Hunter, W.W., Council, F.M., and Dutt, A.K. (1977). Project Selection fo r Roadside Hazards Elimination, Vol. 1: Final Report. Chapel Hill NC: University of North Carolina Highway Safety Research Center.

PROJECT SELECTION FOR ROADSIDE HAZARDS ELIMINATION

VOLUME I

FINAL REPORT

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May 1977

UNC/HSRC-77/5/2

Prepared by the State of North Carolina

In cooperation with the

U.S. Department of Transportation

Federal Highway Administration

ABSTRACT

This report (Volume I) describes the development of a computerized system to facilitate the prioritizing of roadside fixed object treatments. The system was developed for the Traffic Engineering Branch of the North Carolina Division of Highways. Volume II, under separate cover, is a User Manual for the system.

The system is designed to perform economic analyses of various fixed object improvements on an areawide (or roadway segment) basis, such as determining the effect of removing all trees within 30 feet of the edge of pavement on rural, two-lane, secondary roads in the Piedmont area. Inputs to the economic analyses include: (1) a determination of the frequency and severity of the most affectable accidents for a given hazard/treatment combination, (2) the expected reductions in fatal, injury, and property damage only accidents associated with implementation of the treatment, and (3) initial costs, maintenance costs, and repair costs over the service life of each treatment. Through the economic analysis, the Net Discounted Present Value and Benefit/Cost Ratio is computed for each candidate fixed object treatment, and a priority ranking is developed based on comparisons of net present value.

Analyses were concerned with the following fixed object hazards:

1. Utility poles.
2. Trees.
3. Exposed bridge rail ends.
4. Substandard bridge rail.
5. Bridge piers (underpasses).
6. Rigid sign and luminaire supports.
7. Guardrail ends.

8. Median-involved accidents.

Several data files were used to develop the estimates of hazards and affectable accidents used in the analyses, including the Traffic Engineering Branch "Roadside Fixed Object Hazards Inventory," 1973-1975 N. C. Accident Tapes, and the N. C. Division of Highways' mileposted accident tape, mileage inventory file, and structures file.

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ACKNOWLEDGMENTS

The authors would like to express sincere thanks to the many individuals involved with the preparation of this report. A liaison committee was formed to provide project guidance, and this group aided in many decisions, especially the Traffic Engineering Branch personnel. Members of the liaison committee were H.C. Rhudy, J.M. Lynch, R.J. Dodge, G.G. Grigg, Jr., C.D. Adkins, M.L. Webster, K.W. Ivey, and W.H. Michie. Appreciation is also expressed to the other Division of Highway personnel who contributed, especially those in the Roadway Design and Maintenance Branches. Thanks are also given for the aid provided by those from the Federal Government, other research organizations, other state highway departments, and manufacturing concerns.

HSRC staff should also be commended for their efforts in the many phases of report preparation. These included Anita Leung and Nancy Woody for the major programming effort; David Cole and Beth Leggett for data analysis and report preparation; Dennis Ryan, Elizabeth Hamilton, and Rena Headen for supplemental programming; Rebecca Stutts, Bill Pope, and Frank Roediger for graphics; and Teresa Parks, Donna Suttles, Peggy James, Ellen Overman, and Lee Estes for secretarial assistance.

CHAPTER 1 - INTRODUCTION

In recent years, increasing emphasis has been placed on either clearing the roadside of hazardous fixed objects within approximately 30 feet of the edge of pavement or modifying the terrain so that an effective recovery area exists. In other words, the attempt has been to make the roadside more forgiving for those who stray from the roadway through driver error or roadway system misinterpretation or for those who are forced off the roadway by the actions of others. In this regard, increasing amounts of funding to treat these off-road hazards have become available to state highway departments through the Federal Highway Safety Acts. However, these funds are limited, and highway departments have become increasingly concerned with deploying the funding in a cost-effective manner.

This report (Volume I) describes the development of a computerized system to facilitate the prioritizing of roadside fixed-object treatments. The University of North Carolina Highway Safety Research Center (HSRC) performed the work for the Traffic Engineering Branch (TE) of the North Carolina Division of Highways (DOH). Volume II, under seperate cover is a User Manual for the developed system.

The system methodology is developed around economic analyses of various roadside safety improvements on an areawide basis such as the effect of removing all trees within 30 feet of the edge of pavement, protecting exposed bridge piers, etc. Inputs to the economic analyses include a determination of the frequency and severity of the most affectable accidents for a given treatment along with the expected reductions in fatal, injury, and property damage only (PDO) accidents associated with implementation of the treatment. Benefits are developed based on accident savings by assigning dollar costs to fatal accidents, injury accidents, and PDO accidents. Cost components include initial costs, maintenance costs, and repair costs over the service life of each treatment. Through the economic analysis, the Net Discounted Present Value is determined for each candidate program, and a priority ranking is developed based on comparisons of net present value. For alternatives with different service lives, the equivalent annual cash flow is calculated.

The system producing this priority ranking has been designed to analyze "areawide" improvements, and because this differs to some extent from many existing fixed object programs which are aimed at spot locations, some discussion is appropriate. For many years, the Traffic Engineering Branch has used a hazardous spot identification program which detects specific hazardous locations along the roadway based on above-average frequency and/or severity of accidents. These high accident route-specific spots (which are also expanded into longer segments known as "concentrations" and "sections") are then ranked in order to determine priorities for high accident location funding. Thus, with respect to the fixed object collisions of interest in the current study, if a given spot had an inordinately high number and/or severity of accidents involving a particular fixed object (e.g. a bridge end), then this spot location would be detected by the existing program. Upon detection the location would be corrected.

This procedure, of course, is based on the assumption that a given hazard (or a given group of hazards on a short roadway section) will be struck with a high enough frequency to be detected as a high accident spot. This, however, is not usually found to be the case. While trees are involved in quite a few fatal accidents, there are very few times in which a single tree at a given mileposted spot can be identified as a hazardous obstacle which should be removed. Most spots so identified are, in fact intersection locations. Thus, there is a need for a methodology to rank roadside fixed object correction programs on an areawide basis.

It is with this need in mind that this system was developed. In this case the programs studied can be thought of as hazard/treatment/roadway segment combinations--that is, a given hazard with an appropriate treatment for a given type of roadway segment. The type of roadway segment in question is the expanded "spot"--a spot which would include segments on more than one particular roadway route. The developed methodology will allow the engineer to perform the economic analysis for a particular hazard/treatment combination for any expanded "spot" ranging from a statewide area down to a much smaller area defined by the following variables:

1. Location (urban or rural)
2. Area in the state (Coastal Plain, Piedmont, Mountainous).
3. Highway type (Interstate, U.S., N.C., secondary roads, city streets)
4. Number of lanes (two-lane, four or more lanes undivided, four or more lanes divided)

and in some cases the highway segment is further defined by:

5. Highway character (intersection, non-intersection)
6. Highway features (tangent section, curve section)
7. Median width (1-12 feet, 13-30 feet, 31-60 feet, 61+ feet)

Thus, the design methodology will allow one to analyze a combination such as a program aimed at removing all trees from the roadside on all curved, non-intersection segments of two-lane, N.C. highways in the rural regions of the Coastal Plain. This particular combination could then be compared to any other hazard/treatment/segment combination defined by the engineer.

Disucssions with the project liaison committee led to the selection of the following candidate treatment programs which are designed to affect a variety of fixed objects (e.g. sign posts, bridge ends, trees, etc):

1. Improved recovery areas - paved shoulders, cleared roadside, etc.
2. Improved railroad grade crossing hardware - if related to fixed

object accidents.

3. Delineation - if related to fixed object accidents.
4. Skidproofing - if related to fixed object accidents.
5. Bridge rail and bridge end treatment.
6. Guardrail treatment - including terminal.
7. Median barrier treatment - including terminal.
8. Impact attenautors.
9. Signing and lighting supports - removal, protected, or made breakaway.
10. Utility poles - removal, protected, or made breakaway.
11. Tree elimination.
12. Other fixed object treatments - as related to curbs, culverts, raised inlets, etc.

As many of these concepts were evaluated as possible. Candidate programs were eliminated if basic input data, such as estimates of most affectable accidents or expected reductions in accident severities, could not be determined (e.g. skidproofing) or if examination of accident data revealed no significant accident frequency (e.g. railroad grade crossing hardware.)

A number of data files were used to develop the estimates of hazards and affectable accidents used in the economic analyses. The Traffic Engineering Branch "Roadside Fixed Object Hazards Inventory" (Grigg, 1974), a one-time sample of roadside hazards as required by Section 210 of the Federal Highway Safety Act of 1973, was used extensively, along with the DOH structures and mileage inventory files to categorize fixed object hazards by: (1) location (urban or rural), (2) area within state (basically mountainous, piedmont, or coastal plain), (3) highway type (Interstate, U.S., N.C. Secondary Road, and City Streets) and (4) number of lanes (2-lane, 4-lane divided, and 4-lane undivided.)

The affectable accident information was gathered primarily from the 1973-1975 N.C. Accident Tapes. Table 1 presents both the frequency and the resulting severity of all single vehicle fixed objects accidents occurring on N.C. roadways in 1975. Because of the need for more specific information, this base data was supplemented by information from the 05 tape[1], the mileage inventory file, the structures file, the 1971-1972 Accident tapes (which contain information on curves versus tangent sections), and hard copies of accident reports concerned with bridges and guardrails. For the latter category, the sketch and narrative had to be used to determine the point of impact (bridge end, bridge rail, guardrail end, guardrail section, etc.). Two complete years of accident narratives involving these fixed objects were examined.

Finally, considerable effort was involved in the development of appropriate accident reduction factors (for fatal, injury, and PDO accidents). A literature review was conducted which included several computer searches. Contacts were made with various other state highway departments (including California, Texas, Pennsylvania, New York, Washington and Ohio) and other research agencies (including Southwest Research Institute, Texas Transportation Institute, and CALSPAN Corporation) in an attempt to gather results relating to fixed-object accident research from either past or present contracts. Visits were also made to several offices within the Federal Highway Administration. The FHWA office of Research was particularly helpful in their recommendations concerning contacts with agencies performing ongoing research. Finally, the U.S. Department of Transportation Library was searched for applicable publications.

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[1]The 05 tape contains data on all reported traffic accidents on or within 500 feet (on intersecting roads) of all rural primary roadways in N.C. The data is arranged by county, route, and milepost.

Table 1. Object struck by accident severity for all single vehicle fixed object accidents occurring in North Carolina in 1975.

Object Struck	Fatal	Injury	Property Damage Only	Not Stated	Total
Tree	106 (2.6%)	1948 (48.5%)	1802 (44.9%)	158 (3.9%)	4014 (11.6%)
Utility Pole	40 (1.0%)	1953 (47.0%)	2044 (49.2%)	117 (2.8%)	4154 (12.0%)
Fence, Fence Post	15 (1.0%)	401 (26.1%)	1051 (68.3%)	72 (4.7%)	1539 (4.4%)
Guardrail, Post (Median)	5 (2.0%)	86 (33.7%)	161 (63.1%)	3 (1.2%)	255 (0.7%)
Guardrail, Post (Shoulder)	5 (0.8%)	227 (35.1%)	400 (61.8%)	15 (2.3%)	647 (1.9%)
Bridge	41 (4.7%)	371 (42.8%)	429 (49.5%)	25 (2.9%)	866 (2.5%)
Underpass	6 (6.7%)	32 (36.0%)	51 (57.3%)	0 (0.0%)	89 (0.3%)
Traffic Island, Curb	14 (1.3%)	475 (42.9%)	592 (53.5%)	25 (2.3%)	1106 (3.2%)
Sign, Sign Post	12 (0.8%)	429 (30.3%)	937 (66.1%)	39 (2.8%)	1417 (4.1%)
Animal	0 (0.0%)	36 (41.4%)	49 (56.3%)	2 (2.3%)	87 (0.3%)
Ditch Bank	149 (1.2%)	5449 (43.2%)	6571 (52.0%)	457 (3.6%)	12626 (36.5%)
Parked Vehicle	0 (0.0%)	21 (61.8%)	12 (35.3%)	1 (2.9%)	34 (0.1%)
Other Object	0 (0.0%)	11 (73.3%)	4 (26.7%)	0 (0.0%)	15 (0.0%)
Pedestrian	35 (1.0%)	1347 (37.0%)	2121 (58.3%)	133 (3.7%)	3636 (10.5%)
None	58 (1.5%)	1691 (43.9%)	1996 (51.8%)	105 (2.7%)	3850 (11.1%)
Not Stated	5 (1.7%)	106 (36.6%)	167 (57.6%)	12 (4.1%)	290 (0.8%)
Total	491 (1.4%)	14583 (42.1%)	18387 (53.1%)	1164 (3.4%)	34625 (100.0%)

This methodology requiring all these efforts has been developed in an attempt to provide the highway administrator/engineer with a rational tool for comparing programs so that limited safety improvement dollars can be applied to the most effective treatments. However, the priority ranking alone cannot be used to formulate the most appropriate budget package, since the ranking itself does not guarantee the global maximization of benefits and does not consider all existing funding constraints. A further refinement, the use of allocation procedures such as dynamic or linear programming algorithms , would likely be necessary in the development of a budget package that maximizes benefits. However, even with this added sophistication, the system would remain only a very useful tool -- it would not be the sole basis for final decisions. It would certainly be hoped, however, that the system detailed in the following sections can and will serve as an important aid.

CHAPTER 2 - METHODOLOGY

The methodology developed and used in this study is an extension of a system employed in an earlier study (Council and Hunter, 1975) performed for the Motor Vehicle Manufacturers Association of the United States, Incorporated (MVMA). The basic differences are: (1) the current study deals only with fixed object accidents and related countermeasures rather than roadway safety countermeasures of all types, and (2) the quality of the accident and hazards data is much higher than in the original study.

The basic tasks leading to the priority ranking of fixed-object improvement programs are shown in Figure 1. A variety of inputs are necessary before an economic analysis can be undertaken. A discussion of these basic tasks follows.

Determination of Accident Reduction Factors

Perhaps the most important input to the economic analysis phase is the determination of accident frequency and severity reduction factors. In terms of fixed-object improvements some programs, such as removal of trees within 30 feet of the edge of pavement, intuitively should result in a change in both the frequency and severity of accidents. Other programs, like the installation of breakaway supports to rigid signposts, should not change accident frequency but should decrease the accident severity associated with striking the rigid support. Determination of these factors was a multiphased effort.

Review of the literature.

It was hoped that most of the inputs to the determination of accident reduction factors would emerge from a review of the available literature on fixed-object countermeasure evaluations. It was felt that the earlier MVMA study (Council and Hunter, 1975), which contained a large-scale liter-

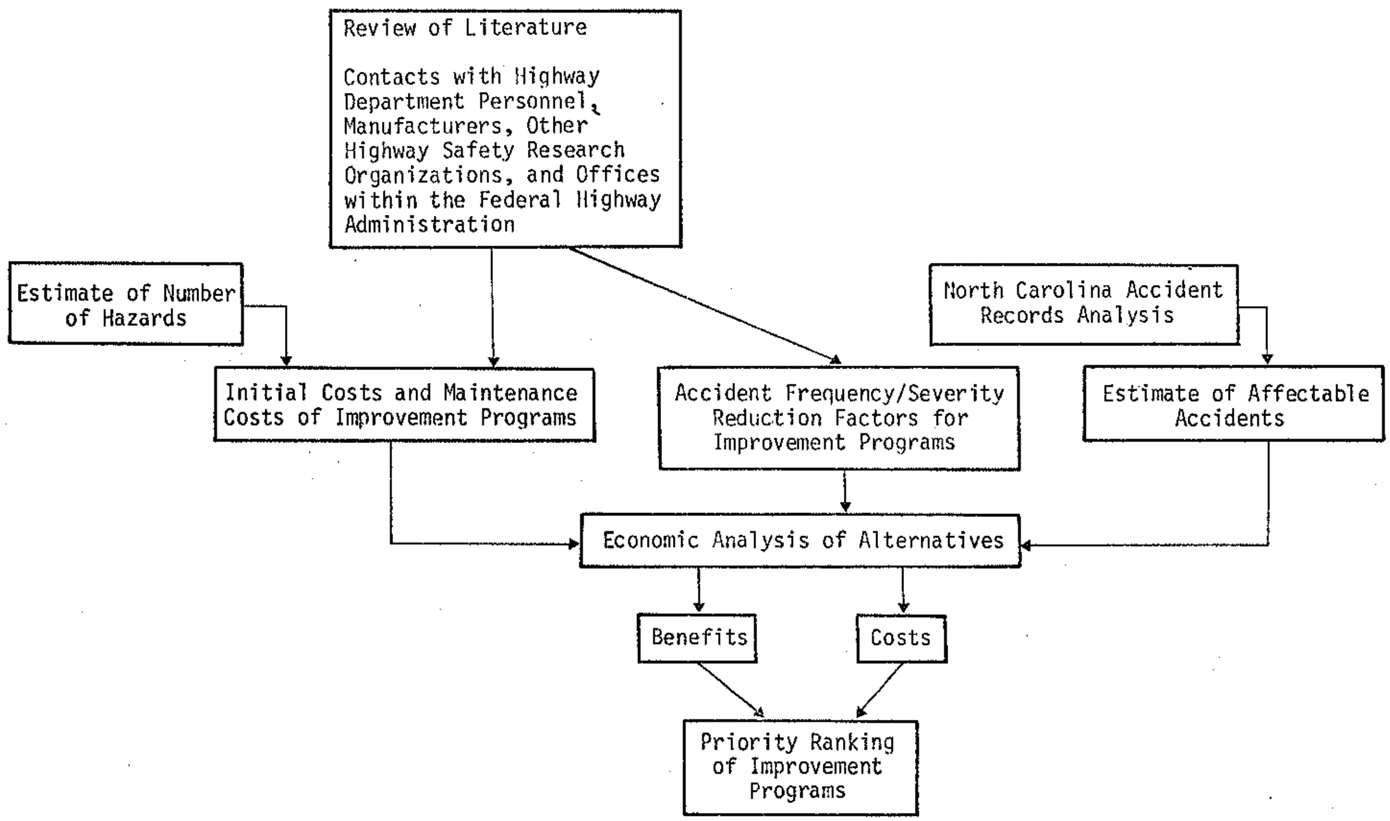

Figure 1. Schematic representation of project methodology.

ature review, could be updated with later computer searches to provide information on the effectiveness of various fixed-object treatments. Then, after reviewing the studies, a concensus could be made as to the most appropriate accident reduction factors, with heavy emphasis on those evaluations with good study designs.

Several literature searches were performed for this project including: (1) an update of an earlier Transportation Research Board (Highway Research Information Service) computer search dealing with roadway design, (2) a National Technical Information Service Search concerned with "various structures and mechanical devices for promoting highway safety" (Adams, 1976), covering 1964 through March, 1976, and (3) a review of several years of the Government Reports Annual Index. After reviewing these searches, a large number of publications were compiled, categorized, and reviewed. A listing of all reports that were reviewed, categorized by treatment area, is contained in the reference section.

Upon reviewing most of the publications in a given category, however, it was found that effectiveness results varied widely. Furthermore as in the earlier study, many of the reports had poor study designs, a large majority being before-after with no control group. Since high accident locations were studied in many instances, regression to the mean effects were likely widespread. Thus, the literature review phase left much to be desired in terms of determining effectiveness estimates.

Several of the publications alluded to the need for more evaluations pertaining to these types of improvements. In particular, "it is highly desirable that agencies make a greater effort toward documenting and reporting the in-service performance of traffic barriers. Without it, the engineer is significantly handicapped in his evaluation of candidate barrier systems" (Ross, Kohutek, and Pledger, 1976). While this quote applies only to barrier systems, it could generally be applied to all categories of fixed-object treatments.

North Carolina before-after studies.

Since the literature review was not providing a large amount of information, it was apparent that other sources would have to be investigated. One of these was the file of before-after studies compiled by the Traffic Engineering Branch (TE) of the N.C. DOH. The file contained some 400 studies of all types of traffic engineering improvements, including delineation, special signing projects, signal installations, channelization, etc. The individual studies were categorized and then aggregated. Unfortunately, most of the studies did not pertain to roadside fixed-object treatments. For those few that did, the numbers of analyzed accidents were generally very small. Thus, this data source provided limited information.

Contacts with other state highway departments.

While investigating the TE before-after studies, HSRC also began contacting personnel in other state highway departments for any available information, particularly accident studies. Twelve states were contacted, including the more progressive states of California, Texas, Pennsylvania, New York, and Michigan. A few of the states could furnish annual reports (or portions of annual reports) concerned with implemented projects and subsequent results. Most of these were in the form of aggregated before-after studies.

A few states, such as California and New York, were able to furnish some specific studies of fixed-object improvements. California's CURE (Clean Up the Roadside Environment) program has been directly concerned with the fixed-object problem, while New York has been involved with in-service evaluation of traffic barriers. Pennsylvania's annual reports and the Texas Transportation Institute (TTI) reports concerned various evaluations from those two states. The Michigan and Ohio highway departments provided a series of their periodic study results.

Contacts with offices of the Federal Highway Administration.

In an effort to ensure that the latest research results were being considered, HSRC visited several offices within the Federal Highway Administration including the office of Highway Safety and the Office of Research. Within the Office of Highway Safety, a new program Evaluation Division has been established which will attempt to compile evaluation data from the states. However, no results were currently available.

The Office of Research was particularly helpful. Interviews were obtained with individuals in several groups including Socioeconomic and Environmental Designs, Advanced Vehicle Protective Systems, and Structures and Applied Mechanics. HSRC was able to obtain information about both on-going research and completed but unpublished research. During these visits, the U.S. Department of Transportation Library was also searched for pertinent publications.

Contacts with Other Research Organizations.

Following the interviews with FHWA personnel, HSRC contacted a number of agencies engaged in highway safety research, including Southwest Research Institute, Texas Transportation Institute, CALSPAN Corporation, and the University of Miami. These contacts generated several useful reports but also revealed that some very promising research is presently underway which will not be completed in time to be incorporated into this project. However, the developed system will allow for inclusion of these updated data when available, and a series of updates is anticipated (See Volume II: User Manual).

Based on the results of the literature review, state evaluation studies, and contacts with federal, state and other research agencies, the final estimates of accident reduction factors were developed (Table 2). As previously mentioned, a scarcity of evaluative data exists for these roadside fixed object programs.

Some of the treatment categories, such as median barriers, contained a number of available studies for review. However, many of the studies suffered from either the lack of good study designs or examination of improper sets of accident files--sets other than the most affectable accidents (In the case of median barriers, the analyst should be concerned with median encroachments or cross-median involvements. This was not always the case.) Other treatments, such as the tree removal, had only a very small number of studies upon which to make accident reduction estimates.

Where there were a number of studies, the accident reduction factors were compared, and more weight was given those with sound study designs. Others were completely discarded. Thus although objective judgements were used as much as possible, some more subjective estimates were necessary. Most of the final composite reductions (or increases) were compared to a series of estimates developed by FHWA research engineers in a current contact being performed by Stanford Research Institute that seeks to prioritize targets for research and development in the future (Stanford Research Institute, 1974). These FHWA estimates were based on accident studies and a large amount of crash test data developed over the past few years. These final estimates were then reviewed by Traffic Engineering Branch Personnel. Thus the figures presented in Table 2 should be considered as best current estimates of effect. These estimates should be systematically updated to reflect the results

Table 2. Hazard/treatment information.

Hazard	Treatment	% Reduction[1] Fatal (%)	Injury (%)	PDO (%)	Initial Cost ($)	Maintenance Cost ($)	Repair Cost ($)	Service Life (Years)	Comments
1. Utility poles	a. Breakaway	30	-1	0	36 per pole	0	250 per pole	10	Rural intersection and non-intersection
		30	-1	0	36 per pole	0	550 per pole	10	Urban intersection and non-intersection
		30	-1	0	36 per pole	0	250 per pole	10	Rural intersection
		30	-1	0	36 per pole	0	550 per pole	10	Urban intersection
	b. Relocate - 30' from edge of pavement	32	-1.7	0	375 per pole	0	200 per pole	20	Rural non-intersection
		32	-1.7	0	375 per pole	0	500 per pole	20	Urban non-intersection
		32	-1.7	0	375 per pole	0	200 per pole	20	Rural intersection
		32	-1.7	0	375 per pole	0	500 per pole	20	Urban intersection
	c. Remove	38	-1.5	0	930 per pole	0	0	20	Rural non-intersection - cost per pole includes $3.30/L.F. to bury cable at pole spacing of 250'
		38	-1.5	0	1600 per pole	0	0	20	Urban non-intersecting - cost per pole includes $6.00/L.F. to bury cable at pole spacing of 250'
		38	-1.5	0	435 per pole	0	0	20	Rural intersection - cost per pole includes $3.30/L.F. to bury cable for 300' of cable required
		38	-1.5	0	850 per pole	0	0	20	Urban intersection - cost per pole includes $6.00/L.F. to bury cable for 500' of cable required

[1]Minus sign indicates an increase in the proportion of accidents.

Table 2. Hazard/treatment information. (Continued)

Hazard	Treatment	% Reduction[1] Fatal (%)	Injury (%)	PDO (%)	Initial Cost ($)	Maintenance Cost ($)	Repair Cost ($)	Service Life (Years)	Comments
2. Trees	Remove	50	25	-20	30 per tree	0	0	10	Rural and urban - without removal of stump
		50	25	-20	60 per tree	0	0	10	Rural and urban - with removal of stump
3. Exposed bridge rail ends	Transition Guardrail	55	20	-50	1950 per end	0	400 per hit	15	Rural and urban - 2 lane with 100' total of approach or trail guardrail per end
		55	20	-50	5550 per end	0	400 per hit	15	Rural and urban - 4 lane-divided and undivided 400' of guardrail per exposed bridge end
4. Substandard bridge rail	Improved rail (thrie beam)	15	5	-3	25 per L.F.	0	50 per hit	20	Rural and urban
5. Underpasses (Bridge piers)	a. Concrete median barrier with end treatment	60	40	-150	12,100 per site	0	350 per hit	20	Rural and urban - 4 lane-divided median piers
		60	40	-150	6,000 per site	0	350 per hit	20	Rural and urban - 2 lane- and 4 lane-undivided - shoulder piers
	b. Attenuators 1. Water filled cushion	75	60	-300	24,000 per site	0	500 per hit	10	Rural and urban - 4 lane-divided-median piers
		75	60	-300	24,000 per site	0	500 per hit	10	Rural and urban - 2 lane-shoulder piers
		75	60	-300	12,000 per site	0	500 per hit	10	Rural and urban - 4 lane-undivided-shoulder piers
	2. Sand filled cell	75	60	-300	10,000 per site	0	800 per hit	10	Rural and urban - 4 lane-divided-median piers
		75	60	-300	10,000 per site	0	800 per hit	10	Rural and urban - 2 lane-shoulder piers
		75	60	-300	5,000 per site	0	800 per hit	10	Rural and urban - 4 lane-undivided-shoulder piers

Table 2. Hazard/treatment information. (Continued)

Hazard	Treatment	% Reduction[1] Fatal (%)	Injury (%)	PDO (%)	Initial Cost ($)	Maintenance Cost ($)	Repair Cost ($)	Service Life (Years)	Comments
	b. Attenuators (continued)								
	3. Steel Barrels	75	60	-300	17,000 per site	0	700 per hit	10	Rural and urban - 4 lane-divided-median piers
		75	60	-300	17,000 per site	0	700 per hit	10	Rural and urban - 2 lane-shoulder piers
		75	60	-300	8,500 per site	0	700 per hit	10	Rural and urban - 4 lane-undivided-shoulder piers
6. Rigid signs or supports									
a. Small sign	Breakaway	70	25	-12	70 per sign	0	100 per sign	5	Rural and urban
b. Large metal support	Breakaway	60	20	-20	300 per pole	0	150 per sign	10	Rural and urban
c. Large metal support	Relocate behind guardrail	55	30	-5	125 per sign	0	100 per sign	10	Rural and urban (Assumes no guardrail cost)
d. All supports combined	Breakaway	68	24	-14	100 per sign	0	110 per sign	5	Rural and urban
7. Guardrail ends	a. Breakaway cable terminal	55	25	-15	350 per end	0	350 per end	15	Rural and urban - median and shoulder
	b. Turned down Texas terminal	55	25	-15	300 per end	0	300 per end	15	Rural and urban - median and shoulder
8. Median-involved accidents									
a. Narrow median	Concrete median barrier	90	10	-10	105,600 per mile (20/L.F.)	0	0	20	Rural and urban - median width-1-12'
		85	5	-25	105,600 per mile	0	0	20	Rural and urban - median width-13-30'
b. Wider median	Double faced guard-rail	75	2	-28	79,200 per mile	0	500 per hit	15	Rural and urban - median width 1-12'
		85	5	-30	79,200 per mile	0	500 per hit	15	Rural and urban - median width 13-30'
		85	5	-30	79,200 per mile	0	500 per hit	15	Rural and urban - median width 31-60'

of new research.

Determination of Initial Costs and Maintenance Costs for Improvement Programs

Other necessary inputs to the economic analysis system are the initial treatment costs and maintenance costs. The literature review provided some cost data, but the major part of the cost data was supplied by state highway departments, research organizations, and manufacturers of safety equipment. Once this information was obtained, all cost figures were compared with current N.C. costs through contacts with N.C. DOH personnel in Roadway Design (especially the Plans and Proposals Section) and Maintenance. Follow-up conversations with field maintenance personnel provided data useful in developing average repair costs for several hazard/treatment categories. All dollar values were then approved by the Traffic Engineering Branch.

After compiling all available accident reduction and cost data, a list of appropriate treatments and accompanying costs for each hazard was developed. Table 2 shows the results.

Discussion of Treatment Programs

This section will contain a brief discussion of the treatment programs associated with the various hazards, as shown in Table 2. Inputs and assumptions used in computing some of the costs will also be discussed. As noted earlier, reference lists by hazard/treatment category are contained at the end of the text.

1. Utility poles - Three treatments were developed for this hazard (Figure 2). The first, making utility poles breakaway, is a relatively new design concept. Limited research with pendulum crash tests seem to indicate that the concept is feasible (Wolfe, Bronstad, Michie, and Wong, 1974); however, researchers feel that more work is needed before the con-

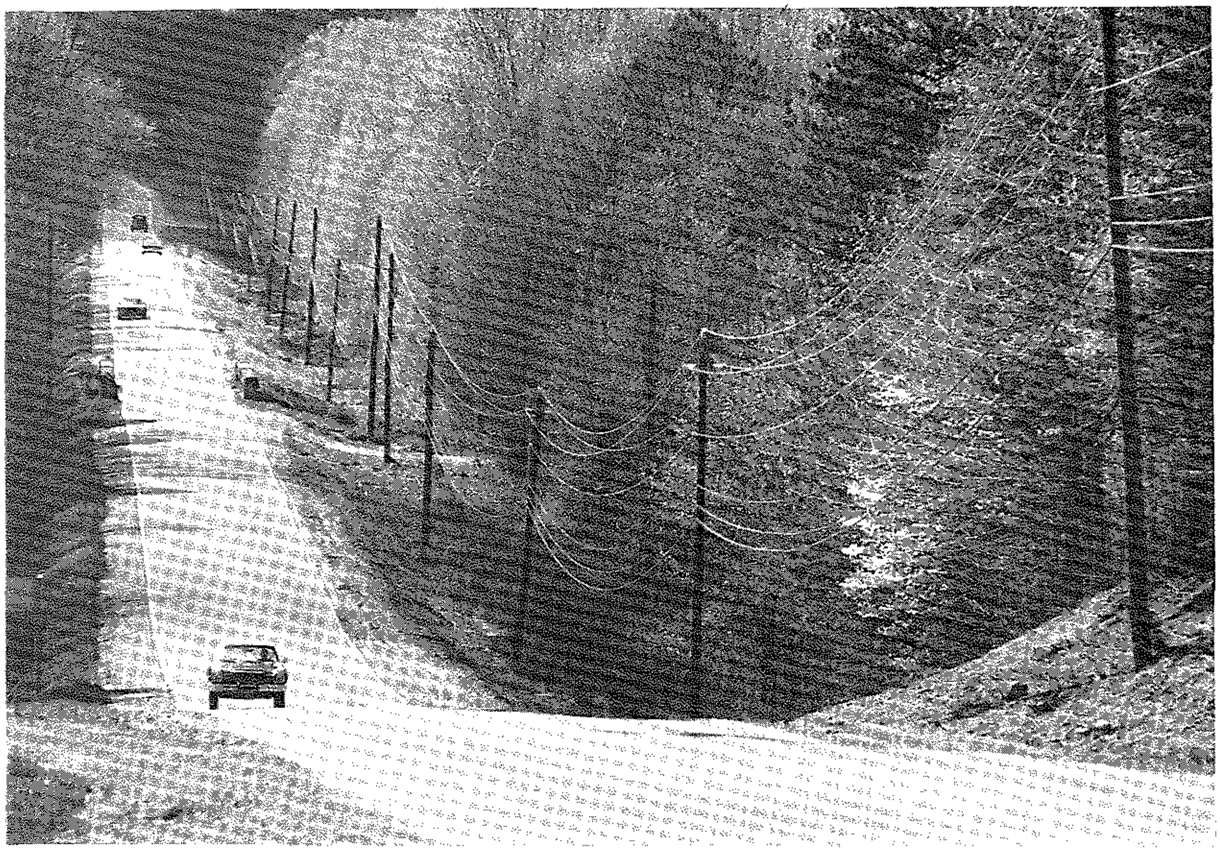

Figure 2. Hazardous utility poles.

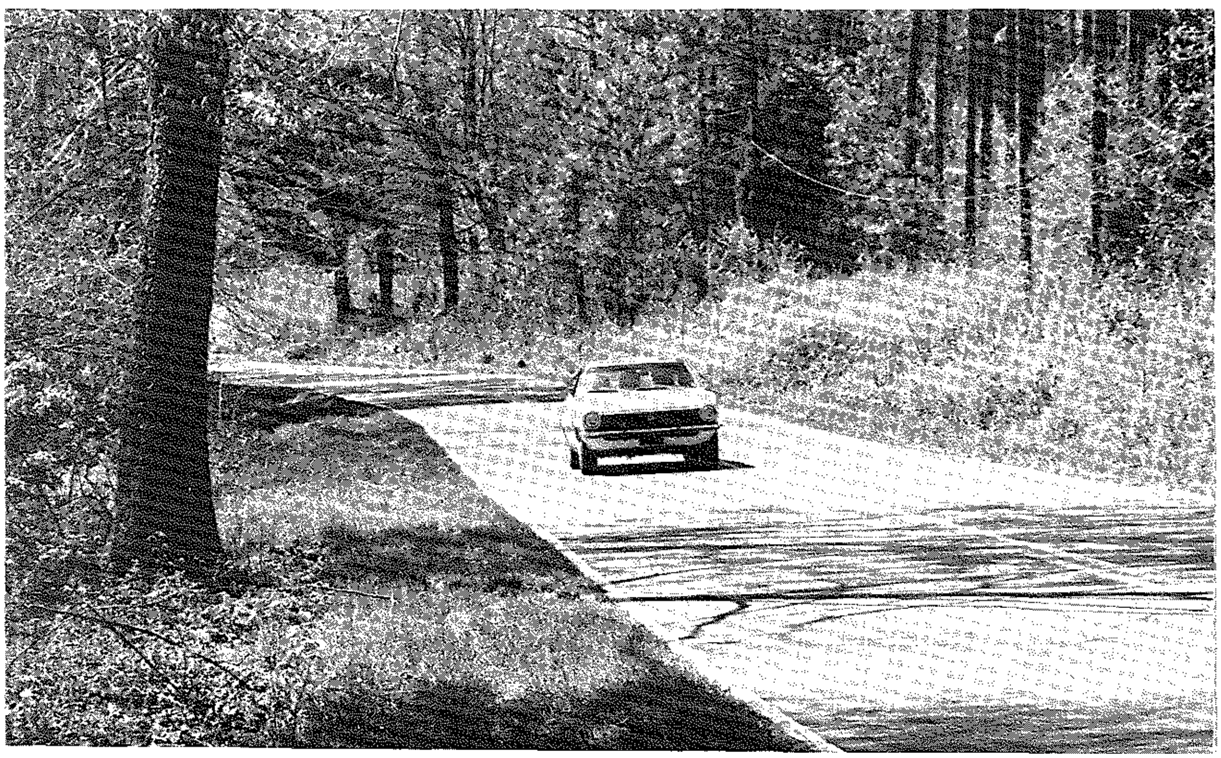

Figure 3. Hazardous tree.

cept can be widely implemented. The breakaway technique is mainly shown here as a comparison to the other 2 treatments. Repair costs (i.e., costs per hit) were based on inputs from various sections within the N.C. DOH, including the Utilities Section of the Roadway Design Branch. Repair costs were developed for replacing poles struck in both rural and urban areas.

The second treatment involved relocating utility poles to a distance greater than 30 feet from the edge of pavement. Costs were obtained from the N.C. DOH and utility companies. It should be noted that the work by Wright and Bright, "Costs of Roadside Hazard Modifications," was also referred to not only for this treatment but also for many others. The repair costs again reflect urban/rural differences.

The third treatment, removing utility poles and replacing them with buried cable, was explored in a study from New York State (Newcomb and Negri, 1972). The reduction factors developed from this study were used to derive those for the first two utility pole treatments.

The initial costs for this program were based on conversations with TE personnel and engineering personnel from General Telephone Company. Pole removal cost was set at $105 per pole, and costs of underground cable (including installation) were set at $3.30 per lineal foot (L.F.) for rural areas and $6 per L.F. for urban areas. It was estimated that poles are spaced approximately 250 feet apart along N.C. highways. For removal of poles at intersections, it was estimated that there were an average of 4 poles at urban intersections and 3 poles at rural intersections, with 500 feet of cable needed at urban intersections and 300 feet needed at rural intersections. These data were combined to develop a cost per pole for both rural and urban intersections and non-intersection locations.

A final comment should be made here. It appears that utility companies are now moving toward underground cable installation wherever possible because of a better long-term payoff. In general, however, utility companies have been very hesitant about removing or relocating poles set close to the edge of pavement because of the rather large costs involved. Federal funding for these corrective actions is now available, but many states are unable to participate because of inappropriate legal authority to pay for the improvements (Graf, Boos, and Wentworth, 1976).

2. Trees - Removal of trees within 30 feet of the edge of pavement was the basic treatment considered for this hazard (Figure 3). A separate treatment included the costs of also removing stumps. Costs were developed from the Wright and Bright report for "average size" trees and stumps. The reduction factors were primarily obtained from a Michigan Highway Department Study (Al-Ashari, 1971).

3. Exposed bridge rail ends - To remedy this hazard (Figure 4), transition guardrail with proper end treatment and bridge attachment was considered (Figure 5). Reduction factors reflect several state highway department studies, including an excellent study performed in California by Glennon and Tamburri (1966). The cost data reflect differences for 2-lane and 4-lane situations. N.C. DOH personnel from several branches aided in the estimates of 100 feet of approach or trail guardrail for the 2-lane situation and 400 feet of guardrail for the 4-lane situation. Cost of w-beam guardrail was given as $12 per L.F. (for short sections) by the N.C. DOH Plans and Proposals section. The repair cost was determined from conversations with several field maintenance personnel and is based on an average damage length of 75 feet per crash, with repair costs being $5-6 per L.F. of guardrail.

4. Substandard bridge rail - In all probability, retrofitting of substandard bridge rail seems to be an area where considerable future

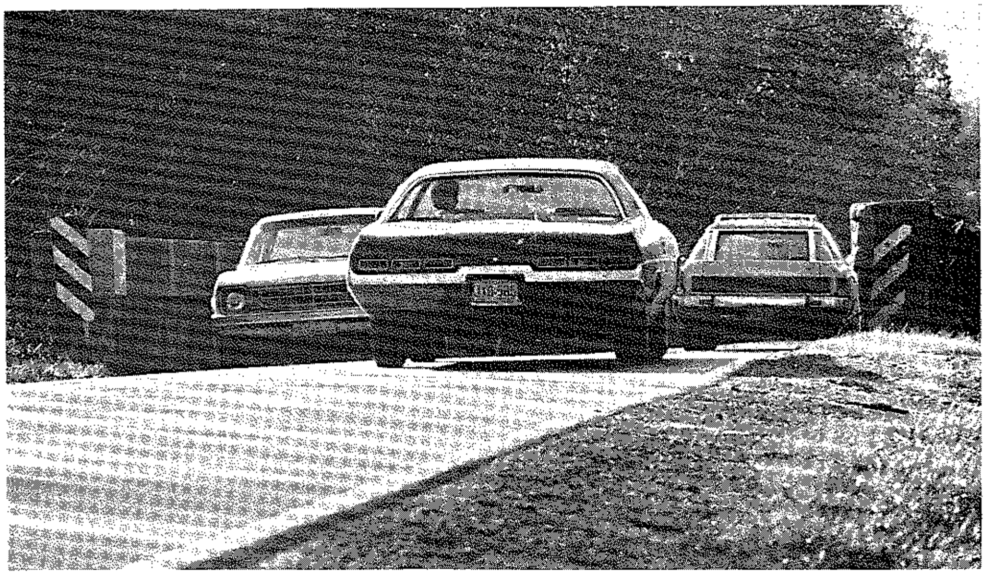

Figure 4. Hazardous bridge ends.

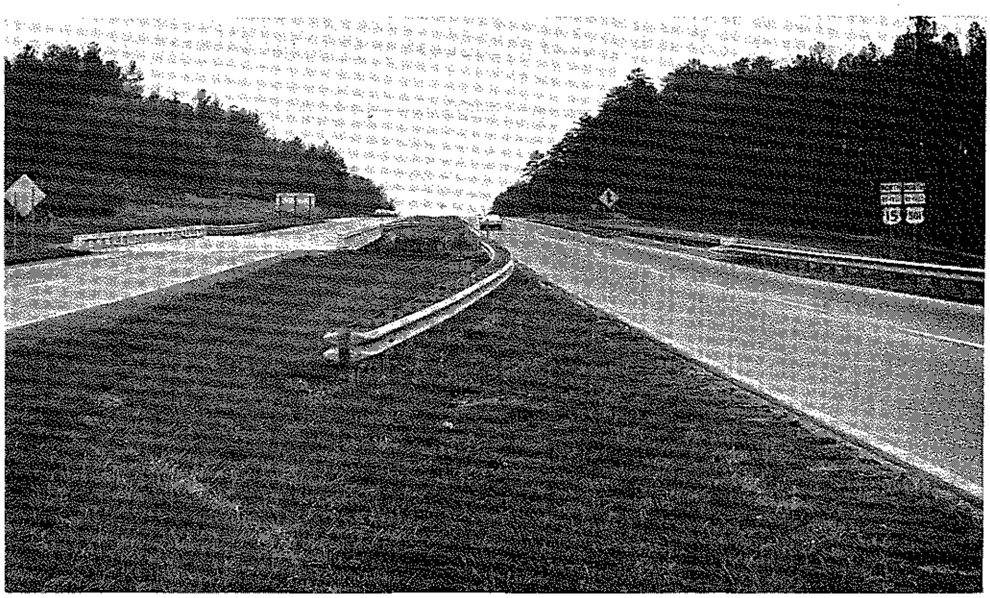

Figure 5. Transition guardrail for hazardous bridge ends.

emphasis will be placed by the Federal Government. The Southwest Research Institute has performed research on classifying present bridge railing systems and identifying candidate replacement systems from crash tests (Michie, Bronstad, Kimball, and Wiles, 1976). One of the more promising candidates is the use of the thrie beam, a triple corrugated traffic railing, with associated hardware. This treatment was considered for those N.C. bridges with substandard railing. Reduction factors basically reflect FHWA estimates from the Stanford report for improved bridge railing systems. Thrie beam initial costs were obtained from a guardrail manufacturer and the N.C. DOH Roadway Design Branch. Because such a small amount of this type of railing has been installed to date in any state, repair costs were estimated from photographs of crash test results.

5. Underpasses (bridge piers or abutments) - Two treatments were considered for exposed bridge peirs or abutments (on both shoulder and in median). The first, the use of precast concrete median barrier (CMB) sections with w-beam guardrail sections attached to the ends of the CMB (Figure 6), has already been implemented on some N.C. roadways. Costs were developed from conversations with Roadway Design Branch personnel. Reduction factors were developed from several state highway department studies.

The second treatment, the use of impact attenuators, was developed from the literature review. Three types of attenuation systems, water-filled cushions, sand-filled cells , and a steel barrel configuration (Figures 7-9) were considered. Several studies had available reduction factors. Costs were obtained from manufacturers and several state highway departments. Final costs reflect national averages.

6. Rigid signs or supports - Several treatments were developed for signs or supports of various sizes, although only a few accident studies

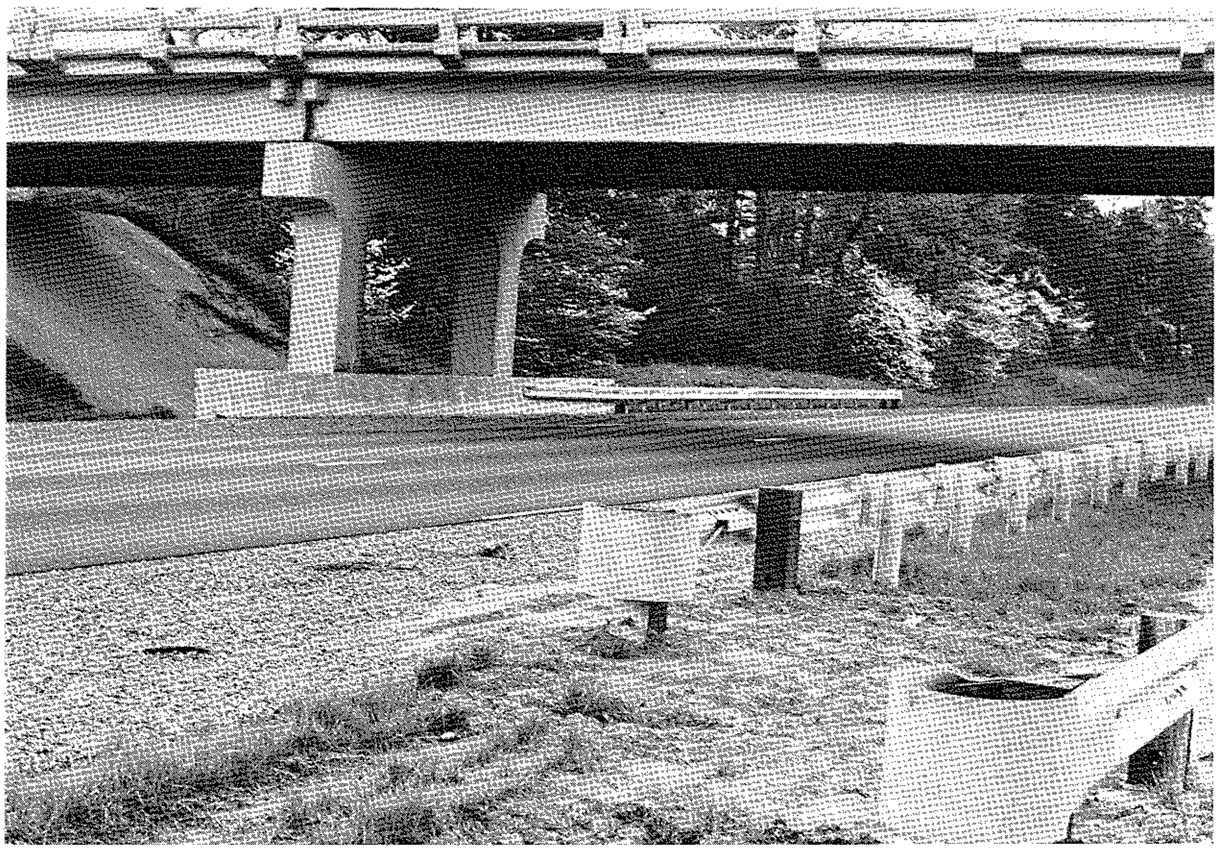

Figure 6. Concrete median barrier and guardrail treatment for hazardous bridge piers.

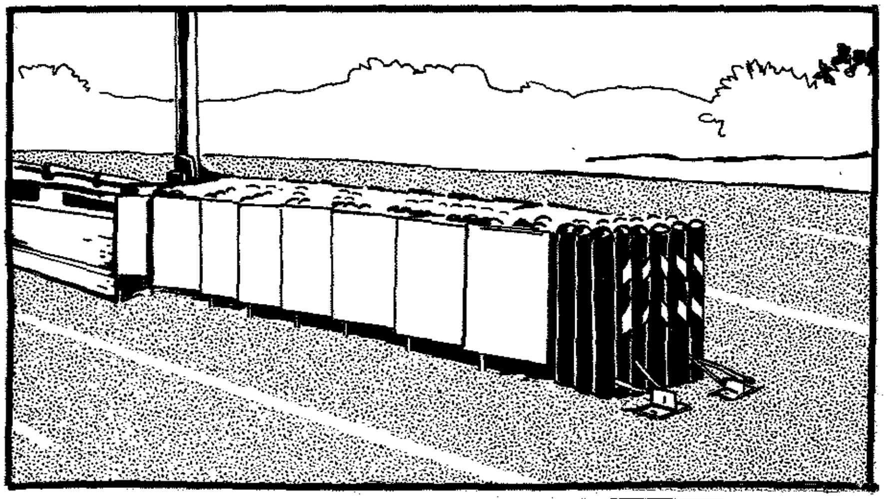

Figure 7. Water-filled cushion attenuation system.

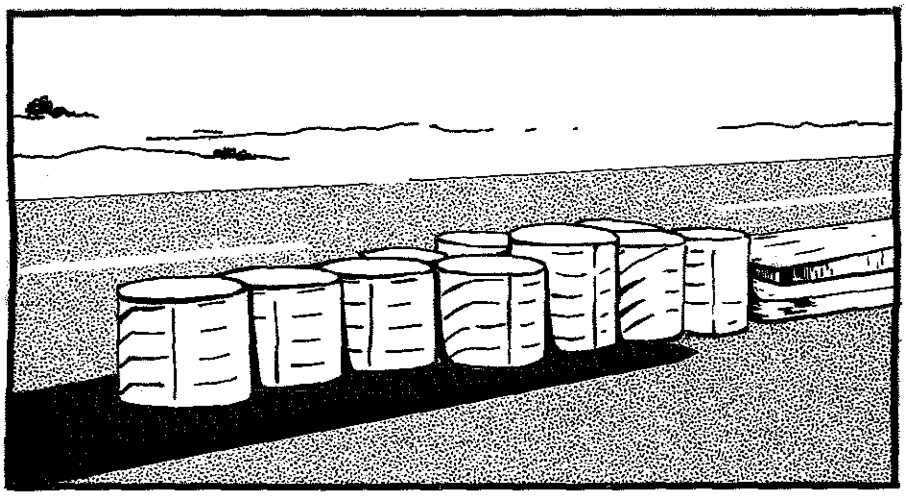

Figure 8. Sand-filled cell attenuation system.

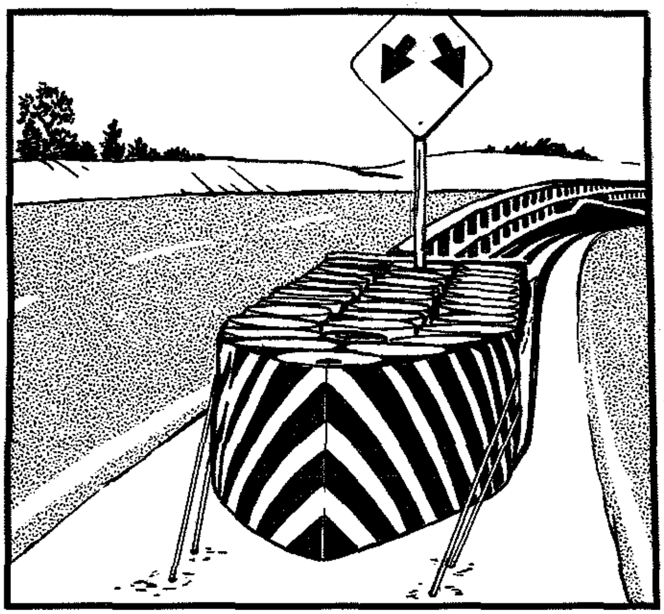

Figure 9. Steel barrel attenuation system.

exist. Severity indices for signs of various sizes are reported in NCHRP Report 148 (Glennon, 1974). In the final analysis for this project, only the breakaway treatment for "All supports combined" could be used, because the N.C. hazard inventory (Grigg, 1974) aggregated hazardous sign supports and luminaries and the N.C. accident report form (Appendix A) does not adequately differentiate between signs and luminaries in the "fixed-object struck" codes. Thus, this treatment was used for accidents concerned with signs or sign posts, and the composite treatment reduction factors and costs were accordingly weighted with this in mind. Cost estimates were obtained from both N.C. DOH field maintenance personnel and the Roadway Design Branch.

7. Guardrail ends - Relatively new designs are now available for hazardous guardrail ends. The treatments are designed to properly decelerate the vehicle during end-on impacts and minimize the possibility of spearing. The breakaway cable terminal (BCT)(Figure 10) has gained in popularity over the past few years. The Texas Transportation Institute (TTI) has recently performed crash test research on the turned-down terminal (Figure 11) to improve decelerative forces and remove vehicle rollover for end impacts (Hirsch, Nixon, Buth, Hustace, and Cooner, 1977). The TTI technique involves practically nothing other than removal of bolts from the first few wooden posts until the terminal is barely supported under its own weight. When impacted end-on, the terminal collapes, and the vehicle is decelerated as it impacts the wooden posts and straddles the top of the guardrail. In basic crash tests, decelerative g-forces have been satisfactory. The reduction factors again basically reflect FHWA estimates, while costs were obtained from the Roadway Design Branch. It should be noted that the BCT is the end treatment most often used in N.C. (greater than 95 percent of the time).

Figure 10. Breakaway cable terminal for exposed guardrail end.

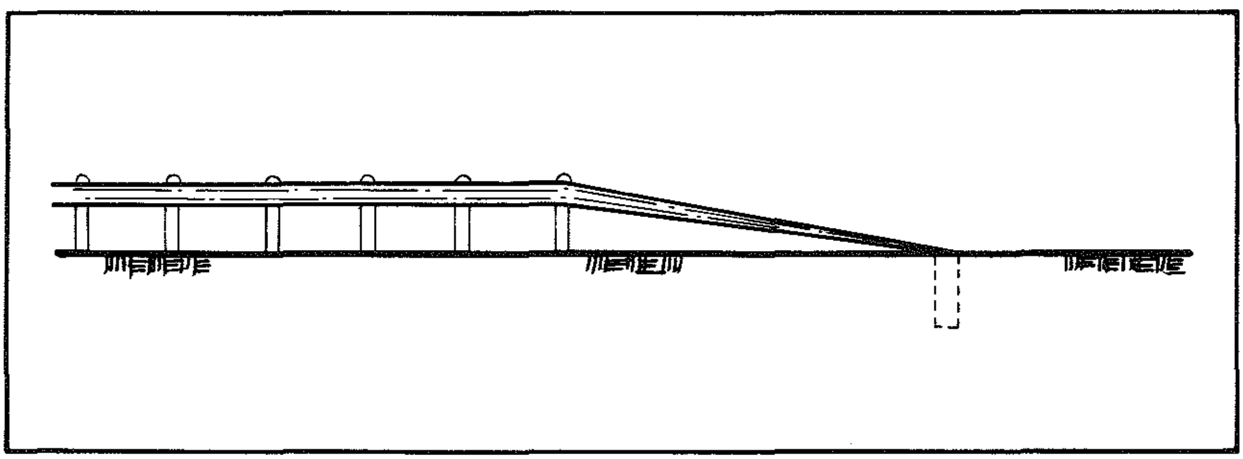

Figure 11. Texas twist (turned down) terminal for exposed guardrail end.

8. Median-involved accidents - This class of hazards involves median encroachments in which either a fixed object such as a bridge pier, raised drainage inlet, or ditch bank is struck, or encroachments in which vehicles in opposing lanes or objects associated with the opposing lanes are struck. The treatments are barriers designed to prevent these median encroachments.

The first treatment, the concrete median barrier (CMB), is generally associated with narrow medians. It appears to be most effective for medians less than 12 feet wide, where encroachment angles are shallow, allowing the excellent redirective properties of the barrier to function. However, the CMB appears to be receiving more widespread application, and the N.C. Roadway Design Branch policy is to use this barrier (if the frequency of encroachments warrant the use of a barrier) in medians up to 30 feet wide.

The reduction factors for the CMB were developed from a number of studies performed by various state highway departments. These reduction factors are associated with median encroachments only; they do not pertain to all accidents occurring on the section where the barrier is placed. The reduction factors change when the CMB is applied to the wider median, taking into account the better performance for the smaller approach angles. Initial costs were based on Roadway Design estimates of $20 per L.F. for long sections of CMB barrier. Since the barriers are struck many times without need of repair, maintenance and repair costs were assumed to be zero.

The second treatment, a double-faced steel guardrail, is a more flexible type of guardrail (e.g. 2 sided w-beam or box beam) normally associated with wider medians. The reduction factors were developed for 3 median widths (0-12 feet, 13-30 feet, and 31-60 feet). It should be noted, however, that present Roadway Design Branch policy is generally to use no median barrier when the median width exceeds 30 feet. Initial costs were based on the Roadway Design estimates of $15 per L.F. for the double-faced guardrail.

Other programs not analyzed.

As stated in the "INTRODUCTION," there were a number of other fixed-object programs to be reviewed. However, not all of these could be analyzed due to a variety of missing data. As indicated, necessary input items included: (1) the number of affectable accidents based on N.C. data, (2) accident reduction factors, (3) number of fixed-object hazards, and (4) treatment cost data. Reasons for not analyzing these other programs will be discussed briefly:

1. Improved recovery areas - This broad category was to include such programs as paving shoulders, clearing the roadside of hazardous objects within roughly 30 feet from edge of pavement, improving alignment and superelevation on curves, etc. In terms of shoulder paving, there were numerous studies in the literature, but practically all were concerned with before-after total accident experience on the improved roadways. In other words, the shoulder paving effect on single vehicle fixed-object accidents was not determined. Thus, accident severity reduction factors could not be obtained.

It should be noted here that the state of Ohio has performed a rather extensive study concerned with stabilizing shoulders (Foody and Long, 1974). Their analyses indicate that this treatment would be as effective as pavement widening on the single vehicle fixed-object accident experience on Ohio roadways. The recommendation was made to implement the shoulder stabilization treatment on rural, 2-lane roadways. Hopefully, good follow-up evaluative information will follow.

TE before-after studies and studies from other state highway departments were reviewed for treatments such as pavement widening, curve realignment, and superelevation. Again, reduction factors for single vehicle fixed-object accidents could not be determined. Estimates of affectable accidents were also not possible, as curve and grade data for N.C. roadways reside on straight-line diagrams, rather than the mileage inventory computer file, a known problem which is currently under study.

The cleared roadside concept has assumed increasing importance in recent years, and most states have attempted to reflect the concept in new construction or scattered spot improvements rather than wholesale hazard elimination on a section-by-section basis. However, the state of Pennsylvania includes such an item (Clear Roadside Projects) in their Annual Report (Pennsylvania Department of Transportation, 1976). Accident information from projects with improvements such as eliminating fixed objects, modifying guardrail and median barriers, etc., was aggregated; and reduction factors were calculated.

For the areawide improvements in this project, it was not possible to develop an accurate estimate of all types of hazards (aggregated) per mile, subdivided by various highway types, etc. There was considerable difficulty in attempting to do this for individual hazards which had been inventoried. (Difficulties in determining aggregated affectable accidents and costs would also have been encountered.) Thus, an analysis of the cleared roadside concept was not attempted.

2. Railroad grade crossing hardware - The hardware associated with railroad grade crossings, such as warning signs, gates, flashers, etc., is not a specific "object struck" on the N.C. accident report form. In an attempt to determine the magnitude of the problem, two years of narratives (as written by the investigating officer) were examined. The list was developed by using HSRC's Narrative Search Program to print all narratives from the subset of all fixed-object accidents occurring at railroad grade crossings in which a train was not involved. After reading the narratives, it was determined that approximately 30 accidents per year involved this type of fixed object. Because of the low frequency of occurrence, further analysis was not attempted.

3. Delineation - A number of state highway departments, including North Carolina, have before-after accident data concerned with delineation improvements, including such items as pavement marking, raised markers, special signs or delineators on curves, and delineators at bridges. While some of the studies were concerned with ran-off-road accidents, none was associated with fixed-object accidents. Thus, appropriate reduction factors could not be developed. Also, no appropriate data was available to identify which sections of roadway were delineated. Based on the individual studies, it should be noted that delineation, on the whole, is cost-beneficial.

4. Skidproofing - These treatments include both pavement grooving and pavement overlays. Before-after accident data was again available from several states, but none could be tied to fixed-object accidents. And, similar to the delineation treatment, no computerized file of N.C. skid inventory information yet exists. Skidproofing also appears to be cost-beneficial at properly selected locations.

5. Other fixed-object treatments - Other treatments associated with objects like curbs, culverts, raised inlets, and ditch banks were also investigated. Because of lack of hazard counts, lack of accident information, and, in some cases lack of an appropriate treatment, these hazards were not included in the analysis system. Given development of proper data, they could be included later.

Estimate of Affectable Accidents

It was usually possible to identify which specific types of accidents could be reasonably expected to be related to an improvement program -- the "affectable accident". Just as in a well-conducted evaluation, this process of proper criterion selection often only involved nothing more than matching the chosen treatment with the fixed object or hazard that was struck. In other words, if one is considering placing transition sections of guardrail around unprotected bridge ends, then the affectable accidents are those involvements where the bridge end was struck. If the treatment is tree removal, then one needs knowledge about the number of trees struck within a designated distance from the edge of pavement.

After specifying the set of definitions for the fixed object related affectable accidents, various files of North Carolina accident data were analyzed to determine what proportion of the total statewide accidents these affectable accidents constituted on a treatment by treatment basis. While details of the analytical procedures followed in developing these proportions are presented below, the overall process may be summarized as follows:

1. A composite estimate of the proportion for each treatment/hazard combination was developed based on individual annual estimates from three accident years (1973-75). This was done in an attempt to provide stability to the composite estimate.

2. An estimated number of total accidents for 1979, the base year used in all subsequent analyses, was developed from trends in past accident data.

3. The treatment by treatment composite proportions were multiplied by the 1979 totals to derive affectable frequencies of accidents for each hazard/treatment combination. These frequencies were used in all subsequent economic analyses.

Information from different data files had to be combined in a step-by-step procedure to develop the yearly proportions of affectable accidents. First, 1973-1975 N.C. Accident Data Tapes were used to form various cross-tabulations for those accidents in which a single vehicle struck a fixed object. Only single-vehicle accidents were considered because the earlier described estimates of treatment effectiveness in terms of accident or severity reduction were associated with these single vehicle crashes. In multivehicle collisions when a fixed object is struck, there is no way of accurately determining when injury occurs, whether during the vehicle to vehicle crash or the subsequent vehicle to fixed object collision. Thus, an injury or death occurring in a multivehicle collision may or may not be affected by treating a fixed object.

The restricting of affectable accidents to those involving only single vehicles will, of course, cause the final economic analysis outputs to be somewhat conservative. As shown in Table 3, multivehicle impacts with fixed objects account for varying percentages of total fixed object crashes. It is quite probable that treating a fixed object will have some beneficial effect in these multivehicle crashes, even though the effect might be much smaller than in single vehicle crashes with the same object.

Because the amount of this effect cannot be quantified from existing studies, no related correction was made in the reduction factors or affectable accident frequencies used in the final analysis. Thus, when interpreting the final results (and in subsequent use of the developed computerized system), the reader should be aware that programs which are shown to pay off would, in reality, pay off at a slightly higher rate

Table 3. Proportion of fixed object collisions by involvement type (1975 accidents).

Object Struck	Single Vehicle Involvements	Multi-Vehicle Involvements	Total
Trees	4014 (86.8%)	611 (13.2%)	4625
Utility Poles	4154 (80.9%)	983 (19.1%)	5137
Median Guardrail	255 (68.4%)	118 (31.6%)	373
Shoulder Guardrail	647 (73.4%)	235 (26.6%)	882
Bridges	866 (82.2%)	187 (17.8%)	1053
Underpass	89 (84.0%)	17 (16.0%)	106
Sign or Sign Post	1417 (61.4%)	890 (38.6%)	2307

and those programs which are close to the breakeven point (i.e., a Net Discounted Present Value which is slightly negative) might, in truth, be cost beneficial.

Following extraction from the Accident Data Tapes, the 3 years of single-vehicle fixed-object accidents were then subdivided by the following factors: (1) area, (2) rural/urban, (3) highway type, (4) accident severity, and (5) fixed object struck. The "area" classification was derived by combining the 14 highway divisions in the State into the categories of coastal plain, piedmont, or mountain. Area 1, coastal plain, included Divisions 1, 2, 3, 4, and 6. Area 2, piedmont, included Divisions 5, 7, 8, 9, 10, and 12. Area 3, mountain, included Divisions 11, 13, and 14 (Figure 12). The rural/urban breakdown was based on the investigating agency. The rural category was made up of accidents investigated by the State Highway Patrol, rural or county police, and Sheriff's departments, while the urban category included accidents investigated by municipal police and other traffic investigation agencies.[1] The highway types used were Interstate, U.S., N.C., secondary road routes, and city streets. Accidents were also categorized by 3 levels of severity, whether a fatal, injury, or property damage only (PDO) accident, with the worst injury being used as the classification criterion. Injury accidents included A, B, and C injuries combined. The final breakdown of the data was by fixed object struck (including median-

[1]Since there is no specific rural/urban category on the N.C. accident report form, the investigating agency variable is considered to form the best indication of this breakdown.

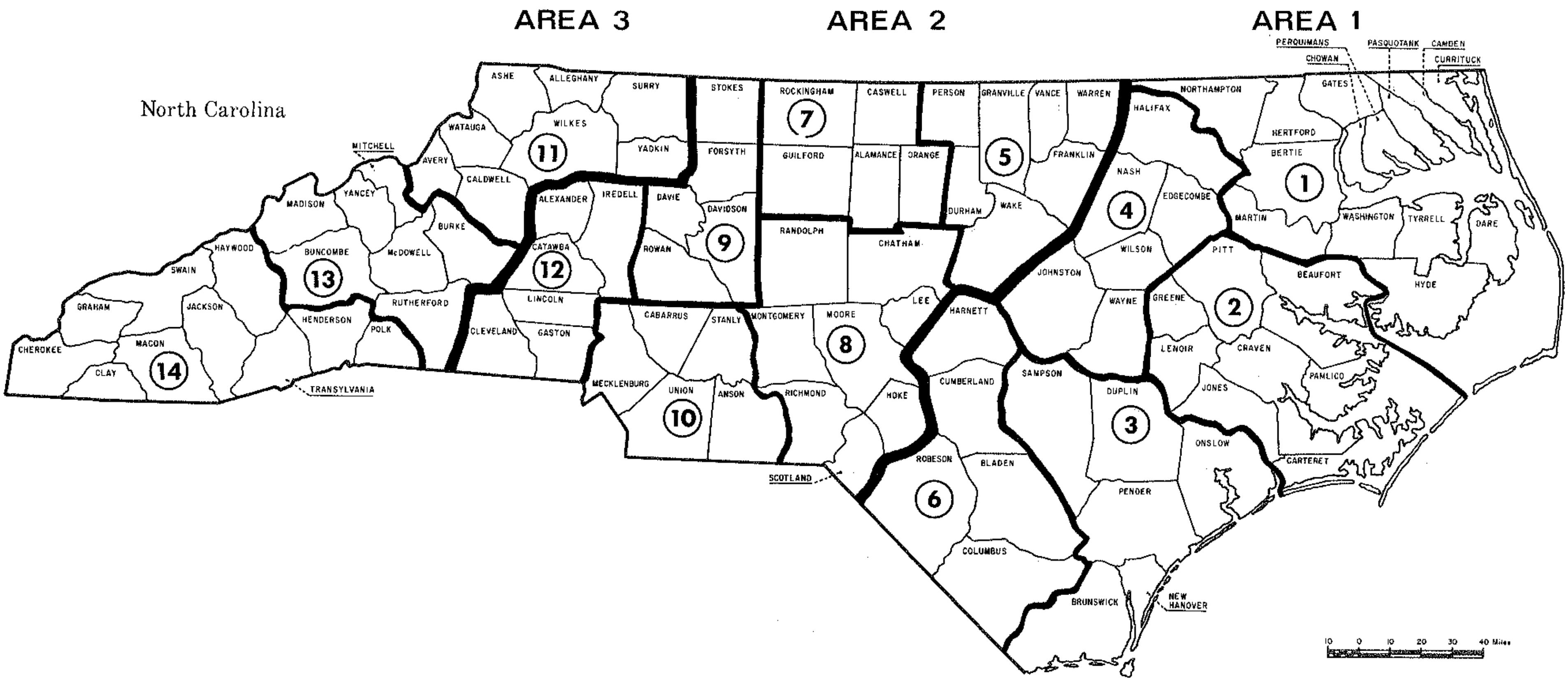

Figure 12. Map of the three area designations.

involved accidents). These tabulations were developed for all of the following fixed objects:

1. Tree
2. Utility pole[1]
3. Fence or fence post
4. Guardrail post-median
5. Guardrail post-shoulder
6. Bridge rail
7. Bridge end
8. Underpass (bridge pier)
9. Sign or sign post
10. Median-involved accidents
11. Other object struck
12. No object struck

Some additional effort was required to develop the bridge and guardrail information. Two complete years (1974 and 1975) of accident report hard copies for these types of fixed-object accidents were examined to develop the frequencies of bridge end and bridge rail impacts and guardrail end and guardrail section impacts. The accident sketch and narrative were used to ascertain these impact points.

As an additional check to verify if all the affectable accidents had been determined for the various hazards a two-way table of hazards by accident type was developed for the 1975 accident data. Table 4 shows the frequencies obtained for four hazards. As shown, the investigating officer coded 332 bridge accidents as "collision of motor vehicle with fixed object" when they should have been coded as "ran off road - right/left/straight ahead" and included in the single vehicle accident category. These 332 accidents were identified by their case number and hard copies were examined to ascertain the bridge impact point. The results were

[1]In addition, the accidents involving utility poles were further subdivided by intersection versus non-intersection.

Table 4. Example of accident coding errors by object struck.

Object Struck	Corrected Coded Single-Vehicle Ran-off-Road Accidents[1]	Incorrectly Coded Single-Vehicle Collisions With Fixed Objects
Guardrail in median	232	46
Guardrail on shoulder	650	55
Bridge	619	332
Underpass	38	58

[1]Differences between these frequencies and Tables 1 and 3 are due to misclassification of accident type.

added to the corresponding frequencies already determined for 1975 bridge end accidents. A similar procedure was applied to the other three hazards shown. In the case of underpasses, however, it was found that most of the 58 miscoded accidents involved trucks striking the top of an underpass. Thus, the investigating officer was correct in coding these as "collision of motor vehicle with fixed object". For other hazards such as trees, sign posts, etc., the error in miscoding was less than 1 percent and therefore no corrective steps were taken.

The next step in the development of the affectable accidents involved the use of the 1971-1972 N.C. Accident Data Tapes. These tapes contain curve/tangent information.[1] Since it was desirable to expand the tabulations developed from the 1973-1975 tapes by proportion of curve versus tangent sections, the 1971-1972 tapes were used to form the same tabulations as above (area, urban/rural, highway type, etc.), but with the additional curve/tangent breakdown. This was done for all fixed-object categories except underpasses, bridges and guardrails. Some preliminary tabulations indicated that it would be impractical to try to further expand these three categories by the curve/tangent dichotomy.

After the 1971-1972 accident tabulations were formed, another set of these same tabulations was developed with the 05 tape being the basic data source. Six years (1970-1975) of data were used, and for the rural primary highways, the tabulations were further expanded by number of lanes. In this case, number of lanes referred to either 2 lanes, 4 or more lanes undivided (4U), or 4 or more lanes divided (4D). The

[1]This information item was deleted as of January 1, 1973, when a new statewide accident report form was introduced. There have been only slight revisions to the form since this date.

median-involved accidents were expanded not only by number of lanes but also by median width. Thus, 3 distinct sets of tabulations were now created, the basic sources being the 1974-1975 Accident Tapes, the 1971-1972 Accident Tapes, and the 1970-1975 05 tape.

It was then necessary to merge these 3 sets of tabulations. First, the 1973-1975 tables for each fixed object category were expanded by the number of lane proportions developed from the 05 tape. The assumption was made that the six-year 05 tape proportions were stable enough to hold for each year individually on the 1973-1975 accident tapes. Again, it should be noted that this expansion was only possible for the rural primary highways. No comparable information was available for the urban category.

Finally, the tables with number of lane information were again expanded by the curve/tangent proportions developed from the 1971-1972 tapes. It was assumed that these earlier curve/tangent proportions were applicable to the later years. Thus, 3 years of accident data were tabulated by a host of other variables, the final breakdown being the proportion of total accidents, and an accident severity distribution comprised of the proportions of fatal, injury, and PDO accidents for a particular fixed object. For example:

Fixed object = Trees
Roadway Segment = Rural, Area 1, Interstate, 4D, Tangent

1973		1974		1975	
Accident Severity Proportions	Overall Proportion	Accident Severity Proportions	Overall Proportion	Accident Severity Proportions	Overall Proportion
Fatal = 0.000		Fatal = 0.068		Fatal = 0.127	
Inj. = 0.434	.000100387	Inj. = 0.308	.000106619	Inj. = 0.404	.000106371
PDO = 0.566		PDO = 0.625		PDO = 0.469	

These three years are then used to form a:

Composite Estimate

Accident Severity	Overall Proportion
Fatal = 0.080	
Inj. = 0.325	.000107000
PDO = 0.595	

As indicated in the example calculations, the final proportions for each accident type for each of the 3 years (1973-1975) were then used to develop the best composite estimate of these porportions for the particular row combination (roadway segment).

The second basic step involved estimating the predicted statewide total number of accidents for the analysis base year, 1979. This base year was chosen after discussion with Traffic Engineering personnel indicated that budgetary decisions for 1977-78 had already been made and that no new fixed object treatment programs could be implemented before 1979. Table 5 presents the number of North Carolina reportable accidents by year and the percentage change between years. While these data do not indicate clear-cut trends, when the change in PDO reporting level and "energy crisis" years are accounted for, they do point to a general yearly increase in accidents of some 5-7 percent. This increase also is similar to the N.C. Department of Transportation estimate of yearly traffic growth. Thus, an increase in accidents of 6 percent per year was used to arrive at the estimated total of 164,889 for 1979. This total was then used for all analyses.

Table 5. Reportable accidents in North Carolina by year.

Year	Number of Reportable Accidents	% Change
1967	101,615	-
1968	109,383	+7.6%
1969	120,493	+10.2%
1970	124,784	+3.6%
1971	132,986	+6.6%
1972	127,870	-3.8%[1]
1973	125,825	-1.6%
1974	121,568	-3.4%
1975	128,683	+5.8%
1976	138,444	+7.6%

[1]Beginning in January, 1972, the minimum level of reportable property damage accidents increased from $100 to $200, resulting in a decrease in PDO accidents from the year before. However, injury accidents increased 7.1% between 1971 and 1972.

In the example cited above, the two sets of estimates were then applied to the predicted number of accidents occurring in the base year (or year zero) in the analyses. For example:

Total Statewide Accidents (Predicted) in Base Year	x	Overall Proportion	=	Affectable Accidents for Row Combination
164,889	x	.000107000	=	17.6

Then, subdividing the Affectable Accidents for the Row Combination,

Predicted Severity	x	Affectable Accidents For Row Combination	=	No. of Affectable Accidents by Severity
Fatal = .080		17.6		F = 1.4
Inj. = .325		17.6		I = 5.7
PDO = .595		17.6		PDO = 10.5

The predicted severity distributions and the overall proportion (by fixed object) for each row combination are shown in Appendix B of Volume II: User Manual. The number of affectable accidents by severity for each row combination is an internal calculation of the final output system (See Volume II: User Manual).

Estimate of Hazards

The final major component of the overall analysis methodology is the number of hazardous fixed objects beside the roadway. In order for the developed methodology to be implemented, frequency counts had to be developed for each of the ten categories of hazards listed earlier subdivided by location, area of the state, roadway type, number of lanes, and in some cases roadway feature and roadway character.

Data concerning hazardous fixed objects were developed from two basic sources. First, where retrievable data existed, DOH computer files were analyzed to determine the necessary frequencies. As will be noted later, computerized information was available for hazardous bridge components (i.e., bridge ends, bridge rails, and bridge piers), and for hazardous medians on divided highways. Where such DOH data files did not exist, the basic source of information was a 1974 Traffic Engineering Branch report entitled, "Roadside Fixed Object Hazard Inventory" (Grigg, 1974). A detailed discussion of each of these two basic data sources, the methodology employed in merging data from these sources, and a hazard by hazard summary of how final estimates were developed follows.

Data from the Traffic Engineering Branch hazard inventory.

In the Grigg study, frequencies of roadside fixed objects were developed from samples collected on different roadway segments in 17 counties across the State of North Carolina. In each sampling area, actual counts of hazardous obstacles were made in a "windshield survey." Technicians conducting the inventory were instructed concerning what was to be considered hazardous in all cases. For example, hazardous utility poles and trees were defined as all unprotected trees and utility poles which were within 30 feet of the roadway in areas where the speed limit was greater than 40 mph, and all such obstacles within 10 feet of the pavement where the speed limit was less than 40 mph. Hazardous guardrail ends were those guardrail ends which were not flared, buried or cushioned. The data from these samples were expanded to provide estimates of the fixed object frequencies for the entire state. These final estimates of inventory frequencies are shown in

Table 6 on the following page. Data from this table concerning (1) guardrail ends, (2) signs and luminaires, (3) trees, and (4) utility poles were further analyzed in this current study to provide the hazard estimates needed.

As can be seen in Table 6, the statewide estimates of hazards were only subcategorized according to location (rural-urban) and highway type (Interstate, U.S., N.C. and secondary roads). No subcategorization was made according to area in the state, number of lanes, roadway curvature, or roadway character (intersection or nonintersection). Such categorization was necessary in the current efforts in order to make the hazards data compatible with the previously described accident information.

Using information in an appendix to the Grigg report, it was possible to further subdivide the data by number of lanes within a given highway type with estimates of hazards being presented as hazards per mile. It was initially hoped that this more detailed data would allow for subdivision by area within the state. However, the categorization by number of lanes resulted in sample sizes (i.e., inventoried roadway lengths) so small that further sbucategorization by area was not possible.

These estimates of hazards per mile (grouped by location, highway type, and number of lanes) were further studied in order to determine where obvious inconsistencies appeared either between highway types, between number of lanes within highway types, or between rural and urban areas. Such inconsistencies in the estimates of hazards per mile, which could have easily resulted from the size of the sample, were then modified based on discussions between HSRC and DOH personnel. The

Table 6. North Carolina Department of Transportation roadside fixed object hazard inventory. (Taken from Grigg, Roadside Fixed Object Hazards Inventory, 1974, Table 2a.)

SYSTEM	MILEAGE	LENGTH INVENTORIED	PERCENT INVENTORIED	ESTIMATED OBJECTS* TYPE NO.1	TYPE NO.2	TYPE NO. 3	TYPE NO. 4	TYPE NO. 5	TYPE NO. 6	TYPE NO. 7	TYPE NO. 8
Rural -											
Primary	11,862	1,376.12	11.60	6,087	164,600	6,753	3,672	9,780	667,005	67,940	9,702
Interstate	533	85.38	16.02	1,361	25	375	943	1,760	549	194	25
US Routes	4,498	389.38	8.66	2,634	66,607	2,899	1,259	5,337	154,123	30,081	4,228
NC Routes	6,831	901.36	13.20	2,092	97,968	3,479	1,470	2,683	512,333	37,665	5,449
Rural -											
Secondary	59,218	5,380.61	9.09	7,227	695,043	32,473	12,217	2,489	7,136,637	558,428	61,102
Paved	37,471	3,116.50	8.32	6,132	532,409	19,045	9,787	2,345	3,861,250	412,824	36,215
Unpaved	21,747	2,264.11	10.41	1,095	162,634	13,428	2,430	144	3,275,387	145,604	24,887
Mun.-											
Primary	1,611	244.56	15.18	10,787	64,997	1,998	2,051	977	41,430	26,432	694
Interstate	59	25.28	42.85	383	5	145	310	252	147	47	12
US Routes	915	139.54	15.25	6,793	38,694	1,134	1,469	629	19,187	13,659	354
NC Routes	637	79.74	12.52	3,611	26,298	719	272	96	22,096	12,726	328
Mun. -											
Secondary	2,223	265.17	11.93	3,949	70,420	1,861	1,610	654	69,783	34,405	1,073
Tot. -											
Primary	13,473	1,620.68	12.03	16,874	229,597	8,751	5,723	10,757	708,435	94,372	10,396
Interstate	592	110.66	18.69	1,744	30	520	1,253	2,012	696	241	37
US Routes	5,413	528.92	9.77	9,427	105,301	4,033	2,728	5,966	173,310	43,740	4,582
NC Routes	7,468	981.10	13.14	5,703	124,266	4,198	1,742	2,779	534,429	50,391	5,777
Tot. -											
Secondary	61,441	5,645.78	9.19	11,176	765,463	34,334	13,827	3,143	7,206,420	592,833	62,175
Total State	74,914	7,266.46	9.70	28,050	995,060	43,085	19,550	13,900	7,914,855	687,205	72,571

* See page 3 for definitions of estimated objects

Object Type Titles

(1) Light & Sign Supports
(2) Utility poles
(3) Bridge rail ends
(4) Bridge abutments & piers
(5) Guardrail ends
(6) Trees
(7) Other man-made hazards
(8) Other natural hazards

general assumptions used in making these corrections concerned: (1) the similarity of certain roadway types (e.g., four-lane divided U.S. and four-lane divided N.C. are basically new sections of roadways), and (2) observation of trends within a given highway type when shifting from one roadway class to a higher order roadway class (i.e., the trend from U.S. 2-lane to 4-U to 4-D segments should be similar to the trend from N.C. 2-lane to 4-U to 4-D). Based on these assumptions and the resulting discussions, corrected estimates were made. These final estimates are shown in Table 7.

The estimates per mile were then converted to total frequencies per segment for each of the roadway segments by multiplying by the number of miles in each segment. Mileage information was extracted from the DOH Mileage Inventory (characteristics) File (Table 7).

It should be noted that estimated hazard frequencies for the three areas of the state were calculated by multiplying these average estimates of hazards per mile by the mileage figures for the different areas (Coastal Plain, Piedmont, Mountains). Thus, the underlying assumption was that the same number of hazards per mile would be found in all of the three areas across the state. This critical assumption could very definitely be questioned. However, this approach was used because there were no other area-specific data available.

Data extracted from the DOH structures file.

Information concerning the number of hazardous bridge rail ends, hazardous bridge rails, and hazardous bridge piers was developed using data from the Structures File residing in the DOH Bridge Maintenance branch. This file contains information concerning all structures such as bridges, pedestrian walkways, culverts, overhead sign structures,

Table 7. Number of hazardous guardrail ends, signs, utility poles, and trees.

Location	Area	Hwy. Type	No. of Lanes	Mileage	GUARDRAIL ENDS Hazards/ Mile	GUARDRAIL ENDS Total	SIGNS Hazards/ Mile	SIGNS Total	UTILITY POLES Hazards/ Mile	UTILITY POLES Total	TREES Hazards/ Mile	TREES Total
Urban	1	I	4D	4.47	4.27	19	6.49	29	0.08	0	2.49	11
		US	2	197.28	0.29	57	6.83	1347	43.60	8601	21.72	4285
			4U	52.59	0.36	19	7.09	373	61.37	3227	15.28	803
			4D	55.05	1.64	90	8.60	473	22.57	1242	25.19	1387
		NC	2	211.10	0.06	13	5.56	1174	41.41	8742	32.82	6928
			4U	21.41	0.25	5	7.23	155	44.28	948	53.11	1137
			4D	8.46	1.00	8	5.00	42	17.39	147	30.00	254
		City St.	2	2753.62	0.08	220	1.30	3580	36.13	99488	47.58	131017
			4U	499.23	0.25	125	4.46	2227	57.55	28721	23.75	11857
			4D	428.81	3.00	1286	6.00	2573	20.00	8576	25.00	10720
Urban	2	I	4D	65.42	4.27	279	6.49	425	0.08	5	2.49	163
		US	2	198.88	0.29	58	6.83	1358	43.60	8671	21.72	4320
			4U	80.13	0.36	29	7.09	568	61.37	4918	15.28	1224
			4D	133.97	1.64	220	8.60	1152	22.57	3024	25.19	3375
		NC	2	274.79	0.06	16	5.56	1528	41.41	11379	32.82	9019
			4U	41.82	0.25	10	7.23	302	44.28	1852	53.11	2221
			4D	28.52	1.00	29	5.00	14	17.39	496	30.00	856
		City St.	2	3193.99	0.08	256	1.30	4152	36.13	115399	47.58	151970
			4U	821.88	0.25	205	4.46	3666	57.55	47299	23.75	19520
			4D	1096.19	3.00	3289	6.00	6577	20.00	21924	25.00	27405
Urban	3	I	4D	1.87	4.27	8	6.49	12	0.08	0	2.49	5
		US	2	124.61	0.29	36	6.83	851	43.60	5433	21.72	2707
			4U	28.02	0.36	10	7.09	199	61.37	1720	15.28	428
			4D	25.55	1.64	42	8.60	220	22.57	577	25.19	644
		NC	2	64.69	0.06	4	5.56	360	41.41	2679	32.82	2123
			4U	9.51	0.25	2	7.23	69	44.28	421	53.11	505
			4D	2.09	1.00	2	5.00	10	17.39	36	30.00	63
		City St.	2	1276.97	0.08	102	1.30	1660	36.13	46137	47.58	60758
			4U	253.29	0.25	63	4.46	1130	57.55	14577	23.75	6016
			4D	186.03	3.00	558	6.00	1116	20.00	3721	25.00	4651

Table7. (Cont.)

Location	Area	Hwy. Type	No. of Lanes	Mileage	GUARDRAIL ENDS Hazards/ Mile	GUARDRAIL ENDS Total	SIGNS Hazards/ Mile	SIGNS Total	UTILITY POLES Hazards/ Mile	UTILITY POLES Total	TREES Hazards/ Mile	TREES Total
Rural	1	I	4D	126.13	3.30	416	2.55	322	0.05	6	1.03	130
		US	2	1486.71	0.85	1264	0.50	743	16.37	24337	37.51	55766
			4U	26.96	1.20	32	6.00	162	45.00	1213	25.00	674
			4D	249.29	1.85	461	0.96	239	1.70	424	11.50	2867
		NC	2	3127.37	0.40	1251	0.29	907	14.46	45222	75.62	236492
			4U	7.12	1.00	7	6.00	43	45.00	320	25.00	178
			4D	43.76	1.25	55	1.00	44	2.50	109	15.00	656
		SR	2	13807.76	0.04	552	0.12	1657	11.38	157132	123.07	1699321
Rural	2	I	4D	313.43	3.30	1034	2.55	799	0.05	16	1.03	323
		US	2	1135.20	0.85	965	0.50	568	16.37	18583	37.51	42581
			4U	26.91	1.20	32	6.00	161	45.00	1211	25.00	673
			4D	373.99	1.85	692	0.96	359	1.70	636	11.50	4301
		NC	2	2537.27	0.40	1015	0.29	736	14.46	36689	75.62	191868
			4U	15.70	1.00	16	6.00	94	45.00	707	25.00	393
			4D	34.37	1.25	43	1.00	34	2.50	86	15.00	516
		SR	2	18016.21	0.04	721	0.12	2162	11.38	205024	123.07	2217255
Rural	3	I	4D	152.80	3.30	504	2.55	390	0.05	8	1.03	157
		US	2	929.24	0.85	790	0.50	465	16.37	15212	37.51	34858
			4U	25.80	1.20	31	6.00	155	45.00	1161	25.00	645
			4D	137.19	1.85	254	0.96	132	1.70	233	11.50	1578
		NC	2	1109.95	0.40	444	0.29	322	14.46	16050	75.62	83934
			4U	8.34	1.00	8	6.00	50	45.00	375	25.00	209
			4D	4.50	1.25	6	1.00	5	2.50	11	15.00	68
		SR	2	5918.09	0.04	237	0.12	710	11.38	67348	123.07	728339

etc. on primary and secondary roadways across the state. Computer runs were made in order to determine the number of bridges by location, area, highway type, and number of approach lanes. This latter variable had to be captured because it provided the only information concerning lane type. Because twin bridges on four-lane roads would each have two approach lanes and single bridges on 2-lane roads would also have 2 approach lanes, some assumptions had to be made in distributing these bridges by the total number of highway lanes within a given highway type. The assumptions concerned the distribution of mileage between 4-lane divided and 2-lane roadway in each area. Bridges were redistributed according to these mileage ratios. Using this process, final estimates of the number of bridges by area in the state, urban-rural location, highway type,and number of lanes were developed. Based on these bridge frequencies, the number of "possible" hazardous bridge ends was calculated.

Additional runs were made on the same file concerning the number of bridges crossing over roadways (i.e., based on "route under the structure" rather than "route on the structure"). Using this information coupled with data concerning the number of main spans and distance to a bridge pier in a median, the overhead bridges were redistributed by area, highway type and number of lanes. The resulting frequencies could be considered possible hazardous bridge piers.

The earlier referenced hazards inventory (Grigg, 1974) also contained estimates of the number of hazardous bridge rail ends and bridge piers. An attempt was made to merge this information with the information described above in order to calculate and verify the number of hazardous bridge ends and piers. Under the previously noted assumption of an equal number of hazardous bridges per mile across all areas of the state, estimates of the numbers of hazardous bridge piers and bridge ends were obtained from the Grigg data and were then compared to the number of possible hazardous bridge features calculated above. These calculations indicated percentages of possible ends and piers which were considered hazardous varied widely across the state, and that data in certain cells were obviously inaccurate in that the final estimates of hazardous features were greater than the total number possible, probably as a result of the earlier mentioned assumption of equal hazards per mile statewide. For this reason a secondary method of determining the number of hazardous bridge piers and bridge ends was used.

In cooperation with Traffic Engineering personnel, estimates of the percentage of mileage built to lower standards, and thus estimates of the percentages of non-corrected bridge piers, bridge ends, and bridge rails were developed for each area, highway type and number of lanes. In these discussions, factors such as the date in which certain mileage segments were upgraded (e.g., the newness of most N.C. four-lane divided mileage) and information concerning special projects of mileage upgrading (e.g., recently upgraded Interstate segments) were brought to light. For example, a detailed examination of all Interstate roadway mileage in the state was conducted to determine the years in which given segments had been either completed or upgraded. This provided information concerning which of the segments would include bridges which should be considered non-hazardous (i.e., built to the latest standards) and which segments would contain bridges which were hazardous. The final estimated proportions of hazardous bridges by roadway type, mileage and area within the state are contained in Table 8. These

Table 8. Number of hazardous bridge ends, shoulder bridge piers, and median bridge piers.

Location	Area	Hwy. Type	No. Of Lanes	BRIDGE ENDS: Total Ends	BRIDGE ENDS: % Hazardous	BRIDGE ENDS: No. Of Hazardous Ends	BRIDGE PIERS (SHOULDER): Total Piers	BRIDGE PIERS (SHOULDER): % Hazardous	BRIDGE PIERS (SHOULDER): Total Hazardous Piers	BRIDGE PIERS (MEDIAN): Total Piers	BRIDGE PIERS (MEDIAN): % Hazardous	BRIDGE PIERS (MEDIAN): Total Hazardous Piers
Rural	1	I	4D	66	52	34	132	52	69	66	52	34
		US	2	924	80	739	20	80	16	0	80	0
			4U	44	75	33	6	75	5	0	75	0
			4D	188	30	56	44	30	13	22	30	7
		NC	2	2008	85	1707	12	85	10	0	85	0
			4U	12	75	9	6	75	5	0	75	0
			4D	32	30	10	4	30	1	2	30	1
		SR	2	3558	90	3202	26	90	23	0	90	0
			4U	-	-	-	-	-	-	-	-	-
			4D	-	-	-	-	-	-	-	-	-
Rural	2	I	4D	318	34	108	328	34	112	164	34	56
		US	2	576	80	461	112	80	90	0	80	0
			4U	88	75	66	38	75	29	0	75	0
			4D	332	45	149	174	45	78	86	45	39
		NC	2	1404	85	1193	48	85	41	0	85	0
			4U	32	75	24	4	75	3	0	75	0
			4D	28	45	13	14	45	6	2	45	1
		SR	2	8328	90	7495	110	90	99	0	90	0
			4U	-	-	-	0	-	-	0	-	-
			4D	-	-	-	20	-	-	6	-	-
Rural	3	I	4D	238	76	181	146	76	111	73	76	55
		US	2	752	80	602	22	80	18	0	80	0
			4U	60	75	45	8	75	6	0	75	0
			4D	144	30	43	62	30	19	28	30	8
		NC	2	984	85	836	30	85	26	0	85	0
			4U	12	75	9	4	75	3	0	75	0
			4D	8	30	2	8	30	2	4	30	1
		SR	2	6558	90	5902	140	90	126	0	90	0
			4U	-	-	-	2	-	-	0	-	-
			4D	-	-	-	4	-	-	2	-	-

Table 8. (cont.)				BRIDGE ENDS			BRIDGE PIERS(SHOULDER)			BRIDGE PIERS(MEDIAN)		
Location	Area	Hwy. Type	No.Of Lanes	Total Ends	Hazardous	No. Of Hazardous Ends	Total Piers	% Hazardous	Total Hazardous Piers	Total Piers	% Hazardous	Total Hazardous Piers
Urban	1	I	4D	20	52	10	4	100	4	2	100	2
		US	2	48	80	38	6	80	5	0	80	0
			4U	88	75	66	12	75	9	0	75	0
			4D	20	30	6	20	30	6	8	30	2
		NC	2	96	85	82	8	85	7	0	85	0
			4U	20	75	15	0	75	0	0	75	0
			4D	4	30	1	4	30	1	0	30	0
		SR	2	-	-	-	4	-	-	0	-	-
			4U	-	-	-	2	-	-	0	-	-
			4D	-	-	-	0	-	-	0	-	-
Urban	2	I	4D	198	34	67	200	85	170	100	85	85
		US	2	100	80	80	62	80	50	0	80	0
			4U	236	75	177	30	75	23	0	75	0
			4D	218	45	98	154	45	69	71	45	32
		NC	2	128	85	109	22	85	19	0	85	0
			4U	84	75	63	6	75	5	0	75	0
			4D	18	45	8	28	45	13	11	45	5
		SR	2	-	-	-	62	-	-	0	-	-
			4U	-	-	-	14	-	-	0	-	-
			4D	-	-	-	26	-	-	9	-	-
Urban	3	I	4D	4	76	3	12	100	12	6	100	6
		US	2	152	80	122	4	80	3	0	80	0
			4U	68	75	51	10	75	8	0	75	0
			4D	50	30	15	22	30	7	11	30	3
		NC	2	52	85	44	6	85	5	0	85	0
			4U	16	75	12	4	75	3	0	75	0
			4D	4	30	1	0	30	0	0	30	0
		SR	2	-	-	-	10	-	-	0	-	-
			4U	-	-	-	4	-	-	0	-	-
			4D	-	-	-	8	-	-	4	-	-

percentages were then multiplied by the number of bridges previously defined as possibly hazardous to result in a number of hazardous bridges by roadway type, mileage, area, and location (Table 8).

Information was also extracted from the bridge file concerning the lengths of bridges. After being redistributed by area, highway, and number of lanes by the same mileage-based process described above, this length data provided a means of estimating the number of feet of existing bridge rail by the various categories. These lengths of possible hazardous rail were converted to feet of hazardous railing using percentage estimates similar to those above developed by HSRC and DOH (Table 9). Since the latest standards for acceptable (non-hazardous) bridge railing are newer than the standards for bridge end and pier protection, the percentages of hazardous railing are higher than those percentages used in the preceding calculations concerning ends and piers.

Median-related data extracted from mileage inventory file.

A third major data source, the Mileage Inventory File, provided information concerning the final hazardous category analyzed -- cross median accidents. The treatment to be used would be a median barrier of some type.[1] In order to obtain the necessary estimates of hazardous medians, a count of the number of miles of median by roadway type, area, location, and number of lanes was extracted from this file. This information was further subdivided by grouping medians into widths of 1-12 feet, 13-30 feet, 31-60 feet and 60+ feet. The resulting figures for total median length by width, area, location, number of lanes, and

[1]It is acknowledged that current DOH policy is to install no barrier on medians greater than 30 feet wide.

Table 9. Feet of Hazardous Bridge Rail

Location	Area	Hwy. Type	No.of Lanes	Total Feet of Rail	% Hazardous	Feet of Hazardous Bridge Rail
Urban	1	I	4D	6296	90	5666
		US	2	17397	95	16527
			4U	20320	95	19304
			4D	13669	85	11619
		NC	2	10810	95	10270
			4U	2430	95	2309
			4D	914	85	777
Urban	2	I	4D	41394	90	37255
		US	2	9368	95	8900
			4U	20798	95	19758
			4D	42414	85	36052
		NC	2	11733	95	11146
			4U	7366	95	6998
			4D	3017	85	2564
Urban	3	I	4D	792	90	713
		US	2	13836	95	13144
			4U	13866	95	13173
			4D	8846	85	7519
		NC	2	3465	95	3292
			4U	1134	95	1077
			4D	647	85	550

Table 9. (Continued)

Location	Area	Hwy. Type	No.of Lanes	Total Feet of Rail	% Hazardous	Feet of Hazardous Bridge Rail
Rural	1	I	4D	19304	90	17374
		US	2	194039	95	184337
			4U	11622	95	11041
			4D	76863	85	65334
		NC	2	225487	95	214213
			4U	980	95	931
			4D	6929	85	5890
		SR	2	385748	95	366460
Rural	2	I	4D	75974	90	68377
		US	2	68284	95	64870
			4U	8704	95	8269
			4D	71196	85	60517
		NC	2	130308	95	123793
			4U	4154	95	3946
			4D	4108	85	3492
		SR	2	558070	95	530167
Rural	3	I	4D	55784	90	50206
		US	2	59853	95	56860
			4U	5100	95	4845
			4D	22519	85	19141
		NC	2	62132	95	59025
			4U	1318	95	1252
			4D	876	85	745
		SR	2	306826	95	291485

highway type are shown in Table 10. Final estimates of unprotected (hazardous) median lengths in each of these categories were calculated by deleting those sections (especially Interstate segments) where barriers currently exist and by a slight modification to account for short sections now protected by barriers around bridge piers.

Data Extracted from Mileage Inventory Files Concerning Intersection and Nonintersection Locations

One of the categories of hazards -- utility poles -- is categorized and analyzed by road characteristic (i.e., whether at intersection or non-intersection locations). In order to distribute the number of these hazards into intersection/non-intersection locations, information was extracted from the mileage inventory file concerning the number of intersections by location, area, and number of lanes for each of the roadway types to be analyzed. This information existed for all primary roadways, including those instances in which a primary roadway was crossed by a secondary roadway. Information did not exist on the secondary roadways since these are not yet available on the file. However, estimates of the number of intersections on secondary roadways were obtained using trends based on the numbers of intersections on the other roadways and based on the number of miles of secondary roadway that exist in the state.

Data Concerning Curve and Tangent Segments

Finally, the hazard categories relating to utility poles, trees, and signs were further subcategorized by whether the hazard was located on a curve or tangent segment. As noted in a preceding section, accident data for curves was obtained from 1971-72 accident files.

Table 10. Miles of Hazardous Median For Rural Locations

Area	Highway Type	Median Width (ft.)	Miles of Median	Hazardous Miles of Median
1	I	1-12	0	0
		13-30	41.93	41.51
		31-60	55.63	55.07
		61+	28.57	28.28
	US	1-12	19.77	19.77
		13-30	95.67	95.67
		31-60	98.55	98.55
		61+	35.37	35.37
	NC	1-12	1.51	1.51
		13-30	11.37	11.37
		31-60	25.43	25.43
		61+	5.45	5.45
2	I	1-12	0.08	0.08
		13-30	80.26	79.46
		31-60	145.77	144.31
		61+	87.32	86.45
	US	1-12	28.76	28.76
		13-30	156.49	156.49
		31-60	150.58	150.58
		61+	38.02	38.02
	NC	1-12	3.94	3.94
		13-30	11.93	11.93
		31-60	14.77	14.77
		61+	3.73	3.73
3	I	1-12	26.73	18.71
		13-30	34.09	23.86
		31-60	83.16	83.16
		61+	8.82	8.82
	US	1-12	21.40	21.40
		13-30	25.31	25.31
		31-60	88.05	88.05
		61+	2.40	2.40
	NC	1-12	2.38	2.38
		13-30	1.76	1.76
		31-60	0.36	0.36
		61+	0.00	0.00

Because comparable data did not exist in the hazard inventory file, and because information on the number and length of curves does not exist on the roadway inventory file, certain assumptions had to be made in order to obtain necessary estimates. (Note: This lack of curve data is one of the more serious problems in the existing North Carolina inventory system. As will be seen in the RECOMMENDATIONS section, it is strongly recommended that an inventory be conducted to collect this data.)

To obtain this information, independent estimates of the percent of total roadway which are curved segments were obtained from traffic engineering and design personnel within the Division of Highways. The estimated percentages were to be specific to area, location, roadway type and number of lanes. These estimates, some of which were based on samples taken from drawings of roadway segments, were then combined to result in the final percentages shown in Table 10. In distributing the number of hazards to the curve and tangent sections, the assumption was made that the number per mile would be the same on curve sections as on tangent sections.

<u>Summary</u>.

In the remainder of this section a summary is presented of: (1) the definition of each hazardous object, and (2) the method for obtaining the frequency of hazardous objects. In many cases the detailed discussion of data sources above will be referred to in the individual data collection methodology descriptions. The hazards will be described and discussed in the order in which they appear in the computerized Roadside Hazard Correction Ranking program (see Volume II).

1. Hazardous bridge rail ends

Description: Unprotected bridge rail ends or bridge rail ends without guardrail properly attached to the rails.

Data collection methodology: Estimates of hazardous bridge rail ends were developed using data from the bridge file and estimates of the percent of upgraded roadway provided by Division of Highways personnel.

2. Hazardous bridge rails

Description: Any bridge rail which when struck, could result in vehicle pocketing or vehicle instrusion (i.e., any bridge rail which does not meet the most current Interstate standards).

Data collection methodology: Estimates of the number of feet of hazardous bridge rail by various subcategories were developed from both the bridge file data and estimates of upgraded bridges developed by HSRC and DOH personnel.

3. Hazardous guardrail ends on the shoulders

Description: Guardrail ends which are not flared, buried, or cushioned and are without proper anchorage (approach ends only).

Data collection methodology: This estimate of hazardous guardrail ends was developed from the above referenced traffic engineering inventory data (Grigg, 1974) combined with data concerning the amount of mileage by roadway type and number of lanes from the Mileage Inventory File.

4. Hazardous guardrail ends in the median

Description: Same as above.

Data collection methodology: Same as above.

5. Hazardous sign and/or luminaire supports

Description: All non-breakaway or non-yielding light or sign supports within 20 feet of the edge of the travel way(within 10 feet in urban areas)except those located in protected areas.

Data collection methodology: The estimates of hazardous signs were based on the above referenced traffic engineering inventory (Grigg, 1974). The estimates were further subcategorized using data from the Mileage Inventory Tape and by curve and tangent information provided by DOH personnel.

6. Hazardous trees

Description: Trees located within 30 feet of the edge of the travel area (within 10 feet in urban areas) except those in protected locations.

Data collection methodology: Basic estimates were obtained from the Traffic Engineering inventory (Grigg, 1974). These estimates were further subdivided using data from the mileage inventory file and estimates of curve and tangent information provided by DOH personnel.

7. Hazardous bridge piers on the shoulder

Description: Any bridge pier without proper guardrail or shielding treatment located on the shoulder of a highway.

Data collection methodology: Estimates obtained from the above described DOH bridge file were modified using inputs from DOH personnel concerning the percent of hazardous roadway and percent of hazardous bridges in each roadway segment category.

8. Hazardous bridge piers on the median

Description: Same as above except only those piers located in the median of a four-lane divided roadway.

Data collection methodology: Same as above.

9. Hazardous utility poles

Description: Utility poles within 30 feet of the edge of travel way (within 10 feet in urban areas) except those installed in protected locations.

Data collection methodology: The basic estimates of the numbers of hazardous utility poles were taken from the Traffic Engineering inventory (Grigg, 1974). These estimates were further subcategorized based on lane information taken from the roadway inventory figures, on intersection/non-intersection information taken from the roadway inventory tape, and on curve and tangent information provided by DOH personnel. The percentage of utility poles located at intersection locations was based on assumptions involving the percentage of roadway accounted for by intersection locations weighted by the average number of poles per intersection.

10. Cross median accidents

Description: Any median associated with a four-lane divided roadway in which a median barrier is not present.

Data collection methodology: The calculations of the lengths of unprotected medians were based on length of median from the roadway inventory file for each roadway segment type. The final calculation of miles of hazardous medians was based on these figures modified by the percent with segments known to have barriers installed and by a factor related to barriers associated with protected bridge piers.

In summary, the above described methodology was used to estimate the number of hazards for each of the roadway segments to be analyzed. The validity of the estimates is dependent on both the adequacy of the sample used to develop the Roadside Fixed Object Hazard Inventory and the viability of the assumptions used. The overall hazard correction methodology developed in this report would be much stronger if estimates of some of the hazards could be updated (see RECOMMENDATIONS section).

Economic Analysis Methodology for Evaluating Potential Improvements

When considering the economic evaluation of various highway safety improvements, calculations involving costs, benefits, cost-effectiveness, or some combination of these are generally considered. In an attempt to provide administrators concerned with engineering improvements with a better tool for deciding how to allocate resources, NCHRP Report 162, "Methods for Evaluating Highway Safety Improvements," was developed. However, this report discusses several economic techniques without necessarily recommending one technique over others, although the benefit/cost ratio is recommended in the User's Guide. It should also be noted that NCHRP Report 162 has generated some comment concerning the ranking of alternatives from Dr. G. A. Fleischer of the University of Southern California (Fleischer, 1977).

Alternative methods.

Fleischer's criticism is that it is basically unsound to rank competing alternatives on the basis of a calculated benefit-cost (B/C) ratio.[1] He points out that the placement of certain costs, such as maintenance or repair costs, in either the numerator or denominator of the B/C ratio can affect the calculation in such a way as to alter any subsequent ranking based on B/C ratio. Indeed, it would appear that the numerator-denominator issue has spawned considerable debate, without a definite resolution of the issue.

Many references recommend the use of the net present worth or net discounted present value (NDPV) technique for ranking of alternatives. The NDPV method calculates the algebraic difference in the present worths of both outward cash flows (costs) and inward cash flows (benefits or incomes). The alternative with the greater NDPV is identified as the one with the greater economy.

The NDPV technique was used to rank alternatives in the earlier MVMA study (Council and Hunter, 1975) where the following specific rules were formulated:

[1]Most texts agree (Winfrey, 1969; Grant and Ireson, 1964), pointing out that if alternatives are to be ranked based on a B/C ratio, then incremental B/C ratios should be considered.

(1) For each investment in a particular safety measure, compute for the service life of the project the NDPV of the measure including capital and maintenance costs, and accident benefits, using appropriate discount rates.

(2) If the choice lies between accepting or rejecting the investment, accept if the NDPV is greater than zero and reject if the NDPV is less than zero.

(3) When comparing alternative investments, each having a NDPV greater than zero, where only one can be selected, accept the alternative for which the present value is greatest. If the time periods (service lives) encompassed by the alternative investments are not comparable, simply convert the two investments into average annual cash flows. Accept the alternative with the largest present value.

The NDPV method was also used to develop the priority ranking in the current project. Due to the popularity of the calculation, the B/C ratio was also developed for each alternative, with repair costs per crash subtracted from the calculated accident benefits in the numerator part of the ratio. This was done after discussions with TE personnel indicated a general concensus that for most of the fixed-object crash-related repairs, the associated costs more closely represented a negative benefit. The denominator part of the ratio includes initial costs and maintenance costs.

Other considerations.

In the performance of an economic analysis technique, numerous input data are involved. Some of the more important variables used are described below.

1. Discount rate - Selection of an appropriate discount rate(s) is a critical step in any analysis of investment opportunities, as it can easily affect outcomes. The choice of the discount rate may depend on a number of factors, including the current marginal borrowing

rate of the public agency making the investment. Economists might argue that the marginal rate of return in marginal long-term investment in the private sector and the social rate of discount be considered also.[1] TE personnel felt that the discount rate associated with long-term borrowing for roadway construction[2] was the overriding factor, and, based on North Carolina trends a discount rate of 6 percent was chosen for the value to be used in the development of the priority ranking. The discount rate is an input variable in the basic system, and thus may be easily changed (See Volume II: User's Manual).

2. Inflation rate - An inflation factor designed to reflect the increasing costs of accidents and treatments with time has also been included as a basic input variable. Since inflation seems to vary widely over time, average inflation rates have been estimated that correspond to 3 basic service lives of 5, 10, and 20 years, as shown below:

Service Life	Estimated Average Inflation Rate	Inflation Factor
5 years	6.7%	1.067
10 years	5.7%	1.057
20 years	4.7%	1.047

The appropriate inflation factor is applied to the maintenance costs, repair costs, and accidents costs in the economic analysis.

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[1]For a more formal discussion, see Council and Hunter, "Implementation of Proven Technology in Making the Highway Environment Safe." pp. 153-154.

[2]As indicated in NCHRP Report 162, these rates are available from the publication entitled The Bond Buyer.

Recognizing the difficulty in predicting future inflation rates, NCHRP Report 162 recommends that no inflation factor be used in a highway economic study. However, after discussions with TE personnel, it was decided that the above inflation factors would be used in developing the priority ranking, since TE currently uses similar inflation factors in other studies. Appropriate values may be input at any time the system is used in the future.

3. Service lives - Service life is the time estimate that a roadside fixed-object improvement may reasonably affect accident frequency and/or severity. For the improvements used in this project, 20 years was the maximum value used. Values for specific treatments are shown earlier in Table 2. These values resulted from knowledge obtained in the literature review and discussions with both manufacturers of certain systems and various highway department personnel.

4. Salvage values - Salvage values are appropriate to many economic analyses. However, it was felt that the use of these would have a minimal effect on the outcome of the fixed-object improvements analyzed, and thus zero salvage values were assumed in all cases.

5. Accident growth factor - An annual growth rate of 4 percent for untreated accidents was a fifth input into the analysis system. This growth rate was estimated by the N.C. DOH and represents the approximate increase in yearly traffic volume. The internal computation algorithms assume that accidents are directly proportional to change in yearly traffic volume (or vehicle miles). This growth rate is also assumed to be constant over the service life of the project.

6. Starting year - Starting year is a basic input to the economic analysis and represents the year in which the treatment is implemented

(i.e., the year preceding the initial benefit accumulation). Based on TE budget requirements, the starting year (or year zero) for the development of the priority ranking presented in the RESULTS section was 1979. Thus, accident benefits would first accrue in 1980.

7. Accident costs - In this analysis, benefits are derived from accident savings. Thus, costs must be associated with fatal, injury, and PDO accidents. To some, this notion of assigning costs to lives and injuries is totally unacceptable. To others, it is a necessary ingredient in the economic analysis of highway safety improvements. The concept has been used for many years by TE in their internal analyses.

Estimates of these accident costs vary widely, but the basis for the costs used in this study is a 1974 study by Barrett entitled, "Crashes and Costs: Societal Losses in North Carolina Motor Vehicle Accidents." Using a methodology similar to that employed by the National Safety Council, Barrett developed the following costs in 1973 dollars:

Fatality	$84,400
Non-fatal injury	$ 5,350
PDO	$ 325[1]

Expanding these numbers from an occupant to an accident base[2] and applying the change in the Consumer Price Index, these costs were updated from the end of 1973 to 1976 dollars with the following results:

[1]This $325 was based on all PDO accidents, whether reportable (≥ $200 or not). Based on a traffic engineering analysis of reportable accidents, the PDO value used in all later analyses was $585.

[2]Using 1973 N.C. Accident data: (1) the average number of fatalities per fatal accident = 1.180, (2) the average number of injuries per fatal accidents = 1.118, and (3) the average number of injuries per injury accident = 1.601.

Fatal accident	$133,637
Injury accident	$ 10,946
PDO accident	$ 743

These costs are internal inputs in the basic system. To inflate these 1976 costs to 1979 figures, an average annual inflation rate of 6.7 percent was used by the system. As explained in the Volume II: User Manual, the computerized system expands 1976 costs to appropriate starting year dollars automatically, with the average inflation rate used being dependent on the length of time between 1976 and the starting year.

Computerized system

As has been alluded to above, a major project goal was the development of a computerized system which would perform the economic analysis by combining all the inputs depicted in Figure 1, the schematic representation of the project methodology. The accident frequency/severity reduction factors, the estimate of affectable accidents, the estimate of hazard occurrence, the cost data, the linkage of the affectable accidents with the proper reduction factor, and the economic analysis of the alternatives are all computerized in the developed system. While operation of the system is fully detailed in Volume II: User Manual, a brief explanation is presented at this point.

The economic analysis component of the system may be activated for any hazard/treatment/roadway segment combination or combinations (i.e., any row(s) of an internal input matrix) by submitting certain required user input cards. For example, one may be interested in determining the NDPV and the B/C ratio for the removal of trees within 30 feet of the edge of pavement for the following roadway segment:

Area	Rural or Urban	Highway Type	No. of Lanes	Curve or Tangent
1	Rural	U.S.	2	Tangent

The information pertinent to the economic analysis (i.e., the accident, hazard, and treatment data) would be linked, the economic analysis portion of the system would be activated, and 2 output tables would be developed (Tables 11 and 12).

Table 11 presents the accident reduction information used to derive the dollar benefits. It is assumed that the untreated accidents would increase at the growth rate of 4 percent per year. The reduction factors for the tree removal treatment (50% for fatal car tree crashes, 25% for injury crashes, and a 20% increase in PDO crashes) are applied to the untreated accidents to produce the number of treated accidents. The last set of columns indicates the number of accidents reduced. As indicated by the totals below the final three reduction columns, the treatment is predicted to result in reductions of 41.79 fatal crashes and 167.78 injury accidents at a tradeoff for increasing PDO crashes by 87.89 over its ten year life.

Table 12 presents the layout for the computation of the NDPV and the B/C ratio. The treatment cost is the product of the number of hazards present for this row combination and the cost to improve each hazard and is assumed to occur when the improvement is completed (in the starting year). The treatment cost plus the discounted annual maintenance costs must be exceeded by the cumulative total of the annual discounted benefits over the service life of the treatment for the NDPV to be positive.

Table 11. Example of accident information needed for the economic analysis.

ACCIDENT REDUCTION TABLE (A)

PREDICTED ACCIDENTS = 164889
TRAFFIC GROWTH RATE = 1.0400
INFLATION FACTOR = 1.0570

STARTING YEAR : 1979

% FAT. REDUCED = 50.00
% INJ. REDUCED = 25.00
% PDO REDUCED = -20.00

(06 06) TREES TREES - REMOVAL

RURAL AREA(1) N.C. 2-LANE TANGENT

YEAR	NUMBER OF UNTREATED ACCIDENTS			NUMBER OF TREATED ACCIDENTS			NUMBER OF ACCIDENTS REDUCED		
	FATAL	INJURY	PDO	FATAL	INJURY	PDO	FATAL	INJURY	PDO
0	6.69	53.75	35.19	0.00	0.00	0.00	0.00	0.00	0.00
1	6.96	55.90	36.60	3.48	41.92	43.92	3.48	13.97	-7.32
2	7.24	58.13	38.07	3.62	43.60	45.68	3.62	14.53	-7.61
3	7.53	60.46	39.59	3.77	45.34	47.51	3.77	15.11	-7.92
4	7.83	62.88	41.17	3.92	47.16	49.41	3.92	15.72	-8.23
5	8.14	65.39	42.82	4.07	49.04	51.38	4.07	16.35	-8.56
6	8.47	68.01	44.53	4.24	51.01	53.44	4.24	17.00	-8.91
7	8.81	70.73	46.31	4.40	53.05	55.58	4.40	17.68	-9.26
8	9.16	73.56	48.17	4.58	55.17	57.80	4.58	18.39	-9.63
9	9.53	76.50	50.09	4.76	57.37	60.11	4.76	19.12	-10.02
10	9.91	79.56	52.10	4.95	59.67	62.51	4.95	19.89	-10.42
						TOTAL :	41.79	167.78	-87.89

Table 12. Example of computation of Net Discounted Present Value and Benefit Cost ratio.

ECONOMIC ANALYSIS TABLE (B)

NUMBER OF HAZARDS = 184464.00 STARTING YEAR : 1979

(06 06) TREES TREES - REMOVAL

RURAL AREA(1) N.C. 2-LANE TANGENT

YEAR	TREATMENT COST ($)	ANNUAL MAINT COST ($)	ANNUAL REPAIR COST ($)	ACCIDENT BENEFITS ($)	PWORTH FACTOR @.06	PWORTH OF BENEFITS ($)	PWORTH OF COSTS ($)	PWORTH OF NET CASH FLOW ($)	CUMULATIVE BALANCE ($)
0	5533920	0	0	0	1.0000	0	5533920	-5533920	-5533920
1	0	0	0	786754	0.9434	742221	0	742221	-4791699
2	0	0	0	864863	0.8900	769725	0	769725	-4021975
3	0	0	0	950726	0.8396	798248	0	798248	-3223727
4	0	0	0	1045114	0.7921	827829	0	827829	-2395898
5	0	0	0	1148873	0.7473	858505	0	858505	-1537393
6	0	0	0	1262934	0.7050	890318	0	890318	-647075
7	0	0	0	1388318	0.6651	923310	0	923310	276236
8	0	0	0	1526150	0.6274	957525	0	957525	1233761
9	0	0	0	1677666	0.5919	993008	0	993008	2226769
10	0	0	0	1844225	0.5584	1029805	0	1029805	3256574

THE NDPV = $ 3256574

THE ANNUAL BENEFITS = $ 412911

BENEFIT / COST RATIO = 1.588475

The annual maintenance cost is the cost to maintain the treated hazards yearly, and the annual repair cost is the cost to fix treated hazards after they are struck. (In this example, both are zero.) The accident benefits are derived by multiplying the yearly number of reduced fatal, injury, and PDO accidents by their associated costs and then subtracting the annual repair costs. If an inflation factor is used, the maintenance, repair, and accident costs are increased by this amount annually.

Present worth factors are shown for the designated discount rate. The present worth of benefits is the product of the accident benefits and the present worth factor for each year. The present worth of costs is the product of the initial cost and the yearly maintenance costs multiplied by the present worth factor. The present worth of the net cash flow is the algebraic difference of the present worth of benefits and the present worth of costs. Finally, the cumulative balance is obtained by summing the present worth of the net cash flow for each successive year while retaining the positive or negative sign. The last amount in this final column then represents the NDPV of the improvement at the end of the service life. The NDPV is also printed at the bottom of the table. Thus the NDPV actually represents the cumulative present worth of net cash flow of:

[Accident savings - initial costs - maintenance costs - repair costs]

Two other values are also shown at the bottom of the table. The annual benefits are obtained by converting the NDPV to an annualized amount (i.e., the average annual benefit over the entire service life) by multiplying the NDPV by the appropriate capital recovery factor.

This is done in order to allow comparison of alternative investments with unequal service lives. The benefit/cost ratio is calculated internally, and the necessary columns are not printed in this table. The B/C ratio represents the cumulative present worth of:

(Accident savings - repair costs) ÷ (Initial costs + maintenance costs)

While this example only refers to one hazard/treatment/segment combination, the system will analyze any number of such combinations. In addition, another feature of the computerized system which should be mentioned is a subroutine which was developed to allow users to collapse row combinations. For example, the analysis has been concerned with removal of hazardous trees on roadway segments defined as follows:

Area 1   Rural   U.S.   2-lanes   tangent

This row collapse subroutine would allow the user to sum over certain roadway segment identifiers. For example,

Area 1 + 2   Rural   U.S. + N.C.   2-lanes   tangent

could be studied in a subsequent economic analysis. In this example, Areas 1 and 2 and U.S. and N.C. highway types are combined for rural, 2-lane, tangent roadway sections. This feature provides the user with a large amount of flexibility.

The collapsing of row combinations takes into account the variations in such variables as proportion of affectable accidents; number of hazards; proportion of fatal, injury, and PDO accidents; costs; and reduction factors. Weighting techniques are used to combine some of these variables when the collapsing option is used. (The collapsing procedures are fully described in Volume II: User Manual - Appendix C).

CHAPTER 3 - RESULTS

The previous section was concerned with a description of the basic parts of the system needed to compare alternative fixed-object improvement programs. This chapter will describe the results of the comparisons. The basic input variables include: (1) a starting year of 1979, (2) 164,889 predicted accidents in 1979, (3) discount rate of 6 percent, (4) a traffic growth rate of 4 percent, and (5) an inflation factor of 1.057.

Priority Ranking of Programs

Economic analyses were performed for each row combination (i.e., hazard/treatment/segment combination) built into the internal matrix of the system. This involved some 942 rows. Of this number, 279 were found to have a positive Net Discounted Present Value. These were then ranked, based on NDPV. The first 20 rows of the ranking are contained in Table 13. The entire priority ranking is shown in Appendix B. This is the most specific information generated by the system. A ranking based on B/C ratio was also developed.

The program shown to have the largest payoff was the use of transition guardrail at hazardous bridge ends for rural, Interstate (4 lane divided) roadway in the Piedmont. The annual benefits for this program amount to $4.7 million, and the B/C ratio is 80.54. The cost of this treatment over this area is approximately $600,000.

It is instructive to note that the top 20 programs in Table 13 are all concerned with either bridge ends, cross median involvements, or trees. These top 20 programs, however, have a combined total cost of approximately $103 million.

Table 13. First 20 rows (of 279 rows with positive Net Discounted Present Value) of the priority ranking.

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (01 01)	BRIDGE ENDS RURAL AREA(2) INTERSTATE 4-DIV	BRIDGE END TRANSITION GUARDRAIL	4717396	80.535399	599400
2 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 4-DIV 13-30 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB	3392460	5.756200	8390975
3 (01 01)	BRIDGE ENDS RURAL AREA(2) N.C. 2-LANE	BRIDGE END TRANSITION GUARDRAIL	3296543	15.320512	2326350
4 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 4-DIV 13-30 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	2493450	5.004071	6293231
5 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) U.S. 4-DIV 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	1649800	3.136113	7805159
6 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) N.C. 4-DIV 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	1495312	8.503002	2014055
7 (01 01)	BRIDGE ENDS RURAL AREA(1) INTERSTATE 4-DIV	BRIDGE END TRANSITION GUARDRAIL	1138157	61.954433	188700
8 (06 06)	TREES URBAN AREA(2) C.S. TANGENT	TREES - REMOVAL	1131649	2.759765	5071800
9 (06 06)	TREES RURAL AREA(2) N.C. 2-LANE CURVE	TREES - REMOVAL	1025099	5.681971	1726800
10 (06 06)	TREES RURAL AREA(2) S.R. 2-LANE CURVE	TREES - REMOVAL	978562	1.290065	26607060

Table 13. Continued

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) U.S. 1-12 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB 4-DIV	931789	4.609299	3037055
12 (06 06)	TREES URBAN AREA(2) C.S. CURVE	TREES - REMOVAL	926591	9.164806	895050
13 (06 07)	TREES URBAN AREA(2) C.S. CURVE	TREES - (STUMP REMOVED)	813105	4.582403	1790100
14 (06 07)	TREES RURAL AREA(2) N.C. CURVE	TREES - (STUMP REMOVED) 2-LANE	806153	2.840985	3453600
15 (06 06)	TREES RURAL AREA(1) U.S. TANGENT	TREES - REMOVAL 2-LANE	692221	5.079126	1338390
16 (06 06)	TREES RURAL AREA(1) N.C. CURVE	TREES - REMOVAL 2-LANE	687806	4.475465	1560840
17 (06 06)	TREES RURAL AREA(1) S.R. CURVE	TREES - REMOVAL 2-LANE	685183	1.424009	12744900
18 (01 01)	BRIDGE ENDS RURAL AREA(1) S.R.	BRIDGE END TRANSITION GUARDRAIL 2-LANE	636453	2.030114	6243900
19 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) U.S. 13-30 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB 4-DIV	635862	1.740425	10102751
20 (01 01)	BRIDGE ENDS RURAL AREA(3) INTERSTATE	BRIDGE END TRANSITION GUARDRAIL 4-DIV	616845	7.205543	1004550

Other interesting findings can be gained from the examination of the row by row results for a specific treatment class (Table 14). The transition guardrail for bridge ends pays off for practically all rural locations, but only two Interstate locations in urban areas. Improved bridge rails, which may become a high priority item with FHWA in the near future, does not pay off on any roadway segment. This treatment, however, is relatively expensive.

The breakaway cable terminal (BCT) for shoulder guardrail ends appears to be most effective for rural locations in Area 3, the mountainous area. The Texas twist end treatment, which was inserted primarily for comparison purposes, exhibits similar characteristics. Both the BCT and Texas twist treatments pay off on almost all rural divided roadways and also on urban divided roadways in Area 2 for median guardrail ends.

The breakaway sign support treatment pays off on practically all rural roadway segments and quite a few of the urban segments. The same is true for the tree removal treatments, both with and without stump removed.

For unprotected shoulder bridge piers, the concrete median barrier (CMB) with guardrail treatment pays off better in Area 1 rural locations and Area 2 urban locations than elsewhere. The 3 attenuator treatments for the shoulder bridge piers do not pay off nearly as well. For the unprotected median piers, both the CMB and attenuator treatments tend to pay off on rural U.S. and N.C. roadways in Areas 1 and 2.

Breakaway utility poles pay off for many rural U.S. and N.C. roadway/ segments in Areas 1 and 2. Removing and relocating utility poles follow the same trend but do not pay off in nearly as many cases.

Table 14. Annual benefits, benefit-cost ratios, and treatment costs for individual hazard/treatment/segment rows with positive Net Discounted Present Value.

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(1) INTERSTATE 4-DIV	1138157	61.954433	188700
2 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(1) U.S. 2-LANE	87034	1.610360	1441050
3 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(1) U.S. 4-DIV	12898	1.419412	310800
4 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(1) N.C. 4-DIV	10866	2.978658	55500
5 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(1) S.R. 2-LANE	636453	2.030114	6243900
6 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(2) INTERSTATE 4-DIV	4717396	80.535399	599400
7 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(2) U.S. 2-LANE	490632	6.515639	898950
8 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(2) U.S. 4-DIV	411537	6.029275	826950
9 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(2) N.C. 2-LANE	3296543	15.320512	2326350
10 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL RURAL AREA(2) N.C. 4-DIV	1178	1.165005	72150

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (01 01)	BRIDGE ENDS RURAL AREA(3) INTERSTATE 4-DIV	BRIDGE END TRANSITION GUARDRAIL	616845	7.205543	1004550
12 (01 01)	BRIDGE ENDS RURAL AREA(3) U.S. 2-LANE	BRIDGE END TRANSITION GUARDRAIL	275846	3.374716	1173900
13 (01 01)	BRIDGE ENDS RURAL AREA(3) U.S. 4-DIV	BRIDGE END TRANSITION GUARDRAIL	19815	1.839124	238650
14 (01 01)	BRIDGE ENDS RURAL AREA(3) N.C. 2-LANE	BRIDGE END TRANSITION GUARDRAIL	26584	1.164802	1630200
15 (01 01)	BRIDGE ENDS URBAN AREA(1) INTERSTATE	BRIDGE END TRANSITION GUARDRAIL	410793	75.800569	55500
16 (01 01)	BRIDGE ENDS URBAN AREA(2) INTERSTATE	BRIDGE END TRANSITION GUARDRAIL	40057	2.088649	371850

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (03 03) GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(1) INTERSTATE 4-DIV	436	1.043264	101850
2 (03 03) GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(3) U.S. 2-LANE	153547	6.612077	276500
3 (03 03) GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(3) U.S. 4-DIV	37025	8.033378	53200
4 (03 03) GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(3) N.C. 2-LANE	140420	10.131749	155400
5 (03 03) GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(3) N.C. 4-DIV	754	6.443250	1400
6 (03 03) GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT URBAN AREA(3) C.S.	4776	3.652508	18200

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(1) INTERSTATE 4-DIV	2178	1.252215	87300
2 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) INTERSTATE 4-DIV	3177	1.147846	217200
3 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) U.S. 4-DIV	376	1.030554	124500
4 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) U.S. 2-LANE	157914	7.733605	237000
5 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) U.S. 4-DIV	38124	9.449267	45600
6 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) N.C. 2-LANE	142971	11.847222	133200
7 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) N.C. 4-DIV	781	7.583778	1200
8 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) S.R. 2-LANE	833	1.118537	71100
9 (03 04) GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT URBAN AREA(3) C.S.	5395	4.495122	15600

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(1) INTERSTATE 4-DIV	41151	10.505648	43750
2	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(1) U.S. 4-DIV	36396	6.711542	64400
3	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(2) INTERSTATE 4-DIV	31733	3.955689	108500
4	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(2) U.S. 4-DIV	123517	13.875212	96950
5	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(2) N.C. 4-DIV	37460	64.625403	5950
6	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(3) INTERSTATE 4-DIV	16005	4.060476	52850
7	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(3) U.S. 4-DIV	63043	18.846171	35700
8	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(3) N.C. 4-DIV	33218	480.577366	700
9	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT URBAN AREA(2) U.S. 4-DIV	16036	3.806291	57750
10	(04 03) GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT URBAN AREA(2) N.C. 4-DIV	4768	7.258581	7700

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(1) INTERSTATE 4-DIV	42017	12.323393	37500
2	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(1) U.S. 4-DIV	37449	7.856250	55200
3	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) INTERSTATE 4-DIV	33498	4.640124	93000
4	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) U.S. 4-DIV	125331	16.241742	83100
5	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) N.C. 4-DIV	37671	75.647791	5100
6	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) INTERSTATE 4-DIV	16867	4.763041	45300
7	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) U.S. 4-DIV	63769	22.060538	30600
8	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) N.C. 4-DIV	33339	562.543741	600
9	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT URBAN AREA(2) INTERSTATE 4-DIV	880	1.193961	45900
10	(04 04) GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT URBAN AREA(2) U.S. 4-DIV	17035	4.477976	49500

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (04 04)	GUARDRAIL END - MEDIAN URBAN AREA(2) N.C.	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	5000	8.657254	6600

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) INTERSTATE 4-DIV TANGENT	16248	3.755169	29000
2	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) INTERSTATE 4-DIV CURVE	1237	2.902126	3200
3	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) U.S. 2-LANE TANGENT	92860	8.687311	59400
4	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) U.S. 2-LANE CURVE	100976	34.324358	14900
5	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) U.S. 4-UNDIV CURVE	682	2.398117	2400
6	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) U.S. 4-DIV TANGENT	12513	3.862047	21500
7	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) U.S. 4-DIV CURVE	21083	44.196781	2400
8	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 2-LANE TANGENT	28698	2.996022	70700
9	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 2-LANE CURVE	125996	31.978249	20000
10	(05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 4-UNDIV TANGENT	385	1.512258	3700

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 4-UNDIV CURVE	907	8.437544	600
12 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 4-DIV TANGENT	16036	20.713948	4000
13 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 4-DIV CURVE	30384	374.521849	400
14 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) S.R. 2-LANE TANGENT	25840	2.022255	124300
15 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) S.R. 2-LANE CURVE	197468	24.454527	41400
16 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) INTERSTATE 4-DIV TANGENT	29158	3.243809	63900
17 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) INTERSTATE 4-DIV CURVE	647	1.199058	16000
18 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) U.S. 2-LANE TANGENT	46002	6.310101	42600
19 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) U.S. 2-LANE CURVE	62116	22.510252	14200
20 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) U.S. 4-UNDIV CURVE	468	1.657834	3500

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
21 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) U.S. TANGENT	SIGNS - BREAKAWAY 4-DIV	24173	5.141783	28700
22 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) U.S. CURVE	SIGNS - BREAKAWAY 4-DIV	30225	21.643177	7200
23 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) N.C. TANGENT	SIGNS - BREAKAWAY 2-LANE	117054	12.176602	51500
24 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) N.C. CURVE	SIGNS - BREAKAWAY 2-LANE	326856	73.726732	22100
25 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) N.C. TANGENT	SIGNS - BREAKAWAY 4-UNDIV	508	1.342369	7300
26 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) N.C. CURVE	SIGNS - BREAKAWAY 4-UNDIV	3158	8.396604	2100
27 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) N.C. TANGENT	SIGNS - BREAKAWAY 4-DIV	478	1.872182	2700
28 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) N.C. CURVE	SIGNS - BREAKAWAY 4-DIV	2084	15.645252	700
29 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) S.R. TANGENT	SIGNS - BREAKAWAY 2-LANE	155496	6.895344	129700
30 (05 05) SIGNS AND LUMINAIRES RURAL AREA(2) S.R. CURVE	SIGNS - BREAKAWAY 2-LANE	201924	12.478958	86500

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
31 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) INTERSTATE 4-DIV CURVE	1876	1.941682	9800
32 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) U.S. 2-LANE TANGENT	7903	3.384288	16300
33 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) U.S. 2-LANE CURVE	8298	2.351223	30200
34 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) U.S. 4-DIV TANGENT	1684	1.836456	9900
35 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) U.S. 4-DIV CURVE	3198	5.766208	3300
36 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) N.C. 2-LANE TANGENT	4792	3.429608	9700
37 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) N.C. 4-DIV TANGENT	484	6.961466	400
38 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) N.C. 4-DIV CURVE	248	13.226785	100
39 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) S.R. 2-LANE TANGENT	13247	4.680307	17700
40 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) S.R. 2-LANE CURVE	9508	1.877248	53300

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
41 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(1) INTERSTATE TANGENT	1039	3.322762	2200
42 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(1) C.S. CURVE	1349	1.052801	125700
43 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(2) INTERSTATE TANGENT	96752	15.914273	31900
44 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(2) INTERSTATE CURVE	4102	2.902915	10600
45 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(2) U.S. TANGENT	59766	2.206951	243500
46 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(2) C.S. TANGENT	11376	1.045722	1223500
47 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(2) C.S. CURVE	90891	3.069186	216000
48 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(3) INTERSTATE TANGENT	5917	33.331562	900
49 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(3) U.S. CURVE	75824	10.251981	40300
50 (05 05) SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(3) N.C. TANGENT	4997	1.862249	28500

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
51 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(3) N.C. CURVE	SIGNS - BREAKAWAY	55188	18.622131	15400

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(06 06) TREES TREES - REMOVAL RURAL AREA(1) INTERSTATE 4-DIV TANGENT	204703	460.963974	3510
2	(06 06) TREES TREES - REMOVAL RURAL AREA(1) INTERSTATE 4-DIV CURVE	2111	43.700305	390
3	(06 06) TREES TREES - REMOVAL RURAL AREA(1) U.S. 2-LANE TANGENT	692221	5.079126	1338390
4	(06 06) TREES TREES - REMOVAL RURAL AREA(1) U.S. 2-LANE CURVE	591771	14.949098	334590
5	(06 06) TREES TREES - REMOVAL RURAL AREA(1) U.S. 4-UNDIV TANGENT	973	1.446593	17190
6	(06 06) TREES TREES - REMOVAL RURAL AREA(1) U.S. 4-UNDIV CURVE	1146	3.984566	3030
7	(06 06) TREES TREES - REMOVAL RURAL AREA(1) U.S. 4-DIV TANGENT	120070	13.234883	77400
8	(06 06) TREES TREES - REMOVAL RURAL AREA(1) U.S. 4-DIV CURVE	102197	94.614104	8610
9	(06 06) TREES TREES - REMOVAL RURAL AREA(1) N.C. 2-LANE TANGENT	412910	1.588475	5533920
10	(06 06) TREES TREES - REMOVAL RURAL AREA(1) N.C. 2-LANE CURVE	687806	4.475465	1560840

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (06 06)	TREES RURAL AREA(1) N.C. TANGENT	TREES - REMOVAL 4-UNDIV	606	2.055277	4530
12 (06 06)	TREES RURAL AREA(1) N.C. CURVE	TREES - REMOVAL 4-UNDIV	863	9.411050	810
13 (06 06)	TREES RURAL AREA(1) N.C. TANGENT	TREES - REMOVAL 4-DIV	4950	3.206096	17700
14 (06 06)	TREES RURAL AREA(1) N.C. CURVE	TREES - REMOVAL 4-DIV	5638	23.457681	1980
15 (06 06)	TREES RURAL AREA(1) S.R. TANGENT	TREES - REMOVAL 2-LANE	470209	1.450346	8234730
16 (06 06)	TREES RURAL AREA(1) S.R. CURVE	TREES - REMOVAL 2-LANE	685183	1.424009	12744900
17 (06 06)	TREES RURAL AREA(2) INTERSTATE TANGENT	TREES - REMOVAL 4-DIV	116055	119.257702	7740
18 (06 06)	TREES RURAL AREA(2) INTERSTATE CURVE	TREES - REMOVAL 4-DIV	4856	20.643491	1950
19 (06 06)	TREES RURAL AREA(2) U.S. TANGENT	TREES - REMOVAL 2-LANE	334646	3.754796	958080
20 (06 06)	TREES RURAL AREA(2) U.S. CURVE	TREES - REMOVAL 2-LANE	347222	9.575236	319350

Table 14. Continued

	TITLE (HAZARD, TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
21 (06 06)	TREES RURAL AREA(2) U.S. TANGENT	TREES - REMOVAL 4-UNDIV	12204	7.111257	15750
22 (06 06)	TREES RURAL AREA(2) U.S. CURVE	TREES - REMOVAL 4-UNDIV	11784	21.933656	4440
23 (06 06)	TREES RURAL AREA(2) U.S. TANGENT	TREES - REMOVAL 4-DIV	59747	5.564757	103230
24 (06 06)	TREES RURAL AREA(2) U.S. CURVE	TREES - REMOVAL 4-DIV	52856	17.157944	25800
25 (06 06)	TREES RURAL AREA(2) N.C. TANGENT	TREES - REMOVAL 2-LANE	536403	2.049961	4029240
26 (06 06)	TREES RURAL AREA(2) N.C. CURVE	TREES - REMOVAL 2-LANE	1025099	5.681971	1726800
27 (06 06)	TREES RURAL AREA(2) N.C. TANGENT	TREES - REMOVAL 4-UNDIV	2283	2.955754	9210
28 (06 06)	TREES RURAL AREA(2) N.C. CURVE	TREES - REMOVAL 4-UNDIV	3381	11.335836	2580
29 (06 06)	TREES RURAL AREA(2) N.C. TANGENT	TREES - REMOVAL 4-DIV	6643	5.229090	12390
30 (06 06)	TREES RURAL AREA(2) N.C. CURVE	TREES - REMOVAL 4-DIV	8162	21.834267	3090

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)				ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
31 (06 06)	TREES RURAL	 AREA(2) TANGENT	 S.R.	TREES - REMOVAL 2-LANE	324613	1.258327	9910590
32 (06 06)	TREES RURAL	 AREA(2) CURVE	 S.R.	TREES - REMOVAL 2-LANE	978562	1.290065	26607060
33 (06 06)	TREES RURAL	 AREA(3) TANGENT	 INTERSTATE	TREES - REMOVAL 4-DIV	6553	15.600138	3540
34 (06 06)	TREES RURAL	 AREA(3) CURVE	 INTERSTATE	TREES - REMOVAL 4-DIV	243	2.638132	1170
35 (06 06)	TREES RURAL	 AREA(3) TANGENT	 U.S.	TREES - REMOVAL 2-LANE	199676	5.302804	366000
36 (06 06)	TREES RURAL	 AREA(3) CURVE	 U.S.	TREES - REMOVAL 2-LANE	567912	7.589370	679740
37 (06 06)	TREES RURAL	 AREA(3) TANGENT	 U.S.	TREES - REMOVAL 4-UNDIV	6657	5.522648	11610
38 (06 06)	TREES RURAL	 AREA(3) CURVE	 U.S.	TREES - REMOVAL 4-UNDIV	20826	22.221607	7740
39 (06 06)	TREES RURAL	 AREA(3) CURVE	 U.S.	TREES - REMOVAL 4-DIV	6369	5.239371	11850
40 (06 06)	TREES RURAL	 AREA(3) TANGENT	 N.C.	TREES - REMOVAL 2-LANE	325746	4.401004	755400

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
41 (06 06)	TREES RURAL AREA(3) N.C. CURVE	TREES - REMOVAL 2-LANE	260288	2.164665	1762620
42 (06 06)	TREES RURAL AREA(3) N.C. CURVE	TREES - REMOVAL 4-UNDIV	198	1.620149	2520
43 (06 06)	TREES RURAL AREA(3) N.C. CURVE	TREES - REMOVAL 4-DIV	213	4.122613	540
44 (06 06)	TREES URBAN AREA(1) INTERSTATE TANGENT	TREES - REMOVAL	5216	172.431778	240
45 (06 06)	TREES URBAN AREA(1) N.C. TANGENT	TREES - REMOVAL	1701	1.066880	200700
46 (06 06)	TREES URBAN AREA(1) C.S. TANGENT	TREES - REMOVAL	54641	1.110030	3916620
47 (06 06)	TREES URBAN AREA(1) C.S. CURVE	TREES - REMOVAL	118188	2.348581	691200
48 (06 06)	TREES URBAN AREA(2) INTERSTATE TANGENT	TREES - REMOVAL	6599	15.220964	3660
49 (06 06)	TREES URBAN AREA(2) INTERSTATE CURVE	TREES - REMOVAL	2080	14.339676	1230
50 (06 06)	TREES URBAN AREA(2) U.S. CURVE	TREES - REMOVAL	12421	2.746325	56100

Table 14. Continued

No.	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
51 (06 06)	TREES URBAN AREA(2) C.S. TANGENT	TREES - REMOVAL	1131649	2.759765	5071800
52 (06 06)	TREES URBAN AREA(2) C.S. CURVE	TREES - REMOVAL	926591	9.164806	895050
53 (06 06)	TREES URBAN AREA(3) U.S. TANGENT	TREES - REMOVAL	7728	1.788081	77340
54 (06 06)	TREES URBAN AREA(3) U.S. CURVE	TREES - REMOVAL	1505	1.329506	36030
55 (06 06)	TREES URBAN AREA(3) N.C. CURVE	TREES - REMOVAL	611	1.172000	28020
56 (06 06)	TREES URBAN AREA(3) C.S. TANGENT	TREES - REMOVAL	166337	1.818460	1602870
57 (06 06)	TREES URBAN AREA(3) C.S. CURVE	TREES - REMOVAL	110861	2.619528	539880

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) INTERSTATE 4-DIV TANGENT	204258	230.481987	7020
2	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) INTERSTATE 4-DIV CURVE	2062	21.850152	780
3	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) U.S. 2-LANE TANGENT	522522	2.539563	2676780
4	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) U.S. 2-LANE CURVE	549347	7.474549	669180
5	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) U.S. 4-UNDIV CURVE	762	1.992283	6060
6	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) U.S. 4-DIV TANGENT	110256	6.617441	154800
7	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) U.S. 4-DIV CURVE	101105	47.307052	17220
8	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 2-LANE CURVE	489903	2.237732	3121680
9	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-UNDIV TANGENT	31	1.027638	9060
10	(06 07) TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-UNDIV CURVE	761	4.705525	1620

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-DIV TANGENT	2706	1.603048	35400
12 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-DIV CURVE	5386	11.728840	3960
13 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) INTERSTATE 4-DIV TANGENT	115074	59.628851	15480
14 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) INTERSTATE 4-DIV CURVE	4609	10.321745	3900
15 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 2-LANE TANGENT	213168	1.877398	1916160
16 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 2-LANE CURVE	306731	4.787618	638700
17 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 4-UNDIV TANGENT	10207	3.555628	31500
18 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 4-UNDIV CURVE	11221	10.966828	8880
19 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 4-DIV TANGENT	46658	2.782378	206460
20 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 4-DIV CURVE	49585	8.578972	51600

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
21 (06 07)	TREES RURAL AREA(2) N.C. TANGENT	TREES - (STUMP REMOVED) 2-LANE	25524	1.024980	8058480
22 (06 07)	TREES RURAL AREA(2) N.C. CURVE	TREES - (STUMP REMOVED) 2-LANE	806153	2.840985	3453600
23 (06 07)	TREES RURAL AREA(2) N.C. TANGENT	TREES - (STUMP REMOVED) 4-UNDIV	1116	1.477877	18420
24 (06 07)	TREES RURAL AREA(2) N.C. CURVE	TREES - (STUMP REMOVED) 4-UNDIV	3053	5.667918	5160
25 (06 07)	TREES RURAL AREA(2) N.C. TANGENT	TREES - (STUMP REMOVED) 4-DIV	5072	2.614545	24780
26 (06 07)	TREES RURAL AREA(2) N.C. CURVE	TREES - (STUMP REMOVED) 4-DIV	7770	10.917133	6180
27 (06 07)	TREES RURAL AREA(3) INTERSTATE TANGENT	TREES - (STUMP REMOVED) 4-DIV	6104	7.800069	7080
28 (06 07)	TREES RURAL AREA(3) INTERSTATE CURVE	TREES - (STUMP REMOVED) 4-DIV	94	1.319066	2340
29 (06 07)	TREES RURAL AREA(3) U.S. TANGENT	TREES - (STUMP REMOVED) 2-LANE	153270	2.651402	732000
30 (06 07)	TREES RURAL AREA(3) U.S. CURVE	TREES - (STUMP REMOVED) 2-LANE	481726	3.794685	1359480

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)				ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
31 (06 07)	TREES RURAL	 AREA(3) TANGENT	 U.S.	TREES - (STUMP REMOVED) 4-UNDIV	5185	2.761324	23220
32 (06 07)	TREES RURAL	 AREA(3) CURVE	 U.S.	TREES - (STUMP REMOVED) 4-UNDIV	19845	11.110803	15480
33 (06 07)	TREES RURAL	 AREA(3) CURVE	 U.S.	TREES - (STUMP REMOVED) 4-DIV	4867	2.619685	23700
34 (06 07)	TREES RURAL	 AREA(3) TANGENT	 N.C.	TREES - (STUMP REMOVED) 2-LANE	229966	2.200502	1510800
35 (06 07)	TREES RURAL	 AREA(3) CURVE	 N.C.	TREES - (STUMP REMOVED) 2-LANE	36800	1.082332	3525240
36 (06 07)	TREES RURAL	 AREA(3) CURVE	 N.C.	TREES - (STUMP REMOVED) 4-DIV	145	2.061306	1080
37 (06 07)	TREES URBAN	 AREA(1) TANGENT	 INTERSTATE	TREES - (STUMP REMOVED)	5186	86.215889	480
38 (06 07)	TREES URBAN	 AREA(1) CURVE	 C.S.	TREES - (STUMP REMOVED)	30549	1.174290	1382400
39 (06 07)	TREES URBAN	 AREA(2) TANGENT	 INTERSTATE	TREES - (STUMP REMOVED)	6135	7.610482	7320
40 (06 07)	TREES URBAN	 AREA(2) CURVE	 INTERSTATE	TREES - (STUMP REMOVED)	1924	7.169838	2460

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
41 (06 07) TREES URBAN AREA(2) U.S. CURVE	TREES - (STUMP REMOVED)	5308	1.373162	112200
42 (06 07) TREES URBAN AREA(2) C.S. TANGENT	TREES - (STUMP REMOVED)	488581	1.379882	10143600
43 (06 07) TREES URBAN AREA(2) C.S. CURVE	TREES - (STUMP REMOVED)	813105	4.582403	1790100
44 (06 07) TREES URBAN AREA(3) C.S. CURVE	TREES - (STUMP REMOVED)	42408	1.309764	1079760

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(1) INTERSTATE 4-DIV	23754	1.675013	414000
2	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(1) N.C. 2-LANE	6419	2.258754	60000
3	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(1) S.R. 2-LANE	2574	1.219436	138000
4	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(2) INTERSTATE 4-DIV	374713	7.559766	672000
5	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(3) U.S. 2-LANE	174015	19.954895	108000
6	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL URBAN AREA(2) INTERSTATE	64617	1.563088	1350000
7	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL URBAN AREA(2) U.S.	61917	1.697701	1044000
8	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL URBAN AREA(2) N.C.	11459	1.534977	252000
9	(07 08) BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL URBAN AREA(3) N.C.	333	1.081660	48000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (07 09)	BRIDGE PIERS - SHOULDER ATTENUATORS - WATER-FILLED CUSHIONS RURAL AREA(2) INTERSTATE 4-DIV	160460	1.941614	1344000
2 (07 09)	BRIDGE PIERS - SHOULDER ATTENUATORS - WATER-FILLED CUSHIONS RURAL AREA(3) U.S. 2-LANE	80215	2.464463	432000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (07 10)	BRIDGE PIERS - SHOULDER ATTENUATORS - SAND-FILLED CELLS RURAL AREA(2) INTERSTATE 4-DIV	258017	4.633838	560000
2 (07 10)	BRIDGE PIERS - SHOULDER ATTENUATORS - SAND-FILLED CELLS RURAL AREA(3) U.S. 2-LANE	107723	5.720005	180000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (07 11)	BRIDGE PIERS - SHOULDER BRIDGE PIERS - STEEL BARREL ATTNTS. RURAL AREA(2) INTERSTATE 4-DIV	208930	2.730892	952000
2 (07 11)	BRIDGE PIERS - SHOULDER BRIDGE PIERS - STEEL BARREL ATTNTS. RURAL AREA(3) U.S. 2-LANE	93228	3.402886	306000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	59537	9.338175	84000
2 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	16285	16.965540	12000
3 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(2) INTERSTATE	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	86913	2.521508	672000
4 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	245006	7.158718	468000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (08 09)	BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	30561	2.434711	168000
2 (08 09)	BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	10417	4.423368	24000
3 (08 09)	BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	99014	1.834308	936000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(08 10) BRIDGE PIERS - MEDIAN ATTENUATORS - SAND-FILLED CELLS RURAL AREA(1) U.S. 4-DIV	41508	5.676732	70000
2	(08 10) BRIDGE PIERS - MEDIAN ATTENUATORS - SAND-FILLED CELLS RURAL AREA(1) N.C. 4-DIV	11808	10.313453	10000
3	(08 10) BRIDGE PIERS - MEDIAN ATTENUATORS - SAND-FILLED CELLS RURAL AREA(2) INTERSTATE 4-DIV	37842	1.532960	560000
4	(08 10) BRIDGE PIERS - MEDIAN ATTENUATORS - SAND-FILLED CELLS RURAL AREA(2) U.S. 4-DIV	165789	4.352711	390000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(08 11) BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	BRIDGE PIERS - STEEL BARREL ATTNTS. 4-DIV	35788	3.371916	119000
2	(08 11) BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	BRIDGE PIERS - STEEL BARREL ATTNTS. 4-DIV	11049	6.126076	17000
3	(08 11) BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	BRIDGE PIERS - STEEL BARREL ATTNTS. 4-DIV	131992	2.570149	663000

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(09 12) UTILITY POLES RURAL AREA(1) U.S. ION	UTILITY POLES - BREAKAWAY 2-LANE INTERSECT	24897	2.493985	131436
2	(09 12) UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	16733	1.886167	148932
3	(09 12) UTILITY POLES RURAL AREA(1) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	1349	1.912819	11664
4	(09 12) UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	22645	138.811912	1296
5	(09 12) UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	61505	2.612364	300852
6	(09 12) UTILITY POLES RURAL AREA(1) N.C. SECTION TANGENT	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	10886	29.734403	2988
7	(09 12) UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	21114	514.961830	324
8	(09 12) UTILITY POLES RURAL AREA(1) S.R. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	75499	1.495358	1202076
9	(09 12) UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	18482	1.372477	391356
10	(09 12) UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	23479	2.419371	130464

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (09 12) UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	15817	9.728867	14292
12 (09 12) UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	16248	36.955796	3564
13 (09 12) UTILITY POLES RURAL AREA(2) N.C. SECTION TANGENT	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	84976	1.917577	730404
14 (09 12) UTILITY POLES RURAL AREA(2) N.C. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	132762	4.345092	313020
15 (09 12) UTILITY POLES URBAN AREA(2) U.S. ION	UTILITY POLES - BREAKAWAY INTERSECT	14789	1.500103	233244
16 (09 12) UTILITY POLES URBAN AREA(2) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY NON-INTER	43408	2.188602	288036
17 (09 12) UTILITY POLES URBAN AREA(2) N.C. SECTION TANGENT	UTILITY POLES - BREAKAWAY NON-INTER	19757	1.629871	247392

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (09 13)	UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - REMOVAL 4-DIV NON-INTER	49628	18.438289	33480
2 (09 13)	UTILITY POLES RURAL AREA(1) N.C. SECTION TANGENT	UTILITY POLES - REMOVAL 4-DIV NON-INTER	18344	3.795716	77190
3 (09 13)	UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - REMOVAL 4-DIV NON-INTER	44321	63.294153	8370
4 (09 13)	UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - REMOVAL 4-DIV NON-INTER	10405	1.331537	369210
5 (09 13)	UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - REMOVAL 4-DIV NON-INTER	31755	5.057511	92070

Table 14. Continued

TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (09 14) UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - RELOCATE 4-DIV NON-INTER	38980	34.967808	13500
2 (09 14) UTILITY POLES RURAL AREA(1) N.C. SECTION TANGENT	UTILITY POLES - RELOCATE 4-DIV NON-INTER	17196	7.499733	31125
3 (09 14) UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - RELOCATE 4-DIV NON-INTER	36752	129.106818	3375
4 (09 14) UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - RELOCATE 4-DIV NON-INTER	18523	2.463704	148875
5 (09 14) UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - RELOCATE 4-DIV NON-INTER	26287	9.329871	37125
6 (09 14) UTILITY POLES RURAL AREA(2) N.C. SECTION CURVE	UTILITY POLES - RELOCATE 2-LANE NON-INTER	27807	1.100328	3260625

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(1) INTERSTATE 4-DIV 13-30 MEDIAN	179425	1.481531	4383455
2 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(1) U.S. 4-DIV 1-12 MEDIAN	196883	2.109419	2087711
3 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(1) U.S. 4-DIV 13-30 MEDIAN	635862	1.740425	10102751
4 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(1) N.C. 4-DIV 1-12 MEDIAN	5856	1.432045	159455
5 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(2) INTERSTATE 4-DIV 1-12 MEDIAN	77705	109.206445	8447
6 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(2) INTERSTATE 4-DIV 13-30 MEDIAN	3392460	5.756200	8390975
7 (10 15)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(2) U.S. 4-DIV 1-12 MEDIAN	931789	4.609299	3037055

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(1) INTERSTATE 4-DIV 13-30 MEDIAN	49163	1.151125	3287591
2	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(1) INTERSTATE 4-DIV 31-60 MEDIAN	217426	1.503787	4361543
3	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(1) U.S. 4-DIV 1-12 MEDIAN	4233	1.027324	1565783
4	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(1) U.S. 4-DIV 13-30 MEDIAN	286187	1.381702	7577063
5	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(1) U.S. 4-DIV 31-60 MEDIAN	1649800	3.136113	7805159
6	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(1) N.C. 4-DIV 31-60 MEDIAN	1495312	8.503002	2014055
7	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(2) INTERSTATE 4-DIV 1-12 MEDIAN	41428	67.077587	6335
8	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(2) INTERSTATE 4-DIV 13-30 MEDIAN	2493450	5.004071	6293231
9	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(2) INTERSTATE 4-DIV 31-60 MEDIAN	262106	1.231755	11429351
10	(10 16) CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(2) U.S. 4-DIV 1-12 MEDIAN	396399	2.758707	2277791

Table 14. Continued

	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (10 16)	CROSS MEDIAN ACCIDENTS CROSSMEDIAN ACC. -DOUBLE FACE GDRL. RURAL AREA(3) INTERSTATE 4-DIV 31-60 MEDIAN	293753	1.450731	6586271

Finally, in terms of cross median accidents, both the CMB and double-faced guardrail pay off for a number of rural Area 1 and 2 segments. Area 3 does not show as favorable results because most of the Interstate mileage in Area 3 already has the CMB in place.

Collapsing Within Treatments

While the creation of a priority ranking such as the one above is informative, it was felt that further comparisons of treatments would be helpful. Table 15 presents the results of implementing all treatments "statewide" (i.e., collapsing across areas, highway types, number of lanes, etc.) for rural locations. Table 17 presents similar information for urban locations.

For the rural locations, using transition guardrail at hazardous bridge ends is again the top ranked program. Removing trees is the second ranked program, while use of double-faced median barrier is third. Making rigid support posts breakaway appears to be quite effective also.

To try to further clarify these rural results, the treatments were examined within highway type. These results are shown in Table 16. Transition guardrail for bridge ends pays off on all highway types except secondary roads but is also very expensive (approximately $15.2 million for I, U.S., and N.C. routes). The Interstate routes have the highest payoff.

Tree removal (without stumps) pays off across all road types, but the costs are again extreme (almost $1 billion, including $79 million on secondary roads). The results indicate that U.S. and N.C. routes should have priority. Double-faced median barrier is most effective on Interstate routes. Making rigid sign and luminaire supports breakaway

Table 15. Annual benefits, benefit/cost ratios, and treatment costs for rural "statewide" treatments.

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (01 01)	BRIDGE ENDS	BRIDGE END TRANSITION GUARDRAIL	10041539	3.136068	47507249
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
2 (06 06)	TREES	TREES - REMOVAL	8417187	1.669790	99113460
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
3 (10 16)	CROSS MEDIAN ACCIDENTS	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	3686870	1.390672	95371847
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
4 (10 15)	CROSS MEDIAN ACCIDENTS	CROSSMEDIAN ACCIDENTS - CMB	3240984	1.663810	57436895
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
5 (05 05)	SIGNS AND LUMINAIRES	SIGNS - BREAKAWAY	1715087	8.490576	1125900
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
6 (04 04)	GUARDRAIL END - MEDIAN	GUARDRAIL END - TEXAS TWIST TRTMENT	389293	12.020058	357000
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
7 (04 03)	GUARDRAIL END - MEDIAN	GUARDRAIL ENDS - BCT	381764	10.263071	416500
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
8 (08 08)	BRIDGE PIERS - MEDIAN	BRIDGE PIERS - CMB AND GUARDRAIL	344270	2.670803	2424000
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
9 (07 08)	BRIDGE PIERS - SHOULDER	BRIDGE PIERS - CMB AND GUARDRAIL	302779	1.651650	5466000
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
10 (03 04)	GUARDRAIL END - SHOULDER	GUARDRAIL END - TEXAS TWIST TRTMENT	179777	1.628218	2892000
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
11 (08 10)	BRIDGE PIERS - MEDIAN	ATTENUATORS - SAND-FILLED CELLS	153597	1.599706	2020000
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				
12 (03 03)	GUARDRAIL END - SHOULDER	GUARDRAIL ENDS - BCT	127970	1.383299	3374000
	** LOC(1) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)				

Table 16. Annual benefits, benefit cost ratios, and treatment costs for rural "statewide" treatments by highway type.

Hazard/Treatment/Highway Type	Annual Benefits ($)	Benefit/Cost Ratio	Treatment Costs ($)
1. Bridge Ends - Transition Guardrail:			
Interstate	6,472,400	37.49	1,792,650
US	1,221,785	3.17	5,689,500
NC	3,258,093	5.30	7,657,050
SR	-910,738	0.72	32,368,050
2. Trees - Removal:			
Interstate	334,524	145.17	18,300
US	3,127,921	6.71	4,318,290
NC	3,280,957	2.67	15,429,420
SR	1,673,786	1.17	79,347,450
3. Cross Median Accidents - Double Face Guardrail:			
Interstate	2,979,142	1.85	35,335,872
US	-344,510	0.94	54,218,736
NC	1,052,239	2.83	5,817,240
SR[1]	-	-	-
4. Cross Median Accidents - CMB:			
Interstate	3,263,570	3.22	17,278,272
US	227,198	1.07	36,685,440
NC	-249,783	0.15	3,473,184
SR	-	-	-
5. Signs - Breakaway:			
Interstate	46,865	2.53	151,100
US	407,847	7.72	298,400
NC	656,889	15.45	223,500
SR	603,486	7.55	452,900

[1]Missing information.

Table 16. Continued

Hazard/Treatment/Highway Type	Annual Benefits ($)	Benefit/Cost Ratio	Treatment Costs ($)
6. Guardrail End (median) - Texas Twist:			
Interstate	92,384	6.31	175,800
US	226,552	14.56	168,900
NC	70,358	58.81	12,300
SR	-	-	-
7. Guardrail End (median) - BCT:			
Interstate	88,890	5.38	205,100
US	222,957	12.43	197,050
NC	69,917	50.24	14,350
SR	-	-	-
8. Bridge Piers (median) - CMB and Guardrail:			
Interstate	33,641	1.23	1,740,000
US	296,384	6.38	648,000
NC	14,246	5.66	36,000
SR	-	-	-
9. Bridge Piers (shoulder) - CMB and Guardrail:			
Interstate	352,843	3.37	1,752,000
US	80,202	1.57	1,644,000
NC	-27,394	0.45	582,000
SR	-102,872	0.19	1,488,000
10. Guardrail End (shoulder)- Texas Twist:			
Interstate	-4,420	0.89	410,400
US	131,868	2.12	1,187,400
NC	83,783	2.01	841,200
SR	-31,454	0.30	453,000

Table 16. Continued

Hazard/Treatment/Highway Type	Annual Benefits ($)	Benefit/Cost Ratio	Treatment Cost ($)
11. Bridge Piers (median) - Sand Filled Attenuators			
Interstate	-52,829	0.71	1,450,000
US	197,154	3.88	540,000
NC	9,273	3.44	30,000
SR	-	-	-
12. Guardrail Ends (shoulder) - BCT:			
Interstate	-12,422	0.74	478,800
US	110,605	1.81	1,385,300
NC	69,249	1.71	981,400
SR	-39,462	0.25	528,500

Table 17. Annual benefits, benefit/cost ratios, and treatment costs for urban "statewide" treatments.

RANK	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (06 06)	TREES TREES - REMOVAL ** LOC(2) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)	2498704	2.408533	13991130
2 (06 07)	TREES TREES - (STUMP REMOVED) ** LOC(2) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)	724728	1.204266	27982260
3 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY ** LOC(2) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)	179919	1.236109	3747100
4 (07 08)	BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL ** LOC(2) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)	100076	1.374460	3144000
5 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL ** LOC(2) AREA(1,2,3) HWY(0,1,2,3,4,5) #LANES(0,1, 2,3) INT(0,1,2) FEATURES(0,1,2,3,4,5,6)	97212	1.232903	4218159

Table 18. Annual benefits, benefit/cost ratios, and treatment costs for urban "statewide" treatments by highway type.[1]

Hazard/Treatment/Highway Type	Annual Benefits ($)	Benefit/Cost Ratio	Treatment Costs ($)
1. Trees - Removal:			
Interstate	13,866	21.37	5,370
US	-14,738	0.80	575,190
NC	-8,693	0.90	693,150
City Street	2,508,270	2.55	12,717,420
2. Trees - Stump removal:			
Interstate	13,185	10.68	10,740
US	-87,665	0.40	1,150,380
NC	-96,580	0.45	1,386,300
City Street	895,791	1.28	25,434,840
3. Bridge Ends - Transition Guardrail:			
Interstate	449,203	11.22	444,000
US	-225,361	0.09	2,494,460
NC[2]	-	-	-
City Street	-	-	-
4. Signs - Breakaway:			
Interstate	107,608	12.36	46,600
US	80,636	1.61	654,100
NC	11,486	1.15	378,300
City Street	-19,810	0.96	2,668,100

[1]Urban secondary road routes were eliminated for lack of information.
[2]Missing information.

Table 18. Continued

Hazard/Treatment/Highway Type	Annual Benefits ($)	Benefit/Cost Ratio	Treatment Costs ($)
5. Bridge Piers (shoulder) - CMB and Guardrail:			
Interstate	52,377	1.41	1,494,000
US	39,986	1.36	1,302,000
NC	7,713	1.26	348,000
City Street	-	-	-

also pays off across all highway types, with N.C. routes appearing to have priority. The remaining results are self-explanatory.

For the urban locations, only 5 treatments pay off (Table 17). Removal of trees, without and with stump removed, respectively, constitute the top 2 programs. Transition guardrail for bridge ends, breakaway supports, and concrete median barrier for shoulder bridge piers follow in order. Tree removal (without stump) pays off on both Interstates and city streets, although far greater on city streets (Table 18). This reflects the large number of hazardous trees on city streets. Tree removal, including the stump, follows the same trend. The costs for these tree removal treatments, however, are enormous.

Bridge end transition guardrail pays off only on Interstate routes. No bridge end hazard estimates were available on city streets. Breakaway supports pay off on all highway types except on city streets, with the Interstate system receiving priority. Protecting shoulder bridge piers with concrete median barrier also pays off on all routes except city streets, with Interstate and U.S. routes having precedence.

CHAPTER 4 - RECOMMENDATIONS

As an outgrowth of the tasks performed for this project, and in an attempt to add further insight to the single vehicle fixed-object accident problem, a set of recommendations has been developed. The reader will note that some of the following recommendations refer to a "merged data system." This system being currently developed in a companion project performed by HSRC for the N.C. Board of Transportation, will merge the N.C. accident data with various roadway characteristics data files in a computerized system. After examining data elements in numerous files, parts of the following sources were selected for utilization in the final merged system:

1. Mileposted accident tape
2. Mileage inventory tape
3. Location inventory tape
4. Structures inventory file
5. Federal railroad crossing inventory file

The merged data system should be a powerful tool for examining the relationships between accidents and roadway design elements.

The following recommendations concern three basic areas: (1) uses, modifications, and extensions of the developed system, (2) general data needs, and (3) needs in the evaluation area. The reader should also note that related recommendations concerning areas other than fixed object collisions may be found in the previously cited MVMA report (Council and Hunter, 1975).

Uses, Modifications, and Extensions to the Developed System

1. Update the affectable accident matrix when the "merged system" is complete. As mentioned above, the "merged system" will offer analysts

a larger, more complete file with which to formulate many accident cross-tabulations and subsequent analyses. Because it was necessary to use several files (e.g. the 05 type, mileage inventory tape, etc.) to extrapolate or project the basic N.C. accident data to many categories, the "merged system" should be used to update one of the basic ingredients of the computerized system, namely, the affectable accident matrix. Crosstabulations should be performed and comparisons made to see if the output from the "merged system" indicates that changes need to be made in rows of the input matrix shown in Appendix A of Volume II: User Manual. If there are many changes necessary, the economic analysis concerned with these rows of the matrix should also be redone, as any large changes in accident frequency or severity could easily affect the priority ranking.

2. Update the matrix information concerning number of hazards if data becomes available. The hazards inventory (Grigg, 1974) was developed as a one-time survey requirement by FHWA. Hopefully, as needs arise, the hazards inventory can be refined and perhaps new data elements added. As an example of refinement, it would be helpful to have separate estimates of signpost and luminaire supports, as opposed to the grouping of the two in the present inventory. In its present state, assumptions must necessarily be made to "break out" one of these two hazards from the combined total. In terms of new data elements, consideration could be given to obtaining counts of treated hazards (e.g., a sign support made breakaway) in order to obtain a better feel for exposure to risk. In addition, it would obviously be helpful to have data concerning distance from edge of pavement to fixed object in the inventory.

Even though refining or adding new data to the inventory would require a large effort, the chances of these events taking place are not as remote as one might think. There has been a movement underway for some time for North Carolina to take part in an FHWA program based on earlier work performed by Glennon[1], et al. concerned with the probability of striking a hazardous fixed object. The program would involve gathering large amounts of inventory data concerned with roadside obstacles (length, distance from edge of pavement, etc.) for one or more selected counties in the state. With such federal assistance, it might indeed be possible to gather enough sample data to expand or refine the present hazards inventory.

3. Use previously developed Traffic Engineering computer programs to identify fixed-object improvement locations. The TE Branch has developed a very useful set of computer programs to facilitate the identification and ranking of hazardous spots, concentrations, or sections based on accident experience (e.g., a "sliding window" program which examines the accidents on successive segments of a given highway route). It seems logical to make use of these programs in conjunction with the output from the present system to better identify locations where fixed object improvements should be made. At least two possible procedures could be followed. First, a fixed object accident tape could be developed from the merged system which would include location information. This tape could be analyzed on a route-by-route basis using the existing "window" program to identify hazardous locations (based on a critical

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[1]Glennon, J.C. and Wilton, C.J. Effectiveness of Roadside Safety Improvements - Vol. 1. "A Methodology for Determining the Safety Effectiveness of Improvements on all Classes of Highways", Midwest Research Institute, 1974.

rate). Then using the priority ranking output from the present system to identify which hazards should be treated first, a rational array of projects to be considered for funding could be developed.

The second procedure would involve using the priority listing developed in this report (Table 13) as a guide to which hazard/treatment/roadway segment combinations should be further analyzed. These top ranked roadway segments could then be analyzed on a route-by-route basis using the "window" program to determine which locations within a given segment should be funded first. For example, the top ranked program in Table 13 is a program involving addition of transition guardrail to all hazardous bridge ends on rural Interstates in Area 2, the Piedmont section. Using the window program, each section of all Interstate routes in this area could be examined to determine which sections have higher bridge end collision frequencies. In this manner, information concerning which specific route sections (and thus bridges) to be treated first could be generated.

4. Perform sensitivity analyses. A priority ranking of fixed-object improvements was developed in this project, but this was based on specific guidelines to the input data. The guidelines reflect the concensus of TE and HSRC personnel as to the most rational current values for variables such as discount rate, rate of traffic growth, inflation rate, accident and treatment costs, etc. A sensitivity analysis concerned with many combinations of these variables and with the hazard and accident related variables was beyond the scope of the current project, but such an analysis should be considered by TE personnel as they use the system in the future. Changes in these input variables could obviously have a considerable effect on any ranking scheme.

In addition to the sensitivity analysis, some periodic consideration should be given to the possible addition of other costs into the system, such as the cost of time, vehicle operating costs, pollution effects, etc. Some of these variables could take on more significance in the future as related to the system output.

5. Consider linear or dynamic programming algorithms for budget development. The development of a priority ranking provides the highway administrator with a rational tool for comparing alternatives, but when budget constraints are introduced, use of the ranking alone to formulate the budget package will not guarantee the global maximization of benefits. When constraints are such that programs become financially mutually exclusive, many combinations of budget packages may have to be examined if the administrator is concerned with overall benefit maximization. Linear or dynamic programming packages have been developed to deal with such problems. The TE Branch may want to consider the development and use of such packages in conjunction with the ranking system.

Data Needs

1. Make inputs to the regular revisions of the N.C. accident report form. These recommendations logically follow the above. Even though the "merged system" will enhance accident analyses, there are basic data items which, if added to the N.C. accident report form, would greatly facilitate fixed-object accident research. First, the curve/tangent/grade information that was deleted from the form with the latest revision should be reinstated. This information was contained in the "ROAD CHARACTER" section of the old form. Second, the distance from the edge of pavement to any fixed-object struck should be added to the form.

Third, the "object struck" coding instructions in the manual should be clarified. (See next Recommendation.) When bridge piers, guardrails, or other objects not located in the roadway (between the pavement edges) are struck, these should be coded as "ran off road" accidents. A large number of these cases involving various kinds of fixed objects are miscoded. The largest number of miscodings appear to occur when a bridge pier or guardrail in the median of a divided highway is struck.

There are also other changes that should be considered:

a. Add an urban - rural variable defined by city limits to match the existing characteristics data.

b. Add a road type variable that denotes number of lanes and presence or absence of median, such as 2-L (two lanes), 4-U (four lanes undivided), and 4-D (four lanes divided).

c. Add a variable which will better determine if an accident occurs in an interchange and, if so, what part of the interchange (e.g., deceleration ramp, gore, etc.).

d. Differentiate between underpass and bridge pier accidents; for example, an underpass accident can involve the top of a truck trailer striking the bridge structure when there is inadequate vertical clearance. Also denote whether or not the bridge pier was protected.

e. When a bridge is impacted, designate whether the bridge rail or bridge end is struck. The same would apply to guardrail.

The engineering community should continue to actively participate in the periodic revisions that are made to the accident report form. It is important that their needs and views be known.

2. Work toward upgrading accident location information. The developed system and, to an even greater extent, the companion merged data system are highly dependent on the quality of accident data provided by the investigating officer. The efforts in both these projects have

indicated a need for better accuracy on the part of the officer when filling out the location section of the form. While Traffic Engineering personnel currently participate in police officer training schools and stress the importance of location information, it appears that not nearly as much emphasis is placed on this section of the form by training officers in other sessions. Examination of accident data has indicated that there are definite problems in the location data, whether due to training deficiencies, lack of compliance, or some other reasons. It is recommended that the engineering personnel strive for correction of this problem through: (1) changes in police training, subject content and emphasis regarding the location section, (2) establishment of a firm requirement for locations to be identified to the nearest hundredth of a mile, and (3) development of a system in which erroneous location data is identified at an early point in the system so that the form could be returned to the investigating officer for correction. Obviously, this procedure will require a cooperative effort between DOH, the Department of Motor Vehicles, and the State Highway Patrol.

In addition to the changes in location section training, Traffic Engineering personnel should also work with the State Highway Patrol to correct the above noted "object struck" and "accident type" coding errors. This may require changes in training materials.

3. Add curve and grade data to the "merged system." Curve and grade data presently reside only on straight line diagrams, and there are problems in trying to match mileposts with those shown on other data sources, such as the characteristics tape. Curves are shown only as points (center of the curve) with no length of curve information available.

Conversion of these data to a computer usable form would require tremendous effort, but these are important numerical variables for analysis (as opposed to the qualitative type of information that could be added to the accident form) and should be added to the "merged system" as soon as it it practical. Various possibilities should be explored, but it seems likely that some on-road inventory process will be necessary to gather the curve and grade data.

Evaluation and Research Needs

1. Perform more evaluations of fixed-object treatments. As can be seen from the literature review, there is a scarcity of good evaluations concerning fixed-object improvement programs. Where such evaluations exist, they generally are the before-after type with no control group, and thus are subject to accident fluctuations, regression to the mean, and other artifacts. As projects concerned with fixed-object improvements become implemented in North Carolina, the TE Branch, perhaps in conjunction with the Roadway Design Branch, should evaluate the effects of the programs as thoroughly as possible.

This includes programs of all types and sizes, from minor spot improvements to wholesale redesigns. Indeed, the smaller projects which emphasize a certain type of improvement may yield better program effectiveness information than some of the broader and more costly redesigns. For example, evaluation of some projects now being funded will be quite different, because the redesign may include such things as flattening slopes, lowering inlets, installing breakaway hardware to sign supports, and adding or improving guardrail, etc. Thus, if improvement in the accident experience is seen, it may be hard to apportion the benefits (i.e., the accident reductions) to the appropriate treatment. Answers to questions such as, "How effective was the breakaway hardware in reducing accident severity?" or "How much of an accident reduction is attributable to slope flatening?" may be very hard to quantify.

The converse may also be true, in that small-scale improvements involve such a small number of accidents that several improvements may be aggregated to try to determine the effect of the program. However, the several projects may have such dissimilar characteristics that combining them is inappropriate.

The only solution to such problems is to try to carefully build the evaluation process into the project, and this includes the use of control (or comparison) groups. While control groups or sections are often very difficult to identify in this subject area, every attempt should be made to incorporate these comparison groups into the study design.

When an evaluation is completed, it is very important that the knowledge gained be transmitted to others in the highway safety field, including other state highway departments, research organizations, and federal organizations. It is apparent that the publishing of technical information is a rather low priority item in most highway departments, but there is an urgent need for dissemination of the results of evaluative efforts by these agencies. HSRC is very willing to assist in such efforts locally in the form of inputs to an in-house newsletter, formal papers, or the like. When the "merged system" is complete, North Carolina will have an excellent data base from which to work, which could lead to important findings.

2. Obtain follow-up information concerning fixed-object improvements from field maintenance personnel and TE Branch field investigators. This concept follows close behind the need for more evaluations, and pertains to both the TE Branch and the Roadway Design Branch. It is important that both designers and evaluators communicate with field personnel who witness first hand the effects of various designs or other hardware changes. NCHRP Project 22-3A (Elliott, 1975) found that a large amount of good information concerning the effectiveness of vehicle barrier systems can be obtained from interviews with field personnel. It is hoped that this kind of liaison is present in North Carolina.

The TE Branch has for some time utilized a force of field accident investigators to help determine what programs or areas need further study. These investigators fill out a 5-page report concerned with items such as condition and accident data, causal factors and possible treatment, proposed improvement and cost estimates, and benefit-cost analysis. It is hoped that maximum use will be made of these teams, with an open line of communication that results in a large amount of information exchange.

3. Analyze other fixed-object treatments as information becomes available. The literature review indicated that delineation and skid-proofing treatments appeared to be cost-beneficial when considering all types of accidents; however, no evaluations were concerned specifically with fixed-object accidents. The TE Branch should consider evaluating these and perhaps other treatments in relation to fixed-object accidents as information becomes available. For example, the skid inventory may become a usable part of the "merged system." If so, this treatment could be analyzed.

In summary, the development of a computerized methodology for ranking roadside hazard correction programs has pointed out shortcomings within the existing data banks and new areas into which the methodology could be extended. However, these are not grave obstacles and delineation of these areas of need should not cause undue concern about the utility of the system. The system should be used and "fine tuned" as refinements become available to further develop analysis capabilities. The authors would hope that the developed system and the stated recommendations can be important tools to enhance the engineer's decision making process.

REFERENCE LIST

The reference list for this report is divided into three main sections:

1. General References - sources that are cited in the text.

2. Accident and Economic Data References - sources reviewed in order to calculate the accident reduction factors and perform the economic analyses. This section is divided into ten subject areas by hazard treatments.

3. Miscellaneous References - sources that were consulted but are not incorporated in the text.

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APPENDIX A

North Carolina Accident Report Forms

LOCATION

Date of Accident ____ 19 ____ Day of Week ____ Hour ____ A.M. ☐ P.M. ☐

Do not write in this space

Accident Occurred In ____ County ☐ In ☐ Near City or Town of ____

Outside City or Town ____ Miles ☐ N ☐ E ☐ S ☐ W of ☐ Limits ☐ Center

On ____ Hwy. No. (I., U.S., N.C., R.P., R.U.) If No., or within corporate limits, identify by name

Patrol Area

____ ☐ Miles ☐ Feet (0 Ft. if Intersec.) ☐ N ☐ E ☐ S ☐ W At or From ____ Hwy. No., or Adjacent County Line ____ Toward ____ Hwy. No., City, or Adjacent County Line

ACCIDENT TYPE

Ran off Road			Non-Collision in Road		Collision of Motor Vehicle in Road With:						
1. Right	2. Left	3. Straight Ahead	4. Overturn	5. Other in Road	6. Pedestrian	7. Parked Vehicle	8. Train	9. Bicycle	10. Animal	11. Fixed Obj.	12. Other Obj.

Collision of M.V. in Road With Another M. V.

13. Rear End Slow or Stop	14. Rear End Turn	15. Left Turn Same Roadway	16. Left Turn Cross Traffic	17. Right Turn Same Roadway	18. Right Turn Cross Traffic	19. Head On	20. Sideswipe	21. Angle	22. Backing

No. of Vehicles Involved ☐

VEHICLE NO. 1

Driver: ____ First ____ Middle ____ Last Name

Address: ____

City: ____ State: ____

Is above address same as on Driver's License? Yes ☐ No ☐

Race/Sex: ____ Driver's Lic: ____ State: ____

Date of Birth: ____ Month Day Year Specify Restriction: ____

Member of Armed Forces Yes ☐ No. ☐ Veh. Year: ____ Veh. Make: ____ Veh. Type: ____

Lic. Plate No. ____ State: ____ Year: ____

VIN ____ ODOM. __ __ __ __ __ . __

Owner: ____

Address: ____

City: ____ State: ____

Parts Damaged (TAD) ____ Amount of Damage $ ____

Drivable: Yes ☐ No ☐ Vehicle Removed to: ____

By: ____ Authority: ____

VEHICLE NO. 2 or PEDESTRIAN

Driver: ____ First ____ Middle ____ Last Name

Address: ____

City: ____ State: ____

Is above address same as on Driver's License? Yes ☐ No ☐

Race/Sex: ____ Driver's Lic. ____ State: ____

Date of Birth: ____ Month Day Year Specify Restriction: ____

Member of Armed Forces Yes ☐ No. ☐ Veh. Year: ____ Veh. Make: ____ Veh. Type: ____

Lic. Plate No. ____ State ____ Year: ____

VIN ____ ODOM. __ __ __ __ __ . __

Owner: ____

Address: ____

City: ____ State: ____

Parts Damaged (TAD) ____ Amount of Damage $ ____

Drivable: Yes ☐ No ☐ Vehicle Removed to: ____

By: ____ Authority: ____

Other Property Damaged ____ Amt. of Dam. $ ____ Owner and Address ____

INJURY SECTION INSTRUCTIONS

Give injury class, restraint used, race, sex and age of all occupants in the space corresponding to the seat occupied. Names and addresses are necessary for persons who were injured. For type of Restraint (Res.) used: N — None, L — Lap Belt, LS — Lap and Shoulder, S — Shoulder Belt only, YR — Child Restraint System.

K=Killed	A=Incapacitating	B=Nonincapacitating – Injury other than K or A evident at the scene	C=No visible sign of injury but complaint of pain, momentary unconsciousness	O=No injury

SEAT	Inj cl	Res usd	Race, sex	Age	INJURED NAMES AND ADDRESSES First Name / Last	SEAT	Inj cl	Res usd	Race sex	Age	INJURED NAMES AND ADDRESSES First Name / Last
Left Front					DRIVER 1	Left Front					DRIVER 2 OR PEDESTRIAN
Center Front						Center Front					
Right Front						Right Front					
Left Rear						Left Rear					
Center Rear						Center Rear					
Right Rear						Right Rear					

Total No. Occupants ____ Total No. Inj. ____ Total No. Occupants ____ Total No. Inj. ____

Injured taken to: ____

WITNESSES Name ____ Address ____ Phone No. ____

Name ____ Address ____ Phone No. ____

Arrests: Name ____ Charge(s) ____ (Cit. No.) ____

Name ____ Charge(s) ____ (Cit. No.) ____

Sign Here ____ Officer's Rank and Name ____ Number ____ Department ____ Date of Report

TRAFFIC ACCIDENT REPORT

N. C. Department of Motor Vehicles DMV-349 (Rev. 1-1-73)

ADDED BY ____ (Initial)

MARKS

TRAFFIC ACCIDENT REPORT

N. C. Department of Motor Vehicles
DMV-349 (Rev. 4-1-65)

DATE — Date of Accident ________ 19 ___ Day of Week ________ Hour ________ A.M. ☐ P.M. ☐

LOCATION

Accident occurred: in ______________ County, or In City or town of ______________

Outside City or Town ______ Miles ☐ N ☐ E ☐ S ☐ W of ______________ (City or Town) ☐ Limits ☐ Center

On ______________ (Hwy. No. (I., U.S., N.C., R.P., R.U.) If no Hwy. No., identify by name.) at its intersection with ______________ (Street or Hwy. no.)

If not at intersection, ________ ☐ Miles ☐ Feet ☐ N ☐ E ☐ S ☐ W From ______________ (Highway No., or Adjacent County Line) toward ______________ (Highway No., City, or Adjacent County Line)

ACCIDENT TYPE

Ran off Road		Non-collision in Road		Collision of Motor Vehicle in Road With:							
1. Right	2. Left	3. Overturned	4. Other in road	5. Pedestrian	6. Other Motor Vehicle	7. Parked Vehicle	8. Train	9. Bicycle	10. Animal	11. Fixed Object	12. Other Object

No. of Vehicles Involved ☐

VEHICLE NO. 1

Driver: ______________ (First, Middle, Last Name, Street or RFD, City and State) Date of Birth ________ (Month, Date, Year)

Age ____ Sex ____ Race ____ Driving Experience ____ Years Driver's License ________ (Number, State) ☐ Oper ☐ Chauff ________ Specify Restriction Member of Armed Forces Yes ☐ No ☐

Veh: Year ______ Make ______ Color [ ] Registration ________ (Number, State, Year) M.V.No. ________

Owned By: ______________ (Name, Street or RFD, City and State) Parts Damaged ________

Drivable: Yes ☐ No ☐ Vehicle Removed To ______________ By ______________

Amount of Damage $______

VEHICLE NO. 2 OR PEDESTRIAN

Driver or Pedestrian: ______________ (First, Middle, Last Name, Street or RFD, City and State) Date of Birth ________ (Month, Date, Year)

Age ____ Sex ____ Race ____ Driving Experience ____ Years Driver's License ________ (Number, State) ☐ Oper ☐ Chauff ________ Specify Restriction Member of Armed Forces Yes ☐ No ☐

Veh: Year ______ Make ______ Color [ ] Registration ________ (Number, State, Year) M.V.No. ________

Owned By: ______________ (Name, Street or RFD, City and State) Parts Damaged ________

Drivable: Yes ☐ No ☐ Vehicle Removed To ______________ By ______________

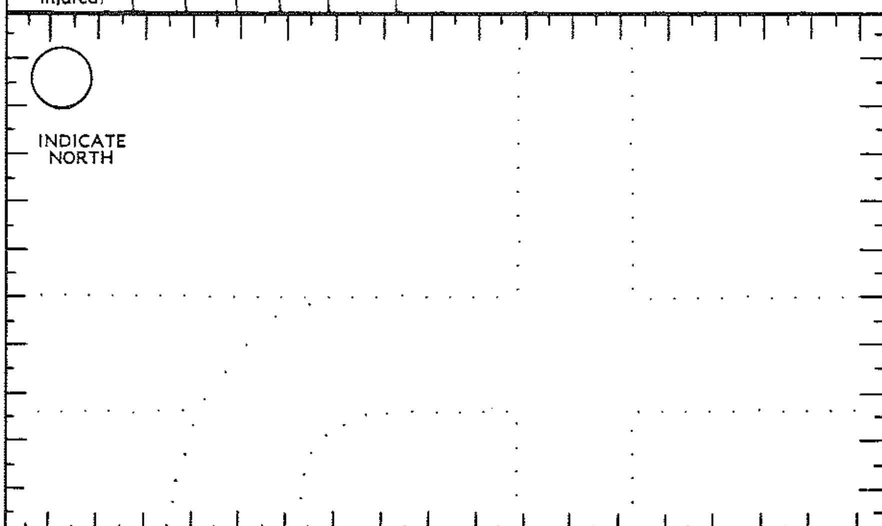
Amount of Damage $______

Amt. of Dam. $______ Other Property Damage ______________ Owner and Address ______________

Injury Class	K. Killed	A. Visible sign of injury as bleeding wound, distorted member or had to be carried from scene.	B. Other visible injury or bruises, abrasions, swelling, limping, etc.	C. No visible sign of injury but complaint of pain or momentary unconsciousness

INJURED PERSONS (Include fatally injured)

Veh.	Age	Sex	Race	Inj. Cl.	Name	Street or RFD	City	State



Injured taken to ______________

Describe what happened: ______________

Tire impressions prior to impact: No. 1 ______ No. 2 ______

Distance of travel after impact: No. 1 ______ No. 2 ______

WITNESSES Name ______________ Address ______________

Name ______________ Address ______________

Arrests: Name ______________ Charge(s) ______________ (Cit. No.) ________

Name ______________ Charge(s) ______________ (Cit. No.) ________

Sign Here ______________ (Officer's rank and name, Number, Department, Date of report)

ADDED BY ______ (Initial)

MARKS

APPENDIX B

Priority Ranking of Hazard/Treatment/Segment Combinations

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
1 (01 01)	BRIDGE ENDS RURAL AREA(2) INTERSTATE 4-DIV	BRIDGE END TRANSITION GUARDRAIL	4717396	80.535399	599400
2 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 4-DIV 13-30 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB	3392460	5.756200	8390975
3 (01 01)	BRIDGE ENDS RURAL AREA(2) N.C. 2-LANE	BRIDGE END TRANSITION GUARDRAIL	3296543	15.320512	2326350
4 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 4-DIV 13-30 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	2493450	5.004071	6293231
5 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) U.S. 4-DIV 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	1649800	3.136113	7805159
6 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) N.C. 4-DIV 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	1495312	8.503002	2014055
7 (01 01)	BRIDGE ENDS RURAL AREA(1) INTERSTATE 4-DIV	BRIDGE END TRANSITION GUARDRAIL	1138157	61.954433	188700
8 (06 06)	TREES URBAN AREA(2) C.S. TANGENT	TREES - REMOVAL	1131649	2.759765	5071800
9 (06 06)	TREES RURAL AREA(2) N.C. 2-LANE CURVE	TREES - REMOVAL	1025099	5.681971	1726800
10 (06 06)	TREES RURAL AREA(2) S.R. 2-LANE CURVE	TREES - REMOVAL	978562	1.290065	26607060

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
11 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) U.S. 1-12 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB 4-DIV	931789	4.609299	3037055
12 (06 06)	TREES URBAN AREA(2) C.S. CURVE	TREES - REMOVAL	926591	9.164806	895050
13 (06 07)	TREES URBAN AREA(2) C.S. CURVE	TREES - (STUMP REMOVED)	813105	4.582403	1790100
14 (06 07)	TREES RURAL AREA(2) N.C. CURVE	TREES - (STUMP REMOVED) 2-LANE	806153	2.840985	3453600
15 (06 06)	TREES RURAL AREA(1) U.S. TANGENT	TREES - REMOVAL 2-LANE	692221	5.079126	1338390
16 (06 06)	TREES RURAL AREA(1) N.C. CURVE	TREES - REMOVAL 2-LANE	687806	4.475465	1560840
17 (06 06)	TREES RURAL AREA(1) S.R. CURVE	TREES - REMOVAL 2-LANE	685183	1.424009	12744900
18 (01 01)	BRIDGE ENDS RURAL AREA(1) S.R.	BRIDGE END TRANSITION GUARDRAIL 2-LANE	636453	2.030114	6243900
19 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) U.S. 13-30 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB 4-DIV	635862	1.740425	10102751
20 (01 01)	BRIDGE ENDS RURAL AREA(3) INTERSTATE	BRIDGE END TRANSITION GUARDRAIL 4-DIV	616845	7.205543	1004550

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
21 (06 06)	TREES RURAL AREA(1) U.S. CURVE	TREES - REMOVAL 2-LANE	591771	14.949098	334590
22 (06 06)	TREES RURAL AREA(3) U.S. CURVE	TREES - REMOVAL 2-LANE	567912	7.589370	679740
23 (06 07)	TREES RURAL AREA(1) U.S. CURVE	TREES - (STUMP REMOVED) 2-LANE	549347	7.474549	669180
24 (06 06)	TREES RURAL AREA(2) N.C. TANGENT	TREES - REMOVAL 2-LANE	536403	2.049961	4029240
25 (06 07)	TREES RURAL AREA(1) U.S. TANGENT	TREES - (STUMP REMOVED) 2-LANE	522522	2.539563	2676780
26 (01 01)	BRIDGE ENDS RURAL AREA(2) U.S.	BRIDGE END TRANSITION GUARDRAIL 2-LANE	490632	6.515639	898950
27 (06 07)	TREES RURAL AREA(1) N.C. CURVE	TREES - (STUMP REMOVED) 2-LANE	489903	2.237732	3121680
28 (06 07)	TREES URBAN AREA(2) C.S. TANGENT	TREES - (STUMP REMOVED)	488581	1.379882	10143600
29 (06 07)	TREES RURAL AREA(3) U.S. CURVE	TREES - (STUMP REMOVED) 2-LANE	481726	3.794685	1359480
30 (06 06)	TREES RURAL AREA(1) S.R. TANGENT	TREES - REMOVAL 2-LANE	470209	1.450346	8234730

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
31 (06 06)	TREES RURAL AREA(1) N.C. TANGENT	TREES - REMOVAL 2-LANE	412910	1.588475	5533920
32 (01 01)	BRIDGE ENDS RURAL AREA(2) U.S.	BRIDGE END TRANSITION GUARDRAIL 4-DIV	411537	6.029275	826950
33 (01 01)	BRIDGE ENDS URBAN AREA(1) INTERSTATE	BRIDGE END TRANSITION GUARDRAIL	410793	75.800569	55500
34 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) U.S. 1-12 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	396399	2.758707	2277791
35 (07 08)	BRIDGE PIERS - SHOULDER RURAL AREA(2) INTERSTATE	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	374713	7.559766	672000
36 (06 06)	TREES RURAL AREA(2) U.S. CURVE	TREES - REMOVAL 2-LANE	347222	9.575236	319350
37 (06 06)	TREES RURAL AREA(2) U.S. TANGENT	TREES - REMOVAL 2-LANE	334646	3.754796	958080
38 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) N.C. CURVE	SIGNS - BREAKAWAY 2-LANE	326856	73.726732	22100
39 (06 06)	TREES RURAL AREA(3) N.C. TANGENT	TREES - REMOVAL 2-LANE	325746	4.401004	755400
40 (06 06)	TREES RURAL AREA(2) S.R. TANGENT	TREES - REMOVAL 2-LANE	324613	1.258327	9910590

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
41 (06 07)	TREES RURAL AREA(2) U.S. CURVE	TREES - (STUMP REMOVED) 2-LANE	306731	4.787618	638700
42 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(3) INTERSTATE 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	293753	1.450731	6586271
43 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) U.S. 13-30 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	286187	1.381702	7577063
44 (01 01)	BRIDGE ENDS RURAL AREA(3) U.S.	BRIDGE END TRANSITION GUARDRAIL 2-LANE	275846	3.374716	1173900
45 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	262106	1.231755	11429351
46 (06 06)	TREES RURAL AREA(3) N.C. CURVE	TREES - REMOVAL 2-LANE	260288	2.164665	1762620
47 (07 10)	BRIDGE PIERS - SHOULDER RURAL AREA(2) INTERSTATE	ATTENUATORS - SAND-FILLED CELLS 4-DIV	258017	4.633838	560000
48 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	245006	7.158718	468000
49 (06 07)	TREES RURAL AREA(3) N.C. TANGENT	TREES - (STUMP REMOVED) 2-LANE	229966	2.200502	1510800
50 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) INTERSTATE 31-60 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	217426	1.503787	4361543

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
51 (06 07)	TREES — TREES - (STUMP REMOVED) RURAL AREA(2) U.S. 2-LANE TANGENT	213168	1.877398	1916160
52 (07 11)	BRIDGE PIERS - SHOULDER — BRIDGE PIERS - STEEL BARREL ATTNTS. RURAL AREA(2) INTERSTATE 4-DIV	208930	2.730892	952000
53 (06 06)	TREES — TREES - REMOVAL RURAL AREA(1) INTERSTATE 4-DIV TANGENT	204703	460.963974	3510
54 (06 07)	TREES — TREES - (STUMP REMOVED) RURAL AREA(1) INTERSTATE 4-DIV TANGENT	204258	230.481987	7020
55 (05 05)	SIGNS AND LUMINAIRES — SIGNS - BREAKAWAY RURAL AREA(2) S.R. 2-LANE CURVE	201924	12.478958	86500
56 (06 06)	TREES — TREES - REMOVAL RURAL AREA(3) U.S. 2-LANE TANGENT	199676	5.302804	366000
57 (05 05)	SIGNS AND LUMINAIRES — SIGNS - BREAKAWAY RURAL AREA(1) S.R. 2-LANE CURVE	197468	24.454527	41400
58 (10 15)	CROSS MEDIAN ACCIDENTS — CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(1) U.S. 4-DIV 1-12 MEDIAN	196883	2.109419	2087711
59 (10 15)	CROSS MEDIAN ACCIDENTS — CROSSMEDIAN ACCIDENTS - CMB RURAL AREA(1) INTERSTATE 4-DIV 13-30 MEDIAN	179425	1.481531	4383455
60 (07 08)	BRIDGE PIERS - SHOULDER — BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(3) U.S. 2-LANE	174015	19.954895	108000

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
61 (06 06)	TREES URBAN AREA(3) C.S. TANGENT	TREES - REMOVAL	166337	1.818460	1602870
62 (08 10)	BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	ATTENUATORS - SAND-FILLED CELLS 4-DIV	165789	4.352711	390000
63 (07 09)	BRIDGE PIERS - SHOULDER RURAL AREA(2) INTERSTATE	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	160460	1.941614	1344000
64 (03 04)	GUARDRAIL END - SHOULDER RURAL AREA(3) U.S.	GUARDRAIL END - TEXAS TWIST TRTMENT 2-LANE	157914	7.733605	237000
65 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) S.R. TANGENT	SIGNS - BREAKAWAY 2-LANE	155496	6.895344	129700
66 (03 03)	GUARDRAIL END - SHOULDER RURAL AREA(3) U.S.	GUARDRAIL ENDS - BCT 2-LANE	153547	6.612077	276500
67 (06 07)	TREES RURAL AREA(3) U.S. TANGENT	TREES - (STUMP REMOVED) 2-LANE	153270	2.651402	732000
68 (03 04)	GUARDRAIL END - SHOULDER RURAL AREA(3) N.C.	GUARDRAIL END - TEXAS TWIST TRTMENT 2-LANE	142971	11.847222	133200
69 (03 03)	GUARDRAIL END - SHOULDER RURAL AREA(3) N.C.	GUARDRAIL ENDS - BCT 2-LANE	140420	10.131749	155400
70 (09 12)	UTILITY POLES RURAL AREA(2) N.C. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	132762	4.345092	313020

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD, TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
71 (08 11)	BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	BRIDGE PIERS - STEEL BARREL ATTNTS. 4-DIV	131992	2.570149	663000
72 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) N.C. CURVE	SIGNS - BREAKAWAY 2-LANE	125996	31.978249	20000
73 (04 04)	GUARDRAIL END - MEDIAN RURAL AREA(2) U.S.	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	125331	16.241742	83100
74 (04 03)	GUARDRAIL END - MEDIAN RURAL AREA(2) U.S.	GUARDRAIL ENDS - BCT 4-DIV	123517	13.875212	96950
75 (06 06)	TREES RURAL AREA(1) U.S. TANGENT	TREES - REMOVAL 4-DIV	120070	13.234883	77400
76 (06 06)	TREES URBAN AREA(1) C.S. CURVE	TREES - REMOVAL	118188	2.348581	691200
77 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) N.C. TANGENT	SIGNS - BREAKAWAY 2-LANE	117054	12.176602	51500
78 (06 06)	TREES RURAL AREA(2) INTERSTATE TANGENT	TREES - REMOVAL 4-DIV	116055	119.257702	7740
79 (06 07)	TREES RURAL AREA(2) INTERSTATE TANGENT	TREES - (STUMP REMOVED) 4-DIV	115074	59.628851	15480
80 (06 06)	TREES URBAN AREA(3) C.S. CURVE	TREES - REMOVAL	110861	2.619528	539880

RANKING BY ANNUAL BENEFTTS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
81 (06 07)	TREES RURAL AREA(1) U.S. TANGENT	TREES - (STUMP REMOVED) 4-DIV	110256	6.617441	154800
82 (07 10)	BRIDGE PIERS - SHOULDER RURAL AREA(3) U.S.	ATTENUATORS - SAND-FILLED CELLS 2-LANE	107723	5.720005	180000
83 (06 06)	TREES RURAL AREA(1) U.S. CURVE	TREES - REMOVAL 4-DIV	102197	94.614104	8610
84 (06 07)	TREES RURAL AREA(1) U.S. CURVE	TREES - (STUMP REMOVED) 4-DIV	101105	47.307052	17220
85 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) U.S. CURVE	SIGNS - BREAKAWAY 2-LANE	100976	34.324358	14900
86 (08 09)	BRIDGE PIERS - MEDIAN RURAL AREA(2) U.S.	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	99014	1.834308	936000
87 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(2) INTERSTATE TANGENT	SIGNS - BREAKAWAY	96752	15.914273	31900
88 (07 11)	BRIDGE PIERS - SHOULDER RURAL AREA(3) U.S.	BRIDGE PIERS - STEEL BARREL ATTNTS. 2-LANE	93228	3.402886	306000
89 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) U.S. TANGENT	SIGNS - BREAKAWAY 2-LANE	92860	8.687311	59400
90 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(2) C.S. CURVE	SIGNS - BREAKAWAY	90891	3.069186	216000

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD, TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
91 (01 01)	BRIDGE ENDS RURAL AREA(1) U.S. 2-LANE	BRIDGE END TRANSITION GUARDRAIL	87034	1.610360	1441050
92 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(2) INTERSTATE 4-DIV	BRIDGE PIERS - CMB AND GUARDRAIL	86913	2.521508	672000
93 (09 12)	UTILITY POLES RURAL AREA(2) N.C. 2-LANE NON-INTER SECTION TANGENT	UTILITY POLES - BREAKAWAY	84976	1.917577	730404
94 (07 09)	BRIDGE PIERS - SHOULDER RURAL AREA(3) U.S. 2-LANE	ATTENUATORS - WATER-FILLED CUSHIONS	80215	2.464463	432000
95 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 4-DIV 1-12 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB	77705	109.206445	8447
96 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(3) U.S. CURVE	SIGNS - BREAKAWAY	75824	10.251981	40300
97 (09 12)	UTILITY POLES RURAL AREA(1) S.R. 2-LANE NON-INTER SECTION CURVE	UTILITY POLES - BREAKAWAY	75499	1.495358	1202076
98 (07 08)	BRIDGE PIERS - SHOULDER URBAN AREA(2) INTERSTATE	BRIDGE PIERS - CMB AND GUARDRAIL	64617	1.563088	1350000
99 (04 04)	GUARDRAIL END - MEDIAN RURAL AREA(3) U.S. 4-DIV	GUARDRAIL END - TEXAS TWIST TRTMENT	63769	22.060538	30600
100 (04 03)	GUARDRAIL END - MEDIAN RURAL AREA(3) U.S. 4-DIV	GUARDRAIL ENDS - BCT	63043	18.846171	35700

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD, TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
101 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) U.S. CURVE	SIGNS - BREAKAWAY 2-LANE	62116	22.510252	14200
102 (07 08)	BRIDGE PIERS - SHOULDER URBAN AREA(2) U.S.	BRIDGE PIERS - CMB AND GUARDRAIL	61917	1.697701	1044000
103 (09 12)	UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	61505	2.612364	300852
104 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(2) U.S. TANGENT	SIGNS - BREAKAWAY	59766	2.206951	243500
105 (06 06)	TREES RURAL AREA(2) U.S. TANGENT	TREES - REMOVAL 4-DIV	59747	5.564757	103230
106 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	59537	9.338175	84000
107 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(3) N.C. CURVE	SIGNS - BREAKAWAY	55188	18.622131	15400
108 (06 06)	TREES URBAN AREA(1) C.S. TANGENT	TREES - REMOVAL	54641	1.110030	3916620
109 (06 06)	TREES RURAL AREA(2) U.S. CURVE	TREES - REMOVAL 4-DIV	52856	17.157944	25800
110 (09 13)	UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - REMOVAL 4-DIV NON-INTER	49628	18.438289	33480

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
111 (06 07)	TREES RURAL AREA(2) U.S. CURVE	TREES - (STUMP REMOVED) 4-DIV	49585	8.578972	51600
112 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) INTERSTATE 13-30 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	49163	1.151125	3287591
113 (06 07)	TREES RURAL AREA(2) U.S. TANGENT	TREES - (STUMP REMOVED) 4-DIV	46658	2.782378	206460
114 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) U.S. TANGENT	SIGNS - BREAKAWAY 2-LANE	46002	6.310101	42600
115 (09 13)	UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - REMOVAL 4-DIV NON-INTER	44321	63.294153	8370
116 (09 12)	UTILITY POLES URBAN AREA(2) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY NON-INTER	43408	2.188602	288036
117 (06 07)	TREES URBAN AREA(3) C.S. CURVE	TREES - (STUMP REMOVED)	42408	1.309764	1079760
118 (04 04)	GUARDRAIL END - MEDIAN RURAL AREA(1) INTERSTATE	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	42017	12.323393	37500
119 (08 10)	BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	ATTENUATORS - SAND-FILLED CELLS 4-DIV	41508	5.676732	70000
120 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(2) INTERSTATE 1-12 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	41428	67.077587	6335

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
121 (04 03)	GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(1) INTERSTATE 4-DIV	41151	10.505648	43750
122 (01 01)	BRIDGE ENDS BRIDGE END TRANSITION GUARDRAIL URBAN AREA(2) INTERSTATE	40057	2.088649	371850
123 (09 14)	UTILITY POLES UTILITY POLES - RELOCATE RURAL AREA(1) U.S. 4-DIV NON-INTER SECTION CURVE	38980	34.967808	13500
124 (03 04)	GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) U.S. 4-DIV	38124	9.449267	45600
125 (08 10)	BRIDGE PIERS - MEDIAN ATTENUATORS - SAND-FILLED CELLS RURAL AREA(2) INTERSTATE 4-DIV	37842	1.532960	560000
126 (04 04)	GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) N.C. 4-DIV	37671	75.647791	5100
127 (04 03)	GUARDRAIL END - MEDIAN GUARDRAIL ENDS - BCT RURAL AREA(2) N.C. 4-DIV	37460	64.625403	5950
128 (04 04)	GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(1) U.S. 4-DIV	37449	7.856250	55200
129 (03 03)	GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(3) U.S. 4-DIV	37025	8.033378	53200
130 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(3) N.C. 2-LANE CURVE	36800	1.082332	3525240

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
131 (09 14)	UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - RELOCATE 4-DIV NON-INTER	36752	129.106818	3375
132 (04 03)	GUARDRAIL END - MEDIAN RURAL AREA(1) U.S.	GUARDRAIL ENDS - BCT 4-DIV	36396	6.711542	64400
133 (08 11)	BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	BRIDGE PIERS - STEEL BARREL ATTNTS. 4-DIV	35788	3.371916	119000
134 (04 04)	GUARDRAIL END - MEDIAN RURAL AREA(2) INTERSTATE	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	33498	4.640124	93000
135 (04 04)	GUARDRAIL END - MEDIAN RURAL AREA(3) N.C.	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	33339	562.543741	600
136 (04 03)	GUARDRAIL END - MEDIAN RURAL AREA(3) N.C.	GUARDRAIL ENDS - BCT 4-DIV	33218	480.577366	700
137 (09 13)	UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - REMOVAL 4-DIV NON-INTER	31755	5.057511	92070
138 (04 03)	GUARDRAIL END - MEDIAN RURAL AREA(2) INTERSTATE	GUARDRAIL ENDS - BCT 4-DIV	31733	3.955689	108500
139 (08 09)	BRIDGE PIERS - MEDIAN RURAL AREA(1) U.S.	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	30561	2.434711	168000
140 (06 07)	TREES URBAN AREA(1) C.S. CURVE	TREES - (STUMP REMOVED)	30549	1.174290	1382400

RANKING BY ANNUAL BENEFITS (NOPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
141 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) N.C. CURVE	SIGNS - BREAKAWAY 4-DIV	30384	374.521849	400
142 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) U.S. CURVE	SIGNS - BREAKAWAY 4-DIV	30225	21.643177	7200
143 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) INTERSTATE TANGENT	SIGNS - BREAKAWAY 4-DIV	29158	3.243809	63900
144 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) N.C. TANGENT	SIGNS - BREAKAWAY 2-LANE	28698	2.996022	70700
145 (09 14)	UTILITY POLES RURAL AREA(2) N.C. SECTION CURVE	UTILITY POLES - RELOCATE 2-LANE NON-INTER	27807	1.100328	3260625
146 (01 01)	BRIDGE ENDS RURAL AREA(3) N.C.	BRIDGE END TRANSITION GUARDRAIL 2-LANE	26584	1.164802	1630200
147 (09 14)	UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - RELOCATE 4-DIV NON-INTER	26287	9.329871	37125
148 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) S.R. TANGENT	SIGNS - BREAKAWAY 2-LANE	25840	2.022255	124300
149 (06 07)	TREES RURAL AREA(2) N.C. TANGENT	TREES - (STUMP REMOVED) 2-LANE	25524	1.024980	8058480
150 (09 12)	UTILITY POLES RURAL AREA(1) U.S. ION	UTILITY POLES - BREAKAWAY 2-LANE INTERSECT	24897	2.493985	131436

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
151 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) U.S. TANGENT	SIGNS - BREAKAWAY 4-DIV	24173	5.141783	28700
152 (07 08)	BRIDGE PIERS - SHOULDER RURAL AREA(1) INTERSTATE	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	23754	1.675013	414000
153 (09 12)	UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	23479	2.419371	130464
154 (09 12)	UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	22645	138.811912	1296
155 (09 12)	UTILITY POLES RURAL AREA(1) N.C. SECTION CURVE	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	21114	514.961830	324
156 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) U.S. CURVE	SIGNS - BREAKAWAY 4-DIV	21083	44.196781	2400
157 (06 06)	TREES RURAL AREA(3) U.S. CURVE	TREES - REMOVAL 4-UNDIV	20826	22.221607	7740
158 (06 07)	TREES RURAL AREA(3) U.S. CURVE	TREES - (STUMP REMOVED) 4-UNDIV	19845	11.110803	15480
159 (01 01)	BRIDGE ENDS RURAL AREA(3) U.S.	BRIDGE END TRANSITION GUARDRAIL 4-DIV	19815	1.839124	238650
160 (09 12)	UTILITY POLES URBAN AREA(2) N.C. SECTION TANGENT	UTILITY POLES - BREAKAWAY NON-INTER	19757	1.629871	247392

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
161 (09 14)	UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - RELOCATE 4-DIV NON-INTER	18523	2.463704	148875
162 (09 12)	UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	18482	1.372477	391356
163 (09 13)	UTILITY POLES RURAL AREA(1) N.C. SECTION TANGENT	UTILITY POLES - REMOVAL 4-DIV NON-INTER	18344	3.795716	77190
164 (09 14)	UTILITY POLES RURAL AREA(1) N.C. SECTION TANGENT	UTILITY POLES - RELOCATE 4-DIV NON-INTER	17196	7.499733	31125
165 (04 04)	GUARDRAIL END - MEDIAN URBAN AREA(2) U.S.	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	17035	4.477976	49500
166 (04 04)	GUARDRAIL END - MEDIAN RURAL AREA(3) INTERSTATE	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	16867	4.763041	45300
167 (09 12)	UTILITY POLES RURAL AREA(1) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 2-LANE NON-INTER	16733	1.886167	148932
168 (08 08)	BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	BRIDGE PIERS - CMB AND GUARDRAIL 4-DIV	16285	16.965540	12000
169 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) INTERSTATE TANGENT	SIGNS - BREAKAWAY 4-DIV	16248	3.755169	29000
170 (09 12)	UTILITY POLES RURAL AREA(2) U.S. SECTION CURVE	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	16248	36.955796	3564

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
171 (04 03)	GUARDRAIL END - MEDIAN URBAN AREA(2) U.S.	GUARDRAIL ENDS - BCT 4-DIV	16036	3.806291	57750
172 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) N.C. TANGENT	SIGNS - BREAKAWAY 4-DIV	16036	20.713948	4000
173 (04 03)	GUARDRAIL END - MEDIAN RURAL AREA(3) INTERSTATE	GUARDRAIL ENDS - BCT 4-DIV	16005	4.060476	52850
174 (09 12)	UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	15817	9.728867	14292
175 (09 12)	UTILITY POLES URBAN AREA(2) U.S. ION	UTILITY POLES - BREAKAWAY INTERSECT	14789	1.500103	233244
176 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) S.R. TANGENT	SIGNS - BREAKAWAY 2-LANE	13247	4.680307	17700
177 (01 01)	BRIDGE ENDS RURAL AREA(1) U.S.	BRIDGE END TRANSITION GUARDRAIL 4-DIV	12898	1.419412	310800
178 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) U.S. TANGENT	SIGNS - BREAKAWAY 4-DIV	12513	3.862047	21500
179 (06 06)	TREES URBAN AREA(2) U.S. CURVE	TREES - REMOVAL	12421	2.746325	56100
180 (06 06)	TREES RURAL AREA(2) U.S. TANGENT	TREES - REMOVAL 4-UNDIV	12204	7.111257	15750

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
181 (08 10)	BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	ATTENUATORS - SAND-FILLED CELLS 4-DIV	11808	10.313453	10000
182 (06 06)	TREES RURAL AREA(2) U.S. CURVE	TREES - REMOVAL 4-UNDIV	11784	21.933656	4440
183 (07 08)	BRIDGE PIERS - SHOULDER URBAN AREA(2) N.C.	BRIDGE PIERS - CMB AND GUARDRAIL	11459	1.534977	252000
184 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(2) C.S. TANGENT	SIGNS - BREAKAWAY	11376	1.045722	1223500
185 (06 07)	TREES RURAL AREA(2) U.S. CURVE	TREES - (STUMP REMOVED) 4-UNDIV	11221	10.966828	8880
186 (08 11)	BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	BRIDGE PIERS - STEEL BARREL ATTNTS. 4-DIV	11049	6.126076	17000
187 (09 12)	UTILITY POLES RURAL AREA(1) N.C. SECTION TANGENT	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	10886	29.734403	2988
188 (01 01)	BRIDGE ENDS RURAL AREA(1) N.C.	BRIDGE END TRANSITION GUARDRAIL 4-DIV	10866	2.978658	55500
189 (08 09)	BRIDGE PIERS - MEDIAN RURAL AREA(1) N.C.	ATTENUATORS - WATER-FILLED CUSHIONS 4-DIV	10417	4.423368	24000
190 (09 13)	UTILITY POLES RURAL AREA(2) U.S. SECTION TANGENT	UTILITY POLES - REMOVAL 4-DIV NON-INTER	10405	1.331537	369210

RANKING BY ANNUAL BENEFITS (NOPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
191 (06 07)	TREES RURAL AREA(2) U.S. TANGENT	TREES - (STUMP REMOVED) 4-UNDIV	10207	3.555628	31500
192 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) S.R. CURVE	SIGNS - BREAKAWAY 2-LANE	9508	1.877248	53300
193 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) U.S. CURVE	SIGNS - BREAKAWAY 2-LANE	8298	2.351223	30200
194 (06 06)	TREES RURAL AREA(2) N.C. CURVE	TREES - REMOVAL 4-DIV	8162	21.834267	3090
195 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) U.S. TANGENT	SIGNS - BREAKAWAY 2-LANE	7903	3.384288	16300
196 (06 07)	TREES RURAL AREA(2) N.C. CURVE	TREES - (STUMP REMOVED) 4-DIV	7770	10.917133	6180
197 (06 06)	TREES URBAN AREA(3) U.S. TANGENT	TREES - REMOVAL	7728	1.788081	77340
198 (06 06)	TREES RURAL AREA(3) U.S. TANGENT	TREES - REMOVAL 4-UNDIV	6657	5.522648	11610
199 (06 06)	TREES RURAL AREA(2) N.C. TANGENT	TREES - REMOVAL 4-DIV	6643	5.229090	12390
200 (06 06)	TREES URBAN AREA(2) INTERSTATE TANGENT	TREES - REMOVAL	6599	15.220964	3660

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
201 (06 06)	TREES RURAL AREA(3) INTERSTATE 4-DIV TANGENT	TREES - REMOVAL	6553	15.600138	3540
202 (07 08)	BRIDGE PIERS - SHOULDER RURAL AREA(1) N.C. 2-LANE	BRIDGE PIERS - CMB AND GUARDRAIL	6419	2.258754	60000
203 (06 06)	TREES RURAL AREA(3) U.S. 4-DIV CURVE	TREES - REMOVAL	6369	5.239371	11850
204 (06 07)	TREES URBAN AREA(2) INTERSTATE TANGENT	TREES - (STUMP REMOVED)	6135	7.610482	7320
205 (06 07)	TREES RURAL AREA(3) INTERSTATE 4-DIV TANGENT	TREES - (STUMP REMOVED)	6104	7.800069	7080
206 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(3) INTERSTATE TANGENT	SIGNS - BREAKAWAY	5917	33.331562	900
207 (10 15)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) N.C. 4-DIV 1-12 MEDIAN	CROSSMEDIAN ACCIDENTS - CMB	5856	1.432045	159455
208 (06 06)	TREES RURAL AREA(1) N.C. 4-DIV CURVE	TREES - REMOVAL	5638	23.457681	1980
209 (03 04)	GUARDRAIL END - SHOULDER URBAN AREA(3) C.S.	GUARDRAIL END - TEXAS TWIST TRTMENT	5395	4.495122	15600
210 (06 07)	TREES RURAL AREA(1) N.C. 4-DIV CURVE	TREES - (STUMP REMOVED)	5386	11.728840	3960

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
211 (06 07)	TREES URBAN AREA(2) U.S. CURVE	TREES - (STUMP REMOVED)	5308	1.373162	112200
212 (06 06)	TREES URBAN AREA(1) INTERSTATE TANGENT	TREES - REMOVAL	5216	172.431778	240
213 (06 07)	TREES URBAN AREA(1) INTERSTATE TANGENT	TREES - (STUMP REMOVED)	5186	86.215889	480
214 (06 07)	TREES RURAL AREA(3) U.S. TANGENT	TREES - (STUMP REMOVED) 4-UNDIV	5185	2.761324	23220
215 (06 07)	TREES RURAL AREA(2) N.C. TANGENT	TREES - (STUMP REMOVED) 4-DIV	5072	2.614545	24780
216 (04 04)	GUARDRAIL END - MEDIAN URBAN AREA(2) N.C.	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	5000	8.657254	6600
217 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(3) N.C. TANGENT	SIGNS - BREAKAWAY	4997	1.862249	28500
218 (06 06)	TREES RURAL AREA(1) N.C. TANGENT	TREES - REMOVAL 4-DIV	4950	3.206096	17700
219 (06 07)	TREES RURAL AREA(3) U.S. CURVE	TREES - (STUMP REMOVED) 4-DIV	4867	2.619685	23700
220 (06 06)	TREES RURAL AREA(2) INTERSTATE CURVE	TREES - REMOVAL 4-DIV	4856	20.643491	1950

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
221 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) N.C. TANGENT	SIGNS - BREAKAWAY 2-LANE	4792	3.429608	9700
222 (03 03)	GUARDRAIL END - SHOULDER URBAN AREA(3) C.S.	GUARDRAIL ENDS - BCT	4776	3.652508	18200
223 (04 03)	GUARDRAIL END - MEDIAN URBAN AREA(2) N.C.	GUARDRAIL ENDS - BCT 4-DIV	4768	7.258581	7700
224 (06 07)	TREES RURAL AREA(2) INTERSTATE CURVE	TREES - (STUMP REMOVED) 4-DIV	4609	10.321745	3900
225 (10 16)	CROSS MEDIAN ACCIDENTS RURAL AREA(1) U.S. 1-12 MEDIAN	CROSSMEDIAN ACC. -DOUBLE FACE GDRL. 4-DIV	4233	1.027324	1565783
226 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(2) INTERSTATE CURVE	SIGNS - BREAKAWAY	4102	2.902915	10600
227 (06 06)	TREES RURAL AREA(2) N.C. CURVE	TREES - REMOVAL 4-UNDIV	3381	11.335836	2580
228 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) U.S. CURVE	SIGNS - BREAKAWAY 4-DIV	3198	5.766208	3300
229 (03 04)	GUARDRAIL END - SHOULDER RURAL AREA(2) INTERSTATE	GUARDRAIL END - TEXAS TWIST TRTMENT 4-DIV	3177	1.147846	217200
230 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(2) N.C. CURVE	SIGNS - BREAKAWAY 4-UNDIV	3158	8.396604	2100

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
231 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(2) N.C. 4-UNDIV CURVE	3053	5.667918	5160
232 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-DIV TANGENT	2706	1.603048	35400
233 (07 08)	BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL RURAL AREA(1) S.R. 2-LANE	2574	1.219436	138000
234 (06 06)	TREES TREES - REMOVAL RURAL AREA(2) N.C. 4-UNDIV TANGENT	2283	2.955754	9210
235 (03 04)	GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(1) INTERSTATE 4-DIV	2178	1.252215	87300
236 (06 06)	TREES TREES - REMOVAL RURAL AREA(1) INTERSTATE 4-DIV CURVE	2111	43.700305	390
237 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) N.C. 4-DIV CURVE	2084	15.645252	700
238 (06 06)	TREES TREES - REMOVAL URBAN AREA(2) INTERSTATE CURVE	2080	14.339676	1230
239 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) INTERSTATE 4-DIV CURVE	2062	21.850152	780
240 (06 07)	TREES TREES - (STUMP REMOVED) URBAN AREA(2) INTERSTATE CURVE	1924	7.169838	2460

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)		ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
241 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) INTERSTATE CURVE	SIGNS - BREAKAWAY 4-DIV	1876	1.941682	9800
242 (06 06)	TREES URBAN AREA(1) N.C. TANGENT	TREES - REMOVAL	1701	1.066880	200700
243 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(3) U.S. TANGENT	SIGNS - BREAKAWAY 4-DIV	1684	1.836456	9900
244 (06 06)	TREES URBAN AREA(3) U.S. CURVE	TREES - REMOVAL	1505	1.329506	36030
245 (09 12)	UTILITY POLES RURAL AREA(1) U.S. SECTION TANGENT	UTILITY POLES - BREAKAWAY 4-DIV NON-INTER	1349	1.912819	11664
246 (05 05)	SIGNS AND LUMINAIRES URBAN AREA(1) C.S. CURVE	SIGNS - BREAKAWAY	1349	1.052801	125700
247 (05 05)	SIGNS AND LUMINAIRES RURAL AREA(1) INTERSTATE CURVE	SIGNS - BREAKAWAY 4-DIV	1237	2.902126	3200
248 (01 01)	BRIDGE ENDS RURAL AREA(2) N.C.	BRIDGE END TRANSITION GUARDRAIL 4-DIV	1178	1.165005	72150
249 (06 06)	TREES RURAL AREA(1) U.S. CURVE	TREES - REMOVAL 4-UNDIV	1146	3.984566	3030
250 (06 07)	TREES RURAL AREA(2) N.C. TANGENT	TREES - (STUMP REMOVED) 4-UNDIV	1116	1.477877	18420

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD, TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
251 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY URBAN AREA(1) INTERSTATE TANGENT	1039	3.322762	2200
252 (06 06)	TREES TREES - REMOVAL RURAL AREA(1) U.S. 4-UNDIV TANGENT	973	1.446593	17190
253 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 4-UNDIV CURVE	907	8.437544	600
254 (04 04)	GUARDRAIL END - MEDIAN GUARDRAIL END - TEXAS TWIST TRTMENT URBAN AREA(2) INTERSTATE 4-DIV	880	1.193961	45900
255 (06 06)	TREES TREES - REMOVAL RURAL AREA(1) N.C. 4-UNDIV CURVE	863	9.411050	810
256 (03 04)	GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) S.R. 2-LANE	833	1.118537	71100
257 (03 04)	GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(3) N.C. 4-DIV	781	7.583778	1200
258 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) U.S. 4-UNDIV CURVE	762	1.992283	6060
259 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-UNDIV CURVE	761	4.705525	1620
260 (03 03)	GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(3) N.C. 4-DIV	754	6.443250	1400

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
261 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) U.S. 4-UNDIV CURVE	682	2.398117	2400
262 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) INTERSTATE 4-DIV CURVE	647	1.199058	16000
263 (06 06)	TREES TREES - REMOVAL URBAN AREA(3) N.C. CURVE	611	1.172000	28020
264 (06 06)	TREES TREES - REMOVAL RURAL AREA(1) N.C. 4-UNDIV TANGENT	606	2.055277	4530
265 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) N.C. 4-UNDIV TANGENT	508	1.342369	7300
266 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) N.C. 4-DIV TANGENT	484	6.961466	400
267 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) N.C. 4-DIV TANGENT	478	1.872182	2700
268 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(2) U.S. 4-UNDIV CURVE	468	1.657834	3500
269 (03 03)	GUARDRAIL END - SHOULDER GUARDRAIL ENDS - BCT RURAL AREA(1) INTERSTATE 4-DIV	436	1.043264	101850
270 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(1) N.C. 4-UNDIV TANGENT	385	1.512258	3700

RANKING BY ANNUAL BENEFITS (NDPV)

RANK	TITLE (HAZARD,TREATMENT ETC.)	ANNUAL BENEFITS	BENEFIT / COST RATIO	TREATMENT COST($)
271 (03 04)	GUARDRAIL END - SHOULDER GUARDRAIL END - TEXAS TWIST TRTMENT RURAL AREA(2) U.S. 4-DIV	376	1.030554	124500
272 (07 08)	BRIDGE PIERS - SHOULDER BRIDGE PIERS - CMB AND GUARDRAIL URBAN AREA(3) N.C.	333	1.081660	48000
273 (05 05)	SIGNS AND LUMINAIRES SIGNS - BREAKAWAY RURAL AREA(3) N.C. 4-DIV CURVE	248	13.226785	100
274 (06 06)	TREES TREES - REMOVAL RURAL AREA(3) INTERSTATE 4-DIV CURVE	243	2.638132	1170
275 (06 06)	TREES TREES - REMOVAL RURAL AREA(3) N.C. 4-DIV CURVE	213	4.122613	540
276 (06 06)	TREES TREES - REMOVAL RURAL AREA(3) N.C. 4-UNDIV CURVE	198	1.620149	2520
277 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(3) N.C. 4-DIV CURVE	145	2.061306	1080
278 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(3) INTERSTATE 4-DIV CURVE	94	1.319066	2340
279 (06 07)	TREES TREES - (STUMP REMOVED) RURAL AREA(1) N.C. 4-UNDIV TANGENT	31	1.027638	9060