council:

I am submitting herewith a thesis written by Ronald Jeffrey Mize, Jr. entitled "An Evaluation of the 'Before and After' Accident Analysis Process with Four Case Studies on Selected Tennessee State Highway Safety Improvement Projects." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

Dr. Frederick J. Wegmann,
Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of the Graduate School

AN EVALUATION OF THE "BEFORE AND AFTER" ACCIDENT ANALYSIS PROCESS WITH FOUR CASE STUDIES ON SELECTED TENNESSEE STATE HIGHWAY SAFETY IMPROVEMENT PROJECTS

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ABSTRACT

AN EVALUATION OF THE 'BEFORE AND AFTER' ACCIDENT ANALYSIS PROCESS WITH FOUR CASE STUDIES ON SELECTED TENNESSEE STATE HIGHWAY SAFETY IMPROVEMENT PROJECTS

by Ronald Jeffrey Mize, Jr.

The "before and after" accident analysis technique presents a systematic method for evaluating the effectiveness of highway safety improvements. Through four case studies involving Tennessee Department of Transportation projects, this thesis describes the procedure of performing a "before and after" evaluation. Certain problems exist in the reliability and practicality of the traffic data that is fundamental for these studies. In addition, current "before and after" procedures as outlined by the TDOT Highway Safety Management Program require a great deal of time-consuming effort that could be eliminated by the incorporation of some computer automation features. Several improved methods of data management, including new technological advancements, were researched which would improve upon the overall reliability and speed of performing these evaluations. By improving upon TDOT's systematic "before and after" process, future engineers would see more a practical, expedient, and cost-effective method of project evaluation.

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GLOSSARY

Accident Rate	Number that provides a basis for comparing an accident location with any other site. Accident rate is determined by dividing the number of accidents that occur at that location in a specified time period by the amount of vehicular exposure to that location in the same period of time. Expressed as accidents per million entering vehicle for intersections & spots, and accidents per million vehicle mile of travel for sections.
ADT	Average Daily Traffic; the total traffic volume during a given time period divided by the number of days in that time period.
Average Accident Rates *(R_A)*	Measured rates for various types of highway locations and highway characteristics used in statistical comparison of accident rates for specific locations. Measurements are taken annually for the various classifications of highways and applied to the previous three-year period.
Collision Diagram	A schematic drawing showing the directions of travel prior to contact, of vehicles, pedestrians, and other factors whose presence contributed to the accidents at a hazardous location. These diagrams use standard graphical symbols in a plan view (not to scale) to visualize accident patterns and identify the nature and causes of accidents at hazardous sites.

Condition Diagram	A *scaled* drawing of the important physical conditions of a hazardous intersection, section, or spot of roadway. It is used to relate the accident patterns on a collision diagram to the roadway and operational elements at the hazardous location.
Critical Rate *(R_C)*	Number derived to reduce the probability that an accident rate results from chance alone; also called the "upper control limit" for average accident rates. Any rate larger than the critical rate is most likely not a result of chance, but rather some unfavorable highway characteristic.
Intersection	A junction of two or more highways, including turning lanes and approach legs up to 0.01 mile from the point of intersection of adjacent curb lines or pavement edge lines.
MUTCD	Manual on Uniform Traffic Control Devices; published by the US Department of Transportation and the Federal Highway Administration in an effort to unify traffic control standards for different classes of roadways.
Poisson Distribution	In statistics, a frequency distribution (probability density function) that may be regarded as an approximation of the binomial distribution when the number of events becomes large and the probability of success becomes small.
Query	A database retrieval process that provides the basis for gathering information on the new TRIMS.
Relational Database	Databases that uses a relationship between tables to help in inquiring and reporting the data for a query. The new TRIMS is a Relational Database.

Section	A highway segment longer than 0.1 mile with uniform characteristics, including geometry, surface type, number of lanes, access control, environment (rural/urban), and traffic.
Severity Index ***(SI)***	Determined by the ratio of the fatal and injury accidents to the total number of accidents at a location. The larger the percentage of fatal and injury accidents, the more hazardous the location.
Spot	A non-intersection highway segment with length equal to 0.1 mile or less.
TDOT	Tennessee Department of Transportation; a division of Tennessee State Government whose mission is to plan, implement, maintain, and manage an integrated transportation system for the people, products, environment, and safety of the State of Tennessee.
TRIMS	Tennessee Roadway Information Management System; a statewide database that provides users with access to traffic record data on all State Roadways.

Chapter 1

INTRODUCTION

One of the highway safety goals of the Tennessee Department of Transportation is to "…evaluate the effectiveness of highway safety improvements…" (12) on state roads. The "before and after" accident analysis technique presents, perhaps, the most systematic method for attaining this goal. The process of performing a "before and after" accident evaluation is one part of the Tennessee Highway Safety Management Program. This program, originally developed in 1978 and under ongoing revision, outlines the operating procedures, functions, and responsibilities for managing highway safety in the State of Tennessee (16).

The significance of the state's highway safety management becomes apparent when the overall magnitude of Tennessee's roadway system is considered. As of March 1998, Tennessee's state road system covered approximately 85,037 miles. Of that distance, 13,552 miles were on state maintained highways, representing 16 percent of the total highway miles within the state and carrying 75 percent of the traffic. During the 1996 year, 167,659 accidents were reported on the state-maintained highways in Tennessee. This

total included 114,803 property-damage only collisions, 51,736 injury accidents, and 1,120 fatal crashes (13).

As can be seen, the Tennessee Department of Transportation is responsible for managing a vast amount of highway mileage. Dealing with such an enormous yearly accident total over these highway miles requires an effective and timely use of resources. TDOT uses the Highway Safety Management Program as a guide for developing and implementing highway safety improvements on state roads (16). The "before and after" step of the Highway Safety Management Program provides engineers with a rational procedure for gauging the effectiveness of individual roadway improvements. This thesis describes the application of the systematic process for conducting such a study and presents actual investigations that analyze the "before and after" conditions on four TDOT highway safety improvements. Following these four case studies, recommendations are made that assess the overall effectiveness of TDOT's systematic "before and after" study methodologies. These recommendations will discuss the accuracy, practicality, and availability of "before and after" information, including accident reports, traffic data, and accident rates. Recommendations will also include strategies that may help implement the "before and after" techniques employed by TDOT Traffic Engineers in the future.

Chapter 2

"BEFORE AND AFTER" STUDY COMPONENTS

Safe roadways are critical for the well-being of a community. Inefficiencies in the roadway system may cause serious losses to society, including loss of human life, serious personal injury, low business productivity, and general inconvenience. Identification of roadway hazards and the implementation of countermeasures are continuing responsibilities for traffic engineers. While these tasks are important, it is equally significant to gauge the effectiveness of roadway improvements. The "before and after" accident analysis technique provides a valuable tool for measuring the efficiency of highway safety improvements. In order to effectively conduct a "before and after" accident analysis, traffic engineers must follow a systematic procedure. The following flow diagram in Figure 2-1 and remainder of this chapter will discuss the systematic process of a "before and after" accident study.

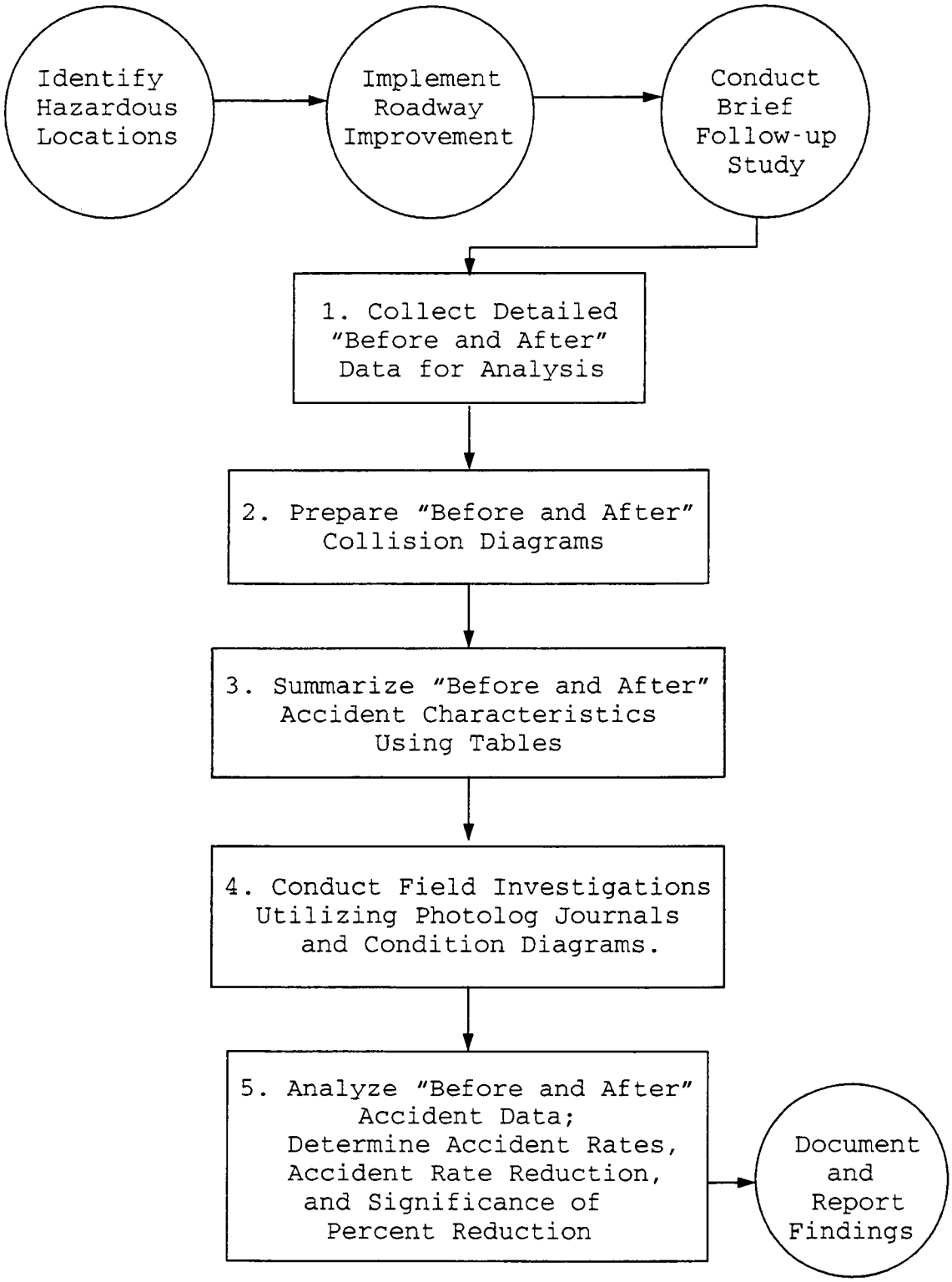


FIGURE 2-1. Systematic procedure for "before and after" accident study.

1. Data Collection

At least one year of accident data is needed to perform a reliable evaluation of safety improvements. This accident data should include the reports for any collision at a specific location resulting in death or injury to any person or in property damage to any one person in excess of $400. The State of Tennessee requires every law enforcement officer in the state who investigates such a motor vehicle accident to forward a written report to the Department of Safety within 24 hours after completing the investigation. If an accident fitting the above description is not investigated by a police officer, the drivers in these cases are required to forward a written report to the Tennessee Department of Safety within twenty days after the accident (16). With the enormous number of accident reports that the Department of Safety constantly receives, it may take two to three years for all of the records to be catalogued; therefore, suitable accident data for more current time periods (usually the past three years) are normally maintained by local, county, and state police departments and are generally available upon a traffic engineer's request.

In a "before and after" study, the time period researched for a "before" condition should include accident data for at least one year, and preferably three years prior

to the last date on which traffic was subjected to the unimproved condition. The accident data for the "after" period should be at least one year from the earliest date on which traffic was subjected to the improved condition. Since construction operations tend to change the everyday working characteristics of a location, accident data obtained during the construction or installation period cannot be considered reliable and should not be used in the evaluations (8). It is preferable, for comparison purposes, to obtain "after" accident records that cover the same time span as the "before" data. For a more refined study, three years of both "before" and "after" accident records should be obtained. Traffic engineers should keep in mind, however, that evaluating the initial impact of a roadway improvement is still important, since an intended improvement could result in unforeseen problems. Rather than potentially sacrifice driver safety until three years worth of "after" accident data becomes available, traffic engineers should perform a quick follow-up study several months after a roadway improvement installation to evaluate the immediate impact of a safety project (7). Engineers should not make the mistake, however, of collecting "after" data immediately following the installation of a countermeasure, because "…drivers may not react instantaneously to a treatment. Drivers encountering a

traffic control device soon after its placement, for example, may not know how to react and may exhibit unusual behaviors that bias any experiment data being collected. If the experimenter allows several weeks to elapse before collecting data, the novelty effect may be much smaller" (4).

Researchers should also use caution to avoid any history or maturation biases that may affect the "before and after" accident data (4). Examples of history bias include studies that fail to account for speed limit changes on a roadway section or experiments that compare a "before" measurement from one season of the year to an "after" measurement from another season. Maturation biases refer to trends in measure of effectiveness values with time (4). Fatal accident rates, for example, have been falling in many developed countries for years due to a number of factors. Such a trend can affect "before and after" experiments measuring those rates (4).

2. Collision Diagrams

Certain circumstances involved in each accident need to be compiled from the individual accident records for further study. These factors are grouped and organized onto a collision diagram, a standard form used to graphically summarize the accident reports for a specific location. A

collision diagram is a schematic drawing that shows the directions of travel prior to contact, of vehicles, pedestrians, and other factors whose presence contributed to the accidents. These diagrams are used to visualize accident patterns and to provide insight into the nature and causes of accidents at previously identified hazardous locations. The important elements to be included for each accident on a collision diagram are the following:

1) Vehicle and pedestrian direction of travel just prior to the collision.
2) The intent of all drivers and pedestrians prior to the collision (make a left turn, stop to park, stop during a turn to allow a pedestrian to cross, etc.).
3) Day of the week and the time of day of the collision. The date is necessary in order to separate accidents that may have occurred before or after an improvement. The day of the week is included to determine whether a particular weekday or weekend factor (such as parking restrictions) may be contributing to accidents. The time of day is relevant because turning restrictions or signal timing may be adjusted to impact only certain hours. Nighttime collisions should also be noted, since poor lighting may be a contributing factor.

4) Unusual weather, pavement, or operational conditions during an accident, including wet pavement, rain, snow, fog, sleet, or ice should be noted. Problems such as nonfunctional traffic control signals should also be shown.

A plan view sketch resembling an aerial photograph of the accident site should be used when preparing a collision diagram. The sketch need not be drawn to scale, but should show the approximate relative position of each leg of an intersection as well as all other physical features that can cause traffic conflicts. Standard symbols are used on collision diagrams to graphically portray individual accident details for: 1) the intent and direction of travel of all drivers and pedestrians, 2) information on accident severity for each collision, and 3) identification of any fixed objects near the collision site (Figure A-1)*.

Many accident studies involve a large number of similar collisions that occur near the same point on the site, hence making the exact graphical placement of each collision symbol an impossible task. In order to avoid visual clutter on a collision diagram, the positioning of these symbols has no relation to the actual first point of contact between the vehicles or to the exact location of the

* All subsequent Figures and Tables for Chapters 2-6 are placed in the Appendices.

vehicles prior to the accident. Graphical symbols should only portray the general directions of the vehicles and their approximate locations on the site during the accident (3).

3. Accident Characteristic Summary Tables

A crucial step in the planning process of a "before and after" accident study involves the grouping and examination of accident data. Once data is gathered from accident records and transferred into a collision diagram format, the summaries should be examined for recurring accident patterns, such as: 1) different types of two or more vehicle collisions (right-angle, left-turn, head-on, or rear-end), 2) collisions with pedestrians, 3) collisions with fixed objects, 4) running off the road at curves, and 5) accidents associated with poor lighting, weather, or pavement conditions or specific hours or days. One way to organize these recurring accident patterns is to group the summary data into tabular form (3). Accident characteristic summary tables present a detailed breakdown of the recurring accident patterns at a location (Table A-1). By recognizing these recurrent accident trends, traffic engineers may better discern the true cause of a hazard and evaluate the effectiveness of a safety improvement.

4. Accident Pattern Tables

For any roadway hazard, there are usually several reasonable improvements that can be implemented. Before an engineer can decide which improvement to endorse for a particular hazard, it is important to analyze as many alternatives as possible. Accident pattern tables provide a tool that pairs accident patterns, which are collected through engineering experience, with probable causes and common improvements. Accident pattern tables can be used to develop a list of feasible countermeasures based on defined accident patterns for a problem location (Table A-2). Using findings obtained from the accident summaries and field reviews of past experience, candidate countermeasures are developed and listed in tabular form. The development of accident pattern tables is based on the following assumptions: 1) Patterns of accident types are directly associated with probable accident causes, and 2) The need for specific improvements can be inferred from analysis of probable accident causes. Using these assumptions, accident pattern tables can be developed (2). The background for the tables stems from traffic safety engineering experience, the past experiences and evaluations of various agencies, and the results of research conducted throughout the United States.

Accident pattern tables have been developed by various groups across the country. While these tables are often consulted before an improvement is endorsed, they can still prove useful after corrective measures have been incorporated. Accident pattern tables allow an engineer to match the accident patterns identified on accident characteristic summary tables to possible accident causes. Obviously, no accident pattern listing can be absolutely complete, as each hazardous location requires good engineering judgment before implementing an improvement. However, in a "before and after" accident study, accident pattern tables can present a basic guide for evaluating how the corrective measures have affected a location, and if any new accident patterns have resulted from the attempted improvement.

5. Field Investigations, Photolog Journals, and Condition Diagrams

The collection of accurate accident data provides a good foundation for a "before and after" accident evaluation; however, researchers must know how to systematize and analyze the information. Collision diagrams, accident characteristic summary tables, and accident pattern tables provide an engineer with valuable, systematic tools that aid in evaluating the scenarios both before and after the

corrective measures were completed for a hazardous location. Other tools that prove useful in conducting a "before and after" evaluation include field investigations, photolog journals, and condition diagrams. It is advisable for the traffic engineer to review and become familiar with the accident summaries collected in the previous steps before conducting a field investigation. Both the before and after accident data may point out conditions that warrant special consideration, and particular attention should be given to any accident patterns that are evident in the data. Also, a review of the photolog coverage should be made, if practical, prior to the on-site visit in order to become familiar with the location. Photolog journals should include photographs of the general layout and any obvious hazards at the location, such as sight distance problems or a fixed object that appears to be too close to the roadway. It is important for a field engineer to make observations from the driver's point of view and to examine such features as geometrics, traffic controls, and visibility. Field investigations should be conducted with two objectives in mind: 1) to identify the recurring safety problem(s) at the location, including contributing factors and probable causes; and 2) to evaluate whether the countermeasures have eliminated or minimized the number and severity of accidents (6).

Another tool that may aid in the "before and after" evaluation of a location is the condition diagram. In contrast to the *collision* diagram, a *condition* diagram is a scaled drawing of the important physical conditions of a hazardous site. Judgment is needed to determine how detailed the diagram should be, as the purpose of the condition diagram is to relate the accident patterns on a *collision* diagram to the roadway and operational elements at the hazardous location (3). It has become common practice for the Tennessee Department of Transportation to prepare collision diagrams on an actual aerial photograph of the site. This practice provides a useful tool that incorporates a *scaled* diagram (in this case, a photograph) of the site with the data from a collision diagram (Figure A-2).

6. Accident Data Analysis

Since chance alone will cause the number of observed accidents at any location to vary from year to year, the general reliability of the accident data must be considered during analysis. Even if conditions at a site are unchanged, there remains a probability that some accidents have resulted from chance alone. Therefore, statistical considerations are needed to determine the probability that the recorded accidents do not result from mere chance (18).

In order to attain valid comparisons of the relative degree of hazard at varying highway locations, one must consider the following:

1) Accident rate per unit of exposure to vehicular travel;
2) Severity of accidents in terms of fatalities, injuries, and property damage; and
3) Statistical methods to analyze the distribution of accidents over a period of time.

The traffic accident rate for any highway location is determined by dividing the number of accidents that occur at that location in a specified time period by the amount of vehicular exposure to that location in the same period of time. Exposure is measured in either *number of vehicle-miles of travel* or *number of entering vehicles*, depending on the location. All highway locations must fit one of three general categories for the purpose of accident analysis: highway sections, highway spots, or intersections. Vehicular exposure is measured in the following terms for each type of location:

1) Sections: Millions of vehicle-miles
2) Spots: Millions of entering vehicles
3) Intersections: Millions of entering vehicles

The specific accident rate formulas for each type of location can be found in Appendix B (16).

Determining the accident rate of a specific location equips one with a basis for comparing that location with any other site; however, additional information is needed to assess the significance of the rate. In order to determine their worth, accident rates are compared to average accident rates for various types of highway locations and highway characteristics. Measurements for average accident rates are taken in both rural and urban settings for locations such as: sections, spots, intersections, bridges, railroad crossings, two-lane and multi-lane highways. Every year the Tennessee Department of Transportation determines average accident rates for the different classifications of highways for the previous three-year period.

Statistical techniques should be employed to be reasonably certain that an observed accident rate differs significantly from the average rate (10). To reduce the probability that an accident rate is resulting from chance alone, upper and lower control limits can be established for the average accident rate. The upper control limit is referred to as the "critical" accident rate, because any rate larger than this value is most likely not resulting from chance, but rather some unfavorable characteristic of the highway condition. The formula for determining the upper control limit (critical rate) can be found in Appendix B

(16). The critical rate is dependent on what *K* factor is selected. The *K* factor is a statistical factor related to the probability that the difference between the average accident rate for a system and the actual accident rate for a specific segment, spot, or intersection is a normal variation and not an indication that there is a problem with the roadway. The larger the *K*-value, the greater the probability that the high accident rate does not result from chance alone. In practice, TDOT uses a *K*-value of 2.327 (Probability =99%) to compute the critical rate for each roadway classification. The following *K*-values should be used when confidence levels other than 99% are required:

Confidence Level (%)	K
99.5	2.576
99.0	2.327
97.5	1.960
95.0	1.645
90.1	1.282

After a critical rate is determined for a location, a ratio of Actual-to-Critical accident rates should be calculated. This ratio is based on the total number of accidents for any location and indicates the relative hazard of that site. Accident severity for a highway location is determined by the ratio of fatal and injury accidents to the total number of accidents at the location. The larger the percentage of fatal and injury accidents, the more hazardous

the location. Accident severity is quantified as a Severity Index (*SI*), and its formula can be found in Appendix B (16).

After accident rates have been determined for both the "before" and "after" time period for a location, a percent reduction in the accident rate can be calculated as a means for evaluating the effectiveness of a project. Prior to determining a true reduction in accident rates, "before and after" data must be adjusted to reflect equal time periods and traffic volumes. The adjusted average number of accidents per year for the "before" and "after" time periods and the percent reduction in accident rates may be calculated from equations found in Appendix B (16).

A test should be made to determine the statistical significance of the change in accident experience. Because of the year-to-year variation in accident occurrence resulting from chance alone, it is entirely possible that a change in the number of accidents is due only to chance and not to the safety improvement. However, as the difference between the number of "before" and "after" accidents increases, the probability that this is a chance occurrence decreases. The accident reduction needed to constitute a significant change, or the *critical percent reduction*, may be calculated from the corresponding equation in Appendix B which is based on the normal approximation of a Poisson

distribution (9). If the actual percent reduction (PR) is greater than the critical value (PR_C), then the reduction is significant at the specified confidence level. If the reduction is found to be significant, then the improvement can be considered a success. If the actual percent reduction (PR) is less than the critical value (PR_C), but greater than zero, then the improvement is probably resulting from chance. If the actual percent reduction (PR) is negative, meaning an increase in accidents, but greater than the negative critical value ($-PR_C$), then the increase is probably due to chance. If the actual percent reduction (PR) is less than the negative critical value ($-PR_C$), then the attempted improvement has significantly worsened the hazard. These conditions are clearly represented by the graph in Figure B-1.

The "before and after" process described in this chapter will be applied to actual Tennessee Department of Transportation highway safety improvement projects in the following four chapters. These four safety improvements were selected from TDOT Regional Traffic Files as projects in need of evaluation.

Chapter 3

LOCATION 1.

THE INTERSECTION OF STATE ROUTE 61 WITH STATE ROUTE 62 ANDERSON COUNTY, TENNESSEE

The intersection of State Route 61 with State Route 62 lies between the communities of Oliver Springs and Oak Ridge in Anderson County, Tennessee. The general layout of the roadways presents State Route 61 as a two lane rural facility which parallels State Route 62 before it intersects State Route 61/62 as a "T"-type intersection (Figure C-1). As an added geometric element for this intersection, State Route 62 experiences a downhill grade on its northbound approach.

The roadway safety improvement for this intersection was installed by the Tennessee Department of Transportation on September 28, 1993. As justification for the improvement, TDOT thoroughly studied this intersection in the "before" condition from March 1987 to June 1990. Furthermore, a general "after" study was conducted for the period from November 1993 to November 1994, during which time, significant safety improvements were observed (14). As can be noted from the above study periods, only one year of

"after" accident data was available when TDOT conducted its follow up study. This chapter will, therefore, review the initial findings of TDOT for the "before" study and analyze three years worth of "after" accident data in order to complete a more refined "before and after" evaluation of this intersection.

In the "before" condition, State Route 61 was controlled by a stop sign for left turns, while right turns were allowed to merge onto State Route 61/62 after yielding to northbound traffic. Motorists who traveled toward the intersection on State Route 61 encountered a vertical and horizontal roadway curve that restricted view of the intersection. State Route 61/62 existed as a four lane median divided roadway that featured a combination left-turn/deceleration lane. The posted speed limit on this section of highway was 40 miles per hour; however, frequent observations cited vehicular speeds in excess of the posted speed limit.

At the request of Senator Randy McNally on November 13, 1989, the Tennessee Department of Transportation conducted an accident safety investigation at the intersection. TDOT obtained accident data from State TRIMS (Tennessee Roadway Information Management System) records, the Anderson County Sheriff's Office, and the Tennessee

Highway Patrol for the period from March 1987 to June 1990. The reported accidents for this time period can be found in collision diagram form in Figure C-2 and summarized in Table C-1. In reviewing these "before" condition accident reports, a total of 35 accidents were recorded which included the following: 18 right-angle accidents, 11 rear-end accidents, 3 out-of-control accidents, 2 sideswipe accidents, and 1 left-turn accident. Twelve of these accidents involved personal injuries and one accident involved a fatality.

During field investigations, TDOT determined the entering movement from State Route 61 (west bound) onto the right turn merge ramp to be difficult. When vehicles cleared the combination vertical/horizontal curve on State Route 61, an immediate decision required drivers to continue on the short acceleration ramp or to stop. In addition, merging from this ramp onto State Route 61/62 appeared to present difficulties as many vehicles were seen stopping on the ramp to wait for traffic to clear before entering the highway. These drivers experienced sight distance problems because of the left turns onto State Route 61, the existing guardrail, and foliage. The accident patterns further support this conclusion, as ten out of the eleven rear-end accidents occurred in this quadrant of the intersection.

In order to further investigate the "before" condition performance of the intersection, TDOT used the Highway Capacity Manual to conduct a capacity analysis for each intersection approach leg. This analysis revealed that a level of service "E" existed for all movements from State Route 61, with indefinite delay and queuing factors (17). With no control devices in place, State Route 61/62 operated with a level of service "A"; however, a safety problem developed from high volumes and excessive speeds of vehicles on State Route 61/62, coupled with lengthy queues and impatient drivers on State Route 61. The downhill grade from the northbound State Route 62 approach contributed to speeds in excess of the posted speed limit. When these high speeds paired with insufficient gaps in the oncoming State Route 61/62 traffic, an excessive number of right-angle accidents resulted where State Route 61 vehicles entered the intersection. Another "before" condition accident pattern had clearly developed as all eighteen right-angle accidents occurred with northbound State Route 62 vehicles. Further capacity analyses indicated that, after the installation of a traffic signal, this intersection would operate with an overall level of service "B" (17). A combination of traffic counts and accident information from this "before" condition revealed that the accident rate ratio of Actual-to-Critical

was 3.97 accidents per million-vehicle-minute (Figure C-3). After carefully reviewing the above considerations, TDOT Traffic Engineers proposed the installation of a traffic signal that became functional on September 28, 1993. In addition, the right turn ramp from the State Route 61 approach was eliminated, and control of right turners was given to the signal.

After the signal was installed and functional, accident reports were acquired through state resources and local and state police departments for the period from September 1994 to December 1997. The accident reports for the "after" condition, compiled in collision diagram format and tallied on an accident characteristic summary table, showed a total of 16 accidents which included the following: 8 rear-end accidents, 7 left-turn accidents, and 1 sideswipe accident (Figure C-4 and Table C-2). Nine of these collisions involved injuries, and no fatalities have occurred since the installation of the signal.

Although the accident total has reduced considerably since the signal installation, some new accident patterns have developed during the "after" condition at this location. Six out of seven of the left-turn collisions are concentrated at the southbound approach of State Route 61/62. This shows a new accident pattern that may be corrected by

investigating the different components of the traffic signal timing. First, the vehicle clearance time for this turning movement may be too short. As northbound through vehicles approach the intersection on a downhill grade, their speeds may be deceiving to left turners from southbound State Route 61/62. Also, the left-turn movement onto State Route 61 may require an exclusive lead/lag only phase; that is, a portion of the signal cycle dedicated solely to this left-turning movement and stopping traffic in all other directions. Another possible countermeasure for this left-turn accident pattern involves investigating the distance between the loop detector and the signal on the northbound approach of State Route 62. The excessive speeds of approaching vehicles on this downhill grade may be affecting the readings made by the loop detector, hence affecting the signal timing and contributing to the left-turn accident pattern.

A second accident pattern has developed since the installation of the traffic signal on the State Route 61 approach to the intersection, as four out of eight of the "after" rear-end accidents occurred on this leg. Although eliminating the right turn ramp from State Route 61 has helped reduce the number of rear-end accidents, this persisting accident pattern suggests that the vertical/horizontal sight distance from State Route 61

continues to present a problem for motorists. TDOT's installation of an advanced flashing signal on State Route 61 has aided in warning drivers of the approaching intersection, however, current placement of the advanced signal and additional signing should be investigated in an attempt to alleviate this rear-end accident pattern.

Before a traffic signal was installed, the intersection of State Route 61 and State Route 62 experienced a serious problem with right-angle and rear-end accidents in different quadrants on the site. The "before and after" study of this intersection reveals that since the traffic signal was installed, a noteworthy decrease in the total number of accidents has occurred. The total number of accidents has declined from twelve to five accidents per year, and the Actual-to-Critical accident rate ratio has been reduced from 3.97 to 1.80 accidents per million-vehicle-minute (Figure C-5). The problem of right-angle accidents has been eliminated, and less than half the number of rear-end accidents have occurred on the State Route 61 approach to the intersection. Although an increase in the number of left-turn collisions has resulted since the installation of the traffic signal, this problem appears to be resulting from a timing component rather than the existence of the traffic signal. This "before and after" study, therefore, concludes

that the overall safety performance of the intersection has substantially improved since the installation of TDOT's safety improvement plan.

Chapter 4

LOCATION 2.

THE INTERSECTION OF STATE ROUTE 170 (EDGEMORE ROAD) WITH MELTON LAKE DRIVE ANDERSON COUNTY, TENNESSEE

The intersection of State Route 170 (Edgemore Road) and Melton Lake Drive is located in the southeast corner of the city of Oak Ridge in Anderson County, Tennessee. The general roadway layout reveals Melton Lake Drive entering State Route 170 in a "T" type intersection approximately 150 feet west of a bridge over the Clinch River, and both Melton Lake Drive and State Route 170 run along the Melton Lake waterway (Figure D-1). The "before" condition presented Melton Lake Drive as a two lane road approximately twenty four feet wide with four-foot shoulders. This southbound approach to the intersection was controlled by a stop sign for left turns, while a separate right turn lane allowed drivers to merge onto State Route 170 after yielding to westbound traffic. Westbound travelers on State Route 170 were provided a limited view of the intersection because of the bridge parapet and guardrail. The width of this bridge, located 150 feet east of the intersection, was

twenty-eight feet from curb to curb, and the posted speed limit on State Route 170 was 55 miles per hour (14).

At the request of numerous local citizens and Anderson County Commissioner, Carl Scarbrough, on February 10, 1989, the Tennessee Department of Transportation conducted an accident safety investigation at the intersection. TDOT obtained accident data from State TRIMS records, the Oak Ridge Police Department, the Anderson County Sheriff's Office, and the Tennessee Highway Patrol for the period from January 1986 to December 1988. The reported accidents for this time period can be found in collision diagram form in Figure D-2a and summarized in Table D-1. In reviewing these "before" condition accident reports, a total of 35 accidents were recorded which included the following: 22 rear-end accidents, 9 right-angle accidents, and 4 out-of-control accidents. Nine accidents occurred at night, five of these accidents involved personal injuries, and no fatalities occurred at this location during the "before" study period.

During field investigations, TDOT determined that the poor site distance caused by the bridge parapet and guardrail had been a major contributor to the accident history for the intersection. Furthermore, a capacity analysis utilizing the Highway Capacity Manual revealed that motorists who approached the intersection from Melton Lake

Drive experienced infinite delay time and queues which, in turn, resulted in very few gaps for vehicles to enter State Route 170 (17). Many "false start" scenarios resulting from the insufficient gaps and sight distance problems were also observed to be contributing to the accidents. The poor sight distance and insufficient gaps created a situation where motorists entering State Route 170 from Melton Lake Drive were actually pulling out in front of oncoming traffic. Often, these drivers would either slam on the brakes, causing a rear-end accident on the Melton Lake Drive approach, or they would find themselves beyond the point of avoiding a right-angle accident with oncoming State Route 170 traffic. The following accident patterns in the intersection further support this evaluation: twenty-one out of the twenty-two rear-end accidents occurred on the Melton Lake Drive approach, and eight out of the nine right-angle accidents occurred with westbound vehicles on State Route 170, approaching from the leg of the intersection that provided poor sight distance for motorists on Melton Lake Drive. A combination of traffic counts and the above accident information from this "before" condition revealed that the accident rate ratio of Actual-to-Critical was 4.03 accidents per million-vehicle-minute (Figure D-3).

After carefully reviewing the above considerations, TDOT Traffic Engineers initially proposed that the intersection be signalized as a semi-actuated two phase system. In addition, an eleven foot left turn lane for the east bound approach of State Route 170 would be installed to enable left turns onto Melton Lake Drive without interruption to the east bound traffic. Further study, however, revealed that the construction of a left turn storage lane on the east approach of State Route 170 would necessitate a roadway width taper that included the widening of a portion of the bridge over the Clinch River at considerable cost. After reviewing this "before" condition and the proposed budgetary constraints, it was decided that the "before" accident pattern did not reflect that the addition of a left turn storage lane would generate any benefits; therefore, the left turn storage lane was eliminated from the proposed plans and further investigation was conducted.

An additional accident study from January 1990 to April 1991 revealed that the traffic flow and geometric problems presented by this intersection continued to cause accidents (Figure D-2b). During this time period, the following 19 accidents were reported: 12 rear-end accidents, 5 right-angle accidents, 1 left-turn accident, and 1

sideswipe accident. The collision data from this additional "before" investigation revealed the same accident patterns as the previous study: ten out of the twelve rear-end collisions occurred on the Melton Lake Drive approach, and all five right-angle accidents occurred with westbound State Route 170 vehicles, approaching from the leg of the intersection with poor sight distance for Melton Lake Drive motorists. As a result of these "before" investigations, State Traffic Engineers recommended that an interim improvement be considered to provide some relief to the motorists on Melton Lake Drive experiencing infinite delay, sight distance difficulties, and accident problems. The installation of a traffic signal excluding all recommended geometric improvements was deemed a suitable interim improvement that would provide the Melton Lake motorists with a protected left and right turn movement. The traffic signal, as an interim improvement, would give the Department of Transportation additional time to determine an optimum solution without continuing to sacrifice driver safety. The traffic signal was installed on April 11, 1992.

After the signal was installed and functional, accident reports were acquired through state resources and local and state police departments for the time period from September 1992 to August 1995. The accident reports for this

"after" condition, compiled in collision diagram format and tallied on an accident characteristic summary table, showed a total of 32 accidents which included the following: 23 rear-end accidents, 6 left-turn accidents, and 3 out-of-control accidents (Figure D-3 and Table D-2). Nine of these collisions involved injuries, and no fatalities have occurred since the signal was installed. During the "after" time period, the Actual-to-Critical accident rate ratio has reduced slightly to 3.34 accidents per million-vehicle-minute (Figure D-5).

Since the signal was installed, the "before" condition accident patterns have been alleviated, as no right-angle accidents have occurred and only four rear-end collisions have been recorded on Melton Lake Drive; however, some new accident patterns have developed during the "after" condition at this location. Eleven out of the twenty three rear-end accidents and five out of the six left-turn collisions occurred on the east bound approach of State Route 170. Many of these accidents could be avoided by the installation of a left turn lane and exclusive left turn signal on the eastbound approach to the intersection. Under current conditions, eastbound vehicles on State Route 170 planning to turn left onto Melton Lake Drive are threatened from behind by vehicles not planning to turn, and when these

eastbound drivers do turn left, they are threatened by westbound motorists who are either traveling through the intersection or turning right onto Melton Lake Drive. The westbound right turners have a yield sign which is frequently ignored, thus contributing to the eastbound left-turn collisions. The addition of a left turn lane, however, was not deemed a viable countermeasure, since the required lane tapers necessitated widening the bridge, which in turn was deemed too costly.

An additional accident pattern has developed on State Route 170 since the signal was installed, as seven out of the twenty-three rear-end collisions occurred on the westbound approach. The lack of a left turn lane for eastbound travelers has contributed to these collisions as well. Both through and right turning westbound traffic on State Route 170 must contend with eastbound vehicles turning left onto Melton Lake Drive. As eastbound left turners become impatient because of the lack of adequate gaps in the westbound traffic flow, they actually pull out in front of the westbound travelers who subsequently must slam on the brakes, which oftentimes causes a rear-end collision.

A traffic capacity analysis which utilized methods outlined in the Highway Capacity Manual was conducted for the "after" traffic condition. This analysis indicates that the

entire intersection is operating at a level of service F for both the morning and afternoon peak hours. An F level of service suggests a severe capacity overload and describes the "after" condition as "forced flow" or, "bumper-to-bumper" traffic which forces vehicles to wait one or more full signal cycles before proceeding through the intersection (17). This capacity analysis indicates that major improvements are needed to adequately accommodate the extremely high traffic volumes and to avoid the resulting accident problems.

Before a traffic signal was installed, the intersection of State Route 170 and Melton Lake Drive experienced a serious problem with right-angle and rear-end accidents in different quadrants on the site. The "before and after" study of this intersection reveals the previous accident patterns that existed for the "before" condition have simply shifted to different points on the site after the traffic signal was installed, and no change in the severity or total number of accidents has occurred. Although the problem of right-angle accidents has been eliminated and less than half the number of rear-end accidents have occurred on the Melton Lake Drive approach to the intersection, new accident patterns have developed since the signal was installed. Rear-end accident patterns have shifted to both the eastbound and westbound legs of State Route 170, and

left-turn accidents are now a problem for eastbound State Route 170 motorists. The rear-end and left-turn accident patterns that have developed on State Route 170 are indicative of excessive delays, stop and go traffic, and frequent unexpected stops by vehicles traveling at speeds near 55 miles per hour. The overall number of accidents and safety performance at this location has remained virtually the same since interim corrective measures were put in place. The Actual-to-Critical accident rate ratio has moved from 4.03 to 3.34 accidents per million-vehicle-minute and the total number of accidents has shifted only slightly from twelve to eleven accidents per year. The interim traffic signal has had no significant effect on the accident performance of this intersection; therefore, further corrective measures are presently being investigated by the Tennessee Department of Transportation for this continuing high hazard location.

Chapter 5

LOCATION 3.

THE I-640 WEST BOUND EXIT RAMP 3B TO STATE ROUTE 9 (CLINTON HIGHWAY) KNOX COUNTY, TENNESSEE

The I-640 west bound exit ramp to State Route 9 (Clinton Highway) lies just west of the I-275 and I-640 interchange in the northwest section of Knoxville in Knox County, Tennessee. The general roadway layout reveals exit 3B from I-640 west bound as a one lane roadway that merges onto northbound State Route 9 (Figure E-1). Both I-640 and State Route 9 are moderately high speed facilities with vehicles traveling in excess of 50 miles per hour. The "before" condition presented the I-640 west bound exit ramp as a one lane entrance approximately 320 meters (1050 feet) long, ending at State Route 9 with yield control signs at the foot of the ramp. State Route 9 existed as a two lane road with no stop or yield controls. The yield signs at the foot of the exit ramp often caught exiting motorists off-guard, thus creating at hazard at this interchange (14).

At the request of numerous local citizens, the Tennessee Department of Transportation conducted an accident safety investigation at the interchange. TDOT obtained

accident data from State TRIMS records, the City of Knoxville Engineering and Police Departments, and the Tennessee Highway Patrol for the period from January 1992 to December 1994. The reported accidents for this time period can be found in collision diagram form in Figure E-2 and summarized in Table E-1. In reviewing these "before" condition accident reports, a total of 22 accidents were recorded which included the following: 12 rear-end accidents, 7 sideswipe accidents, 2 out-of-control accidents, and 1 right-angle accident. Four of these accidents involved personal injuries, and no fatalities occurred at this location during the "before" study period.

During field investigations, TDOT determined the merging movement from the I-640 west bound exit 3B onto State Route 9 to be hazardous. After traveling at speeds near 55 miles per hour along I-640 and the adjoining 320 meter downhill grade of the exit ramp, driver expectancy was violated as the ramp layout gave motorists the false sense of driving on an acceleration lane. Oftentimes, as drivers reached the end of the exit ramp, the yield signs either caught them off-guard and they were forced to slam on the brakes, thus endangering them from behind, or the signs went unnoticed and drivers found themselves already too far onto State Route 9 to avoid a sideswipe collision with northbound

travelers. In addition, vehicles who knowingly observed the yield control at the base of the ramp found themselves in danger of being rear-ended by motorists who falsely perceived the exit ramp as an acceleration lane. Merging was also found to be difficult because of the high speeds and volumes of traffic on northbound State Route 9. The accident patterns support these conclusions, as all twelve rear-end accidents and all seven sideswipe collisions occurred in the above mentioned section of the interchange. A combination of traffic counts and accident information from this "before" condition revealed that the accident rate ratio of Actual-to-Critical was 1.64 accidents per million-vehicle-minute (Figure E-3).

In order to further investigate the "before" performance of this interchange, TDOT explored the geometric layout of all adjacent roadways. Further potential difficulties were found nearby, as State Route 9 intersected a low volume roadway approximately 45 meters (150 feet) north of the I-640 exit ramp. This roadway, named Jenso Drive, was mainly used as a business entrance with extremely low traffic volumes, however, and only one right-angle accident was recorded near this site during the three year "before" study period. Hence, TDOT concluded that the intersection of State Route 9 with Jenso Drive would not require any change. A

second exit ramp that warranted investigation was located approximately 120 meters (400 feet) south of the study site. Northbound traffic from State Route 9 encountered a right lane exit ramp leading to I-640 westbound. Traffic exiting from State Route 9 onto this ramp would not affect the interchange under study, however, as only motorists who continued northbound on State Route 9 would meet merging traffic from westbound I-640 exit 3B.

After carefully reviewing the above considerations, TDOT Traffic Engineers proposed a design that would accomplish two goals at minimal cost: 1) the proposed solution would address driver expectancy problems at the base of the exit ramp and 2) the proposal would induce negligible impact on the traffic flow of northbound State Route 9. In April of 1996, TDOT traffic engineers presented a lane striping plan that would hatch out approximately 120 meters of the right hand lane of northbound State Route 9. The striping would begin just past the entrance ramp to I-640 westbound and end just prior to the exit ramp from I-640 westbound exit 3B. By hatching out this section of roadway, motorists from the I-640 westbound exit ramp would have an uninterrupted lane for merging onto State Route 9. The new lane striping plan forced northbound State Route 9 motorists into the left hand lane until vehicles entering from I-640

were given the opportunity to merge into northbound traffic flow via a separated lane. After the travel distance along the two lanes reached a comfortable point of merger, vehicles were allowed to cross the lane lines, and the remainder of State Route 9 was unaffected as a two lane highway with continuous dashed centerlines (Figure E-4).

TDOT's lane striping plan was installed and made functional in April of 1996, after which time accident reports were acquired through state resources, City of Knoxville Engineering and Police Departments, and the State Highway Patrol for the period from June 1996 to December 1997. The accident reports for the "after" condition, compiled in collision diagram format and tallied on an accident characteristic summary table, show a total of 4 accidents which included the following: 1 rear-end accident, 2 sideswipe accidents, and 1 out-of-control accident (Figure E-5 and Table E-2). None of these collisions involved injuries, and no fatalities have occurred since the installation of the lane striping plan.

Although the accident reports for the "after" time period only cover a time span of one and one-half years, the per-year accident total has been considerably reduced since the lane striping plan was installed. Of the four collisions reported during the "after" period, three different accident

types occurred; therefore, it is reasonable to conclude that all previous accident patterns have been alleviated, and no new accident patterns have developed at this location. TDOT should further investigate this interchange in a more refined study after three years of "after" accident data are available, however, in order to confirm the findings of this study.

Before a new striping plan was installed, the interchange at the exit ramp from I-640 west bound to State Route 9 experienced a serious problem with sideswipe and rear-end accidents at the base of the exit ramp. The "before and after" study of this intersection reveals that since the striping plan was installed, a complete decline in the severity and total number of accidents has occurred. The total number of accidents has declined from more than 7 to less than 3 accidents per year, and the Actual-to-Critical Accident Rate ratio has been reduced from 1.64 to 0.49 accidents per million-vehicle-minute (Figure E-6). The problem of right-angle and rear-end accidents has been eliminated as exit 3B from I-640 has been given a separate lane on which to enter State Route 9. In addition, traffic volumes on State Route 9 seem unaffected, as no additional bottlenecking or capacity problems have been observed during peak hours since the striping plan was put in place. This

"before and after" study therefore concludes that the overall safety performance of the interchange has substantially improved since the installation of TDOT's lane striping design.

Chapter 6

LOCATION 4.

STATE ROUTE 170 (RACCOON VALLEY ROAD) NEAR THE INTERSECTION OF NAFF ROAD KNOX COUNTY, TENNESSEE

The section of State Route 170 (Raccoon Valley Road) near the intersection of Naff Road is located less than one mile east of the Anderson County line in the northwest corner of Knox County, Tennessee. The general roadway layout presents State Route 170 as a two lane rural facility with several hazardous geometric elements near the Anderson/Knox County line. Approximately two-tenths of a mile east of the Anderson County line, Naff Road, which also functions as a two lane rural facility, intersects State Route 170 in a "T" type intersection with stop controls (Figure F-1). The roadway hazards on State Route 170 occur over nearly three-tenths of a mile surrounding the intersection with Naff Road; therefore, this site will be evaluated as a roadway *section* for the purpose of a "before and after" analysis (14).

In the "before" condition, eastbound travelers on State Route 170 in Anderson County experienced a gently rolling roadway with two-foot shoulders on both sides of the traveled lanes. The layout of State Route 170 changed

drastically, however, when vehicles crossed the county line. As motorists reached Knox County, the roadway shoulders were immediately dropped and the highway geometrics became more treacherous. Approximately one-tenth of a mile into Knox County, eastbound State Route 170 motorists experienced a sharp vertical crest that was immediately followed by a horizontal curve. Less than one-tenth of a mile east of these curves, Naff Road intersected State Route 170 in a "T" type intersection. Another one-tenth of a mile east of Naff Road, State Route 170 drivers experienced an additional vertical curve. The posted speed limit on this entire section of State Route 170 was 45 miles per hour in both Anderson and Knox County; however, frequent observations and "before" condition accident reports cited vehicular speeds in excess of the posted speed limit.

At the request of numerous local citizens, the Tennessee Department of Transportation conducted an accident safety investigation for this roadway section in October of 1995. TDOT obtained accident data from State TRIMS (Tennessee Roadway Information Management System) records, the Anderson County Sheriff's Office, and the Tennessee Highway Patrol for the period from January 1992 to December 1994. The reported accidents for this time period can be found in collision diagram form in Figure F-2 and summarized

in Table F-1. In reviewing these "before" condition accident reports, a total of twelve accidents were recorded, including eleven out-of-control accidents and one rear-end accident. Two collisions were alcohol related, six of these accidents involved personal injuries, and no fatalities were recorded on this roadway section during the "before" time period.

During field investigations, TDOT discovered several geometric difficulties that could not be detected on the plan view aerial photographs of this roadway section. The roadway characteristics of eastbound State Route 170 in Knox County differed significantly from the highway layout in Anderson County. Several geometric problems hampered driver sight distances and amplified motorist expectancy problems throughout the roadway section. The most obvious layout problem was found near the first vertical curve that eastbound motorists encountered in Knox County. This vertical crest completely concealed the following horizontal curve, thus creating a "blind hill" situation. For motorists looking westbound, this same vertical crest restricted the sight distance of drivers who attempted to enter State Route 170 from Naff Road. The intersection of Naff Road and State Route 170 faced further sight distance difficulties for drivers looking eastbound, as the following vertical curve created another "blind hill" situation. Hence, motorists who

approached the intersection from Naff Road were forced to enter State Route 170 in a valley with "blind hill" scenarios both to the east and west.

A more subtle layout problem existed at the county line, where driver expectancy was violated by the lack of roadway shoulders and narrowing lane widths. Eastbound State Route 170 drivers in Anderson County experienced a highway with gentle curves, twelve-foot lane widths, and two-foot roadway shoulders that comfortably allowed speeds near 50 miles per hour. As eastbound motorists reached Knox County, the lane widths suddenly narrowed from twelve to ten feet, and the roadway shoulders immediately disappeared. When this drastic narrowing of the roadway coupled with an ensuing series of "blind hills" and horizontal curves, motorists were often caught off guard. Drivers who topped the first vertical crest were immediately faced with a horizontal curve to the left, and at speeds oftentimes in excess of 50 miles per hour, these drivers found themselves out-of-control. With lane widths of only ten feet and no roadway shoulders on this section of State Route 170, drivers had little room for error, and a high number of out-of-control accidents resulted. Further difficulties were found for eastbound State Route 170 motorists at the intersection of Naff Road. If eastbound State Route 170 motorists were able to maintain

vehicle control over the hill crest and around the left curve, they were immediately met by the intersection of Naff Road from the right. This situation endangered both eastbound State Route 170 drivers, and vehicles entering the main highway from Naff Road, whose sight distance was hampered both to the west and east by "blind hills" on State Route 170. When the "before" condition accident data was reviewed, an accident pattern clearly became evident, as ten out the twelve out-of-control accidents occurred near the first eastbound horizontal curve on the roadway section. A combination of traffic counts and accident information from the "before" time period revealed that the accident rate ratio of Actual-to-Critical was 2.47 accidents per million-vehicle-minute (Figure F-3).

After carefully reviewing the above considerations, TDOT Traffic Engineers proposed that advanced warning chevrons and advisory speed signs should be installed in advance of the "blind hill" and hidden horizontal curve on eastbound State Route 170. In addition, "speed zone ahead" signs would be installed east of the county line, and the speed limit would be lowered to 40 miles per hour in Knox County. Engineers recognized that the installation of warning and regulatory signs did not eliminate the geometric hazards on State Route 170; however, these signs were

intended to serve as an inexpensive mechanism for maintaining driver awareness, which would, in turn, eliminate the out-of-control accident pattern along this roadway section. The signs were installed in accordance with state standards by TDOT's Regional Sign and Marking Office on January 18, 1996. TDOT Traffic Engineers also proposed that this location qualified for further study as a safety project.

After the advanced warning signs were installed and functional, accident reports were acquired through state resources and local and state police departments for the period from February 1996 to December 1997. The accident reports for the "after" condition, compiled in collision diagram format and tallied on an accident characteristic summary table, show a total of seven accidents which included six out-of-control collisions and one accident with an object in the roadway (Figure F-4 and Table F-2). Two of these collisions involved injuries, and no fatalities have occurred since the installation of the advanced warning signs and advisory speed signs.

The accident total has remained relatively constant on the Knox County section of State Route 170 since the installation of the advanced warning signs. Likewise, the out-of-control accident pattern has persisted during the "after" study period. Five out of six of the out-of-control

collisions were concentrated near the same hidden horizontal curve on the eastbound approach of State Route 170. In addition, six out of the seven collisions for the "after" period occurred at night. Both the out-of-control and nighttime accident patterns suggest that sight distance and driver expectancy continue to present problems for motorists on eastbound State Route 170.

TDOT's installation of warning chevrons and advisory speed signs may have aided in notifying drivers of the approaching geometric roadway hazard; however, driver performance has shown no improvement during the "after" study period. Despite the installation of the advanced warning signs on eastbound State Route 170, the excessive speeds of approaching vehicles across the vertical crest continue to contribute to the out-of-control accident pattern upon reaching the horizontal curve. In order to ensure motorist safety on this highway section, geometric realignment should be considered as a viable roadway improvement. A possible realignment proposal should consider eliminating both eastbound and westbound vertical curves and the horizontal curve near the intersection of Naff Road on State Route 170. This realignment proposal could include minimal acquisition of structures and highway right-of-way while alleviating several geometric hazards. In addition to flattening out the

"blind hills" and straightening out the horizontal alignment, the existing turning radius and sight distance for Naff Road motorists could be improved by this proposal. In a further effort to maintain driver expectancy along this highway section, roadway shoulders should either be added or tapered in a more gradual manner near the county line. Figure F-5 presents a functional drawing of the above realignment proposal.

Before advanced warning chevrons and advisory speed signs were installed, the section of State Route 170 near the intersection of Naff Road experienced a serious problem with out-of-control accidents. The "before and after" study of this roadway section reveals that, since the advanced warning signs were installed, no change in the severity or total number of accidents has occurred. The total number of accidents has remained constant at nearly 4 accidents per year, and the Actual-to-Critical Accident Rate ratio has changed only slightly from 2.47 to 1.90 accidents per million-vehicle-minute (Figure F-6). The problem of out-of-control accidents has persisted near the hidden horizontal curve on eastbound State Route 170, and the overall safety performance of the roadway section has not varied since the advanced warning signs were installed.

Chapter 7

RESULTS

In order to conduct a "before and after" study such as those found in the previous four case studies, some key sources of data must be made accessible to the traffic engineer. The main necessary data can be found in the form of accident reports and traffic volume counts. These pieces of data form the foundation for calculating accident rates which, in turn, serve as a tool for relating accident frequency to vehicle exposure. Several problems arise, however, when discussing the general reliability of this data. It is important for traffic engineers to fully understand the potential errors and to exercise good engineering judgment when using this data in a "before and after" study. This chapter will analyze the potential data errors found during research and report the results for the four case studies in Chapters 3-6.

1. Accident Reports

A variety of agencies are responsible for the collection of basic "before and after" accident data. The differing incentives and special interests of these agencies

can lead to unintentional biases in the collection of this data. The primary source of questionable "before and after" data lies in the actual accident reports collected at the scene of a collision. Police officers, who uphold multiple responsibilities for traffic, are generally the official agents to inspect an accident scene. As a result of their many on-scene duties, officers must frequently make compromises when collecting information on the factors contributing to an accident. Police must clear the highway of wreckage and restore traffic flow as quickly as possible in order to avoid further safety problems. At the same time, they must collect the evidence necessary to prove any negligence or crime. Because of the time constraints associated with these multiple responsibilities, police are usually unable to investigate an accident beyond superficial levels, and accident reports are often completed in an unclear manner as a lower-level priority (11). Frequently, the type of accident and the position of the vehicles after the wreck are rather vaguely identified. In addition, possible outside factors, such as automotive defects or traffic signal malfunctions often remain unchecked. As a result of these shortcomings in the initial collection of accident data, many final collision reports contain only a brief subjective account from the reporting police officer.

The facts from the scene of a collision must then be implied by engineers or data entry personnel, who inherit the police accident reports second-hand.

Further inaccuracies in the accident data collection process occur during the data entry phase. Since computer entry personnel are the first to receive the police accident reports, they are also responsible for interpreting the accident information. When these reports already contain questionable accounts of the facts from a collision scene, the potential for data error multiplies. Human error also plays a role in increasing the unreliability of accident data, as computer entry personnel inadvertently make key-in errors. Faulty computer key-ins can produce problems, such as misleading accident patterns or inaccurate injury counts, which in turn can skew a traffic engineer's interpretation of the true accident problem.

In the four case studies found in Chapters 3-6, copies of the original police accident reports were obtained from city and state Police Departments for as many years as were available. These reports were thoroughly examined and compared with the accident log data from the State's TRIMS system and each city's computer system. All four case studies contained a number of accident reports that were either logged into the computer systems incorrectly, or the

reports were misinterpreted by data entry personnel. Some collisions were recorded in the wrong location on the site, a few accidents that were included did not actually occur within the specified study limits, and some additional accident reports were found in police files which were not entered into the computer systems. Furthermore, some accident reports contained vague descriptions of the accident scene and required certain assumptions to be made by data key-in personnel. In each of these cases, the errant accident data affected either the "before" or "after" accident total and resulting accident rate. The problems experienced while assimilating the accident reports for these four case studies supports the conclusion that some inaccuracies accompany the current process of collecting "before and after" traffic accident data.

2. Traffic Volume Counts

A second source of necessary "before and after" data lies in the traffic volume counts for each hazardous location. A number of potential errors may occur in the physical collection of volume data. Whether the volume counts are collected by continuous count stations, road tube counters, "click board" intersection counters, or some other traffic counting mechanism, a limited amount of error may

occur in the field during the actual data collection process. Furthermore, when numerous data collection sources, ranging from local and city highway departments to county engineering departments, are compiled for traffic volume information, the potential for error compounds.

The traffic volume data used for the four case studies in Chapters 3-6 was obtained through state resources for the "before" and "after" time periods. Fortunately, the State Regional Traffic Office maintains good working files of data with usable traffic volume counts for each year on locations involving State Highways. A potential for error exists in the traffic volume counts for the four case studies, however, because the general nature of traffic counting is prone to some errant information. The following is a list of some possible causes for volume data error: the time of year, day of the week, and weather conditions during which the volume count was taken; the differing practices of volume collecting agencies; and the effects of roadway construction and development in nearby areas. TDOT is currently reevaluating Tennessee procedures for traffic volume collection. In recognizing a need to collect uniform volume data, TDOT is assessing its own shortcomings as compared to the volume collection policies of other states with a final goal of meeting the standards of the Federal

Highway Administration (12). With adequate training of traffic technicians, careful maintenance and use of volume collecting equipment, and proper upkeep of traffic volume records which may serve as future "before and after" study files, traffic engineers can develop and maintain a reasonably uniform volume data resource.

3. Accident Rates and Percent Accident Rate Reduction

The Tennessee Department of Transportation uses accident rates as a primary criteria for measuring the potential hazard of a location. Accident rates are considered particularly significant since they relate accident frequency to traffic exposure, and they provide a common denominator for comparing the accident experiences of different locations or for comparing an individual hazard against a critical rate (16). Traffic accidents are scarce events when compared to the amount of vehicular exposure a location experiences. Only a few accidents per million vehicle miles of travel occur at any given site. In statistical terms, this describes a "small sample of a large population." When dealing with such a situation, false assumptions and faulty conclusions can easily be made unless the researcher uses well established, statistical control

concepts to determine the significance of the collected accident data.

The accident rates were determined for each of the four case studies in Chapters 3-6, and a corresponding percent reduction in the accident rates was calculated as a means for evaluating the effectiveness of each project. Prior to determining a true reduction in accident rates, the "before and after" accident rates were adjusted to reflect equal time periods and traffic volumes. A summary of the individual accident rates and percent reduction in accident rates for the four case studies in Chapters 3-6 can be found in Table 7-1.

A basic problem encountered when attempting to evaluate safety improvements is that traffic engineers are dealing with a changing system in which most of the elements are continually influenced by factors that are not subject to direct control. Hence, even when a reasonable countermeasure is followed by significant improvement in accident reduction, controversies may still arise regarding what really produced the benefits at a location. Erroneous conclusions can be avoided by applying statistical control methods that make it possible to determine the percent of accident reduction needed to substantiate the effectiveness of a roadway safety improvement.

TABLE 7-1. Table of Results for Four "Before And After" Case Studies.

SITE	*BEFORE*		*AFTER*		*Percent Reduction in Accident Rates*
	Total Number of Accidents	Accident Rate (ACC/MV)	Total Number of Accidents	Accident Rate (ACC/MV)	
LOCATION 1 *S.R.61 @ S.R.62*	35	1.20	16	0.55	**54.5%**
LOCATION 2 *S.R.170 @ MELTON LAKE DR.*	35	1.70	32	1.27	**25.1%**
LOCATION 3 *I-640 WB exit ramp to S.R.9*	22	1.64	4	0.49	**70.1%**
LOCATION 4 *S.R.170 near NAFF RD.*	12	*14.10	7	*13.28	**5.9%**

*Accident rates for section are in units of ACC/MVM.

A serious statistical drawback to "before and after" experiments occurs in what statisticians call *regression to the mean*. Regression to the mean refers to "the tendency for a fluctuating characteristic of an entity to return to a typical value in the time period after an extraordinary value has been observed" (4). In the case of "before and after" evaluation, this occurs when "locations with high accident counts during one time period experience more normal counts during the next time period, even if no causative factor changes" (4). Because of this type of potential for year-to-year variation in accident occurrence resulting from chance alone, the accident rate reduction for each case study was evaluated with the Poisson Test for significance. This test overcomes the bias of regression to the mean by determining at 95 percent confidence level that the significance of change in accident experience results from the installed safety improvement rather than a chance occurrence (9). A critical percent reduction was calculated for each case study to determine the significance of the change in accident rates. Figure 7-1 and Table 7-2 summarize these statistical results for the four case studies in Chapters 3-6.

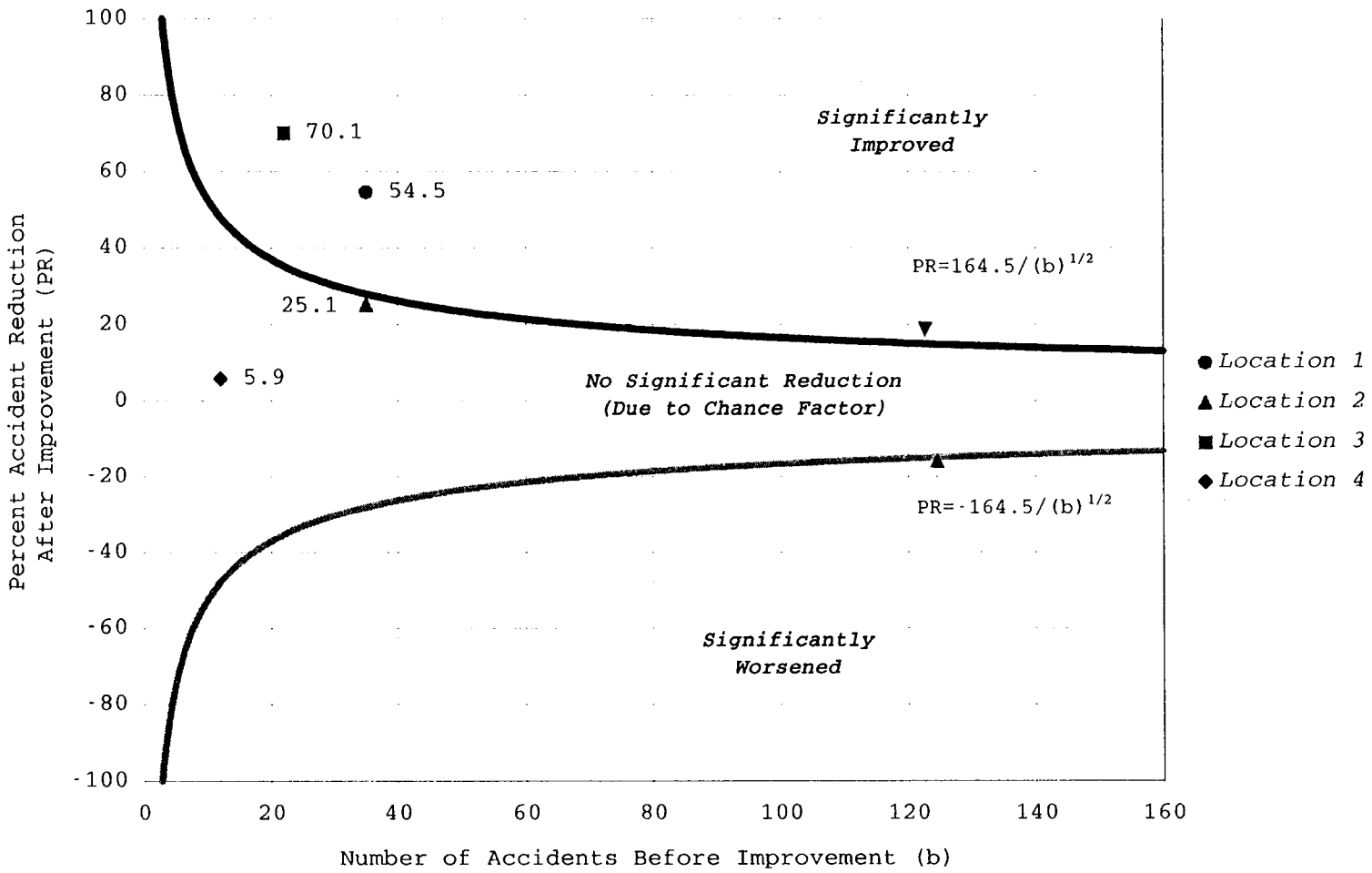


FIGURE 7-1. Poisson Test for Significance of Accident Rate Reduction for Four Case Studies
(At 95% Confidence Level.)

TABLE 7-2. Results of Poisson Test for Significance of Accident Rate Reduction for Four Case Studies.

SITE	Number of Accidents Before Improvement	Percent Reduction in Accident Rates	*Critical Percent Reduction	Significance of Change
LOCATION 1: S.R.61 @ S.R.62	35	54.5%	±27.8%	Improved
LOCATION 2: S.R.170 @ MELTON LAKE DR.	35	25.1%	±27.8%	No Change
LOCATION 3: I-640 WB exit ramp to S.R.9	22	70.1%	±35.1%	Improved
LOCATION 4: S.R.170 near NAFF RD.	12	5.9%	±47.5%	No Change

*Critical percent reduction in accident rates was calculated at 95% confidence level.

The current Tennessee Department of Transportation procedure for conducting the Poisson Test differs slightly from methods described by other references on transportation statistics. TDOT's Highway Safety Program Management Manual suggests plotting the *adjusted annual number of "before" accidents* versus *percent reduction in accident rate* on the Poisson curve (16). Other references, however, propose plotting the *actual* number of *"before" accidents* versus *percent reduction in accident rate* on the Poisson curve (4). While this difference may seem insignificant at first, a noticeable variance is observed when the adjusted "before" accident numbers are compared to the actual "before" accidents. By plotting the *adjusted* number of accidents, the modified Poisson Test adjusts the accident total to represent one year of data, thus failing to take full advantage of the three years worth of available "before" accident data. In the Poisson Test, the more data the researcher acquires, the less the chance for random variation to occur in the data; therefore, by using the *actual* "before" accident total, researchers reduce the chance for random occurrence that may skew the Poisson plot for statistical significance. The TDOT modified Poisson Test can be found in Figure 7-2, and a Table 7-3 compares the *actual* and *adjusted* "before" accident totals for the four case studies found in Chapters 3-6.

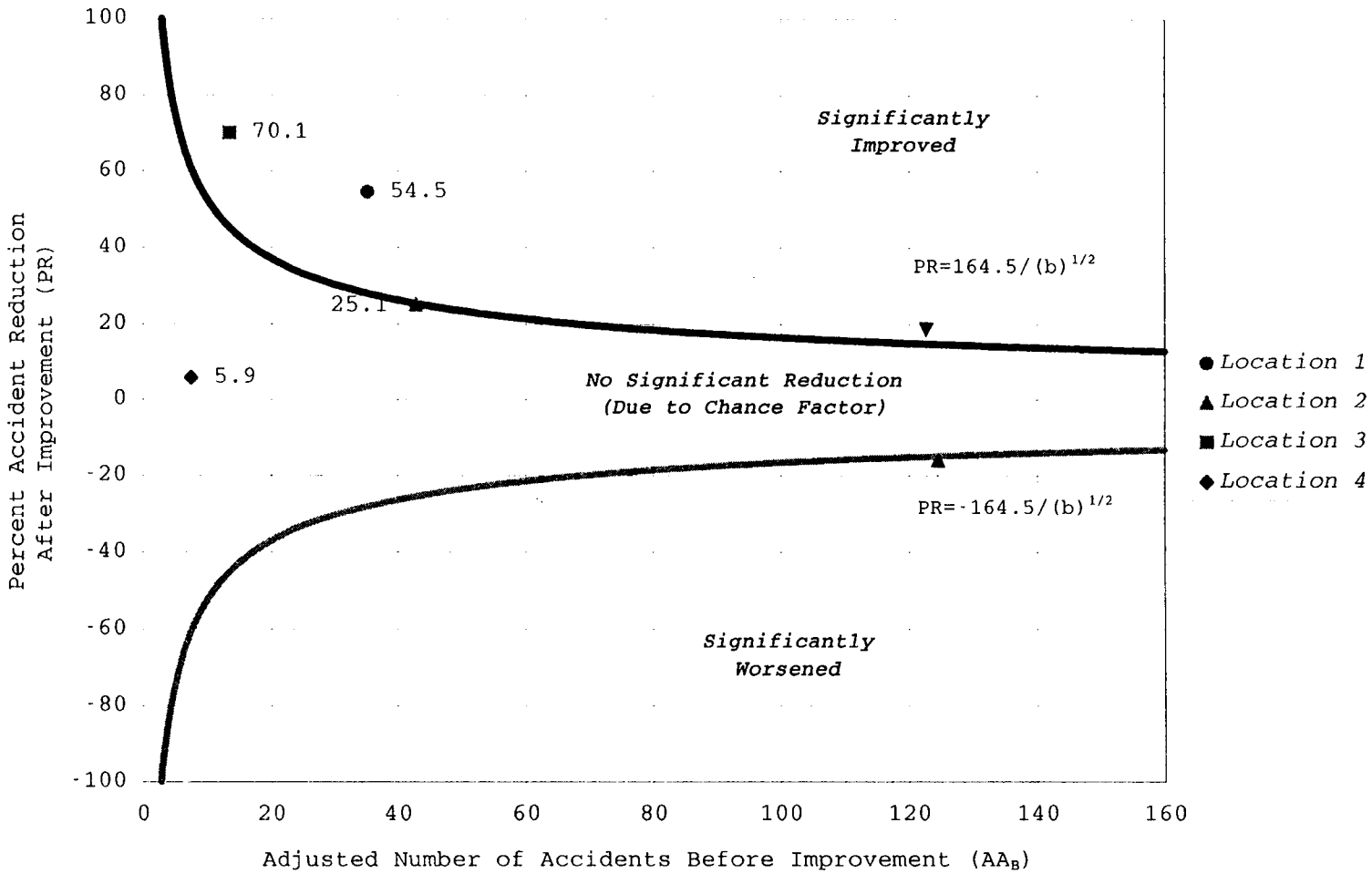


FIGURE 7-2. Modified TDOT Poisson Test for Significance of Accident Rate Reduction for Four Case Studies.
(At 95% Confidence Level.)

TABLE 7-3. Comparison of Data for Standard Poisson Test and Modified TDOT Poisson Test for Significance of Accident Rate Reduction.

			Standard Poisson Test	Modified TDOT Poisson Test
SITE	Average Annual Vehicle Exposure *Ma*	Accident Rates "Before" *Rb*	Actual Number of "Before" Accidents	Adjusted Number of "Before" Accidents *AAb*
LOCATION 1: S.R. 61 @ S.R. 62	*29.333*	*1.20*	*35*	*35*
LOCATION 2: S.R. 170 @ MELTON LAKE DR.	*25.175*	*1.70*	*35*	*43*
LOCATION 3: I-640 WB exit ramp to S.R. 9	*8.176*	*1.64*	*22*	*13*
LOCATION 4: S.R. 170 near NAFF RD.	*0.527*	*14.10*	*12*	*7*

4. Future Recommendations

In review of some of the problems discussed earlier in this chapter, recommendations should be made that assess the overall effectiveness of TDOT's "before and after" study methodologies. A basic problem encountered when attempting to evaluate safety improvements is that traffic engineers are dealing with a foundation of unreliable factors. Oftentimes, engineers are forced to waste valuable time because of missing or unreliable accident data for a "before and after" study. A number of steps should be taken to improve the consistency of accident data collection, thus making the process of a "before and after" evaluation more reliable. If accurate accident information can be collected on a consistent basis, then traffic engineers can avoid the timely process of "backtracking" to investigate the true reliability of data. By saving time without sacrificing data accuracy, the overall cost effectiveness of roadway safety evaluations will drastically improve.

Although accident data management continues to be a challenge for TDOT, new technologies are currently being developed and implemented that will alleviate some potential difficulties and help expedite the process of accident data collection. A new TRIMS (Tennessee Roadway Information Management System) is currently under development by TDOT

which may potentially lessen some of the problems discussed earlier in this chapter (12). The old TRIMS was organized in files, and data searches often required several steps to complete. A search for data at an intersection, for example, had to be run for both intersecting roadways, and the search results often included unnecessary or missing data, thus forcing an engineer to do extended research for accident information.

The new TRIMS is a *Relational Database,* fixed on the concept of using tables rather than files for data management. This new database system, managed by Oracle Database Software, organizes data elements that have some relationship with each other into a table. Tables can be related to each other by one or more columns containing like data. For example, the same route number could be in several tables in the new TRIMS, and the results of a data search would present all of the data from these tables that meet a specified criteria. The database uses a like relationship between the tables to help in inquiring and reporting the data for a query. Different queries allow a user to structure and limit a search for data to suit individual needs. Data in the new TRIMS system is located by *a Location Referencing System* which consists of several specific data characteristics, including the County Number, the Route

Number, and the Log Mile distance measured along a route from its beginning point in a county. Log Miles in TRIMS can be reported to the thousandth of a mile (0.000). The accuracy of this system makes any location on a road unique throughout the state. The cross-referencing concept of tables for the new TRIMS will eliminate the file managing problems of the old TRIMS and improve the accuracy of accident data collection.

In addition to utilizing search tables, the new TRIMS contains several features that will benefit future "before and after" research efforts. One such feature allows users to graphically depict the data from a query onto a map through a GIS (Global Information System) link. After the map of a query is drawn, the graphics can either be manipulated to show only the sections of roads that meet a certain search criteria, or more detail can be added to a map by including additional roads of different functional classifications. This type of mapping tool would prove extremely useful in a "before and after" analysis, as an engineer could instantly produce a map that depicts accident totals on the correct location of a site.

Another special feature of the new TRIMS includes the linking of a Photolog database to the system. The Photolog images for all interstate highways and state routes

have been loaded on the computer server and linked to their corresponding locations in the TRIMS database. There is a color photo for each one one-hundredth of a mile that includes a driver's-eye view of the roadway and roadside elements. A user can enter the County, Route, and Log Mile information for any state road and view a color photograph image of that site on the computer screen. In addition, a Photolog *section* of roadway can be retrieved, and users can view each one one-hundredth of a mile of photos along a section, just as if one is watching a "movie" of a trip along the highway. A tool such as the Photolog addition to the new TRIMS presents numerous benefits for "before and after" researchers. In addition to having quick and easy access to a picture description of the site, engineers can have a tool to aid in visualizing the details of a hazard that might not be recognized from an aerial photograph or plan view diagram. Hazards, such as the "blind hill" situation on State Route 170 near Naff Road, could more easily be evaluated with a Photolog database.

Technological developments such as those previously mentioned for the new TRIMS could improve the time efficiency of the "before and after" study process. If software developers would cater to this process with some additional programming features while designing the new

TRIMS, future "before and after" researchers would see further benefits.

A great deal of time was spent researching and compiling accident data for the four case studies in Chapters 3-6. Much of this time was spent transferring accident data onto a readable collision diagram format. Currently, the Tennessee Department of Transportation does not utilize an automated feature for linking accident data to a collision diagram. As a result, the diagrams must be created by hand or some other means. For the case studies, Microstation™ drafting software was used to create a collision diagram template that could be edited and mass-produced with relative ease. Each accident type was created as a separate drawing "cell" with text fields that could be edited as needed. While these collision diagrams have been created and edited with little trouble, no linking component currently exists with TDOT's traffic accident data. If software developers could format the accident database to automatically produce computer graphic collision diagrams with editing capabilities, an enormous amount of researching time would be saved.

Further tedious efforts could be avoided for a "before and after" researcher in the areas of summing accident totals, calculating accident rates, and managing

these numbers to determine their statistical significance. For the four case studies, a computer spreadsheet was written with Excel™ software that calculated an accident rate from accident totals and volume data that were entered into a summary table. The accident rate was then automatically plotted on a graph to determine its statistical significance. The use of computer spreadsheets created a more time efficient means of managing the accident data for analysis purposes. Again, no software feature currently exists in the TRIMS database that will sum the accident types onto a summary table or input the volume counts to calculate accident rates for a particular query. This is another area of "before and after" research that would benefit greatly from some time-saving automation in the new TRIMS database.

While several computer automated features which are proposed for the new TRIMS may present valuable time saving techniques for future researchers, these new technologies should never grow to take the place of site visits and utilizing good engineering judgment in "before and after" studies (8). No matter how quick and detailed these information technologies become, an engineer must still know how to analyze the collected data in order to perform a reliable "before and after" evaluation.

Chapter 8

CONCLUSIONS

As a part of the Tennessee Department of Transportation Highway Safety Management Program, the "before and after" accident analysis technique presents a systematic method for evaluating the effectiveness of highway safety improvements. Through the four case studies found in Chapters 3-6, the process of performing a "before and after" evaluation was experienced, and certain problems were found with the reliability and practicality of the data that forms the foundation for these studies.

As presented in the Accident Reports section of Chapter 7, the collection of traffic accident reports has traditionally been a responsibility handled by police officers. Because of the multiple responsibilities of an investigating officer, these reports have often been completed in an inconsistent manner with vague accounts from the facts of a collision scene; however, with improved officer training, future accident reports could be documented in a more detailed and uniform fashion. Accident reports with improved accuracy would necessitate less interpretation by engineers and data entry personnel, thus increasing the

reliability of accident databases for future "before and after" studies.

Data collection errors have likewise troubled past research efforts in the area of traffic volume counting. The general nature of volume counting is subject to a variety of influences ranging from the environmental conditions to the procedures of different traffic counting agencies. TDOT is currently endeavoring in a re-engineering program to assess traffic volume collection shortcomings and to compare the techniques utilized by other states with current Tennessee practices in order to work toward a more uniform procedure for collecting traffic volume data. With adequate training of traffic technicians and increased standardization in the upkeep of traffic volume records, a more reliable volume data resource can be accumulated to aid in future "before and after" study efforts.

While certain difficulties have been documented in the area of data collection and with the reliability of accident information, proper care can be taken by traffic engineers to ensure statistical accuracy when utilizing this data, thus making the "before and after" technique an effective measuring tool for project evaluation. In addition, new technologies are currently being developed that will improve the reliability and speed of the "before and

after" process for future engineers. The Tennessee Department of Transportation has taken steps to broaden the availability of several traffic information resources. TDOT's development of a new TRIMS software will introduce time-saving tools such as a feature that links accident data records to GIS mapping capabilities. Furthermore, TDOT will program the new TRIMS system with accessibility to a Photolog database of every one one-hundredth of a mile of state highways.

The GIS link and Photolog resource will provide obvious benefits for "before and after" research; however, further efforts should be made in the area of traffic data automation. With the development of software that automatically plots collision diagrams, produces accident summary tables, and tests for statistical significance, much of the time-consuming workload could be lessened for traffic engineers, thus creating tremendous increases in the speed and efficiency of performing a "before and after" evaluation. Traffic engineers should keep in mind, however, that the increased utilization of technology should not replace the basic concepts of site visitation and using sound engineering judgment when analyzing traffic data.

A general rule of traffic engineering should be to achieve as much uniformity as is possible in implementing

traffic safety improvements (8). Through the Highway Safety Management Program, the Tennessee Department of Transportation has outlined a systematic procedure for records management and project evaluation; however, shortcomings in the current system often require the use of unreliable data and cause unnecessary workloads for traffic engineers. Some re-engineering efforts should, therefore, be addressed to improve upon the practicality of the Highway Safety Management Process. As technology continues to improve, "before and after" accident studies can become a more practical, expedient, and cost effective part of this uniform process. With the capability of performing a "before and after" analysis quickly and efficiently, an entirely new database could be developed for the purpose of safety performance evaluation. In this way, the fundamental resources used for TDOT project evaluation could be updated to reflect new data specific to Tennessee highways that conforms to Federal standards and is easily accessible for research efforts. Furthermore, with advanced reliability in the process of evaluating highway safety improvements, the traffic engineering community can gain increased confidence from legislative bodies that are responsible for the funding of highway safety designs and project implementation.

REFERENCES

REFERENCES

1. City of Knoxville, Engineering Department. (1998). Accident records files.

2. Federal Highway Administration. (1981). Highway Safety Engineering Studies; Accident Patterns, Their Probable Cause and General Countermeasures.

3. Graham, J.L. and Glennon, J.C, Missouri State Highway Commission, Identification, Analysis and Correction of High Accident Locations, Midwest Research Institute, November, 1975.

4. Institute of Transportation Engineers. (1994). Manual of Transportation Engineering Studies, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

5. Institute of Transportation Engineers. (1978). Identifying Hazardous Locations. Self-Instructional Text.

6. Institute of Transportation Engineers. (1978). Identifying Alternative Highway Safety Improvements. Self-Instructional Text.

7. Institute of Transportation Engineers. (1978). Selecting and Making Highway Safety Improvements. Self-Instructional Text.

8. Institute of Transportation Engineers. (1978). Evaluating Completed Highway Safety Improvements. Self-Instructional Text.

9. Michaels, R. M., (1959). "Two Simple Techniques for Determining the Significance of Accident-Reducing Measures", Public Roads—A Journal of Highway Research, Volume 30, Number 10.

10. Morin, Donald A., (1967). "Application of Statistical Concepts to Accident Data," Public Roads—A Journal of Highway Research, Volume 34, Number 7.

11. National Sheriffs' Association. (1992). Rural Initiatives for Traffic Safety: A Guide for the Office of Sheriff and Other Law Enforcement Officials in Rural Communities. National Highway Traffic Safety Administration.

12. Tennessee Department of Transportation. (1998). OIR, Executive Summary and Information Technology Strategy.

13. Tennessee Department of Transportation. (1998). Safety Program Office, Nashville, TN. Annual traffic accident statistics.

14. Tennessee Department of Transportation. (1998). Traffic Department, Knoxville, TN. Accident location files.

15. Tennessee Highway Patrol. (1998). Accident records files.

16. Tidwell, John. (1992, October). State of Tennessee, Department of Transportation and The University of Tennessee Transportation Center. Highway Safety Program Management Manual.

17. Transportation Research Board. (1994). Highway Capacity Manual: Special Report 209, Third Edition. National Research Council, Washington, D.C..

18. United States Department of Transportation. (1967, May). Cost/Effectiveness in Traffic Safety. Arthur D. Little, Inc.: Cambridge.

APPENDICES

APPENDIX A

STANDARD "BEFORE AND AFTER"
STUDY FIGURES AND TABLES

APPENDIX A

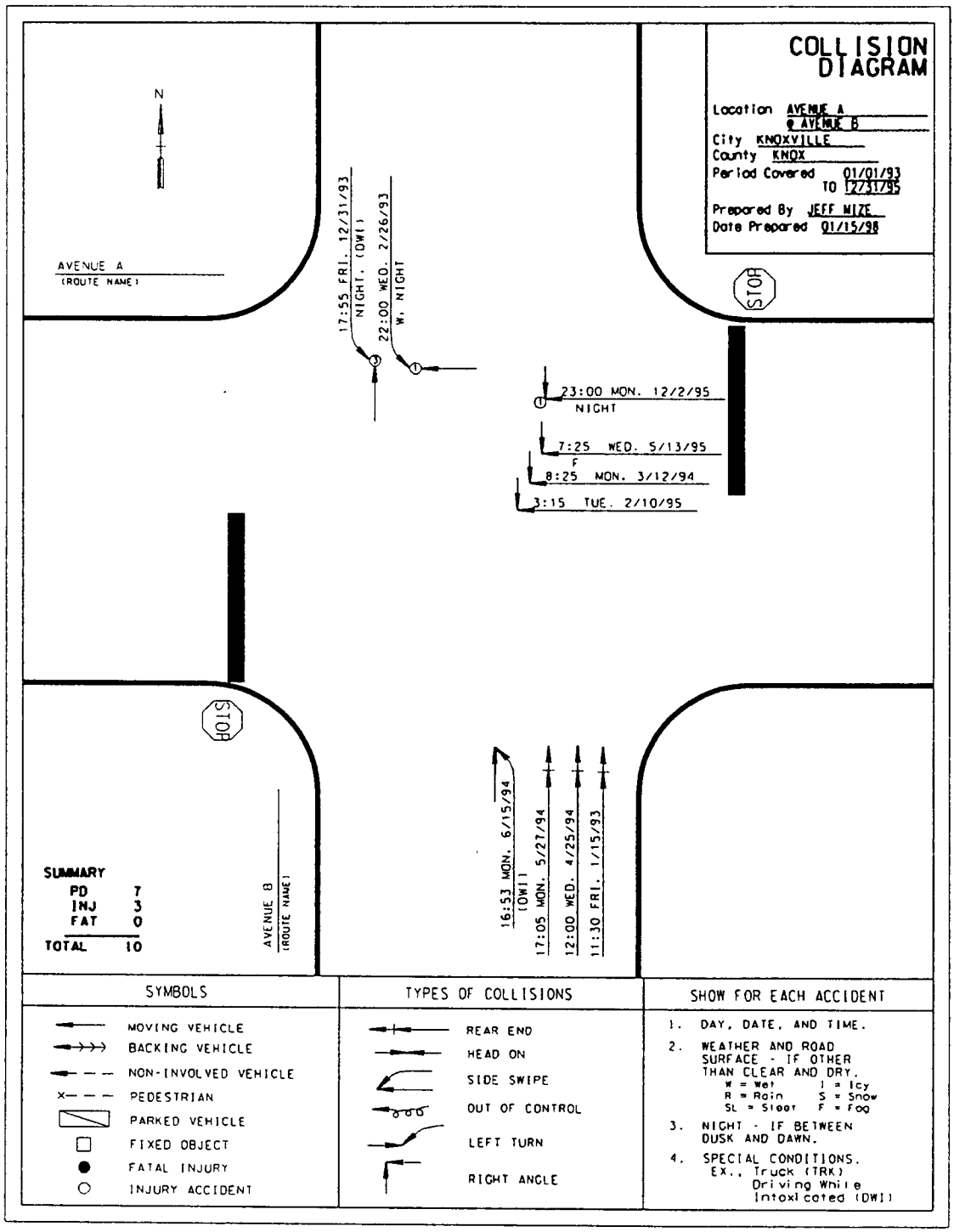


FIGURE A-1. Standard form for collision diagram.

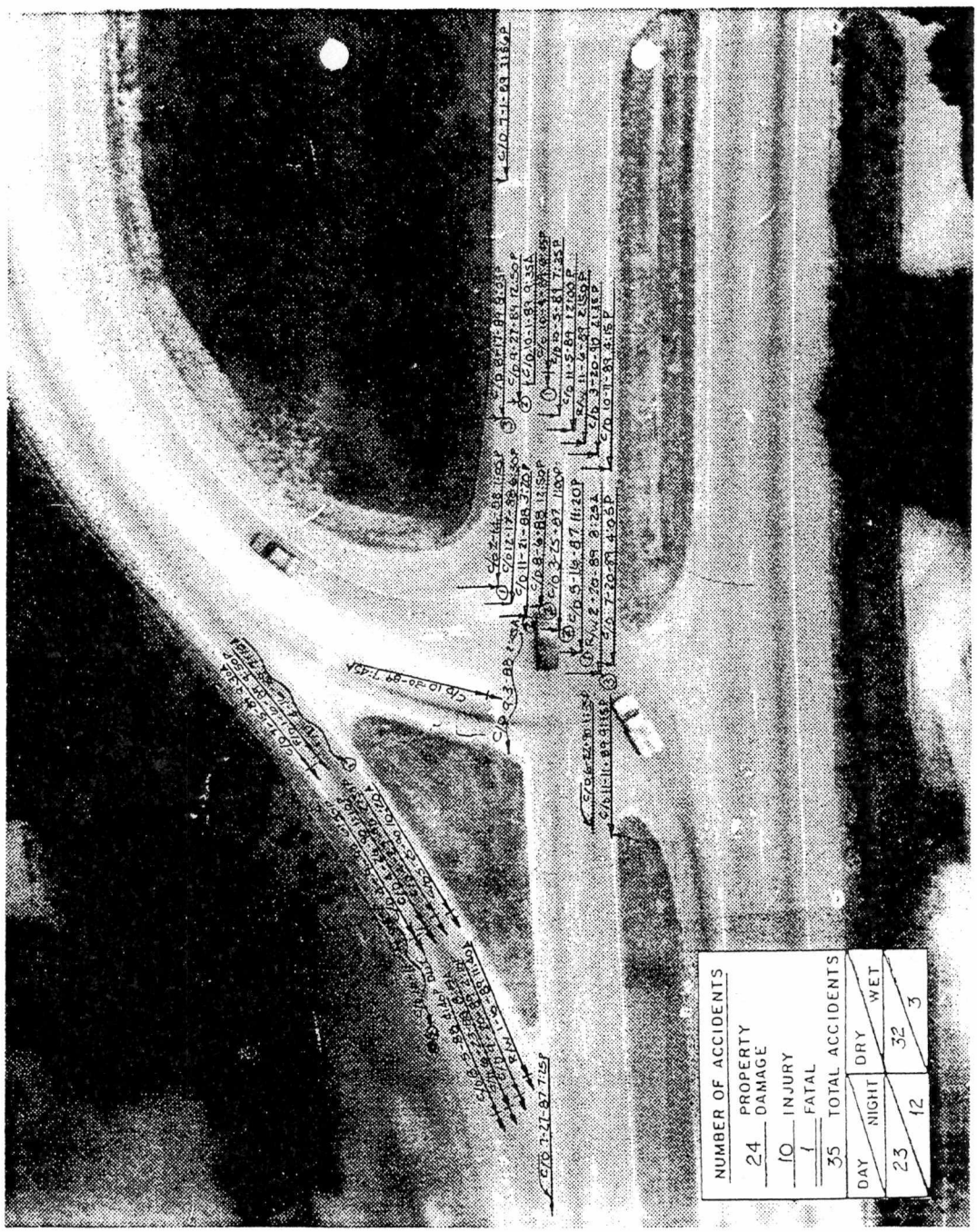


FIGURE A-2. Aerial photograph with collision diagram.

TABLE A-1. Standard form for accident characteristic summary table.

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: _____ Period Covered: _____ From: _____
_____ To: _____

City: _____ Date Prepared: _____
County: _____ Prepared By: _____

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
19__																
19__																
19__																
TOTAL																

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
19__												
19__												
19__												
TOTAL												

Actual Accident Rate _____
Statewide Average Accident Rate _____
Critical Accident Rate _____

TABLE A-2. General accident pattern or trend table.

Accident Pattern or Trend	Possible Causes	General Countermeasure
I. <u>Intersection</u> A. Left-Turn Head-On Collision	1. Large volume of left-turns.	• Create one way street. • Widen road. • Provide left-turn signal phases. • Prohibit left-turns. • Reroute left-turn traffic. • Channelize intersection. • Install stop signs (see MUTCD). • Revise signal sequence. • Provide turning guidelines (if there is a dual left-turn lane). • Provide traffic signal if warranted by MUTCD. • Re-time signals.
	2. Restricted sight distance.	• Remove obstacles. • Provide adequate channelization. • Provide special phase for left-turning traffic. • Provide left-turn slots. • Install warning signs. • Reduce speed limit on approaches.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
A. Left-Turn Head-On Collision	3. Too short amber phase.	• Increase amber phase. • Provide all red phase.
	4. Absence of special left-turning phase.	• Provide special phase for left-turning traffic.
	5. Excessive speed on approaches.	• Reduce speed limit on approaches.
B. Rear-End Collisions at Unsignalized Intersections	1. Drivers not aware of intersection.	• Install/improve warning signs.
	2. Slippery surface.	• Overlay pavement. • Provide adequate drainage. • Groove pavement. • Reduce speed limit on approaches. • Provide "slippery when wet" signs.
	3. Large volume of turning vehicles.	• Create left or right-turn lanes. • Prohibit turns. • Increase curb radii.
	4. Inadequate roadway lighting.	• Improve roadway lighting.
	5. Excessive speed on approaches.	• Reduce speed limit on approaches.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
B. Rear-End Collisions at Unsignalized Intersections	6. Lack of adequate gaps.	• Provide traffic signal if warranted (see MUTCD). • Provide stop signs.
	7. Crossing pedestrians.	• Install/improve signing or marking of pedestrian crosswalks.
C. Rear-End Collisions at Signalized Intersections	1. Slippery surface.	• Overlay pavement. • Provide adequate drainage. • Groove pavement. • Reduce speed limit on approaches. • Provide "slippery when wet" signs.
	2. Large number of turning vehicles.	• Create left or right-turn lanes. • Prohibit turns. • Increase curb radii. • Provide special phase for left-turning traffic.
	3. Poor visibility of signals.	• Install/improve advanced warning device. • Install overhead signals. • Install 12-inch signal lenses (see MUTCD). • Install visors. • Install back plates.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
C. Rear-End Collisions at Signalized Intersections		• Relocate signals. • Add additional signal heads. • Remove obstacles. • Reduce speed limit on approaches.
	4. Inadequate signal timing.	• Adjust amber phase. • Provide progression through a set of signalized intersections. • Add all-red clearance.
	5. Unwarranted signal.	• Remove signals (see MUTCD).
	6. Inadequate roadway lighting.	• Improve roadway lighting.
	7. Excessive speed on approaches.	• Reduce speed limit on approaches.
	8. Crossing pedestrians.	• Install/improve signing or marking of pedestrian crosswalks. • Provide pedestrian "WALK" phase.
D. Right-Angle Collision at Signalized Intersections	1. Restricted sight distances.	• Remove sight obstructions. • Restrict parking near corners. • Install warning signs (see MUTCD).

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
D. Right-Angle Collision at Signalized Intersections	2. Excessive speed on approaches.	• Reduce speed limit on approaches. • Channelize intersections. • Install advance markings to supplement signs.
	3. Poor visibility of signals.	• Install advanced warning devices. • Install 12-inch signal lenses. • Install overhead signal. • Install visors. • Install back plates. • Improve location of signal heads. • Add additional signal heads. • Add illuminated name signs.
	4. Inadequate signal timing.	• Adjust amber phase. • Provide all-red clearance phase. • Add multi-dial controller. • install signal actuation. • Re-time signals. • Provide progression through a set of signalized intersections.
	5. Inadequate roadway lighting.	• Improve roadway illumination.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
D. Right-Angle Collision at Signalized Intersections	6. Inadequate advance intersection warning signs.	• Install advance intersection warning signs.
	7. Large total intersection volume.	• Re-time signals. • Add traffic lane.
E. Right-Angle Collisions at Unsignalized Intersections	1. Restricted sight distance.	• Remove sight obstructions. • Restrict parking near corners. • Install stop signs (see MUTCD). • Install warning signs (see MUTCD). • Reduce speed limit on approaches. • Install signal (see MUTCD). • Install yield signs (see MUTCD). • Channelize intersection. • Install advance markings to supplement signs. • Install limit lines.
	2. Large total intersection volume.	• Install signal (see MUTCD). • Reroute through traffic.
	3. Excessive speed on approaches.	• Reduce speed limit on approaches. • Increase amber phase. • Install rumble strips.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
E. Right-Angle Collisions at Unsignalized Intersections	4. Inadequate roadway lighting.	• Improve roadway illumination.
	5. Inadequate intersection warning signs.	• Install advance intersection warning signs.
	6. Inadequate traffic control devices.	• Upgrade traffic control device. • Increase enforcement.
II. **Link** A. Run-Off Roadway Collisions	1. Slippery surface.	• Overlay existing pavement. • Provide adequate drainage. • Groove existing pavement. • Reduce speed limit. • Provide "slippery when wet" signs.
	2. Roadway design inadequate for traffic conditions.	• Widen lanes. • Relocate islands. • Close curb lanes. • Install guardrails.
	3. Poor delineation.	• Improve/install pavement markings. • Install roadside delineators. • Install advance warning signs.
	4. Inadequate roadway lighting.	• Improve roadway lighting.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
	5. Inadequate shoulder.	• Upgrade roadway shoulders.
	6. Improper channelization.	• Improve channelization.
	7. Inadequate pavement maintenance.	• Perform road surface repair.
	8. Poor visibility.	• Increase size of signs.
	9. Excessive speed on approaches.	• Reduce speed limit.
B. Fixed-Object Accidents	1. Obstructions in or too close to roadway.	• Remove obstacles. • Install breakaway features to light poles, signposts, etc. • Shield objects with guardrail. • Install crash cushioning devices. • Delineate object.
	2. Inadequate roadway lighting.	• Improve roadway lighting.
	3. Inadequate pavement marking.	• Install reflectionized pavement lines.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
B. Fixed-Object Accidents	4. Inadequate signs, delineators, and guardrails.	• Install reflectionized paint and/or reflectors on the obstruction.
	5. Inadequate roadway design.	• Provide proper superelevation. • Improve superelevation at curve. • Install appropriate warning signs and delineators.
	6. Slippery surface.	• Improve skid resistance. • Provide adequate drainage. • Provide "slippery when wet" signs. • Provide wider lanes.
	7. Excessive vehicle speed.	• Reduce speed limit.
C. Parked Vehicle Accidents	1. Improper pavement markings.	• Paint parking stall limits 7 feet from curb face.
	2. Improper parking clearance at driveways.	• Post parking restrictions near driveways.
	3. Angle parking.	• Convert angle parking to parallel parking.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
C. Parked Vehicle Accidents	4. Excessive vehicle speed.	• Reduce speed limit if justified by spot speed studies. • Widen lanes.
	5. Illegal parking.	• Enforcement.
	6. Improper parking.	• Prohibit parking. • Create off street parking.
	7. Large parking turnover.	• Create one-way streets. • Reroute through traffic.
D. Sideswipe or Head-On Collision	1. Inadequate roadway design.	• Create one-way streets. • Provide wider lanes.
	2. Improper road maintenance.	• Perform necessary road surface repairs.
	3. Inadequate shoulders.	• Improve shoulders.
	4. Excessive vehicle speed.	• Reduce speed limit. • Install median devices. • Remove constriction such as parked vehicles.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
D. Sideswipe or Head-On Collision	5. Inadequate pavement markings.	• Install or refinish center lines, lane lines and pavement edge lines. • Install reflectionized lane lines and edge lines.
	6. Inadequate channelization.	• Install acceleration and deceleration lanes. • Channelize intersection. • Provide turning bays.
	7. Inadequate signing.	• Place direction and lane change signs to give proper advance warning. • Add illumination name signs.
E. Driveway-Related Collisions	1. Left-turning vehicles.	• Install median devices. • Install two-way left-turn lanes.
	2. Improperly located driveways.	• Regulate minimum spacing of driveways. • Regulate minimum corner of clearance. • Move driveway to sidestreet. • Install curbing to define driveway location. • Consolidate adjacent driveways.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
E. Driveway-Related Collisions	3. Right-turning vehicles.	• Provide right-turn lanes. • Restrict parking near driveways. • Increase the width of driveways. • Widen through lanes. • Increase curb radii.
	4. Large volume of through traffic.	• Move driveway to sidestreet. • Construct a local service road. • Reroute through traffic.
	5. Large volume of driveway traffic.	• Signalize driveway. • Provide acceleration and deceleration lanes. • Channelize driveway.
	6. Restricted sight distance.	• Remove sight obstructions. • Restrict parking near driveway. • Install/improve street lighting. • Reduce speed limit.
	7. Inadequate roadway lighting.	• Improve street lighting.
	8. Excessive speeds on approaches.	• Reduce speed limit.

TABLE A-2. (continued).

Accident Pattern or Trend	Possible Causes	General Countermeasure
III. **Environment-Related** A. Wet Pavement Accidents	1. Slippery surface.	• Overlay existing pavement. • Groove existing pavement. • Reduce speed limit. • Provide "slippery when wet" signs. • Skidproof roadway.
	2. Inadequate drainage.	• Provide adequate drainage.
	3. Inadequate pavement markings.	• Upgrade pavement markings.
B. Night Accidents	1. Poor visibility or lighting.	• Install/improve street lighting. • Install/improve delineation markings. • Install/improve warning signs.
	2. Poor sign quality.	• Upgrade signing. • Provide illuminated signs.
	3. Inadequate channelization or delineation.	• Install pavement markings. • Improve delineation markings. • Upgrade advance warning signing.

APPENDIX B

STATISTICAL FORMULAS FOR
"BEFORE AND AFTER"
ACCIDENT DATA ANALYSIS

APPENDIX B

STATISTICAL FORMULAS FOR "BEFORE AND AFTER" ACCIDENT DATA ANALYSIS

Accident Rate formulas for each type of highway location:

Section: $$R_S = \frac{A \cdot 10^6}{T \cdot V \cdot L}$$

Spot: $$R_P = \frac{A \cdot 10^6}{T \cdot V}$$

Intersection: $$R_I = \frac{2 \cdot A \cdot 10^6}{T \cdot \Sigma V_j}$$

where

R_S = Accident rate expressed as accidents per million vehicle-miles for highway sections longer than 0.1 mile;

R_P = Accident rate expressed as accidents per million entering vehicles for a "spot" location where a cluster of accidents occurs within a distance of 0.1 mile, or a "point" location such as a bridge or railroad grade crossing;

R_I = Accident rate expressed as accidents per million entering vehicles for intersections or highway "junctions";

A = Number of accidents recorded at the location;

L = Length of section in miles, to the nearest hundredth;

T = Time period, in days, for the number of accidents *(A)*; T = 365 for one year

V = Vehicle volume in average annual daily traffic *(AADT)* on a section or spot;

ΣV_j = $V_1 + V_2 + V_3 + \ldots + V_n$ = Sum of vehicle volumes, in average annual daily traffic *(AADT)*, for all junction legs of an intersection with n junction legs where V_1 is the volume for the first leg, V_2 is the volume for the second leg, and so on;

2 = A constant which effectively reduces the sum of vehicle volumes by a factor of two to avoid double counting of vehicles entering and leaving the intersection; and

10^6 = A constant to convert accidents per vehicle or vehicle-mile to million vehicles or million vehicle-miles.

Formula for determining Critical Accident Rate (R_C):

$$R_C = R_A + K\sqrt{\frac{R_A}{m} + \frac{1}{2m}}$$

where

R_C = Critical accident rate in Accidents per Million Vehicle Mile (MVM) for sections or Accidents per Million Entering Vehicle (MEV) for spots or intersections;

R_A = Average accident rate for the entire population of sections, spots, or intersections for one classification of highway. R_A is determined annually by TDOT;

m = Vehicular travel, in millions of vehicle-miles for sections or millions of vehicles for spots and intersections; and

K = A probability constant. K is a standard normal variable along the x-axis of the standard normal distribution curve [related to the probability, P, that an accident rate greater than R_C does not result from chance - a K of 2.327 corresponds to a confidence level of 99 percent (P)]. A smaller K value will to tend to give more sections out of control and therefore a larger list of sections to study, but it will increase the probability that the rate was due to chance.

Formula for determining Severity Index (*SI*):

$$SI = \frac{F + I}{F + I + PDO}$$

where

SI = Severity Index;

F = Number of Fatality accidents;

I = Number of Injury accidents;

PDO = Number of Property Damage Only accidents.

Formula for determining Average Number of Accidents per year:

$$1) \quad AA_B = R_B * M_A$$

$$2) \quad AA_A = R_A * M_A$$

where

AA_B = Adjusted average annual number of accidents before an improvement; The value, AA_B is the number of accidents that would have occurred for vehicle exposure, M_A, if the improvement had not been made.

AA_A = Average annual number of accidents after an improvement;

R_B = Accident rate before improvement, in accidents per million vehicles of vehicle miles;

R_A = Accident rate after improvement, in accidents per million vehicles or vehicle miles; and

M_A = Average annual vehicle exposure after improvement, in millions of vehicles or vehicle miles.

Formula for Percent Reduction in Accident Rate (*PR*):

$$PR = \frac{R_B - R_A}{R_B} * 100$$

PR = Percent Reduction in Accident Rate;

R_B = Accident rate before improvement;

R_A = Accident rate after improvement.

It should be noted that this is equivalent to:

$$PR = \frac{AA_B - AA_A}{AA_B}$$

PR = Percent Reduction in Accident Rate;

AA_B = Adjusted average annual number of accidents before an improvement;

AA_A = Average annual number of accidents after an improvement.

Formula for Critical Percent Reduction in Accident Rate (PR_C):

$$PR_C = \frac{100 * K}{\sqrt{AA_B}}$$

PR_C = Critical Percent Reduction in Accident Rate;

AA_B = Adjusted average number of accidents before improvement;

K = Standard normal variable along the x-axis of the standard normal distribution curve. K is related to the probability, P, that the percent reduction, PR_C will not be exceeded as a result of chance. Values for K and corresponding probabilities are as follows:

K	P	Confidence Level (%)
2.576	0.995	99.5
2.327	0.990	99.0
1.960	0.975	97.5
1.645	0.950	95.0
1.282	0.900	90.0

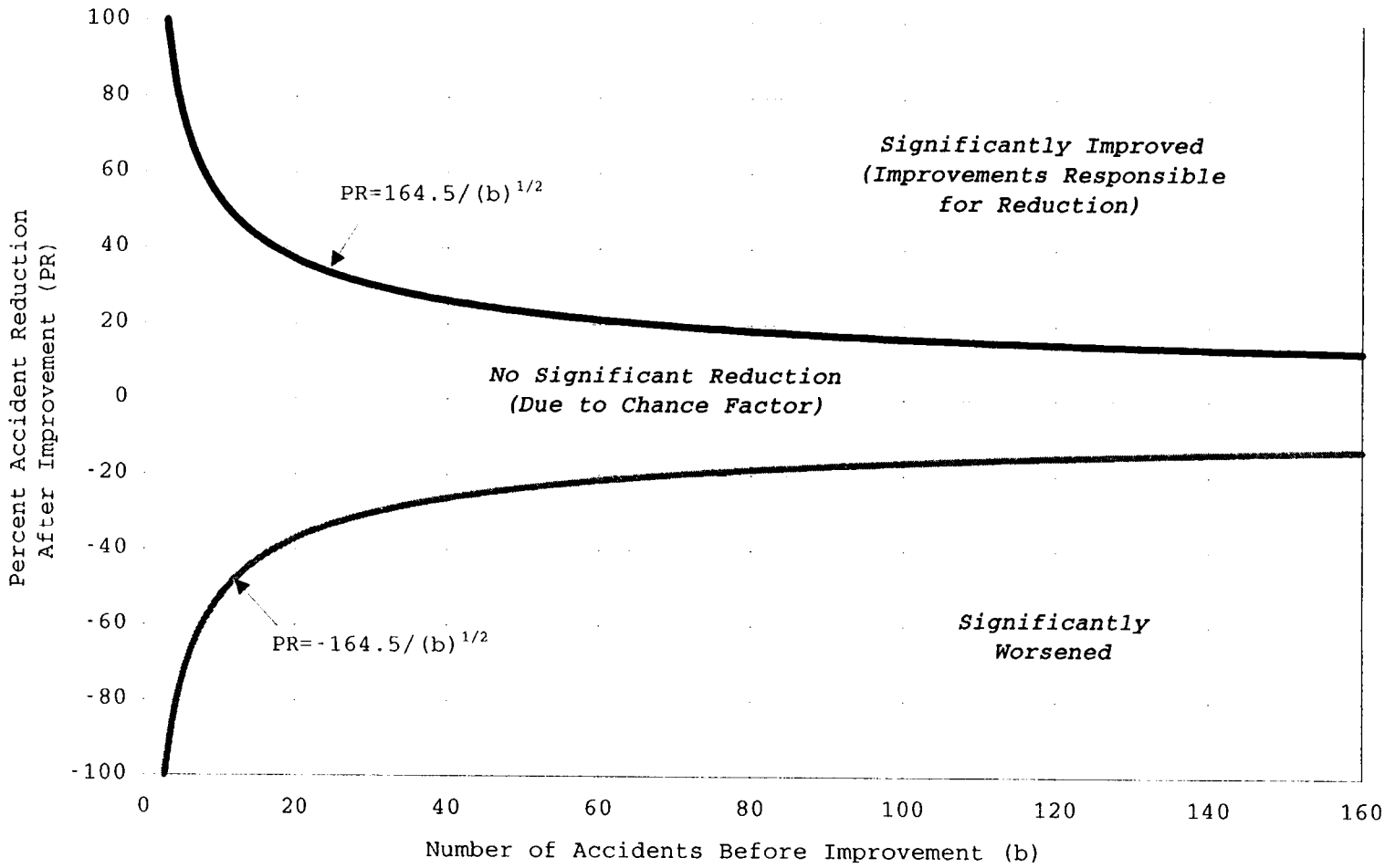


FIGURE B-1. Poisson Test for Significance of Accident Rate Reduction

(At 95 percent Confidence Level, Adapted from 1994 ITE Manual of Transportation Engineering Studies))

APPENDIX C

LOCATION 1.

State Route 61
and State Route 62

APPENDIX C

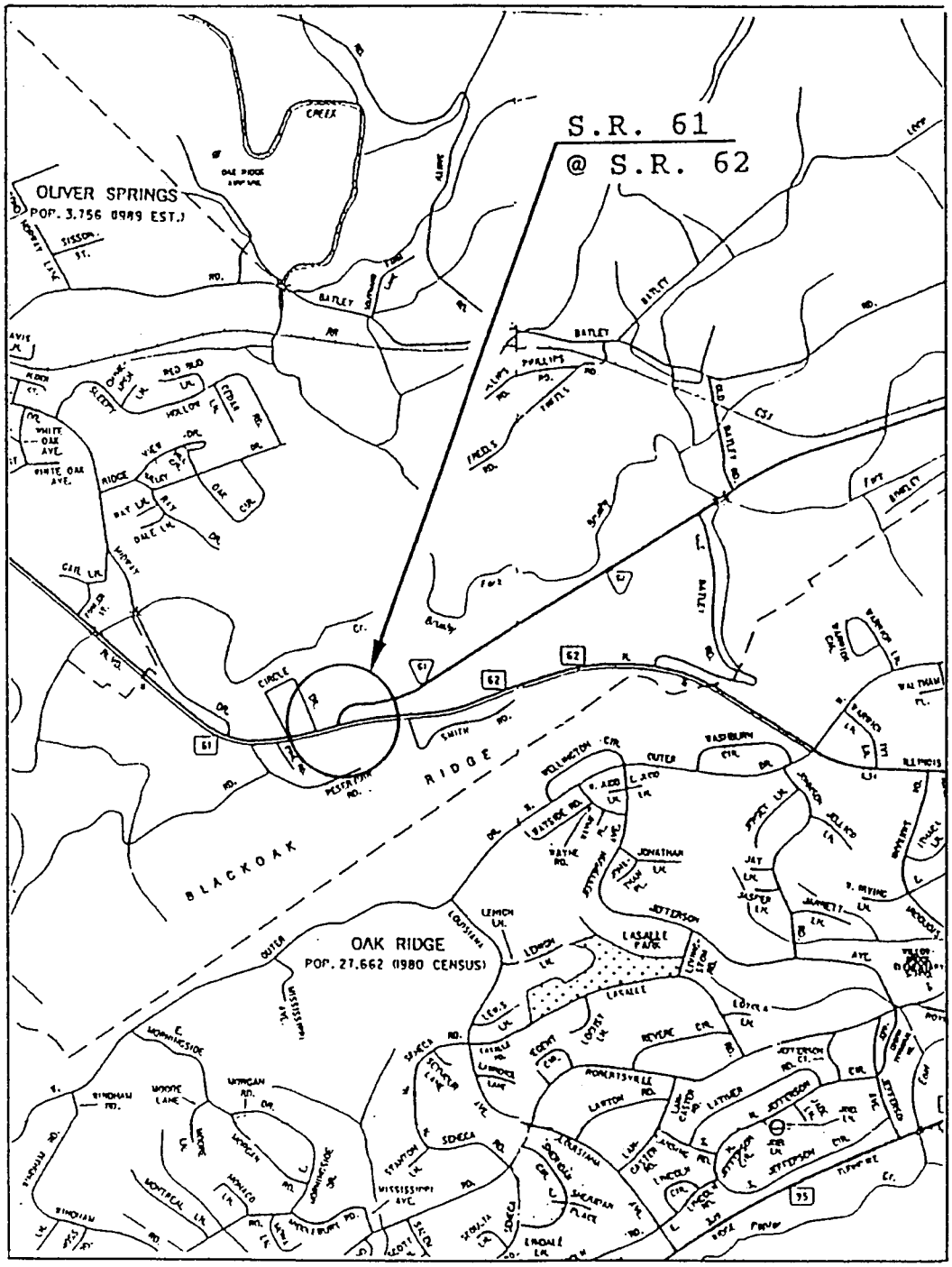


FIGURE C-1. General location map for the intersection of State Route 61 with State Route 62, Anderson County, TN.

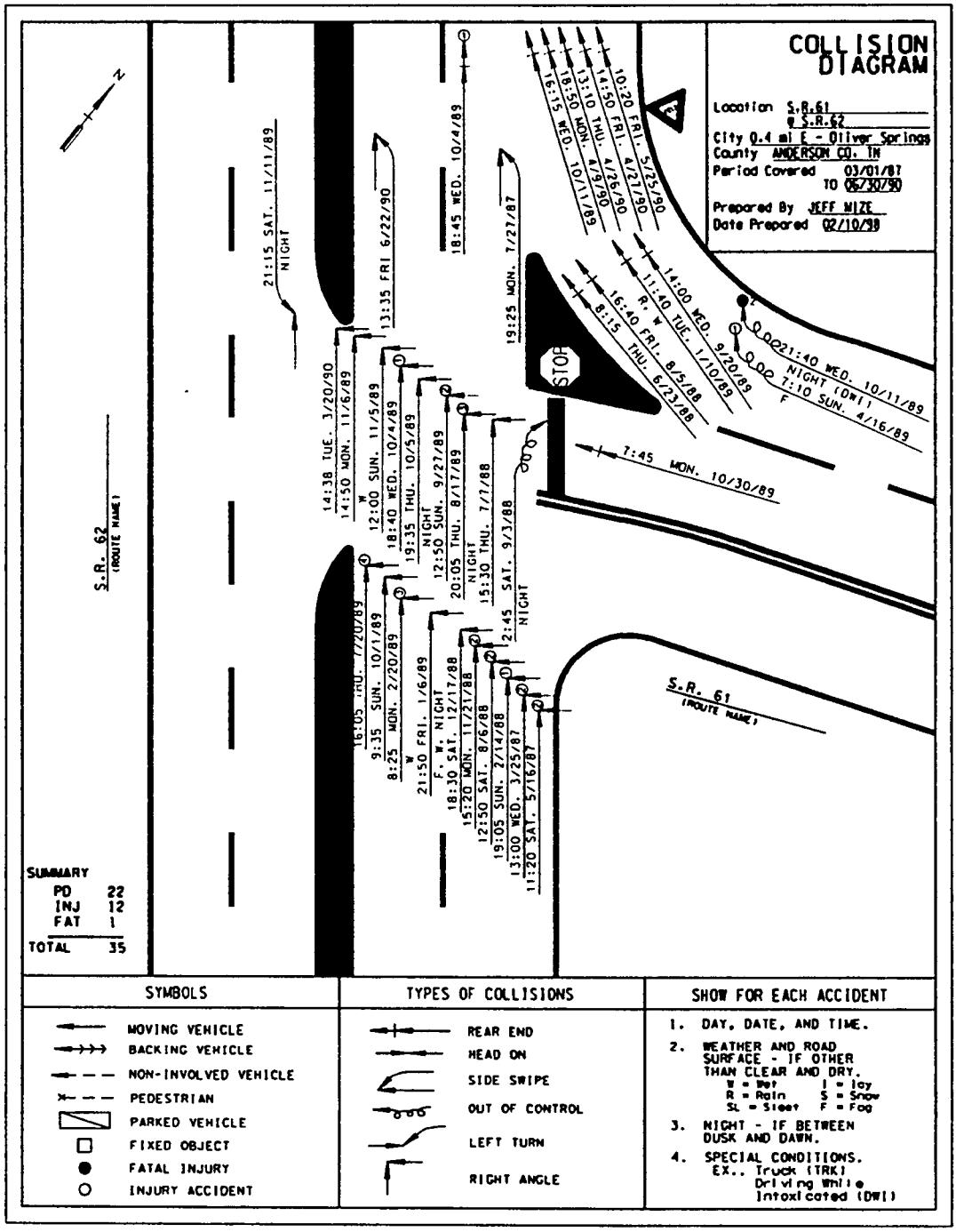


FIGURE C-2. Collision diagram for the intersection of State Route 61 with State Route 62 - **BEFORE.**

TABLE C-1. Accident characteristic summary table for the intersection of State Route 61 with State Route 62 - **BEFORE**.

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: S.R. 61 @ S.R. 62 Period Covered: 3.33-years From: 3/1/87 To: 6/30/90

City: ---- Date Prepared: 4/23/98

County: Anderson Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1987	2			1		1							3	2		1
1988	5	2	1										8	3		5
1989	10	5	2		1								18	7	1	10
1990	1	4		1		1							6			6
TOTAL	18	11	3	2	1	2							35	12	1	22

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1987										1		
1988										1	1	
1989						1		4		4		
1990												
TOTAL						1		4		6	1	

Actual Accident Rate 1.20

Statewide Average Accident Rate 0.13

Critical Accident Rate 0.30

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 5/4/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Intersection)
Location: State Route 61 @ State Route 62
Anderson County

DATA: Period of study: 3/1/87 to 6/30/90
Number of accidents: 35 (A)
Number of days in study: 1217 (T)
TMC date : 10/19/89
Entering volume: 11572 (C)
Day of week: TUES.
Type of highway: 4-Lane Rural
Statewide average accident rate: 0.13 (Ra) from Table I.
Day of week factor: 0.95 (Fd) from Table II
24 hour expansion factor 2.18 (Fp) from Table III.

24 HOUR TOTAL ENTERING VOLUME: (C)*(Fd)*(Fp) = (ΣV)

(11572) * (0.95) * (2.18) = **23965.612 (ΣV)**

EXPOSURE:

(T)*(ΣV)=(1217) * (23966) = **29166150 (E)**

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(\ 29166150\ )}{1000000} =$ **29.166 (M)**

ACTUAL ACCIDENT RATE (Ri):

$$\frac{(A) * 1000000}{(T)*(\Sigma V)} = \frac{(\ 35\ ) * 1000000}{(\ 29166150\ )} =$$

= **1.2000 (R)**

CRITICAL ACCIDENT RATE (Rc):

CONFIDENCE LEVEL (%)
99.0

$Ra + K(Ra/M)^{1/2} + (1/2M) =$

(0.13) + (2.327) * (0.13 / 29.166)$^{1/2}$+(1/2(29.166))=

= **0.302 (Rc)**

SUMMARY:

Actual Accident Rate	:	**1.200 Acc/MV**
Statewide Average Accident Rate:		**0.130 Acc/MV**
Critical Accident Rate	:	**0.302 Acc/MV**

SEVERITY INDEX (SI):

$$SI = \frac{(\text{No. of Fatal Accidents}) + (\text{No. of Injury Accidents})}{(\text{Total Number of Accidents})} =$$

$$SI = \frac{(\ 1\ ) + (\ 10\ )}{(\ 35\ )} =$$

SEVERITY INDEX = 0.314
RATIO: R/Rc = 3.967

FIGURE C-3. Accident rate calculations for the intersection of State Route 61 with State Route 62 - **BEFORE.**

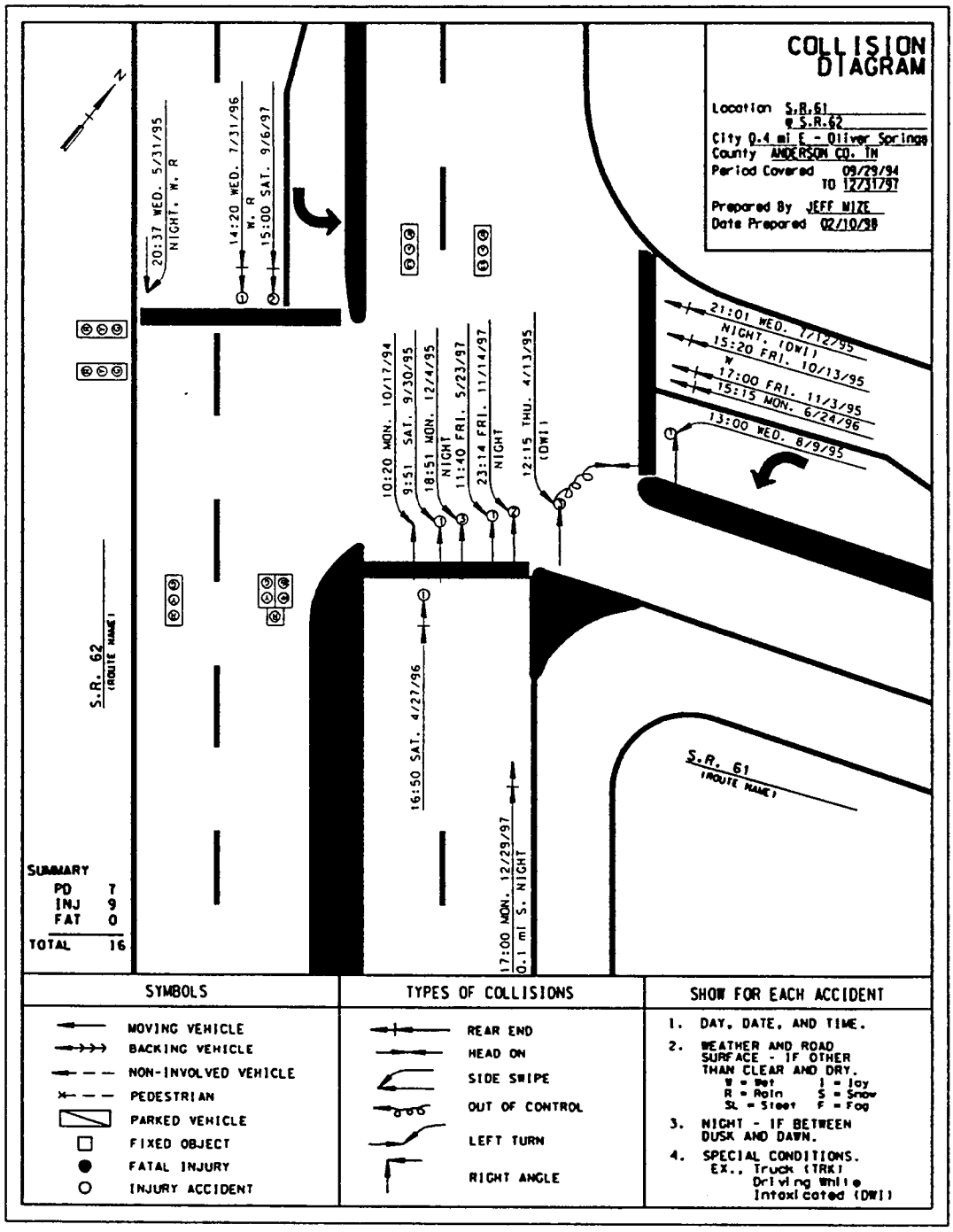


FIGURE C-4. Collision diagram for intersection of State Route 61 with State Route 62 - **AFTER.**

TABLE C-2. Accident characteristic summary table for the intersection of State Route 61 with State Route 62 - **AFTER.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: S.R. 61 @ S.R. 62
Period Covered: 3.33-years
From: 9/29/93
To: 12/31/97
City: ----
Date Prepared: 4/23/98
County: Anderson
Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1994					1								1			1
1995		3		1	4	1							8	4		4
1996		3											3	2		1
1997		2			2								4	3		1
TOTAL		8		1	7	1							16	9		7

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1994												
1995						2		2		3		1
1996								1				1
1997		1								2		1
TOTAL		1				2		3		5		3

Actual Accident Rate 0.55
Statewide Average Accident Rate 0.13
Critical Accident Rate 0.30

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 5/4/98
Calc. by: Jeff Mize
Location: State Route 61 @ State Route 62
Anderson County

**** ACCIDENT RATES
(Intersection)

DATA: Period of study: 9/29/94 to 12/31/97
Number of accidents: 16 (A)
Number of days in study: 1189 (T)
TMC date : 1997 ADT
Entering volume: 24670 (C)
Day of week:
Type of highway: 4-Lane Rural
Statewide average accident rate: 0.13 (Ra) from Table I.
Day of week factor: 1 (Fd) from Table II
24 hour expansion factor 1 (Fp) from Table III.

24 HOUR TOTAL ENTERING VOLUME: (C)*(Fd)*(Fp) = (ΣV)

(24670) * (1) * (1) = **24670.000 (ΣV)**

EXPOSURE:

(T)*(ΣV) = (1189) * (24670) = **29332630 (E)**

EXPOSURE RATE:

$$\frac{(E)}{1000000} = \frac{(\ 29332630\ )}{1000000} = \mathbf{29.333\ (M)}$$

ACTUAL ACCIDENT RATE (Ri):

$$\frac{(A) * 1000000}{(T)*(\Sigma V)} = \frac{(\ 16\ ) * 1000000}{(\ 29332630\ )} =$$

= **0.5455 (R)**

CRITICAL ACCIDENT RATE (Rc):

CONFIDENCE LEVEL (%)
99.0

$Ra + K(Ra/M)^{1/2} + (1/2M) =$

$(0.13) + (2.327) * (0.13 / 29.333)^{1/2} + (1/2(29.333)) =$

= **0.302 (Rc)**

SUMMARY:

Actual Accident Rate	:	**0.545 Acc/MV**
Statewide Average Accident Rate	:	**0.130 Acc/MV**
Critical Accident Rate	:	**0.302 Acc/MV**

SEVERITY INDEX (SI):

$$SI = \frac{(\text{No. of Fatal Accidents}) + (\text{No. of Injury Accidents})}{(\text{Total Number of Accidents})} =$$

$$SI = \frac{(\ 0\ ) + (\ 9\ )}{(\ 16\ )} =$$

SEVERITY INDEX = 0.563
RATIO: R/Rc = 1.806

FIGURE C-5. Accident rate calculations for the intersection of State Route 61 with State Route 62 - **AFTER.**

APPENDIX D

LOCATION 2.

State Route 170
and Melton Lake Drive

APPENDIX D

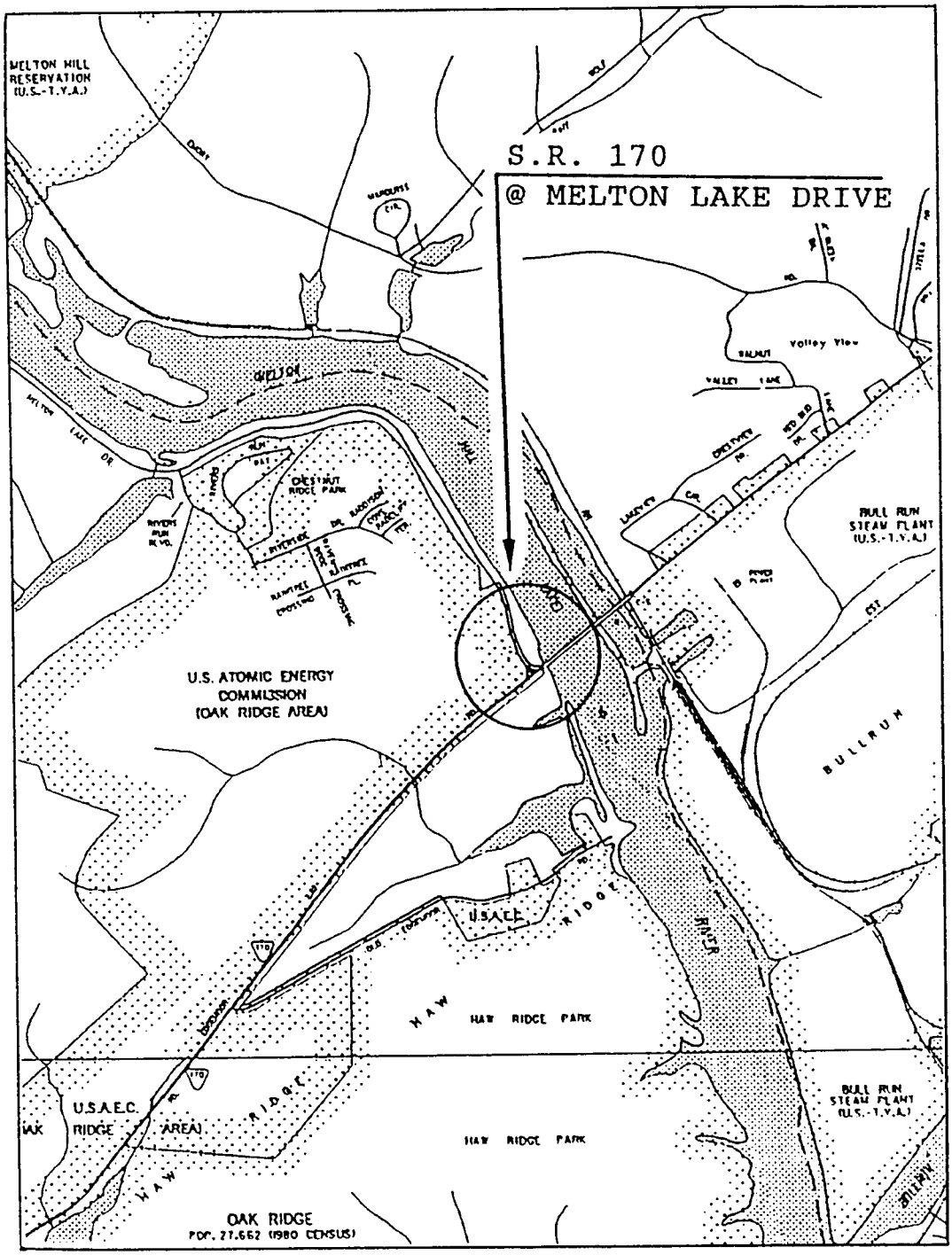


FIGURE D-1. General location map for the intersection of State Route 170 (Edgemore Road) with Melton Lake Drive, Anderson County, TN.

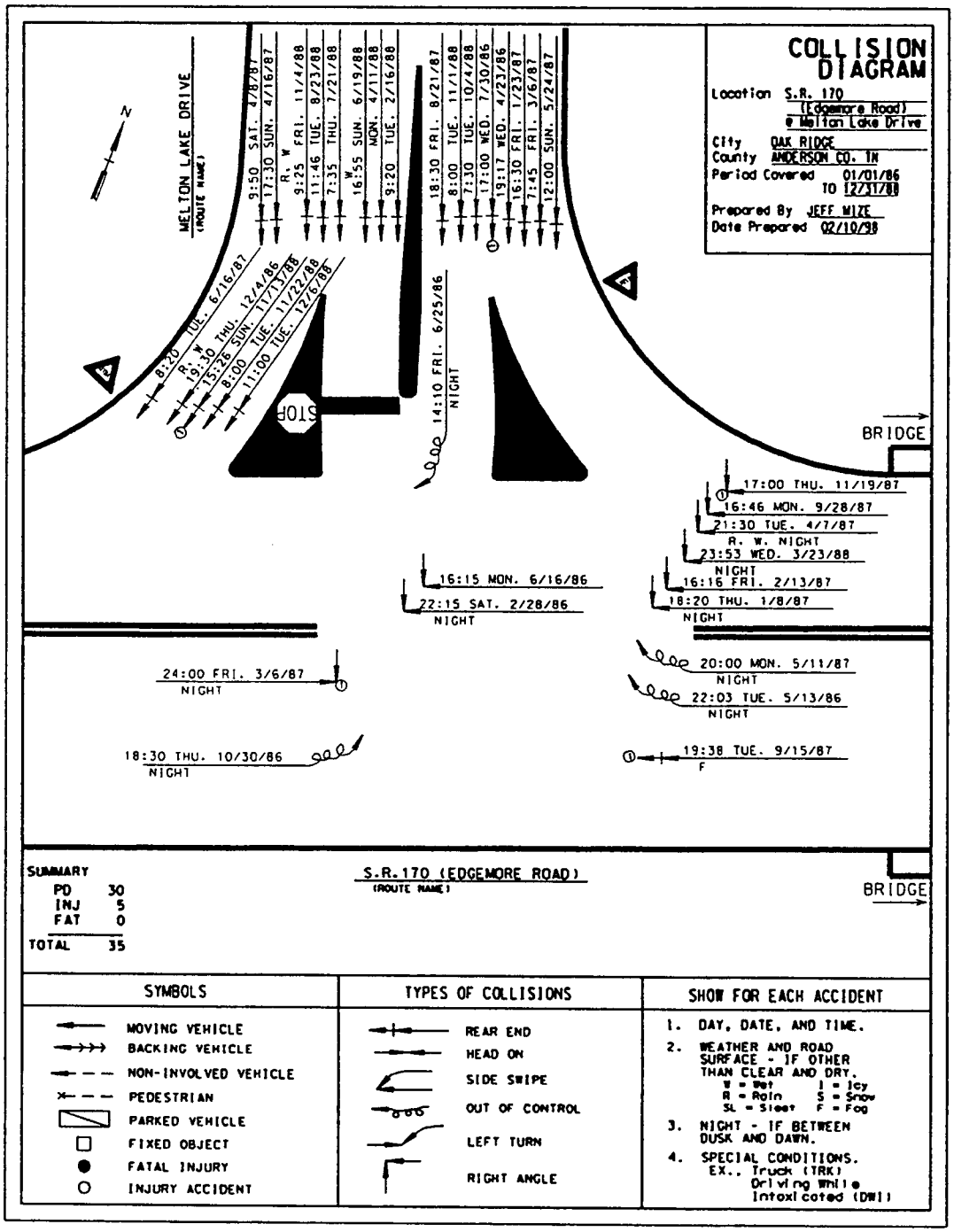


FIGURE D-2a. Collision diagram for intersection of State Route 170 with Melton Lake Drive (1985-1988) - **BEFORE.**

TABLE D-1. Accident characteristic summary table for the intersection of State Route 170 with Melton Lake Drive - **BEFORE.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: S.R.170 (Edgemore Raod) @ Melton Lake Drive

Period Covered: 3-years

From: 1/1/86
To: 12/31/88

City: Oak Ridge
County: Anderson

Date Prepared: 4/23/98
Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1986	2	3	3										8	1		7
1987	6	8	1										15	3		12
1988	1	11											12	1		11
TOTAL	9	22	4										35	5		30

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1986										4		1
1987									3	4	2	2
1988									1	1	4	
TOTAL									4	9	6	3

Actual Accident Rate 1.70
Statewide Average Accident Rate 0.18
Critical Accident Rate 0.42

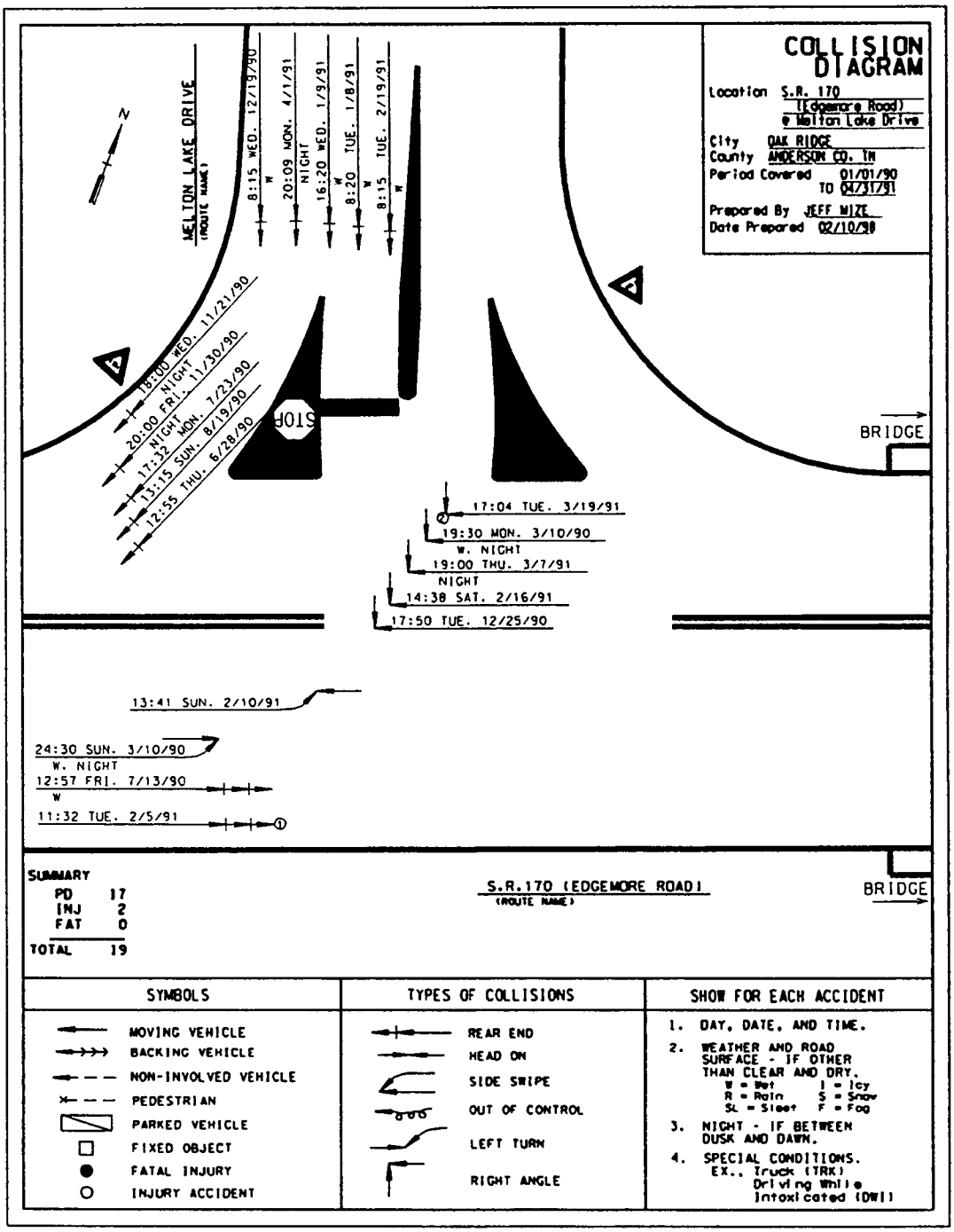


FIGURE D-2b. Accident rate calculations for the intersection of State Route 170 with Melton Lake Drive (1990-1991) - **BEFORE.**

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 5/4/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Intersection)
Location: State Route 170 (Edgemore Road) @ Melton Lake Drive
Anderson County

DATA: Period of study: 1/1/86 to 12/31/88
Number of accidents: 35 (A)
Number of days in study: 1095 (T)
TMC date : 3/16/89
Entering volume: 8499 (C)
Day of week: TUES.
Type of highway: 2-Lane Rural
Statewide average accident rate: 0.18 (Ra) from Table I.
Day of week factor: 1.06 (Fd) from Table II
24 hour expansion factor 2.09 (Fp) from Table III.

24 HOUR TOTAL ENTERING VOLUME: (C)*(Fd)*(Fp) = (ΣV)
(8499) * (1.06) * (2.09) = **18828.685 (ΣV)**

EXPOSURE:
(T)*(ΣV)=(1095) * (18829) = **20617410 (E)**

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(\ 20617410\ )}{1000000} =$ **20.617 (M)**

ACTUAL ACCIDENT RATE (Ri):
$\frac{(A) * 1000000}{(T)*(\Sigma V)} = \frac{(\ 35\ ) * 1000000}{(\ 20617410\ )} =$

= **1.6976 (R)**

CRITICAL ACCIDENT RATE (Rc): CONFIDENCE LEVEL (%) 99.0

$Ra + K(Ra/M)^{1/2} + (1/2M) =$

$(0.18) + (2.327) * (0.18 / 20.617)^{1/2} + (1/2(20.617)) =$

= **0.422 (Rc)**

SUMMARY:
Actual Accident Rate : **1.698 Acc/MV**
Statewide Average Accident Rate: **0.180 Acc/MV**
Critical Accident Rate : **0.422 Acc/MV**

SEVERITY INDEX (SI):
$SI = \frac{(\text{No. of Fatal Accidents}) + (\text{No. of Injury Accidents})}{(\text{Total Number of Accidents})} =$

$SI = \frac{(\ 0\ ) + (\ 5\ )}{(\ 35\ )} =$

SEVERITY INDEX = 0.143
RATIO: R/Rc = 4.026

FIGURE D-3. Accident rate calculations for the intersection of State Route 170 with Melton Lake Drive - **BEFORE.**

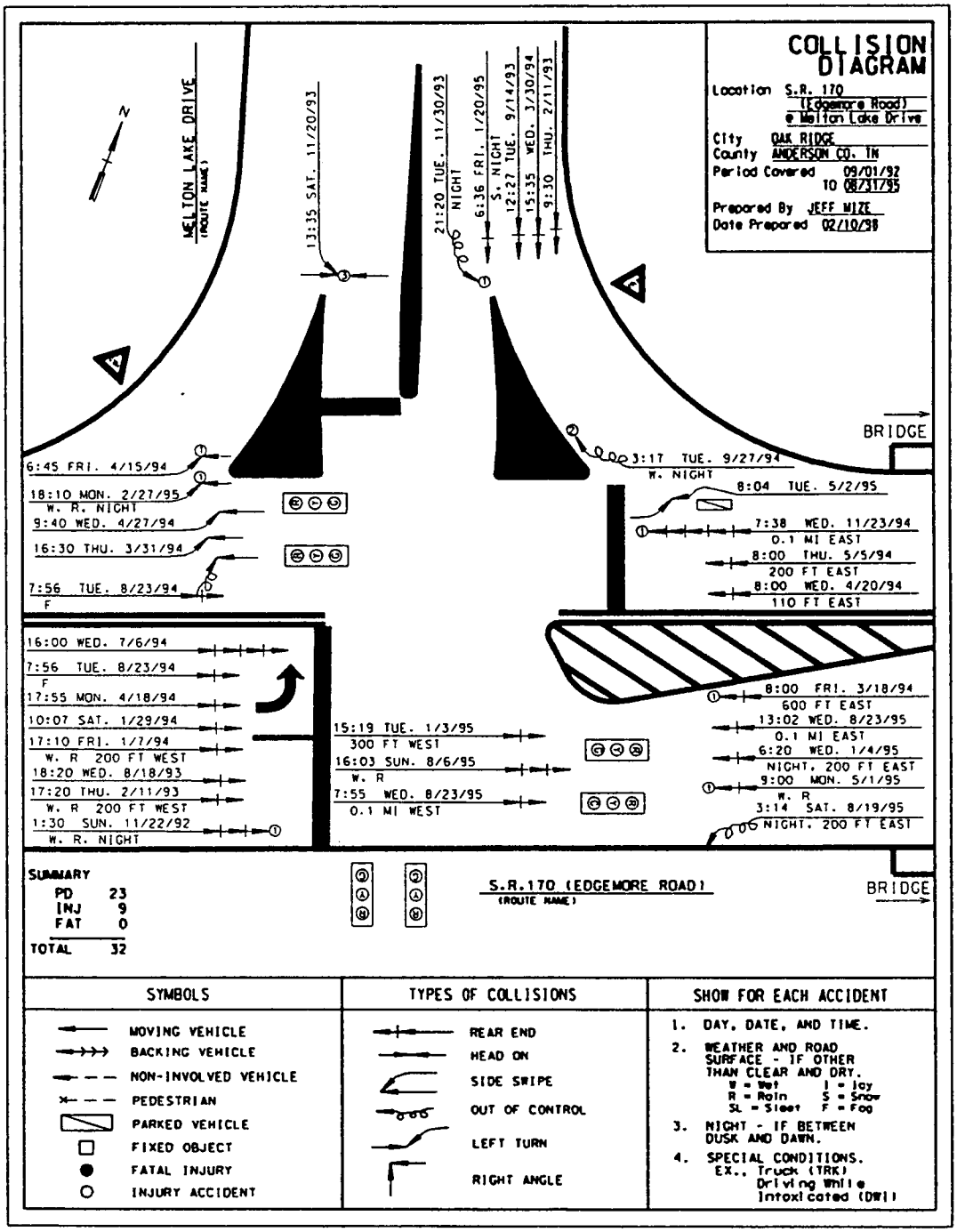


FIGURE D-4. Collision diagram for intersection of State Route 170 With Melton Lake Drive - **AFTER.**

TABLE D-2. Accident characteristic summary table for the intersection of State Route 170 with Melton Lake Drive - **AFTER.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: S.R.170 (Edgemore Raod) @ Melton Lake Drive

Period Covered: 3-years

From: 9/1/92
To: 8/31/95

City: Oak Ridge
County: Anderson

Date Prepared: 4/23/98
Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1992		1											1	1		
1993		4	1										6	2		4
1994		10	1		3								15	4		11
1995		7	1		2		1					1	10	2		8
TOTAL		23	3		6		1					1	32	9		23

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1992								1		1		
1993								1		1		1
1994								2		1	5	2
1995								3		4	2	
TOTAL								7		7	7	3

Actual Accident Rate 1.27
Statewide Average Accident Rate 0.17
Critical Accident Rate 0.37

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 5/4/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Intersection)
Location: State Route 170 (Edgemore Road) @ Melton Lake Drive
Anderson County

DATA: Period of study: 9/1/92 to 8/31/95
Number of accidents: 32 (A)
Number of days in study: 1094 (T)
TMC date : 12/14/94
Entering volume: 10150 (C)
Day of week: WED.
Type of highway: 2-Lane Rural
Statewide average accident rate: 0.17 (Ra) from Table I.
Day of week factor: 1.04 (Fd) from Table II
24 hour expansion factor 2.18 (Fp) from Table III.

24 HOUR TOTAL ENTERING VOLUME: (C)*(Fd)*(Fp) = (ΣV)
(10150) * (1.04) * (2.18) = **23012.080 (ΣV)**

EXPOSURE:
(T)*(ΣV)=(1094) * (23012) = **25175216 (E)**

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(\ 25175216\ )}{1000000} =$ **25.175 (M)**

ACTUAL ACCIDENT RATE (Ri):
$\frac{(A)\ *\ 1000000}{(T)*(\Sigma V)} = \frac{(\ 32\ )\ *\ 1000000}{(\ 25175216\ )} =$

= **1.2711 (R)**

CRITICAL ACCIDENT RATE (Rc):

Ra + K(Ra/M)$^{1/2}$ + (1/2M) =	CONFIDENCE LEVEL (%)
	99.0

(0.17) + (2.327) * (0.17 / 25.175)$^{1/2}$+(1/2(25.175))=

= **0.381 (Rc)**

SUMMARY:

Actual Accident Rate	:	**1.271 Acc/MV**
Statewide Average Accident Rate:		**0.170 Acc/MV**
Critical Accident Rate	:	**0.381 Acc/MV**

SEVERITY INDEX (SI):
SI = (No. of Fatal Accidents) + (No. of Injury Accidents) =
(Total Number of Accidents)

SI = (0) + (9) =
(32)

SEVERITY INDEX = 0.281
RATIO: R/Rc = 3.335

FIGURE D-5. Accident rate calculations for the intersection of State Route 170 with Melton Lake Drive - **AFTER.**

APPENDIX E

LOCATION 3.

I-640 West Exit Ramp
to State Route 9

APPENDIX E

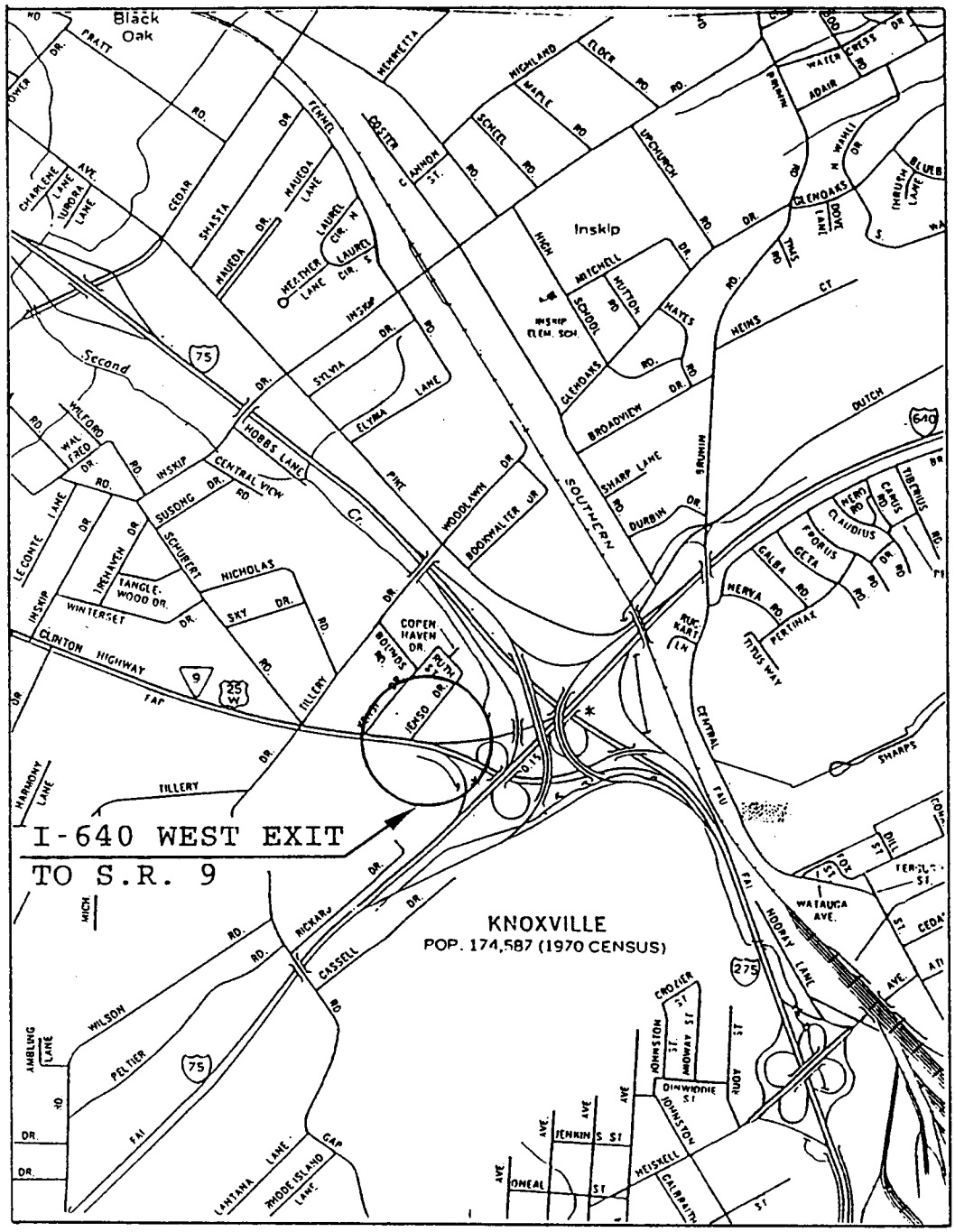


FIGURE E-1. General location map for the I-640 West Bound Exit Ramp to State Route 9 (Clinton Highway), Knox County, TN.

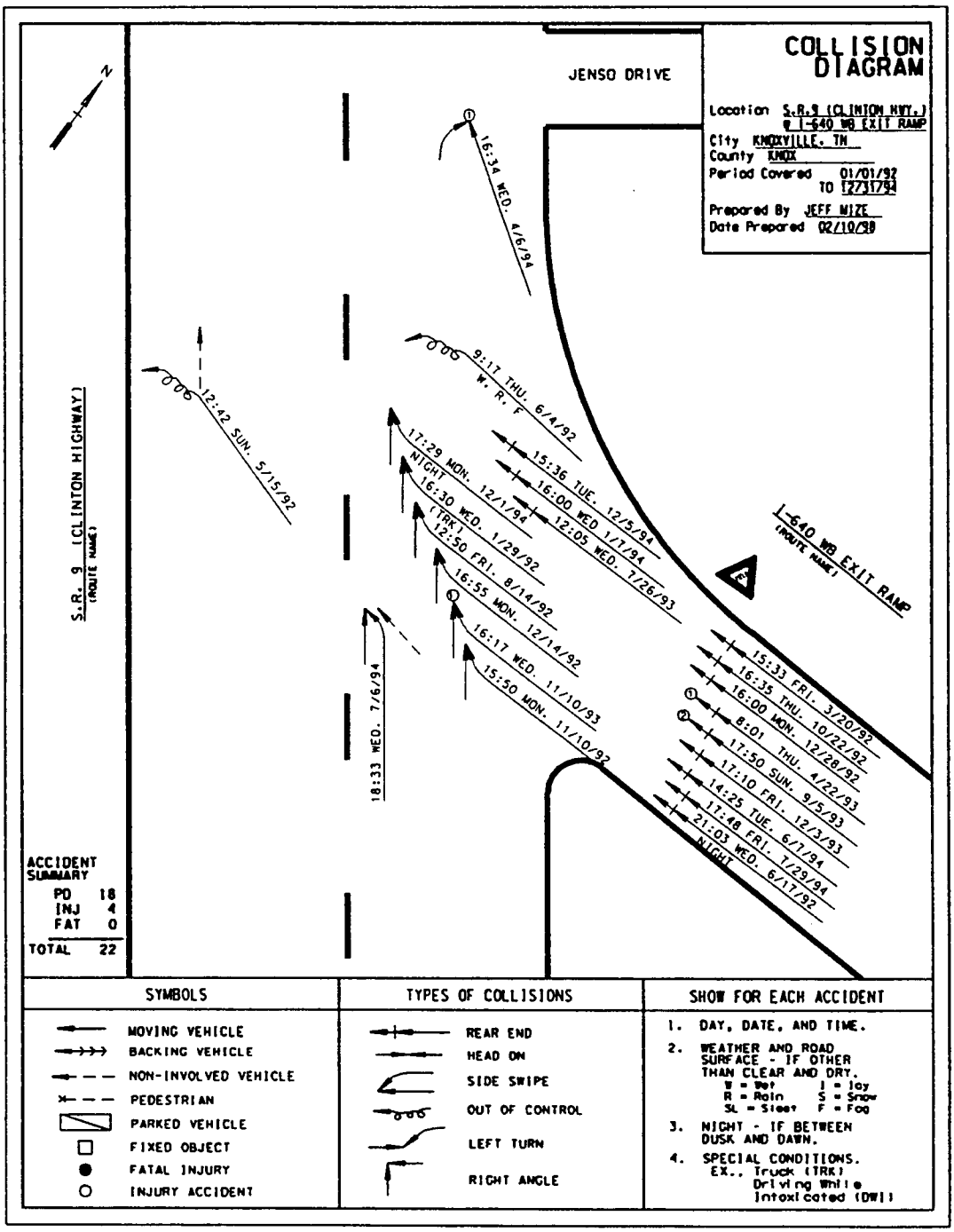


FIGURE E-2. Collision diagram for the I-640 West Bound Exit Ramp to State Route 9 - **BEFORE.**

TABLE E-1. Accident characteristic summary table for the I-640 West Bound Exit Ramp to State Route 9 - **BEFORE.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: I-640 exit ramp @ S.R. 9 (Clinton Highway)
City: Knoxville
County: Knox

Period Covered: 3-years
Date Prepared: 4/23/98
Prepared By: Jeff Mize

From: 1/1/92
To: 12/31/94

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1992		4	2	4					3				10			7
1993		4		1					1				5	3		1
1994		4		2		2			1				7	1		4
TOTAL		12	2	7		2			5				22	4		12

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1992								1		1		1
1993											1	2
1994												1
TOTAL								1		1	1	4

Actual Accident Rate 1.64
Statewide Average Accident Rate 0.34
Critical Accident Rate 0.75

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 5/4/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Intersection)
Location: I-640 exit ramp @ S.R. 9 (Clinton Highway)
Knox County

DATA: Period of study: 1/1/92 to 12/31/94
Number of accidents: 22 (A)
Number of days in study: 1095 (T)
TMC date : 1994 ADT
Entering volume: 12271 (C)
Day of week:
Type of highway: 4-Lane Urban
Statewide average accident rate: 0.34 (Ra) from Table I.
Day of week factor: 1 (Fd) from Table II
24 hour expansion factor 1 (Fp) from Table III.

24 HOUR TOTAL ENTERING VOLUME: (C)*(Fd)*(Fp) = (ΣV)
(12271) * (1) * (1) = **12271.000 (ΣV)**

EXPOSURE:
(T)*(ΣV)=(1095) * (12271) = **13436745 (E)**

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(13436745)}{1000000} =$ **13.437 (M)**

ACTUAL ACCIDENT RATE (Ri):

$$\frac{(A) * 1000000}{(T)*(\Sigma V)} = \frac{(22) * 1000000}{(13436745)} =$$

= **1.6373 (R)**

CRITICAL ACCIDENT RATE (Rc):

	CONFIDENCE LEVEL (%)
$Ra + K(Ra/M)^{1/2} + (1/2M) =$	99.0

$$(0.34) + (2.327) * \left(\frac{0.34}{13.437} \right)^{1/2} + (1/2(13.437)) =$$

= **0.747 (Rc)**

SUMMARY:

Actual Accident Rate :	**1.637 Acc/MV**
Statewide Average Accident Rate:	**0.340 Acc/MV**
Critical Accident Rate :	**0.747 Acc/MV**

SEVERITY INDEX (SI):

$$SI = \frac{(\text{No. of Fatal Accidents}) + (\text{No. of Injury Accidents})}{(\text{Total Number of Accidents})} =$$

$$SI = \frac{(0) + (4)}{(22)} =$$

SEVERITY INDEX = 0.182
RATIO: R/Rc = 2.191

FIGURE E-3. Accident rate calculations for the I-640 West Bound Exit Ramp to State Route 9 - **BEFORE.**

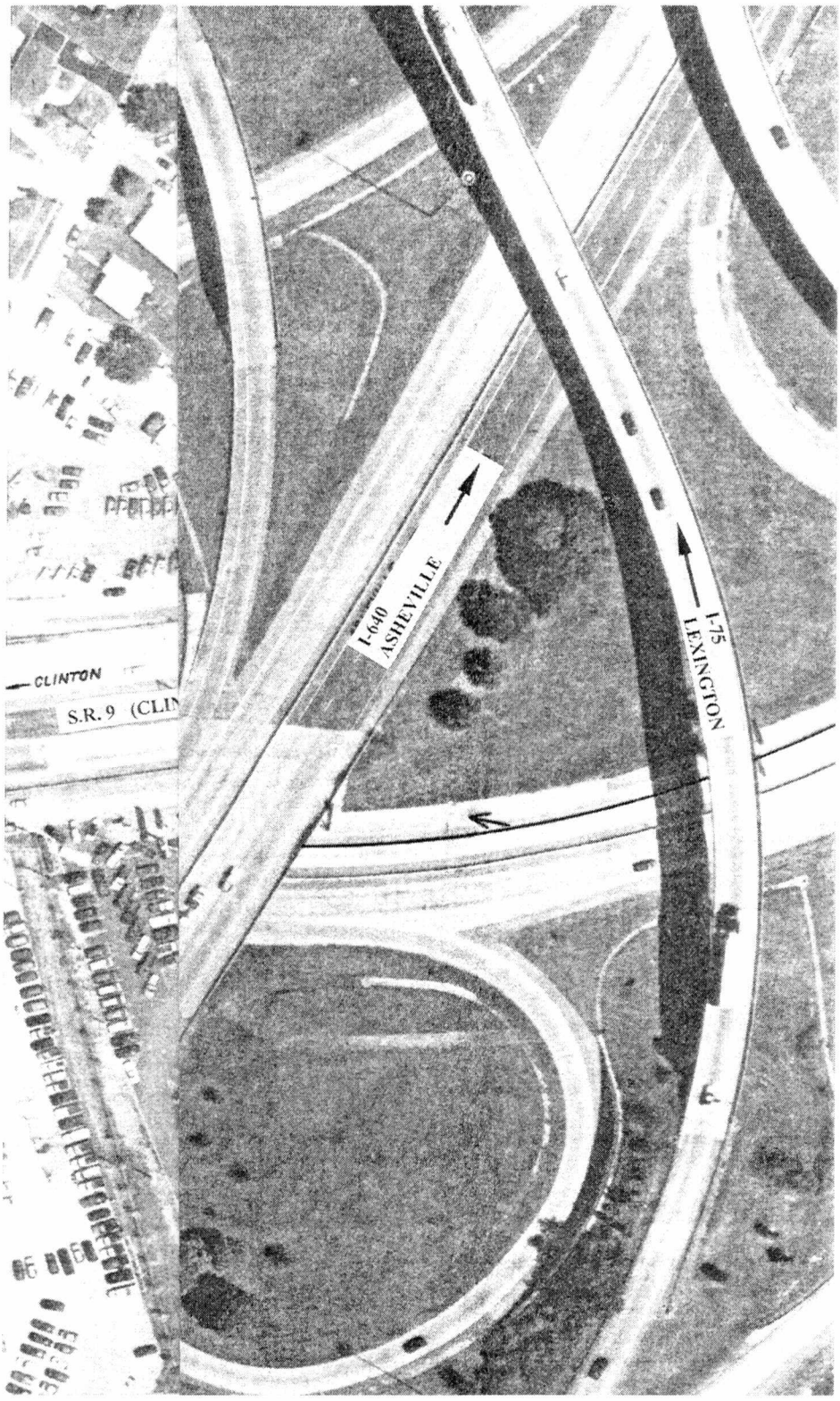


FIGURE E-4.

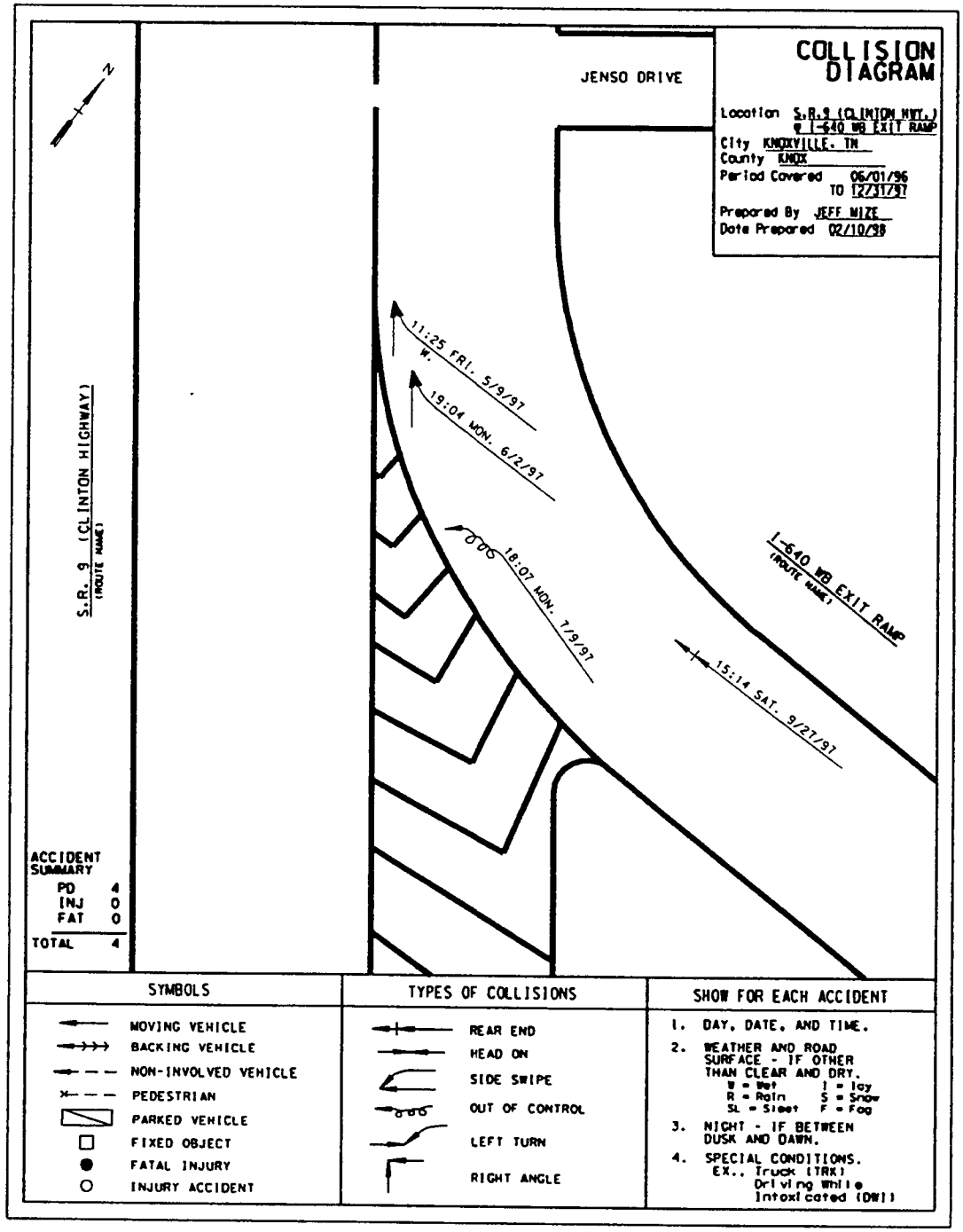


FIGURE E-5. Collision diagram for the I-640 West Bound Exit Ramp to State Route 9 - **AFTER.**

TABLE E-2. Accident characteristic summary table for the I-640 West Bound Exit Ramp to State Route 9 - **AFTER.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: I-640 exit ramp @ S.R. 9 (Clinton Highway)

Period Covered: 1.25-years

From: 6/1/96
To: 12/31/97

City: Knoxville
County: Knox

Date Prepared: 4/23/98
Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1996				2		2							2			4
1997		1	1										2			
TOTAL		1	1	2		2							4			4

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1996											1	
1997												
TOTAL											1	

Actual Accident Rate 0.49
Statewide Average Accident Rate 0.34
Critical Accident Rate 0.88

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 5/4/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Intersection)
Location: I-640 exit ramp @ S.R. 9 (Clinton Highway)
Knox County

DATA: Period of study: 4/1/96 to 12/31/97
Number of accidents: 4 (A)
Number of days in study: 639 (T)
TMC date : 1997 ADT
Entering volume: 12795 (C)
Day of week:
Type of highway: 4-Lane Urban
Statewide average accident rate: 0.34 (Ra) from Table I.
Day of week factor: 1 (Fd) from Table II
24 hour expansion factor 1 (Fp) from Table III.

24 HOUR TOTAL ENTERING VOLUME: (C)*(Fd)*(Fp) = (ΣV)
(12795) * (1) * (1) = **12795.000 (ΣV)**

EXPOSURE:
(T)*(ΣV)=(639) * (12795) = **8176005 (E)**

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(\ 8176005\ )}{1000000} =$ **8.176 (M)**

ACTUAL ACCIDENT RATE (Ri):
$$\frac{(A) * 1000000}{(T)*(\Sigma V)} = \frac{(\ 4\ ) * 1000000}{(\ 8176005\ )} =$$

= **0.4892 (R)**

CRITICAL ACCIDENT RATE (Rc):

CONFIDENCE LEVEL (%)
99.0

$Ra + K(Ra/M)^{1/2} + (1/2M) =$

$(0.34) + (2.327) * (0.34 / 8.176)^{1/2} + (1/2(8.176)) =$

= **0.876 (Rc)**

SUMMARY:

Actual Accident Rate	:	**0.489 Acc/MV**
Statewide Average Accident Rate:		**0.340 Acc/MV**
Critical Accident Rate	:	**0.876 Acc/MV**

SEVERITY INDEX (SI):
SI = (No. of Fatal Accidents) + (No. of Injury Accidents) =
(Total Number of Accidents)

$SI = \frac{(\ 0\ ) + (\ 0\ )}{(\ 4\ )} =$

SEVERITY INDEX = 0.000
RATIO: R/Rc = 0.559

FIGURE E-6. Accident rate calculations for the I-640 West Bound Exit Ramp to State Route 9 - **AFTER.**

APPENDIX F

LOCATION 4.

State Route 170
near Naff Road

APPENDIX F

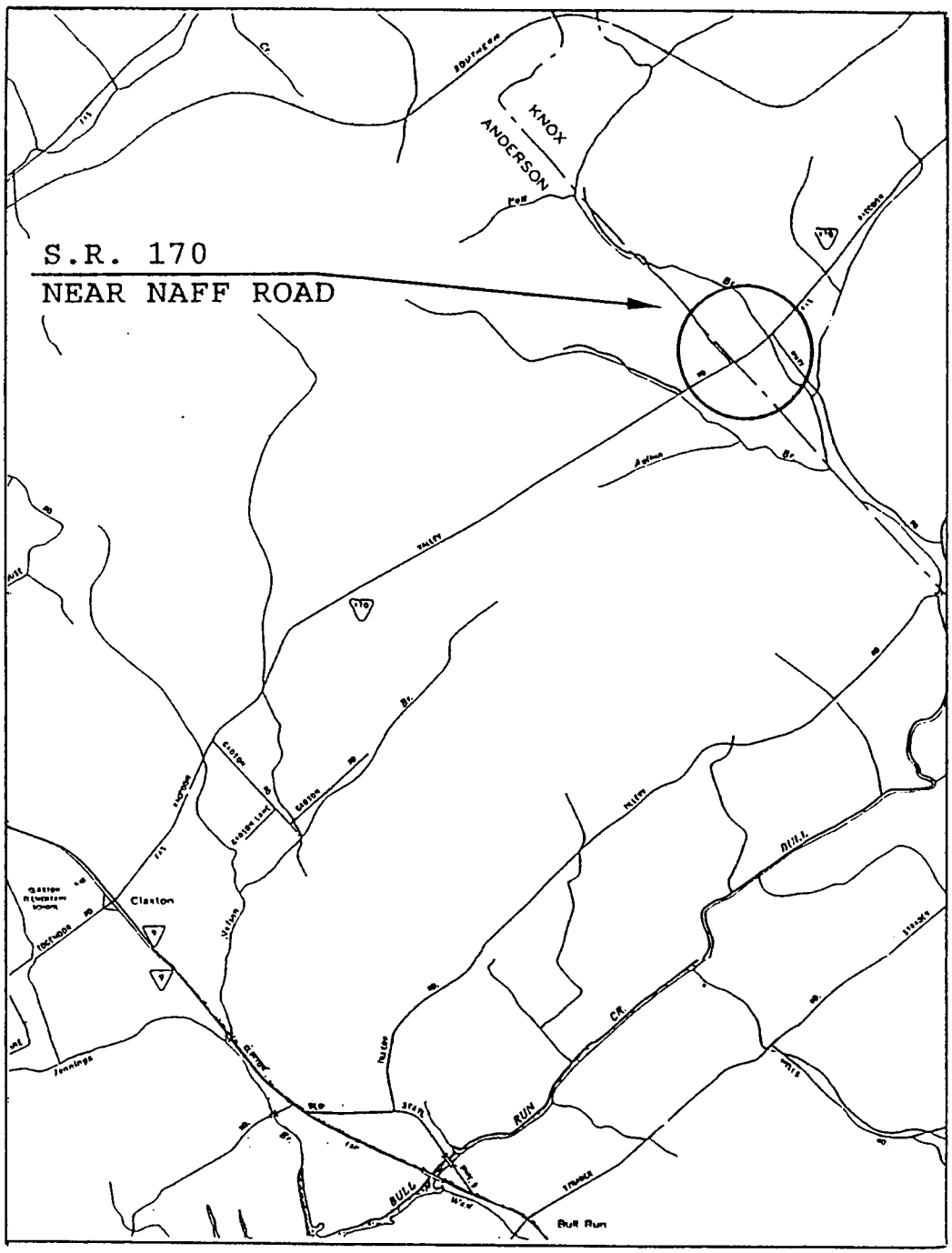


FIGURE F-1. General location map for the State Route 170 (Raccoon Valley Road) near the intersection of Naff Road, Knox County, TN.

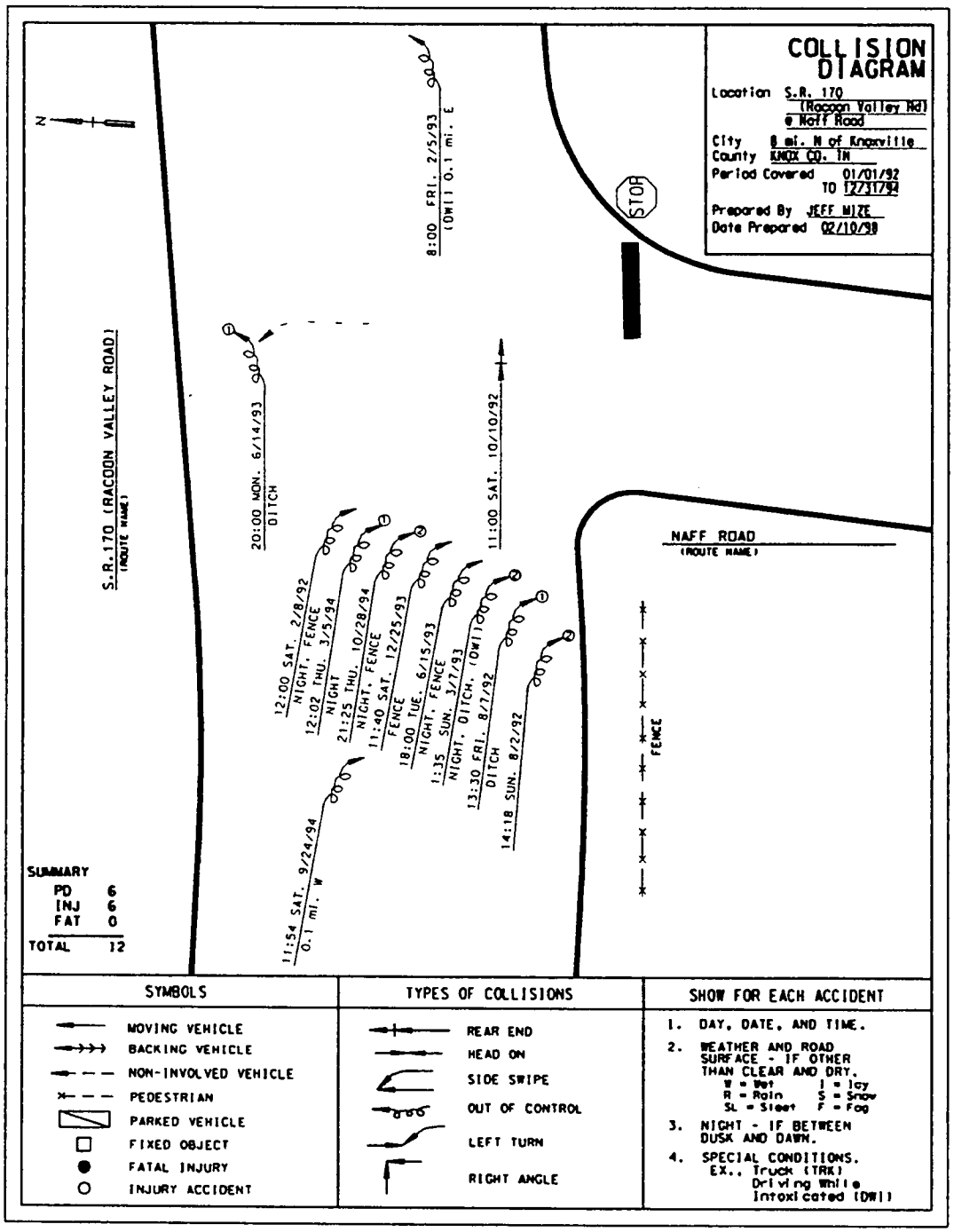


FIGURE F-2. Collision diagram for State Route 170 near the intersection of Naff Road - **BEFORE.**

TABLE F-1. Accident characteristic summary table for State Route 170 near the intersection of Naff Road - **Before.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: S.R.170 (Racoon Valley Road) near intersection of Naff Road

Period Covered: 3-years

From: 1/1/92

To: 12/31/94

City: ----

County: Knox

Date Prepared: 4/23/98

Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1992		1	3										4	2		2
1993			5										5	2		3
1994			3										3	2		1
TOTAL		1	11										12	6		6

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1992	1									1	1	2
1993	1					2				2	2	1
1994										2		
TOTAL	2					2				5	3	3

Actual Accident Rate	14.10
Statewide Average Accident Rate	1.77
Critical Accident Rate	5.71

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 4/23/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Section)
Location: S.R. 170 (Raccoon Valley Rd.) near Naff Rd.
Knox County

DATA: Period of study: 1/1/92 to 12/31/94
Number of accidents: 12 (A)
Number of days in study: 1095 (B)
1994 ADT: 2590 (C)
Length of study section: 0.3 (D)
Type of highway: 2-LANE - RURAL
Statewide average accident rate: 1.77 (Ra) from Table I.

EXPOSURE:
(B)*(C)*(D)= (1095)*(2590)*(0.30) =
850815 (E)

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(\ 850815\ )}{1000000} =$ **0.851 (M)**

ACTUAL ACCIDENT RATE (Rs):
$\frac{(A)*1000000}{(E)} = \frac{(\ 12\ ) * 1000000}{(\ 850815\ )} =$

= **14.104 (R)**

CRITICAL ACCIDENT RATE (Rc):

CONFIDENCE LEVEL (%)
99.0

$Ra + K(Ra/M)^{1/2} + (1/2M) =$

$(1.77) + 2.327 * (1.77 / 0.851)^{1/2} + (1/2 \ 0.851)) =$

= **5.714 (Rc)**

SUMMARY:
Actual Accident Rate : **14.104 Acc/MVM**
Statewide Average Accident Rate: **1.770 Acc/MVM**
Critical Accident Rate : **5.714 Acc/MVM**

SEVERITY INDEX (SI):
SI = (No. of Fatal Accidents) + (No. of Injury Accidents)
(Total Number of Accidents)

$SI = \frac{(\ 0\ ) + (\ 6\ )}{(\ 12\ )} =$

SEVERITY INDEX = 0.500
RATIO: R/Rc = 2.468

FIGURE F-3. Accident rate calculations for State Route 170 near the intersection of Naff Road - **BEFORE.**

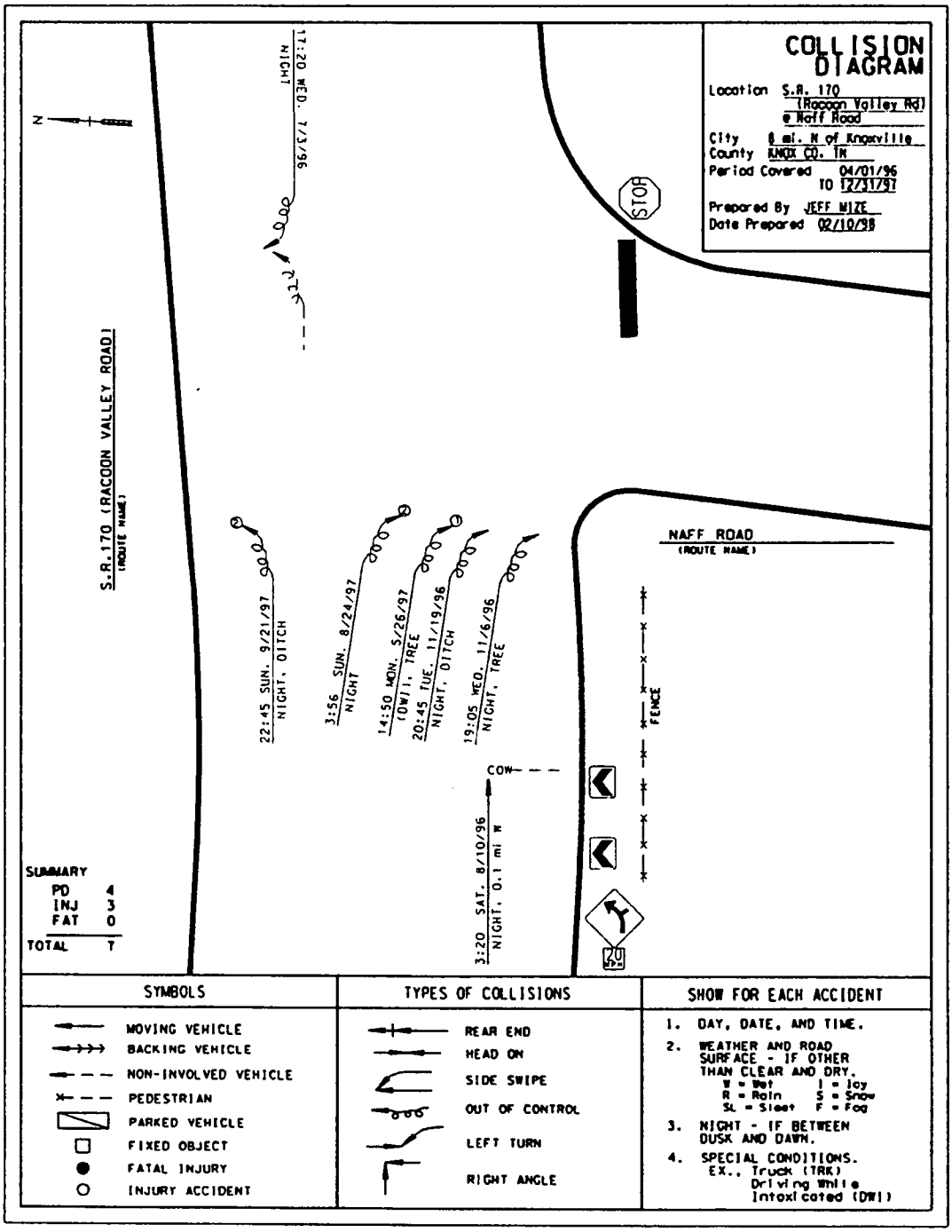


FIGURE F-4. Collision diagram for State Route 170 near the intersection of Naff Road - **AFTER.**

TABLE F-2. Accident characteristic summary table for State Route 170 near the intersection of Naff Road - **AFTER.**

ACCIDENT CHARACTERISTIC SUMMARY TABLE

Location: S.R.170 (Racoon Valley Road) near intersection of Naff Road
Period Covered: 1.75-years
From: 4/1/96
To: 12/31/97

City: ----
County: Knox
Date Prepared: 4/23/98
Prepared By: Jeff Mize

TYPE

YEAR	RIGHT ANGLE	REAR END	OUT OF CONTROL	SIDE SWIPE	LEFT TURN	LANE CHANGE	PASSING	HEAD ON	MERGE	PEDESTRIAN	BACKING VEH	PKD VEH	TOTAL ACC	INJ	FATAL	PROP DAM
1996			3										4			4
1997			3										3	3		
TOTAL			6										7	3		4

CONTRIBUTING FACTORS

YEAR	STOPPED OR SLOWED VEH	SNOW & ICE	MECHANICAL FAILURE	OBJECT IN ROADWAY	PREVIOUS ACCIDENT	DWI	FELL ASLEEP	WET PVMT	OUT OF COUNTY	NIGHT	AM PEAK	PM PEAK
1996				1				2		4		
1997						1				2		
TOTAL				1		1		2		6		0

Actual Accident Rate	13.28
Statewide Average Accident Rate	1.77
Critical Accident Rate	6.98

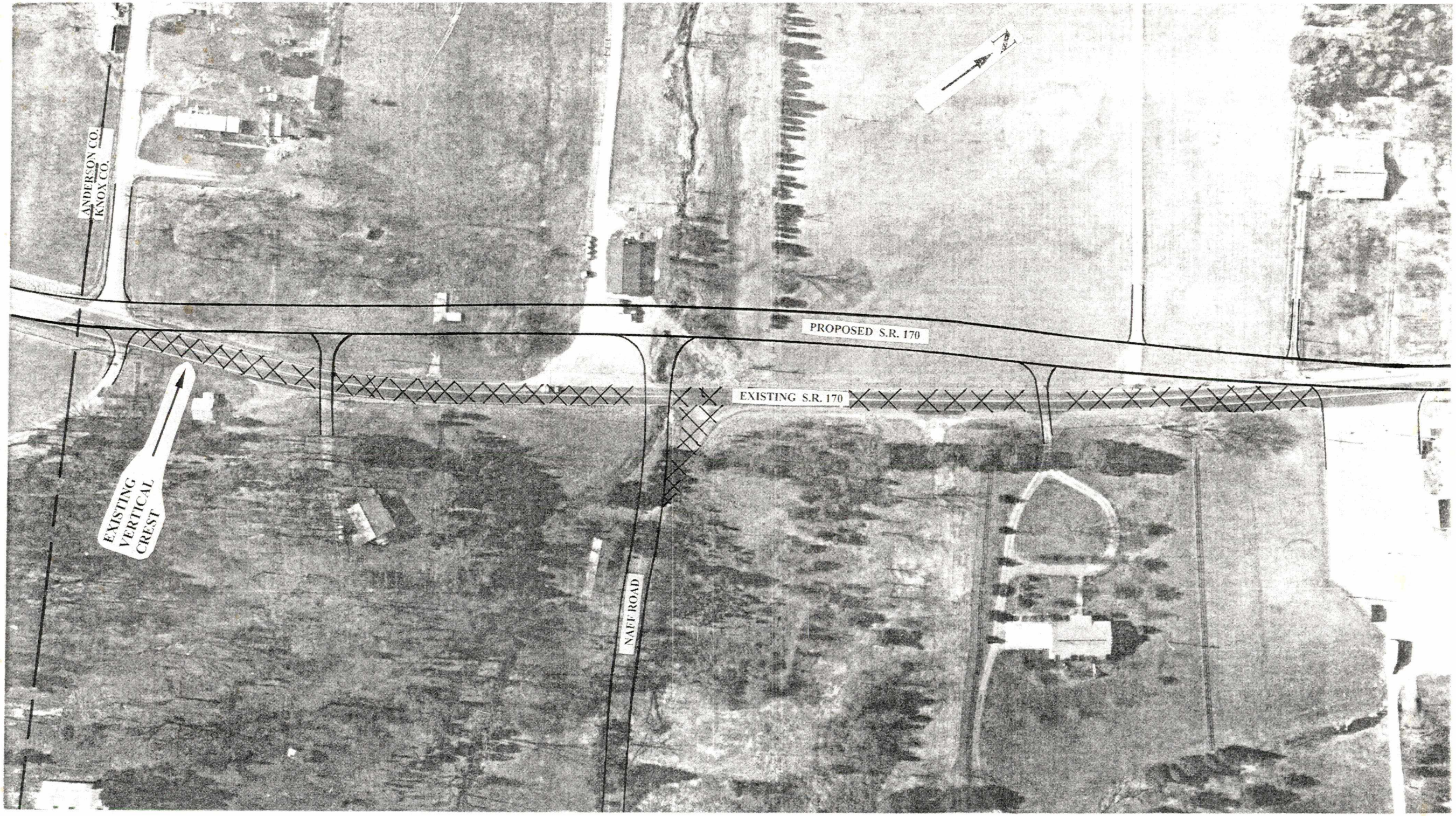


FIGURE F-5. Functional drawing for proposed realignment of State Route 170 near the intersection of Naff Road.

TENNESSEE DEPARTMENT OF TRANSPORTATION
SURVEY & DESIGN DEPARTMENT
KNOXVILLE

Date: 4/23/98 **** ACCIDENT RATES
Calc. by: Jeff Mize (Section)
Location: S.R. 170 (Raccoon Valley Rd.) near Naff Rd.
Knox County

DATA: Period of study: 4/1/96 to 12/31/97
Number of accidents: 7 (A)
Number of days in study: 639 (B)
1997 ADT: 2750 (C)
Length of study section: 0.3 (D)
Type of highway: 2-LANE - RURAL
Statewide average accident rate: 1.77 (Ra) from Table I.

EXPOSURE:
(B)*(C)*(D)= (639)*(2750)*(0.30) =
527175 (E)

EXPOSURE RATE: $\frac{(E)}{1000000} = \frac{(\ 527175\ )}{1000000} =$ **0.527 (M)**

ACTUAL ACCIDENT RATE (Rs):
$\frac{(A)*1000000}{(E)} = \frac{(\ 7\ ) * 1000000}{(\ 527175\ )} =$

= **13.278 (R)**

CRITICAL ACCIDENT RATE (Rc):

CONFIDENCE LEVEL (%)
99.0

$Ra + K(Ra/M)^{1/2} + (1/2M) =$

$(1.77) + 2.327 * (1.77 / 0.527)^{1/2} + (1/2 \ 0.527)) =$

= **6.982 (Rc)**

SUMMARY:
Actual Accident Rate : **13.278 Acc/MVM**
Statewide Average Accident Rate: **1.770 Acc/MVM**
Critical Accident Rate : **6.982 Acc/MVM**

SEVERITY INDEX (SI):
SI = (No. of Fatal Accidents) + (No. of Injury Accidents)
(Total Number of Accidents)

$SI = \frac{(\ 0\ )+(\ 3\ )}{(\ 7\ )} =$

SEVERITY INDEX = 0.429
RATIO: R/Rc = 1.902

FIGURE F-6. Accident rate calculations for State Route 170 near the intersection of Naff Road - **AFTER.**

VITA

Ronald Jeffrey Mize, Jr. was born in Knoxville, Tennessee on June 24, 1973. A native of Fountain City in North Knoxville, Mr. Mize attended the public schools of Knox County where he graduated from Central High School in May of 1991. He entered the University of Tennessee, Knoxville in August of 1991 and chose to pursue a degree in Civil Engineering. While an undergraduate, Mr. Mize added to his academic experience with the Engineering Co-op Program where he served as a Civil Engineer Intern for the City of Maryville, Tennessee until he completed his degree with a Bachelor of Science in Civil Engineering in May of 1996. That same summer, Mr. Mize accepted a graduate assistantship offered by the Southeastern Transportation Center in conjunction with the Civil Engineering Department of the University of Tennessee, Knoxville. While enrolled in graduate school, he served as a Civil Engineer Intern for the Knox County Highway and Public Works Department until January of 1997, when he accepted a full-time position with the Region 1 Design Division of the Tennessee Department of Transportation. He continued to pursue his Master of Science Degree in Civil Engineering while employed at TDOT and received his degree in May of 1998.

Mr. Mize is presently a Roadway Specialist 2 with the Tennessee Department of Transportation and plans to apply for Professional Engineering certification in the spring of 1999.