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METHODOLOGY FOR RANKING

ROADSIDE HAZARD CORRECTION PROGRAMS

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ABSTRACT

This study describes the development and use of a computerized system to facilitate the prioritizing of roadside fixed-object treatments. Developed for the Traffic Engineering Branch of the North Carolina Division of Highways, 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 9 meters (30 feet) of the edge of pavement on rural, two-lane, secondary roads in the Piedmont area of North Carolina.

Developed inputs for the system include: (1) frequency and severity of the most affectable accidents for each 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. System outputs include predicted accident savings, the Net Discounted Present Value and Benefit/Cost Ratio for each candidate fixed-object treatment, and a priority ranking based on comparisons of net present value.

Initial runs using the system indicated that use of transition guardrail at hazardous bridge ends and tree removal in certain locations in North Carolina appear promising. System developmental efforts also reemphasized the continuing presence of a serious national problem -- the lack of sound information concerning effectiveness levels for fixed-object countermeasures.

INTRODUCTION

In recent years, more attention has been given to highway programs that are designed to make the roadside environment safer and, consequently, to lessen the severity of crashes associated with off-the-road hazards. Since funding for such programs is limited, developing cost-effective approaches to the problem is essential.

In an attempt to provide highway administrators and engineers with an economical tool to facilitate the prioritization of roadside fixed-object treatments, a computerized system was developed by the University of North Carolina Highway Safety Research Center (HSRC) for the Traffic Engineering Branch (TE) of the North Carolina Division of Highways (DOH). An accompanying User's Manual was developed as an aid to engineers and computer programmers using the system.

An economic analysis of various roadside safety improvements on an area-wide basis included a determination of the frequency and severity of the most affectable accidents for each treatment based on North Carolina accident data. In addition, the expected reductions in fatal, injury, and property damage only (PDO) accidents associated with the implementation of the treatment were analyzed. Benefits were developed based on accident savings by assigning dollar costs to fatal, injury and PDO accidents. Improvement cost components included initial costs, maintenance costs, and repair costs over the service life of each treatment. The Net Discounted Present Value (NDPV) for each hazard treatment combination was determined through economic analysis, and a priority ranking was developed based on comparisons of net present value. For alternatives with different service lives, the equivalent annual cash flow was calculated.

The system producing the priority ranking of roadside improvement programs was developed to analyze "areawide" improvements rather than "spot" improvements on which most existing fixed-object programs focus. Programs which are aimed at fixed-object spot locations are based on the assumption that a given hazard will be struck with a high enough frequency to be detected. Unfortunately, this is rarely the case. Rather than a specific hazard (e.g., an identifiable tree) being struck numerous times, the roadside hazard problem evolves from the fact that a number of different hazards, perhaps of the same type, are struck numerous times. Any given hazard is struck with very low frequency, (usually less than once per year). Hence, there is a need for a methodology to rank roadside fixed-object correction programs on an areawide basis.

The "areawide" approach attempts to identify hazards along an expanded "spot" that includes roadway segments on more than one route. What will be identified in this procedure is a given hazard with an appropriate treatment for a given type of roadway segment.

This methodology will allow the user 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. The variables defining a specific area include the following:

1. Location (urban or rural).
2. Area in the state (coastal plain, piedmont, mountain).
3. Highway type (Interstate, U.S., N.C., secondary roads, city streets).
4. Number of lanes (two-lanes, four or more lanes, undivided, four or more lanes divided -- for rural areas only).
5. Highway character (intersection, non-intersection).

6. Highway features (tangent section, curve section).

7. Median width -- 0.3-3.6 meters (1-12 feet), 3.9-9 meters (13-30 feet), 9.3-18 meters (31-60 feet), 18.3 + meters (61 + feet).

Table 1 lists the roadside hazards and treatments examined for the analysis program that was developed. For example, 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. The benefits from this particular combination could then be compared to the benefits from any other hazard/treatment/segment combination that is defined.

METHODOLOGY

The basic research design used in the study is an extension of a system employed in an earlier study (1) performed for the Motor Vehicle Manufacturers Association of the United States, Incorporated (MVMA). The current study, however, deals only with fixed-object accidents and related countermeasures rather than roadway safety countermeasures of all types. Also, the accident and hazards data are much more reliable than in the original study. Figure 1 shows a schematic representation of the basic tasks leading to the priority ranking of fixed-object improvement programs.

Determination of Accident Reduction Factors

Calculating the accident reduction factors was perhaps the most important input to the economic analysis phase. First, a literature review of fixed-object countermeasure evaluations was conducted. Many of the reports, unfortunately, had poor study designs, particularly before-after ones with no control groups. It was concluded from this literature search that more well-conducted evaluative studies dealing with fixed-object improvements should be performed and published (See DISCUSSION section).

Another data source that provided limited information was the file of before-after studies compiled by the Traffic Engineering Branch of the North Carolina Division of Highways. It contained approximately 400 improvement studies such as delineation, channelization and signal installation, but few pertaining to roadside fixed-object treatments.

Twelve state highway departments were contacted for any available information. Some states furnished reports in the form of aggregated before-after studies, and a few provided specific studies of fixed-object improvements. Several offices within the Federal Highway Administration were contacted, including the Office of Research which provided useful information concerning both ongoing research and completed, but unpublished, research.

Based on the above data sources, the final estimates of accident reduction factors were developed. Again, it was concluded that very little evaluation data exists for these roadside fixed-object programs. For treatment categories where a number of studies existed, the accident reduction factors were compared, and more weight was given to those with sound study designs. Most of the final composite reductions (or increases) were compared to a series of estimates developed by FHWA research engineers in a current contract that seeks to prioritize targets for future research and development (2). The accident reduction figures, therefore, are best current estimates of effect and should be systematically updated to reflect results 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 (3), 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 North Carolina costs through contacts with N.C. DOH personnel in Roadway Design and Maintenance. Followup meetings with field maintenance personnel provided data useful in developing average repair costs for several hazard/treatment categories.

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.

Estimation of Affectable Accidents

In the analysis of any improvement program it is essential to determine the frequency of accidents that could be reasonably expected to be related to that improvement program. For example, if one is considering placing transition sections of guardrail around unprotected bridge ends, then the affectable accidents are those involvements where the untreated bridge end was struck.

For deriving estimates of affectable accidents, the most useful data source would be one in which accident data is merged with roadway geometric characteristics. While such a data base is currently being developed in North Carolina, it did not exist for this project. Because of this, four different data files had to be merged to obtain estimates of annual proportions of affectable accidents for each roadside hazard.

The process followed in developing estimates of affectable accidents may be summarized as follows:

1. A composite estimate of the accident proportion for each hazard by highway segment (e.g., proportion of total statewide accidents involving utility poles on rural, U.S., 2-lane tangent sections) was developed based on three years of accident data (1973-75).
2. An estimated number of total N.C. accidents for 1979, the base year used in all subsequent analyses, was developed from trends in past accident data. Using a 6 percent incremental factor, a total of 164,889 accidents for 1979 was estimated.
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.

In determining affectable accidents for this study, only single-vehicle accidents were considered. 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 collison may or may not be affected by treating a fixed object.

The restriction of affectable accidents to those involving only single vehicles will, of course, cause the final economic analysis outputs to be somewhat conservative. 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, 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.

As indicated above, development of the composite estimates of these affectable accident proportions was a multistaged effort. First, the 1973-1975 North Carolina Accident Tapes were analyzed to develop tabulations of single-vehicle accident frequencies partitioned by: 1) fixed object struck, 2) geographical area, 3) rural or urban location, 4) highway type and, 5) accident severity. Second, because of the need for more specific information concerning point of impact in bridge-related crashes (i.e., bridge rail, bridge end) and in guardrail crashes (guardrail proper versus guardrail end), the accident sketches and narratives from two complete years (1974 and 1975) of these accident report hard copies were manually examined. Third, because information concerning whether a fixed-object crash occured on a curve or tangent section did not exist on the 1973-75 data set, 1971-72 data (where such a variable did exist) were used to form the same tabulations as above (area, urban/rural, highway types, etc.), but with the additional curve/tangent breakdown. This 1971-1972 information was then used to distribute the 1973-1975 accident data by curve versus tangent sections, assuming that the earlier curve/tangent accident proportions were applicable to the later years. This was done for all fixed-object categories except underpasses, bridges, and guardrails, where preliminary tabulations indicated that further expansion was impractical.

Finally, in order to partition the data by number of lanes, an additional tape containing data for N.C. rural primary highways was developed and analyzed to further distribute the data into the categories of 2 lanes (2), 4 or more lanes undivided (4U), and 4 or more lanes divided (4D).

Thus, three years of single-vehicle accident data were distributed by roadway segment, the proportion of total accidents, and an accident severity distribution comprised of the proportions of fatal, injury, and property damage only (PDO) accidents for a particular fixed object. For example:

Fixed object = Trees
Roadway segment = Rural, Coastal Plain Area, Interstate, 4D, Tangent

1973		1974		1975	
Accident Severity Proportions	Overall Proportion	Accident Severity Proportions	Overall Proportion	Accident Severity Proportions	Overall Proportion
Falal = 0.000		Fatal = 0.068		Fatal = 0.127	
Inj. = 0.434	.000100387	Inj. = 0.308	.000107000	Inj. = 0.404	.000106371
PDO = 0.566		PDO = 0.625		PDO = 0.469	

From these three estimates, a composite estimate shown below was formed.

Composite Estimate

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

As mentioned earlier, 1979 was chosen as a base year since no additional fixed-object treatment programs could be implemented before then. Based on past accident trends, a total of 164,889 accidents were predicted for that year. Thus, to obtain the total number of affectable accidents for the hazard/roadway segment in the above example, the composite overall estimate is multiplied by 164,889. Then the total number of affectable accidents is multiplied by the composite accident severity proportions to provide the distribution of injuries for this hazard/roadway segment. In the computerized system, these overall accident and injury proportions are stored as internal data.

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 (e.g., curve, tangent) and roadway character (e.g., intersection, non-intersection, etc.).

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. 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" (4).

In this study (4), frequencies of 8 classes 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. The data from these samples were expanded in the original study to provide estimates of the fixed-object frequencies for the entire state. In this current study, data concerning guardrail ends, signs and luminaires, trees, and utility poles were extracted.

These estimates of hazards per mile (grouped by location, highway type, and number of lanes) were further examined in order to determine where obvious sample size-related inconsistencies appeared either between highway types, between number of lanes within highway types, or between rural and urban areas. These inconsistencies were then corrected based on two general assumptions concerning: (1) the similarity of certain roadway types (e.g., four-lane divided U.S. and four-lane divided N.C. routes 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). The final estimates of hazards per mile based on these assumptions are shown in Table 3.

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.

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 had to be made because of the lack of other area-specific data.

The estimates of hazardous utility poles were further subcategorized into intersection and non-intersection sites based on the distribution of intersections within each location, area, highway type and lane configuration and on assumptions concerning the average number of poles per intersection.

The estimates of utility poles, trees, and signs were further subcategorized by whether the hazard was located on a tangent or curve section, based on independent DOH estimates of the percent of total roadway which are curves within each roadway segment type.

Information concerning the number of hazardous bridge rail ends, hazardous bridge rails, and hazardous bridge piers was developed using data from an existing Bridge and Structures file containing information concerning all structures on primary and secondary roadways. First, computer runs were made in order to determine the number of bridges and the number of sets of median and shoulder bridge piers categorized by the necessary roadway segment descriptors. Based on these bridge and pier frequencies, the number of "possible" hazardous bridge ends and piers and number of feet of "possible" hazardous bridge rails were calculated.

Next, factors representing the proportions of these "possible" hazards which are true hazardous bridge ends, rails, and piers were then estimated based on the percentage of roadway mileage built to lower standards within each area, highway type, and number of lanes. These percentages were developed from construction/reconstruction dates, segment improvement dates, and inputs from DOH engineers. The proportions were then multiplied by the "possible" frequencies developed above to generate the final frequencies of hazardous ends, piers, and railing lengths.

Finally, in the analysis of cross-median accidents where a median barrier might be an appropriate treatment, the required estimate of hazardous median sections was based on a count of the number of miles of median by roadway type, area, location, and number of lanes from an existing roadway characteristics file. This information was further subdivided by grouping medians into widths of 0.3-3.6 meters (1-12 feet), 3.9-9 meters (13-30 feet), 9.3-18 meters (31-60 feet) and 18.3+ meters (60+ feet). 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.

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.

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 Improvments," (5) 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 (6).

Alternative methods.

One criticism is that it is basically unsound to rank competing alternatives on the basis of a calculated benefit-cost (B/C) ratio (6). 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 (6), (7), (8). 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 this study, and the following specific rules were formulated:

1. For each investment in a particular safety measure, compute 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, convert the two investments into average annual cash flows. Accept the alternative with the largest present value.

Due to its popularity, 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 North Carolina Department of Transportation Traffic Engineering Branch 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 periodic 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 - Based on long term borrowing for roadway construction, a value of 6 percent was chosen.

2. Inflation rate - An inflation factor designed to reflect the increasing costs of accidents and treatments with time was included as a basic input variable. Since inflation seems to vary widely over time, average inflation rates have been estimates that correspond to three basic 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.

Recognizing the difficulty in predicting future inflation rates, NCHRP Report 162 (5) 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 life - For the improvements used in this project, 20 years was the maximum value used. Values for specific treatments were shown earlier in Table 2.

4. Salvage values - It was felt that the use of salvage values would have a minimal effect on the outcome of the fixed-object improvements analyzed. Thus, zero salvage values were used in all cases.

5. Accident growth factor - An annual growth rate of 4 percent for untreated accidents was input into the analysis system. This growth rate was estimated by the N.C. DOT and represents the approximate increase in yearly traffic volume. The internal computation algorithms assume that accidents are directly propor-

tional 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). 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" (9). Using a methodology similar to that employed by the National Safety Council, Barrett developed the folloing costs in 1973 dollars:

Fatality	$84,400
Nonfatal injury	$ 5,350
PDO	$ 325

Expanding these numbers from an occupant to an accident base 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:

Fatal accident	$133,637
Injury accident	$ 10,946
PDO	$ 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. The computerized system expands 1976 costs to appropriate starting year dollars automatically, with the average inflation rate being dependent on the length of time between 1976 and the starting year.

Computerized System

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. Thus, 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.

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 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 9 meters (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	N.C.	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 4 and 5).

Table 4 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 5 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 cost 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.

Two other values are also shown at the bottom of Table 5. 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.

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, this example has been concerned with removal of hazardous trees on roadway segments defined as follows:

Area 1 Rural N.C. 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.

RESULTS

Economic analyses for 942 basic hazard/treatment/segment combinations were performed. Less than one-third of this total, or 279 rows, had positive Net Discounted Present Values.

The results of the ten top-ranked fixed-object improvement programs, based on NDPV, are presented in Table 6. As indicated earlier, the basic input variables included: 1) a starting year of 1979, 2) 164,889 predicted accidents in 1979, 3) discount rate of 6 percent, 4) and a traffic growth rate of 4 percent.

It is instructive to note that the top ten treatment programs in Table 6 are all concerned with either bridge ends, cross-median involvements, or trees. These top ten programs, however, have a combined total cost of approximately $61 million. The program shown to have the largest payoff was the use of transition guardrail at hazardous bridge ends for a rural, Interstate, 4-lane divided roadway in the piedmont section of North Carolina. The annual benefits for this program amount to $4.7 million, and the B/C rate is 80.54. The cost of this treatment for this roadway segment is approximately $600,000.

Other interesting findings can be gained from the examination of other row by row results for the specific treatment classes. 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 could become a high priority item with FHWA in the near future, do 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 for comparative purposes, exhibits similar characteristics. For median guardrail ends, both the BCT and Texas twist treatments pay off on almost all rural divided roadways.

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 coastal plain/rural locations and piedmont/urban locations than elsewhere. The three 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 both the coastal plain and the piedmont areas.

Breakaway utility poles pay off for many rural U.S. and N.C. roadway segments in non-mountainous areas. Removing and relocating utility poles follow the same trend but do not pay off in nearly as many cases.

Finally, in terms of cross-median accidents, both the CMB and double-faced guardrail pay off for a number of rural/coastal plain and piedmont segments. The mountainous area 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 7 presents the results of implementing all treatments "statewide" (i.e., collapsing across areas, highway types, number of lanes, etc.) for rural locations. Similar information was developed 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 8. 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 (leaving ground-level 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 also pays off across all highway types, with N.C. routes appearing to have priority.

For the urban locations, only five treatments pay off. Removal of trees, without and with stump removed, respectively, constitute the top two 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. 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.

DISCUSSION AND RECOMMENDATIONS

This study was performed to respond to several specific needs in North Carolina, one of which is the development of a technique to deploy fixed-object improvement funds in a cost-effective manner. In the past, requisite data and system development have been lacking to formally tie the process together. The project thus represents the first effort at linking together the necessary ingredients of such a system. As such, the system is not without flaws, and various improvements should be considered both in North Carolina and in other states developing a similar system. In addition, the project efforts have pointed out a continuing need on the national level.

The most needed extension to the current system would be the incorporation of linear or dynamic programming algorithms for budget allocation purposes (10), (11). 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 in other areas and a similar application should be considered here.

There is also a continuing need for examination of the effectiveness, cost and injury factors which are the bases for the system, perhaps in some form of sensitivity analysis. The values used 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. 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.

While cost factors may well continue to vary, the fact that such a sensitivity analysis is needed for the effectiveness factors -- the fact that the estimates of effectiveness are not more specifically defined -- is a major roadway safety issue. There is a continuing, very serious need for more well-designed effectiveness 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 across the nation, the Traffic Engineering Branch, perhaps in conjunction with the Roadway Design Branch of each state should evaluate the effects of the programs as thoroughly as possible and incorporate sound results into the developed system.

The only solution to such problems is to try to carefully build the evaluation process into the project -- a planning sequence which can insure that proper evaluation designs (often including control groups or locations) and the proper statistical tests are possible.

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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.

Thus, a system has been developed to aid engineers in decisions concerning fixed-object correction programs. Just like most other tools needed by states, the system is dependent on both in-state and national input variables. The solution of the problems which have been reemphasized here should be of top priority for both the engineers and researchers who work in the roadside safety area.

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FIGURES

Figure 1. Schematic representation of project methodology.

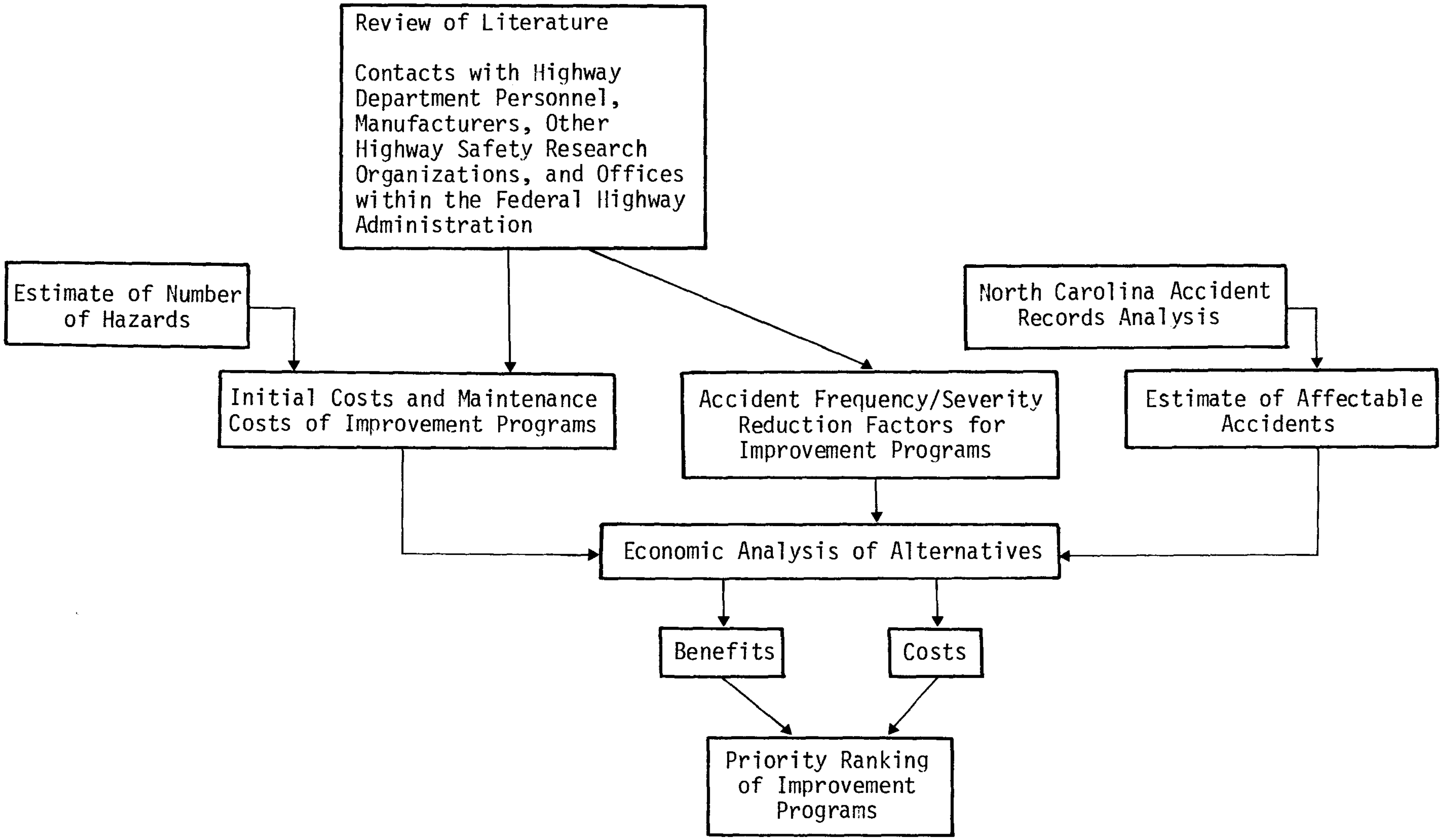

Figure 1. Schematic representation of project methodology.

TABLES

Table 1. Hazard/Treatment Combinations.

Hazard	Treatment
1. Utility poles	a. Breakaway b. Relocate - 9 meters[a] from edge of pavement c. Remove
2. Trees	a. Cut trees b. Cut trees and remove stumps
3. Exposed bridge rail ends	Transition guardrail
4. Substandard bridge rail	Improved rail (thrie beam)
5. Underpasses (Bridge piers)	a. Concrete median barrier with end treatment b. Attenuators 1. Water-filled cushion 2. Sand-filled cell 3. Steel barrels
6. Rigid signs or supports	
a. Small sign	Breakaway
b. Large metal support	Breakaway
c. Large metal support	Relocate behind guardrail
d. All supports combined	Breakaway
7. Guardrail ends	a. Breakaway cable terminal b. Turned down Texas terminal
8. Median-involved accidents	
a. Narrow median	Concrete median barrier
b. Wider median	Double-faced guardrail

[a]1 meter = 3.3 feet

Table 2. Hazard/treatment information.

Hazard	Treatment	% Reduction[a] 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 - 9m[b] 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 $11.00/m to bury cable at pole spacing of 75m
		38	-1.5	0	1600 per pole	0	0	20	Urban non-intersecting - cost per pole includes $20.00/m to bury cable at pole spacing of 75m
		38	-1.5	0	435 per pole	0	0	20	Rural intersection - cost per pole includes $11.00/m to bury cable for 90m cable required
		38	-1.5	0	850 per pole	0	0	20	Urban intersection - cost per pole includes $20.00/m to bury cable for 150m of cable required

[a]Minus sign indicates an increase in the proportion of accidents.
[b]1m = 3.3 ft.

Table 2. Hazard/treatment information. (Continued)

Hazard	Treatment	% Reduction Fatal (%)	% Reduction 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 30m 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 120m of guardrail per exposed bridge end
4. Substandard bridge rail	Improved rail (thrie beam)	15	5	-3	83 per meter	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 Fatal (%)	% Reduction Injury (%)	% Reduction 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	66,000 per km[a] (67/m)	0	0	20	Rural and urban - median width-0.3 - 3.6 m
		85	5	-25	66,000 per km	0	0	20	Rural and urban - median width-3.9 - 9 m

[a] 1 km = 0.6 mile

Table 2. Hazard/treatment information. (Continued)

Hazard	Treatment	% Reduction Fatal (%)	Injury (%)	PDO (%)	Initial Cost ($)	Maintenance Cost ($)	Repair Cost ($)	Service Life (Years)	Comments
8. Median-involved accidents (continued)									
b. Wider median	Double faced guard-rail	75	2	-28	49,500 per km	0	500 per hit	15	Rural and urban - median width 0.3 - 3.6 m
		85	5	-30	49,500 per km	0	500 per hit	15	Rural and urban - median width 3.9 - 9 m
		85	5	-30	49,500 per km	0	500 per hit	15	Rural and urban - median width 9.3 - 18 m

Table 3. Number of hazardous guardrail ends, signs, utility poles, and trees per km of roadway.

Location	Area	Hwy. Type	No. of Lanes	Kilometers[a]	GUARDRAIL ENDS Hazards/Km	GUARDRAIL ENDS Total	SIGNS Hazards/Km	SIGNS Total	UTILITY POLES Hazards/Km	UTILITY POLES Total	TREES Hazards/Km	TREES Total
Urban	1	I	4D	7.45	2.56	19	3.89	29	0.05	0	1.49	11
		US	2	328.80	0.17	57	4.10	1347	26.16	8601	13.03	4285
			4U	87.65	0.22	19	4.25	373	36.82	3227	9.17	803
			4D	91.75	0.98	90	5.16	473	13.54	1242	15.11	1387
		NC	2	351.80	0.04	13	9.27	1174	24.85	8742	19.69	6928
			4U	35.68	0.15	5	4.34	155	26.57	948	31.87	1137
			4D	14.10	0.60	8	3.00	42	10.43	143	18.00	254
		City St.	2	4589.37	0.05	220	0.78	3580	21.68	99488	28.55	131017
			4U	832.05	0.15	125	2.68	2227	34.53	28721	14.25	11857
			4D	714.68	1.80	1286	3.60	2573	12.00	8576	15.00	10720
Urban	2	I	4D	109.03	2.56	279	3.89	425	0.05	5	1.49	163
		US	2	331.47	0.17	58	4.10	1358	26.16	8671	13.03	4320
			4U	133.55	0.22	29	4.25	568	36.82	4918	9.17	1224
			4D	223.28	0.98	220	5.16	1152	13.54	3024	15.11	3375
		NC	2	457.98	0.04	16	9.27	1528	24.85	11379	19.69	9019
			4U	69.70	0.15	10	4.34	302	26.57	1852	31.87	2221
			4D	47.53	0.60	29	3.00	14	10.43	496	18.00	856
		City St.	2	5323.32	0.05	256	0.78	4152	21.68	115399	28.55	151970
			4U	1369.80	0.15	205	2.68	3666	34.53	47299	14.25	19520
			4D	1826.98	1.80	3289	3.60	6577	12.00	21924	15.00	27405
Urban	3	I	4D	3.12	2.56	8	3.89	12	0.05	0	1.49	5
		US	2	207.68	0.17	36	4.10	851	26.16	5433	13.03	2707
			4U	46.70	0.22	10	4.25	199	36.82	1720	9.17	428
			4D	42.58	0.98	42	5.16	220	13.54	577	15.11	644
		NC	2	107.82	0.04	4	9.27	360	24.85	2679	19.69	2123
			4U	15.85	0.15	2	4.34	69	26.57	421	31.87	505
			4D	3.48	0.60	2	3.00	10	10.43	36	18.00	63
		City St.	2	2128.28	0.05	102	0.78	1660	21.68	46137	28.55	60758
			4U	422.15	0.15	63	2.68	1130	34.53	14577	14.25	6016
			4D	310.05	1.80	558	3.60	1116	12.00	3721	15.00	4651

[a] 1 Km = 0.6 miles

Table 3. Continued.

Location	Area	Hwy. Type	No. of Lanes	Kilometers	Hazards/Km	Total	Hazards/Km	Total	Hazards/Km	Total	Hazards/Km	Total
Rural	1	I	4D	210.22	1.98	416	1.53	322	.03	6	.62	130
		US	2	2477.85	.51	1264	.30	743	9.82	24337	22.51	55766
			4U	44.93	.72	32	3.60	162	27.00	1213	15.00	674
			4D	415.48	1.11	461	.58	239	1.02	424	6.90	2867
		NC	2	5212.28	.24	1251	.17	907	8.68	45222	45.37	236492
			4U	11.87	.60	7	3.60	43	27.00	320	15.00	178
			4D	72.93	.75	55	.60	44	1.50	109	9.00	656
		SR	2	230129.93	.02	552	.07	1657	6.83	157132	73.84	1699321
Rural	2	I	4D	522.38	1.98	1034	1.53	799	.03	16	.62	323
		US	2	1892.00	.51	965	.30	568	9.82	18583	22.51	42581
			4U	44.85	.72	32	3.60	161	27.00	1211	15.00	673
			4D	623.32	1.11	692	.58	359	1.02	636	6.90	4301
		NC	2	4228.78	.24	1015	.17	736	8.68	36689	45.37	191868
			4U	26.17	.60	16	3.60	94	27.00	707	15.00	393
			4D	57.28	.75	43	.60	34	1.50	86	9.00	516
		SR	2	30027.02	.02	721	.07	2162	6.83	205024	73.84	2217255
Rural	3	I	4D	254.67	1.98	504	1.53	390	.03	8	.62	157
		US	2	1548.73	.51	790	.30	465	9.82	15212	22.51	34858
			4U	43.00	.72	31	3.60	155	27.00	1161	15.00	645
			4D	228.65	1.11	254	.58	132	1.02	233	6.90	1578
		NC	2	1849.92	.24	444	.17	322	8.68	16050	45.37	83934
			4U	13.90	.60	8	3.60	50	27.00	375	15.00	209
			4D	7.50	.75	6	.60	5	1.50	11	9.00	68
		SR	2	9863.48	.02	237	.07	710	6.83	67348	73.84	728339

Table 4. 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 5. 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

Table 6. First 10 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	1130157	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 7. 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 ** 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)	BRIDGE END TRANSITION GUARDRAIL	10041539	3.136068	47507249
2 (06 06)	TREES ** 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)	TREES - REMOVAL	8417187	1.669790	99113460
3 (10 16)	CROSS MEDIAN ACCIDENTS ** 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)	CROSSMEDIAN ACC. -DOUBLE FACE GDRL.	3686870	1.390672	95371847
4 (10 15)	CROSS MEDIAN ACCIDENTS ** 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)	CROSSMEDIAN ACCIDENTS - CMB	3240984	1.663810	57436895
5 (05 05)	SIGNS AND LUMINAIRES ** 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)	SIGNS - BREAKAWAY	1715087	8.490576	1125900
6 (04 04)	GUARDRAIL END - MEDIAN ** 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)	GUARDRAIL END - TEXAS TWIST TRTMENT	389293	12.020058	357000
7 (04 03)	GUARDRAIL END - MEDIAN ** 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)	GUARDRAIL ENDS - BCT	381764	10.263071	416500
8 (08 08)	BRIDGE PIERS - MEDIAN ** 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)	BRIDGE PIERS - CMB AND GUARDRAIL	344270	2.670803	2424000
9 (07 08)	BRIDGE PIERS - SHOULDER ** 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)	BRIDGE PIERS - CMB AND GUARDRAIL	302779	1.651650	5466000
10 (03 04)	GUARDRAIL END - SHOULDER ** 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)	GUARDRAIL END - TEXAS TWIST TRTMENT	179777	1.628218	2892000
11 (08 10)	BRIDGE PIERS - MEDIAN ** 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)	ATTENUATORS - SAND-FILLED CELLS	153597	1.599706	2020000
12 (03 03)	GUARDRAIL END - SHOULDER ** 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)	GUARDRAIL ENDS - BCT	127970	1.383299	3374000

Table 8. 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[a]	-	-	-
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

[a]Missing information.

Table 8. 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 8. 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