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Use of Benefit-Cost Analysis to Develop Roadside Safety Policies and Guidelines

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TRB Committee A2A04
Roadside Safety Features
Summer Workshop

USE OF BENEFIT-COST ANALYSIS TO DEVELOP ROADSIDE SAFETY POLICIES AND GUIDELINES

July 22-23, 1986
Newport, Oregon

Categories IIA: highway and facility design
IVB: safety and human performance

mode
1 highway transportation

subject areas
21 facilities design
51 transportation safety

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PART 1 OVERVIEW

Preface

This circular presents the proceedings from a Summer Workshop sponsored by TRB Committee A2A04 Roadside Safety Features. The Workshop was held July 22—23, 1986, in Newport, Oregon. This circular includes several invited papers and the recommendations from several Workshop Groups who discussed many issues related to the development and application of B-C methodologies.

The Workshop was planned and developed by a special Subcommittee of TRB Committee A2A04. Its members and responsibilities included:

Hayes Ross, Jr. - Subcommittee Chairman
James Bryden - Moderator
Duane Christensen - Logistics Coordinator
Dean Sicking - Workshop Coordinator
Ken Shearin - Workshop Coordinator

Special appreciation is extended to the Oregon Department of Transportation who, through Duane Christensen, provided the local arrangements and other logistical functions for the Workshop. Ken Shearin, Hayes Ross and William Hunter were primarily responsible for assembling the Workshop material for publication in this circular.

Introduction

For the past several decades, roadside safety professionals have researched, implemented, revised, and refined their approach to making roadside safety decisions. There is a universal recognition that roadside hazards exact a monumental human and economic toll on society. However, roadside safety improvements compete for the limited highway funds with many other needed improvements — pavement, drainage, capacity, traffic control devices, structures, and geometrics. Finding the proper level of expenditure for roadside safety has been a central focus of debate within the highway community for many years.

Until recently, the clear zone and relative severity concepts, supplemented by engineering judgment, have been the driving forces behind roadside safety decisions. These concepts are incorporated into the criteria in the 1977 AASHTO *Guide for Selecting, Locating and Designing Traffic Barriers* (Barrier Guide). However, the relative severity approach has created problems for the highway profession. Many believe it has led to an unnecessary proliferation of roadside barriers with a resulting inefficient allocation of scarce highway funds. Barrier repair needs have also created a burden on highway maintenance resources. In addition, many believe that the current decision-making environment unfairly exposes highway agencies to tort liability losses. If a roadside hazard exists and if it is not shielded by a barrier, then the highway agency may be held liable for the consequences of an accident. Many highway agencies contend that a common sense evaluation of the overall roadside safety problem makes it obvious that it is not reasonable or even possible to correct all roadside hazards or to shield them with a barrier.

In recent years, a major alternative to the approach in the Barrier Guide has emerged. This alternative is to make roadside safety decisions by use of an economic analysis which compares the monetary benefits and costs of the available treatments. In theory, this allows a highway agency to allocate its funds cost effectively for roadside safety. However, efforts to develop benefit-cost models have encountered significant problems. For any B-C method to gain wide acceptance, it must have two major features:

1. Confidence in the accuracy of its outputs, for example, does it reflect real-world conditions.
2. Relative ease of application. Without these features, the probability of success, that is acceptance by the highway community, is greatly lessened.

This environment prompted the Summer Workshop on B-C methodologies. The Workshop's objectives were to discuss the development and application of B-C analyses and to make recommendations to assist in the future direction of their role in roadside safety. In particular, the Workshop was intended to identify future research needs which would enhance the utility of B-C analyses.

Agenda

Figure 1 presents the agenda for the Summer Workshop. The structure of the Workshop included two major components:

• Invited Presentations and Papers. Individuals with varying backgrounds in roadside safety and B-C analysis were invited to make presentations at the Workshop. The speakers included practicing engineers, researchers, economists and lawyers representing the private sector and State and Federal governments.

• Workshop Groups. These were formed to provide a forum for an informal discussion on B-C analyses. Table 1 presents the composition of the breakout groups. Figure 2 presents a list of all the attendees at the Summer Workshop with their affiliation. The attendees worked from prepared discussion topics which addressed many issues related to the development and application of B-C methodologies. One major objective for each group was to recommend, where appropriate, future research to solve any identified problems.

The remainder of this circular presents the invited papers and the findings from the Workshop Groups.

FIGURE 1 AGENDA TRB A2A04 SUMMER WORKSHOP

Use of Benefit-Cost Analysis to Develop Roadside
Safety Policies and Guidelines - Problems,
Solutions, and Needed Research
July 22-23, 1986 Newport, Oregon

Tuesday, July 22, 1986

8:00 a.m. Late Registration

8:30 a.m. **I. Introductions and Welcome**

Hayes E. Ross, Jr., Texas Transportation Institute, Chairman, TRB Committee A2A04

Duane Christensen, Oregon Department of Transportation

8:35 a.m. **II. Workshop Objectives and Format**

James E. Bryden, New York Department of Transportation, Workshop Chairman

III. Presentations

8:45 a.m. A. Overview of Roadside Safety Problem Julie A. Cirillo, Federal Highway Administration, Washington, D.C.

9:15 a.m. B.Overview of B-C Methodologies, W.F. McFarland, Texas Transportation Institute

9:45 a.m. Coffee Break

10:00 a.m. C. Use of B-C Analysis for Roadside Safety on National level, James F. Hatton, Federal Highway Administration, Washington, D.C.

10:30 a.m. D. Use of B-C Analysis for Roadside Safety on State Level, Louis C. Schultz, Jr., Pennsylvania Department of Transportation

11:00 a.m. E. Legal Considerations of Policies Based on B-C Analysis Jack Sollis, Oregon Department of Transportation

11:30 a.m. **IV. Problems and Limitations of Existing B-C Methodologies,** Dean L. Sicking, Texas Transportation Institute

A. Estimation of Frequency and Nature of Roadside Accidents

1. Use of encroachment-probability models
2. Use of accident data
3. Use of combination of 1 and 2

B. Estimation of Limits of Performance of Safety Features

1. Use of analytical and experimental methods
2. Use of accident data

C. Estimation of Accident Severity

1. Use of analytical and experimental methods
2. Use of accident data
3. Relation of societal costs to probability of injury

D. Validation of Methodologies

12:00 Luncheon (included in registration)

1:30 p.m. **V. Breakout Sessions to Discuss Item IV, Including Potential Solutions and Needed Research**

3:00 p.m. Coffee Break

3:15 p.m. Continue Breakout Sessions

4:30 p.m. Recess

6:00 p.m. Social Hour (cash bar)

7:00 p.m. Banquet (included in registration), Speaker: Donald E. Giles - Slide Presentation on Oregon Coast

Wednesday, July 23, 1986

8:30 a.m. **VI. Summary of Breakout Session V Findings by Group Chairpersons**

9:30 a.m. **VII. Problems in the Interpretation and Application of B-C Analysis, R.K. Shearin, Jr., Roy Jorgensen Associates, Inc.**

A. B-C Criteria Used in Decision Process

B. Applications

1. Guidelines for new construction
2. Guidelines for upgrading
3. Guidelines for spot safety improvements

C. B-C Computer Programs

10:00 a.m. Coffee Break

10:15 a.m.	**VIII. Breakout Sessions to Discuss Item VII, Including Potential Solutions and Needed Research**
12:00	Lunch - Picnic on beach
1:30 p.m.	Continue Breakout Sessions
2:45 p.m.	Coffee Break
3:00 p.m.	**IX. Summary of Breakout Session VIII Findings by Group Chairpersons**
4:00 p.m.	**X. Workshop Summary** James E. Bryden, New York Department of Transportation
4:15 p.m.	**XI. Adjourn**

TABLE 1 B-C ANALYSIS WORKSHOP GROUPS

I	II	III	IV
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PART 2 PRESENTATIONS

Roadside Safety: A National Perspective, July 1986

By: **Lawrence McCarthy, Federal Highway Administration**
Presented By: **Julie A. Cirillo, Federal Highway Administration**

Introduction

Each year millions of persons are killed or seriously injured in motor vehicle accidents. In 1984, over 46,000 people died in motor vehicle traffic accidents and another 1,700,000 persons suffered seriously disabling injuries. It is estimated that 200 persons are killed or seriously injured every hour on United States' roadways and that traffic accidents are the leading cause of death for persons age 1 to 37.

While significant progress has been achieved in reducing the number of traffic related deaths per vehicle mile of travel (VMT) in the past twenty years, accident costs continue to increase. In the past two decades the costs associated with traffic accidents, including lost wages, property damage, insurance and medical costs, have risen from 10 billion dollars in 1965 to over 50 billion dollars in 1985. During this time period accident costs per VMT have risen 250 percent.

An examination of the traffic fatality distribution by most harmful event (Figure 1) shows the serious consequences of run-off-road accidents. On all roadways, over

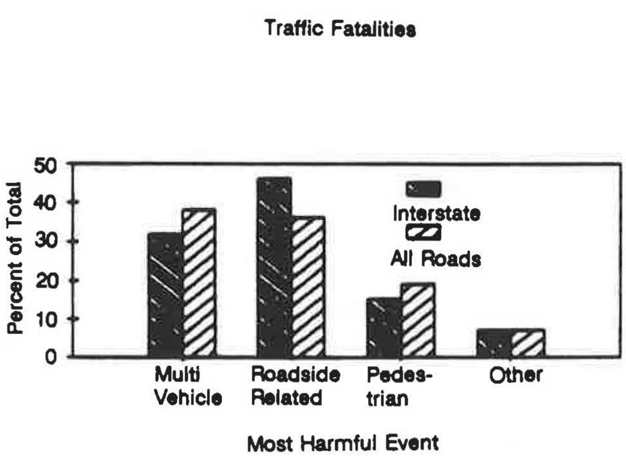

Figure 1

36 percent of the fatalities were incurred from striking roadside objects, such as trees, poles, and embankments. Similarly, a roadside feature was judged to be the most harmful event in 47 percent of the fatalities on the Interstate system. Furthermore, an examination of single-vehicle accident fatalities on the Interstate system (Figure 2) reveals that nearly one-third of the fatalities were from a vehicle striking a longitudinal barrier and another one-third were from vehicle rollover. Clearly, single-vehicle accidents represent a major highway safety problem with massive societal costs.

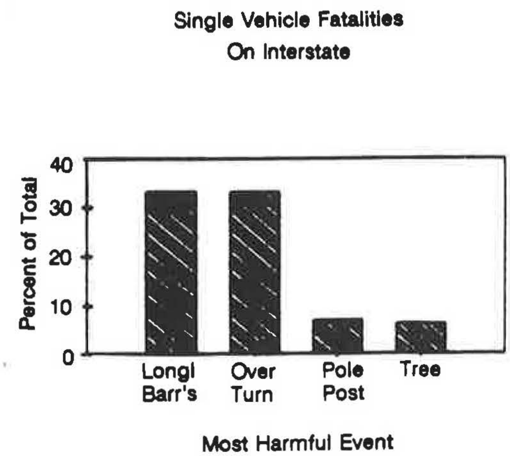

Figure 2

Solving the Problem

The Federal Highway Administration (FHWA) annually spends approximately one-to two-billion dollars in Federal-Aid Highway Safety Funds. These funds are distributed to the States for hazard elimination programs, elimination of hazards at rail-highway crossings, and various highway safety programs. Within the Federally Coordinated Program (FCP) the FHWA also administers significant efforts in research, development, and technology sharing. The FHWA Offices of Research, Development, and Technology are assigned the responsibility of monitoring a number of separate elements under the FCP structure. These include the State Highway Planning and Research Program (HP&R), the National Cooperative Highway Research

Program (NCHRP), the FHWA Administrative Contract Program, and the FHWA Staff Research Program.

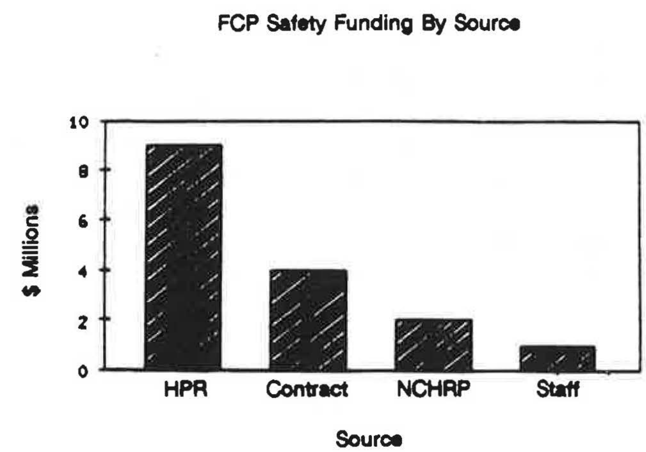

Figure 3

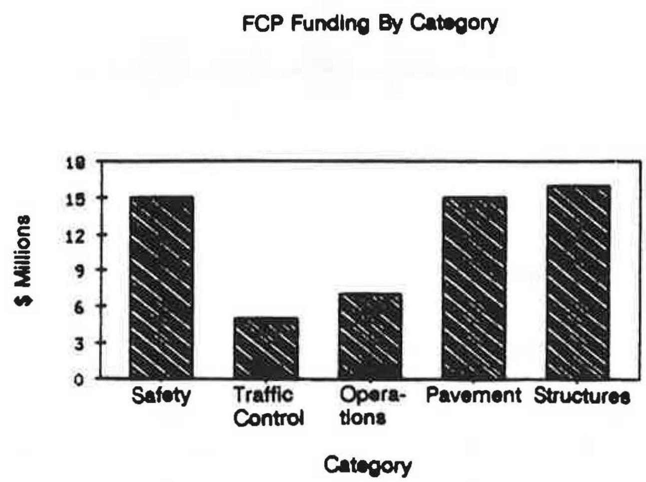

Figure 4

In fiscal year 1985 a total of 78 million dollars was spent in the FCP program (Figures 3 & 4). This included approximately 15 million dollars spent on safety related activities. These safety funds are distributed among eight different FCP project areas. Project 1T Roadside Safety Hardware accounted for approximately one-third ,nearly five million dollars, of these FCP safety funds.

The research and development efforts undertaken within Project 1T have resulted in a number of significant accomplishments in the design of traffic barriers and terminals, signs, supports, poles, and impact attenuators. Recent highlights include:

- A self-restoring barrier (SERB) that can safely redirect vehicles ranging from an 1800-pound car to a 40,000-pound intercity bus;
- A Controlled, Releasing Terminal (CRT) for straight sections of guardrail that is significantly safer for small cars;
- A Vehicle Attenuating Terminal (VAT) which provides a safe terminal where the guardrail end cannot be flared; and
- A 2,250-pound bogie vehicle has been built and validated for testing breakaway supports at the Federal Outdoor Impact Lab (FOIL).

Also within Project 1T, efforts in the development of new technology have provided analysts on-line computer access to a variety of vehicle-barrier simulations, including HVOSM, BARRIER VII, and an updated CRUNCH program. These programs and other analytic tools allow analysts to perform a more economical assessment of the performance of safety appurtenances.

Another significant accomplishment in the area of cost effective roadside safety design has been the development of improved analysis methods for justifying safety improvements and maximizing safety benefits. The use of improved computerized benefit-cost procedures, including integer programming, dynamic programming, and incremental benefit-cost methods are shown to result in significantly greater net benefits as opposed to simple benefit-cost procedures (Figure 5).

Problems in the Design of Safer Roadsides

Cost-effective treatments for run-off-road accidents require warranting criteria based upon accident or encroachment models or both, and an effectiveness estimate of the planned countermeasure. That is, in order to quantify the expected benefits of a safety improvement, estimates are needed as to the expected number and type of vehicle impacts with the safety hardware. This information can then be related to the results from full scale crash testing to estimate the benefits expected from reducing the severity of run-off-road accidents.

In developing warrants for roadside hardware the critical need is to define the encroachment or run-off-road accident rate and type as a function of highway geometry and traffic distribution. As a minimum, this

Cost-Benefit Methods

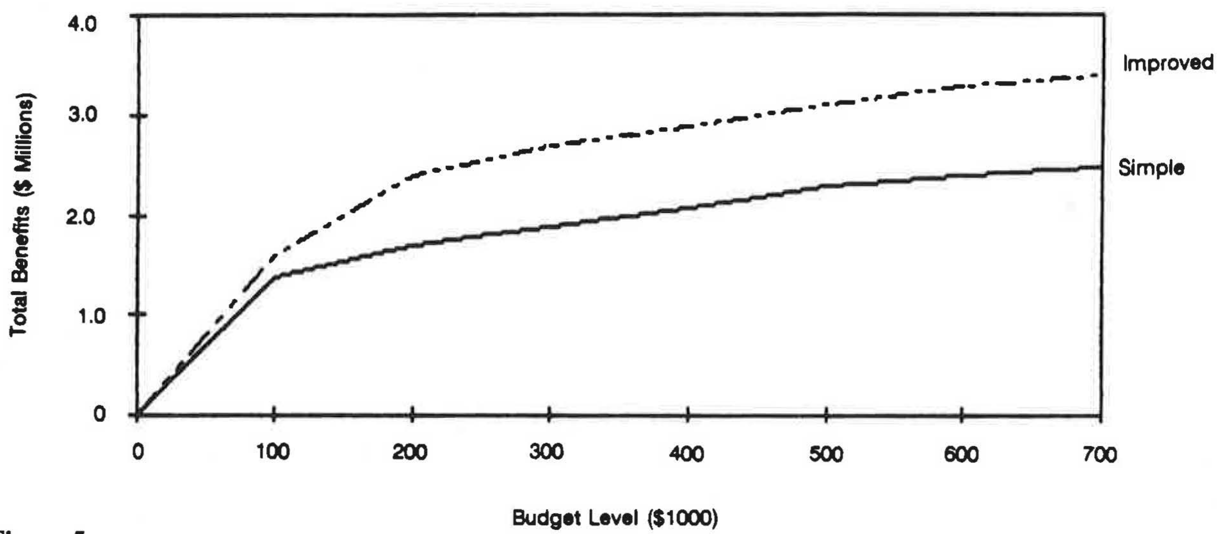

Figure 5

Departure Angle

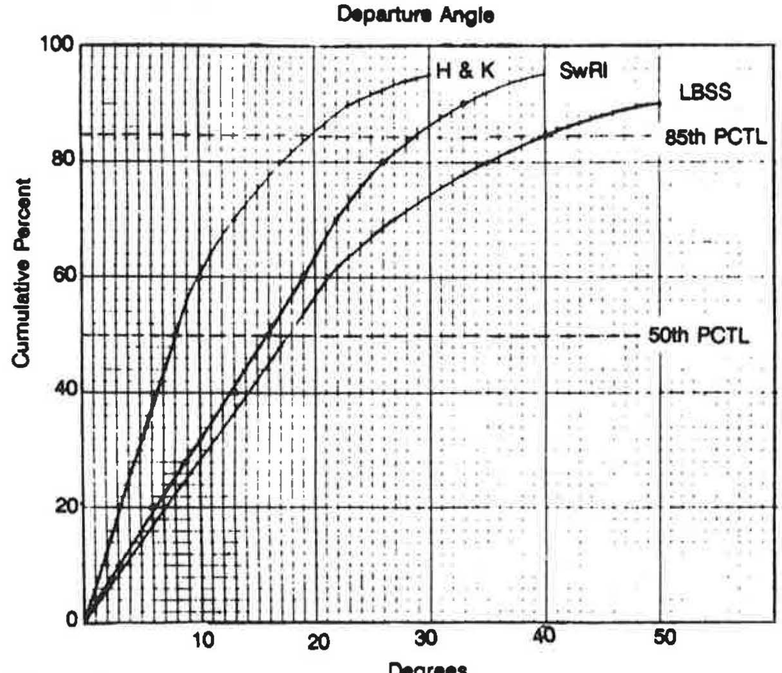

Figure 6

data should include such characteristics as vehicle speed, vehicle departure angle, and the lateral distance travelled from the edge of the roadway. Two different approaches have been used in the past to compile this information:

1. Encroachment model. Where vehicle departures from the roadway are charted and a distribution is compiled. The data collection techniques range from remote sensing equipment to manual observation of vehicle tire tracks off the roadway.

2. Accident model. Where single-vehicle accidents are investigated and reconstructed by a team of specialists to compile the data.

Figure 6 highlights the problems associated with compiling data on these characteristics. Note that the 50th percentile departure angle ranges from 8 to 18 degrees and the 85th percentile ranges from 20 to 40 degrees. The figure reveals that, in general, one can expect more severe departure angles if an accident model is used since only more severe accidents will be investigated. Reliance on such an approach will bias the distribution of both angle and speed toward more severe departures.

The development of an encroachment model also has serious drawbacks. FHWA recently spent over 800,000 dollars in a study to collect such data. A variety of techniques were used to collect the encroachment data, including continuous monitoring of highway sites with video tape recorders, remote sensing equipment and tape switch activated movie cameras. The scant data acquired show how difficult and expensive it is to collect data on such rare events. For example, 36,000 hours of video tape data, approximately 4.1 years, yielded only twelve encroachments for analysis. It should also be noted that the manual method of data collection will not furnish departure speed or vehicle type. Furthermore, there is some evidence that such methods will overestimate encroachment rates by counting vehicle departures when the driver intentionally steered off the roadway, that is, a controlled encroachment. As such, there currently exist no definitive data on these essential elements required for warranting criteria.

Roadside hardware is subjected to full-scale crash tests prior to its acceptance for deployment in the field. The acceptance standards are based upon the appurtenance's structural adequacy, the resulting occupant risk, and the vehicle's after collision trajectory. At issue is whether the current set of test matrices accurately reflect the real world accident characteristics. This is a critical factor in evaluating the hardware's anticipated effectiveness.

Recent analysis of investigated injury accidents at narrow bridge sites related the actual accident impact conditions to the conditions imposed in crash test matrices. As shown in Figure 7, a large number of these severe accidents exceeded at least one of the crash test conditions.

Although these investigated accidents represent a very small sample (n = 81) of severe accidents (injuries and fatalities), the data provide important insight into the actual dynamics of run-off-road accidents. In 70 percent of the reconstructed accidents from Figure 7, the vehicle sustained a secondary impact following a smooth redirection from the initial impact with the barrier. Such secondary impacts tend to dramatically increase the occupant risk due to higher impact angles, vehicle not tracking at impact, collision with unprotected fixed objects, and vehicle rollover. Figure 8 shows that vehicle rollover and secondary impacts with fixed objectives subsequent to the first barrier impact constitute a major safety hazard. As such, the importance of the vehicle's post impact trajectory in current hardware acceptance criteria cannot be overemphasized.

Finally, in addressing the current hardware acceptance standards in terms of cost-effective design, it is useful to examine impact speed distribution as a function of roadway type. Figure 9 shows three such distributions compiled from narrow bridge and pole accident data bases. If one chooses to base the hardware acceptance standard on the 85th percentile impact speed, the appropriate crash test speed will range from 40 m.p.h. on urban arterials to 60 m.p.h. on freeway facilities. Clearly the data indicates the desirability of using a multi-service level approach to roadside safety design in order to maximize the benefit-cost ratio for safety related improvements.

Additional Problems

Besides the problems cited above, difficulties experienced in the implementation, installation, and maintenance of roadside hardware continue to represent troublesome issues to the highway safety practitioner. In general, each roadside safety appurtenance proceeds through five separate stages along the path toward full scale implementation; design, testing, experimental deployment, inservice evaluation, and implementation. Given the interactive nature of these stages, the actual time required to implement new technology often exceeds a 10 year span from its initial conception. Even in a smooth transition through the evaluation stage, there is no guarantee that a wide scale implementation will follow. Given the seriousness of the roadside safety problem confronting us today, the length of time it takes for implementation could use considerable improvement.

Improper installation and maintenance of safety hardware also constitutes a major safety hazard to the driving public as well as an increased liability burden to State and local agencies. Cases recently discovered, for example, include:

• Deformable guardrails to shield non-breakaway poles installed to within 8 inches of the poles;

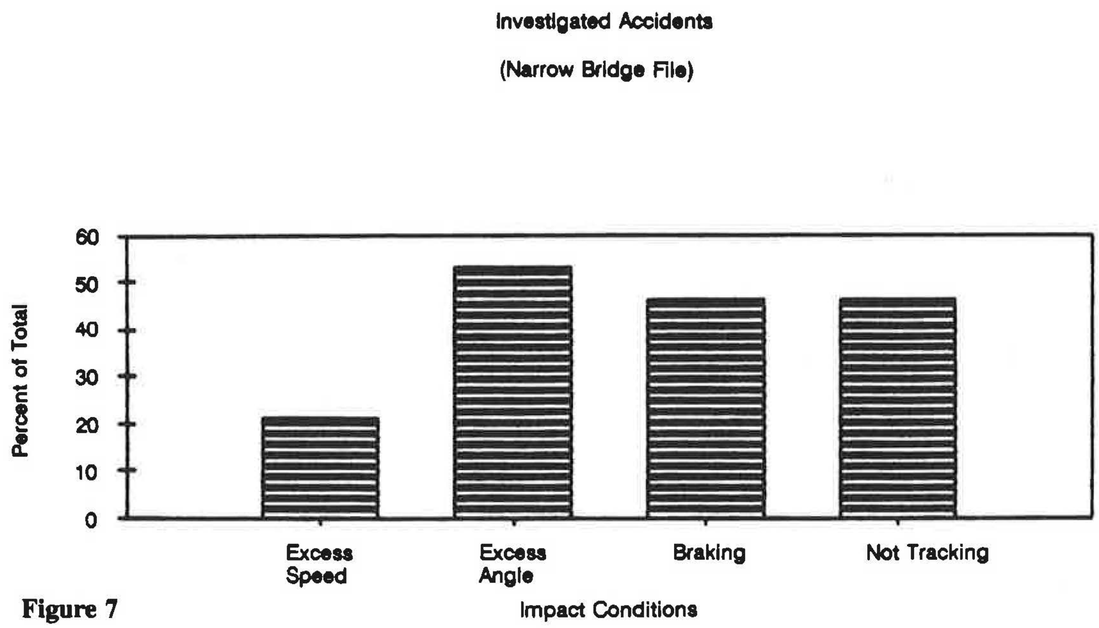

Figure 7

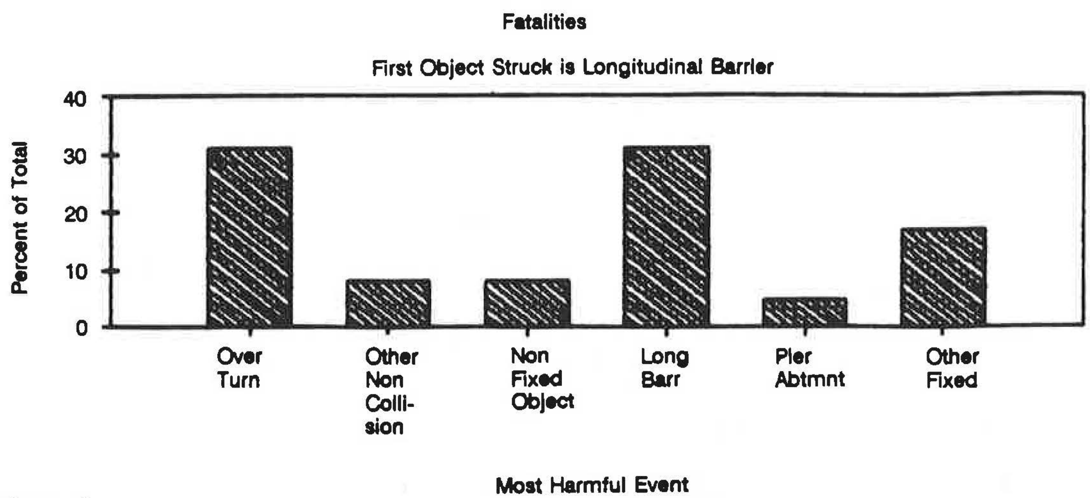

Figure 8

• Improper transition between rigid bridge rails and the deformable approach guardrail; and

• Improper use of washers (on the first 37.5 feet) on breakaway cable terminals (BCT), resulting in significant performance degradation.

Last of all, Federal, State, and local agencies are currently facing severe budget constraints. In this era of Gramm-Rudman-Hollings there is little chance for an expansion of the Federal Government's role in highway safety research. In fact, despite the massive costs associated with traffic accidents, the funds available for roadside safety research and development are projected to decrease. The current trend is shown in Figure 10, specifically as it affects contract funds for Project 1T in the FCP. These estimates show three significant developments:

• Less total safety research funds available,

• Less total funds available for Project 1T, and

• Fewer new starts within Project 1T due to increased use of multi-year programming of funds.

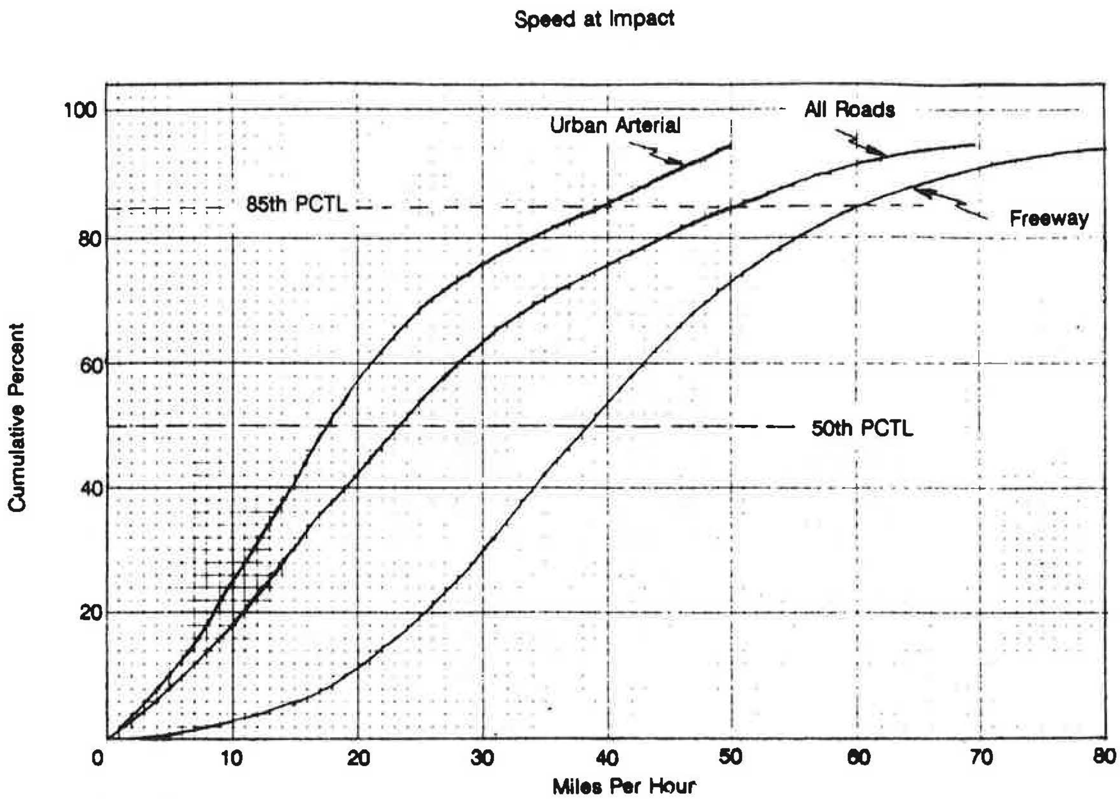

Figure 9

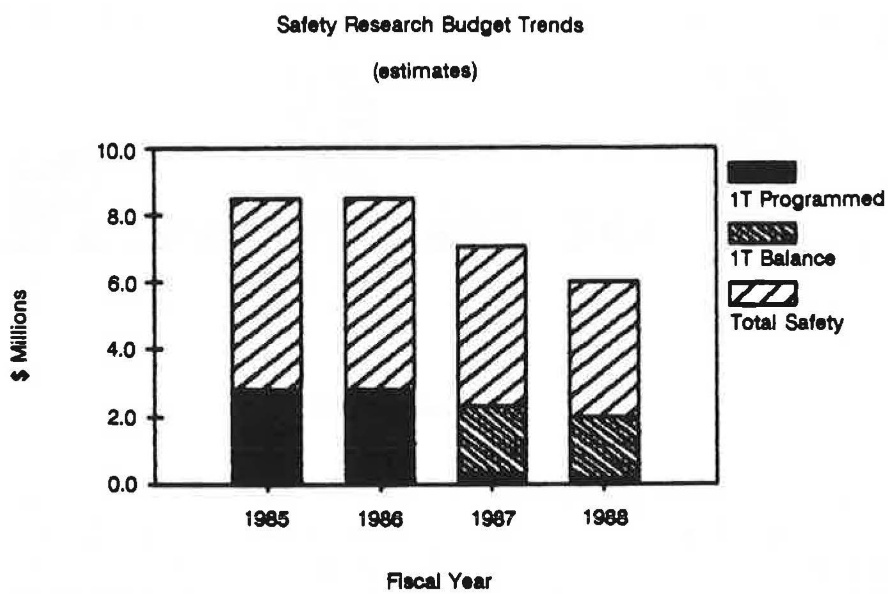

Figure 10

Summary

Although powerful procedures and analytical tools have been developed, critical deficits in the input data continue to undermine researchers' efforts in the cost-effective design of safer roadsides. Careful investigation of the available data shows that closer attention needs to be paid to hardware acceptance criteria such that these standards accurately reflect the real-world dynamics of single-vehicle accidents. The high incidence of multiple-impact accidents graphically demonstrates the significance of this need. These difficulties are compounded by the delays experienced in the deployment of effective hardware as well as the complications arising from improper installation and maintenance. Clearly, significant and continuing commitments in research, development, and technology sharing are urgently needed to address the roadside safety problem.

References

1. *Accident Facts 1985 Edition.* National Safety Council, Chicago, Illinois, 1986.

2. FARS; Fatal Accident Reporting System. 1982, 1983, 1984.

3. *Highway Statistics 1983.* Federal Highway Administration, United States Department of Transportation, Washington, D.C., October 1985.

4. *1984 - 1985 Report of the Offices of RD&T.* United States Department of Transportation, Federal Highway Administration, Washington, D.C., October 1985.

5. McFarland, W.F. and Rollins, J.B., *Cost-Effectiveness Techniques for Highway Safety: Resource Allocation.* Report FHWA-RD-84-011, FHWA, U.S. Department of Transportation, June 1985.

6. Hutchinson, G.W. and Kennedy, T.W., *Medians of Divided Highways - Frequency and Nature of Vehicle Encroachments.* University of Illinois Engineering Experiment Station Bulletin 487, Urbana, Illinois, 1966.

7. Calcote, L.R. et al., *Determination of the Operational Performance Requirements for a Roadside Accident Countermeasure Warrant System.* Report FHWA-RD-85-113, FHWA, U.S. Department of Transportation, October 1985.

8. LBSS; Longitudinal Barrier Special Study (NASS). 1982.

9. Michie, J.D., *NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances.* TRB, National Research Council, Washington, D.C., March 1981.

10. Michie, J.D., *Evaluation of Design Analysis Procedures and Acceptance Criteria for Roadside Hardware.* Draft Final Report, FHWA Contract DTFH61-82-C-00086, FHWA, U.S. Department of Transportation, October 1985.

11. Mak, K.K. et al. Real World Impact Conditions for Ran-Off-The-Road Accidents. In *Transportation Record 1085,* TRB, National Research Council, Washington, D.C., 1986, pp. 45 - 55.

Overview of Benefit-Cost Methods

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Benefit-cost analysis is simply a method for using a common sense approach to investment decisions. The general idea is to select the group of projects that will maximize the present worth of future benefits for an available budget. In a more specific sense, economic analysis can be used to determine the, cutoff level for expenditure and the ranking of projects for a limited budget.

The three most used economic analysis techniques are, simple benefit-cost ratio analysis, rate-of-return analysis, and incremental benefit-cost analysis. According to several surveys, almost all states use some type of economic analysis for comparing alternative projects[1]. This is true for large construction projects and also for safety projects. Recent research has shown that use of benefit-cost analysis, or rate-of-return analysis which gives similar results, can lead to a substantial increase in total benefits as compared to the use of index-based techniques, such as sufficiency ratings[2].

An investment is considered to be economically justified or warranted, if the benefit-cost ration exceeds one. In more general terms, any feasible increment expenditure is economically justified if its incremental benefit-cost ratio is greater than one. In the simplest situation where only one project is considered at each location, where all projects are mutually exclusive, projects are ranked in descending order from the project with the largest benefit-cost ratio to the project with the lowest ratio. If alternatives are not mutually exclusive, then an incremental analysis should be used, as is discussed in more detail later in the paper.

In calculating a benefit-cost ratio, initial costs usually are in the denominator, and the present worth of annual maintenance operating and maintenance costs are also sometimes included in the denominator. The numerator is the present worth of annual reductions in accident costs and other annual benefits. If the present worth of the increase in annual operating and maintenance costs are not added to the denominator then they are subtracted from benefits in the numerator. Also, added to benefits in the numerator is the present worth of the salvage value at the end of the analysis period.

If the investment decision involves allocating a budget for initial costs, the decision is less ambiguous if only initial costs are included in the denominator, and the ranking of projects using benefit-cost ratios will lead to the maximization of future benefits less future costs for a given budget of initial costs. If the present worth of all costs is included in the denominator, then a ranking of projects using benefit-cost ratios will maximize total benefits for a budget of total costs. Since budgets typically are in terms of initial costs, it is consistent to use a ration with only initial costs in the denominator.

Recommended Discount Rate

There has been considerable disagreement over the correct discount rate to be used in calculating the present worth of future benefits and costs. It is possible to distinguish between discount rates for constant dollars and for inflated dollars. In highway economic analyses, future benefits and costs are almost always calculated in constant dollars, so a zero-inflation discount rate should be used. This type of rate is typically calculated to be about three to seven percent with five percent being a good compromise rate. However, if future benefits and costs are calculated in inflated dollars, then the inflation rate used to inflate future benefits can be added to the constant dollar rate. Since the principal use of benefit-cost ratios in safety decision making is to rank competing projects, the principal effect of the discount rate in safety investment decisions is in determining the trade-off between present and future benefits. Therefore, the real effect of a rate of five percent, for example, is that saving one life now is equated to saving 1.05 lives one year in the future, or (1.05 x 1.05 =) 1.1025 lives two years in the future, and so forth. If a discount rate of ten percent is used, instead of five percent, future savings are valued much lower relative to present savings. Since most of the safety benefits and the taxes used to pay for safety improvements, are from passenger car occupants who are typical consumers, it is appropriate to use a discount rate that is representative of the trade-off between the present and the future that is preferred by typical consumers. This rate in real terms, which is adjusted to exclude the effects of inflation, has been found to be about three to five percent.

Use of Incremental Analysis

Another point that is sometimes confusing is whether an incremental benefit-cost analysis should be used in ranking projects. For mutually exclusive alternatives (that is, where there is only one alternative at each accident location), a simple benefit-cost ranking gives the same ranking as an incremental analysis. Since there is only one increment at each location both rankings give the same answers.

If there is more than one alternative improvement at each location, then simple benefit-cost ratios do not give the same benefits as incremental analysis. To maximize total benefits for a fixed budget, it is necessary to use incremental analysis. Three different techniques are available for ranking alternatives when there are multiple alternatives at one or more of the locations being considered. These techniques are, incremental benefit-cost analysis with an improved solution algorithm, dynamic programming, and integer programming. An easy-to-use computer program is available for each of these techniques[3].

Each of these three improved methods has been compared with simple benefit-cost analysis using actual accident locations with multiple alternatives, for Alabama and Texas[3]. Brown earlier made a similar comparison of dynamic programming and simple benefit-cost analysis using the same set of Alabama locations[4]. These comparisons indicate that any of the three improved techniques, all of which use incremental analysis, give an increase in total benefits of about 35 to 40 percent, as compared to simple benefit-cost analysis, if locations with multiple alternatives are being ranked.

Accident Costs

The next thing I would like to discuss is some of the recent research on accident costs. This research has shown that use of a market, or willingness-to-pay, approach supports the use of increased costs for fatalities and injuries. This recent research, using detailed data on injuries, shows that injuries in fatal accidents are much more severe than injuries in injury accidents of the same coding. These research results were taken into account in developing the accident costs in Table 1, which is based on McFarland and Rollins[5]. Estimates of accident costs as related to a severity index for roadside obstacles also have been developed using similar accident cost values[6].

TABLE 1 ACCIDENT COSTS BY AREA AND SEVERITY

Area and Type of Cost	Accident Cost by Severity (1980 dollars) Fatal($)	Injury($)	PDO($)	Average($)
Rural				
Direct	34,695	6,536	1,906	3,715
Indirect	848,442	4,108	202	15,309
Total	883,137	10,644	1,298	19,024
Urban				
Direct	30,186	5,755	1,283	2,581
Indirect	796,670	2,990	236	4,562
Total	826,856	8,745	1,519	7,143

Estimation of Accident Severities and Costs at a Location

A final point I would like to address is a problem that often arises when one attempts to use relatively large accident costs for fatal accidents. The problem typically arises when the actual number of accidents by severity is used to calculate accident costs at each accident location. There are at least four ways that accident severities can be estimated at each accident location:

1. Using actual accidents at each accident location;
2. Using statewide averages for locations of the type being considered;
3. Using a statistical analysis, such as that recommended by Tamburri and Smith[7]; and
4. Using a Bayesian statistical approach, such as that recommended by Flowers[8].

The main point that is made here is that choosing one of the above methods for estimating accident severities is inter-related with the choice of accident costs for each severity. That is, one of the reasons that there is a reluctance to use the higher accident cost values for fatal accidents in benefit-cost analyses of safety improvements is, that their use tends to give distorted estimates for total accident cost at some locations. When using the first method, there may be a problem because locations with fatalities tend to be chosen for correction even when they are similar to other locations that have more accidents, but have less fatal accidents. The second, third, and fourth approaches represent attempts to solve this problem.

The second approach, using statewide averages, entails calculating accident costs using statewide percentages for fatal, injury, and property-damage-only accidents for each type of accident location. One difficulty in implementing this approach is in deciding what categories to use in calculating average percentages. For example, in calculating percentages for tree accidents, should one use trees in general or should trees be divided into subcategories, such as by distance from the edge of the travel lane? Or is it possible to use a fixed object category to represent tree accidents? Another difficulty is that specific locations may be more hazardous than the average location of a type, and this approach does not allow for this consideration.

The third approach uses statistical tests developed by Tamburri and Smith[7]. The principal difficulty with this approach is that the assumed normal distribution is not a good representation for accident severities, especially in urban areas. Any time there is at least one fatal accident at a location, it is likely that this fatal accident will be judged to be statistically significant and the actual proportions by severity will be used, as in approach one. Even though their approach may work fairly well for rural locations with a large number of accidents, for example more than thirty, it is not a good rule for most situations because the assumption of a normal distribution is not met.

The fourth approach is to use a Bayesian procedure. As outlined by Flowers[8], this approach uses a weighted average of the severity proportions at a specific location and the statewide average proportions for the type of location being considered. There are two ways of setting the relative weights placed on the location proportions and the statewide proportions. First, the safety analyst can subjectively set the relative weights, depending on his judgment of how well each of the two sets of proportions represent the true proportions at the location. Second, the weights can be set using formulas provided by Flowers, in which case the resulting numbers are properly called synthetic Bayesian numbers. Since the latter approach could be more uniformly applied throughout a state, it is probably the preferred of the two approaches. The latter approach gives more weight to the specific location proportions when there are a larger number of accidents on which to base such proportions.

It is recommended that states use the higher accident costs given in this paper and also consider using a Bayesian approach, with use of synthetic Bayesian numbers, to estimate the proportions of accidents by severity in calculating accident costs at each accident location.

References

1. McFarland, William F., Comparing Benefits of Safety and Non-Safety Programs, Highway Safety: At the Crossroads, Edited by R.E. Stammer. *Proceedings of a Special Conference of the American Society of Civil Engineers in Cooperation with others*, 1988, 164-181.

2. McFarland, William F. and Memmott, Jeffery L., Ranking Highway Construction Projects: Comparison of Benefit-Cost Analysis with Other Techniques. In *Transportation Research Record 1116*, TRB, National Research Council, Washington, D.C., 1987.

3. McFarland, William F. and Rollins, John B., *Cost-Effectiveness Techniques for Highway Safety: Resource Allocation.* Report No. FHWA-RD-84-011, Federal Highway Administration, U.S. Department of Transportation, June, 1985.

4. Brown, David B., Economic Tradeoffs in Road Improvements. *Traffic Safety,* Vol.74, No.8, August, 1974, pp. 18-20, 36.

5. Rollins, John B. and McFarland, William F., Costs of Motor Vehicle Accidents and Injuries. In *Transportation Research Record 1068,* TRB, National Research Council, Washington, D.C., 1986, pp. 1-7.

6. McFarland, William F. and Rollins, John B., Accident Costs and Severity Indices for Roadside Obstacles. Presented at Annual Meeting of the Transportation Research Board, Washington, D.C., January, 1985.

7. Tamburri, T.N. and Smith, R.N., The Safety Index: A Method of Evaluating and Rating Safety Benefits. In *Highway Research Record 332,* HRB, Washington, D.C., 1970.

8. Flowers, Robert J., *A Procedure for Predicting Future Accident Costs at Specific Locations,* Report TARE-53. Texas Transportation Institute, College Station, Texas, July, 1981.

Pennsylvania's Guide Rail Standards: A Cost-Effective Change

By: Louis C. Shultz, Jr., Pennsylvania Department of Transportation

Over the past seven years, we have seen a revitalization of Pennsylvania's highway system. Under the leadership of Dr. Thomas D. Larson we have seen over 25,000 miles of highway rehabilitated or reconstructed. We have seen almost 500 bridges rehabilitated or reconstructed. We have enacted not one, but two Billion Dollar Bridge Bills. We have transferred ownership of over 2,000 miles of basically local use highways to municipal governments. And we have seen the revenue initiatives necessary to provide the funding for a highly energized staff to meet the challenges associated with these accomplishments. In short, we have made a difference.

One of the priorities of the Larson Administration at PennDOT has been maintenance first. By this, we mean that the rehabilitation and restoration of our existing roads and bridges takes priority over all other functions in the Department. Pennsylvania currently has over 42,000 miles of highway which are owned and maintained by PennDOT. This total exceeds the entire state-owned milage of all the New England states plus New York state. Nevertheless, we have developed a cycle which enables us to restore over 6,000 miles of highway each year. These restoration projects do not merely involve roadway improvements; they are all-inclusive. The roadway surface is improved, shoulders are upgraded, and the appropriate drainage and guide rail improvements are made.

Like all public institutions, PennDOT does not have an endless supply of funds, even though some lawyers might argue that we have deep pockets. To better manage our highway restoration programs, in 1983 we sequestered a task force of some of the Commonwealth's top managers, and charged them with development of a system to manage our paving programs. The result was STAMPP, the Systematic Technique to Analyze and Manage Pennsylvania Pavements. This methodology provided excellent information on the pavement surface, but was still lacking in information on other components of the roadway environment, specifically the drainage and highway safety hardware. A second task force, composed of another group of Department engineers, was charged with developing a methodology to inventory the type, location, and condition of drainage and guide rail along our state highways. Without boring you with a great many details, suffice it to say that this task force was successful in developing and implementing a methodology to survey the amount and condition of all guide rail and drainage facilities. Both surveys were initiated in 1985, the guide rail being update annually, and the drainage being collected over a four-year period and updated periodically based on the type and condition of the particular drainage appurtenance.

One of the major findings of that task force was the fact that we had a significant amount of guide rail along our highways which, in our opinion, was of questionable value. Admittedly we did find a number of guide rail installations which we did not question either the need for, or the adequacy of. However, we did find a lot of substandard guard fence badly in need of replacement. We also found some old and dilapidated guard fence, which in our opinion, was not needed. We found short, non-functional sections which were more of a hazard than the hazard they were trying to protect us from. We found substandard end treatments, which may pose more of a safety hazard than if the slope behind were left unprotected. We found non-functional bridge end treatments. And we found guide rail that met all acceptable standards, but was really not needed. In one case, it could be argued that the guide rail would prevent errant vehicles from entering the school yard, an argument that none of us would question. We also encountered guide rail protecting errant vehicles from brand new vehicles. While I am sure that the Chevrolet dealer appreciates this guide rail, I don't think it is PennDOT's responsibility to protect his new vehicles, given the roadway and geometric conditions prevalent at this site.

Clearly, there was a need to take a hard look at the standards which led to installations such as those which I have just presented. Secretary Larson agreed with this assessment. Enter task force number three. We assembled a multi-talented group of individuals representing highway safety, design, maintenance, research, and program development. We included representatives from all three levels of PennDOT: Central Office, District Offices, and County Maintenance Offices. And, to keep us all honest we included a representative of the Federal Highway Administration's Pennsylvania Division Office. A meeting with top officials in PennDOT, including Secretary Larson and a number of his Deputies, made it very clear that they felt the time was ripe for a change in our thinking regarding guide rail standards and warrants. The task force was charged with a four-point program:

1. Evaluate and reestablish guide rail warrants using a cost-effectiveness analysis.
2. Identify areas where existing guide rail can be removed.
3. Review design standards and recommend areas of cost reduction.
4. Recommend an implementation program.

Our first step was to conduct an exhaustive literature search. Promising articles were distributed among the task force members for review, to sort out the useful and useless. In the end, we resolved that the way to go, at least for Pennsylvania's purposes, was included in AASHTO's Guide for Selecting, Locating and Designing Traffic Barriers. Most specifically, Chapter VII, which presents a cost-effectiveness methodology. This methodology addresses guide rail use based on encroachment frequencies, severity of impacting a warranting feature, embankment slopes and heights, and available clear zone. The analysis considers three options for each situation:

1. Remove or reduce the hazard so that shielding is not necessary, such as flattening slopes;
2. Install a barrier; and
3. Do nothing; leave the hazard unshielded.

Put another way, we all know the purpose of a barrier system:

1. Protect vehicles from embankment slopes,
2. Protection from fixed objects, and
3. Protection from non-traversable roadside hazards.

The trade off, if you will, which we face is at what point is it more cost-effective to leave a slope unprotected and therefore allow vehicles to attempt to negotiate the unprotected slope, rather than installing a barrier which will surely be impacted.

The formula used in the AASHTO Barrier guide is really quite straight-forward: it compares the total annual cost associated with the obstacle to that associated with a barrier. In the case of a slope, the slope, the slope itself is considered the obstacle. The formula takes into account the initial cost, average damage cost per accident, average maintenance cost, average occupant injury and vehicle damage cost per accident, estimated salvage value, and, most importantly, collision frequency.

The collision frequency is characterized by this formula:

$$C_f = E_f \,/\, 10{,}560\ [(L+62.9)P1 + 5.14\ P2]$$

The Formula includes factors for encroachment frequency, Ef, horizontal length of the obstacle, L, probabilities (P1 and P2) of an encroachment equaling or exceeding a given lateral displacement, A. We looked at ADT values of 20,000, 5,000, 2,000, 750, and 400 vehicles per day, which correspond with ADT breaks in PennDOT's design standards. The following chart shows the values used in our analysis.

ADT	A (rail) (feet)	A (slope) (feet)	E_f	P1 (%)	P2 (%)
20,000	10	12	7.5	93	90
5,000	8	10	2.0	95	93
2,000	6	8	3.4	97	95
750	4	6	1.4	98	97
400	2	4	0.8	99	98

For example, given an ADT of 20,000, guide rail was assumed to be placed 10 feet from the edge of the roadway, the slope was assumed to begin 12 feet from the edge of pavement, the encroachment frequency was 7.5 (taken directly from AASHTO's table 5.1.16), and the two probabilities were found to be 93 and 90 percent, again based on AASHTO formulas.

Standard AASHTO-recommended values were modified to incorporate Pennsylvania-specific conditions. A fatal accident was valued at $299,100, an injury accident at $13,080, and PDO accident at $1,680. These are the very same values used in our Highway Safety Improvement Program in Pennsylvania. These figures were combined with Pennsylvania accident history data to develop severity indices using Glennon's formula:

$$SI = 24F + 6I + P/N$$

Guide Rail installation costs were likewise based on actual Pennsylvania experience: $10.00 per linear foot for weak post guide rail, and $16.50 per foot for strong post guide rail. An average damage cost of $400 per incident was determined from previous damage experience. An average maintenance cost of $1.50 per foot, and salvage value of $3.00 per foot were both based on data extracted from Pennsylvania's Highway Maintenance Management System.

Guide rail lengths of 150, 300, 500, 750, and 1,000 feet were then analyzed to determine the total annual cost associated with each guide rail installation. The total annual cost for a slope of the same length was then equated to these figures to, in essence, work backward to determine the maximum height of slope which would be acceptable, from a cost-effectiveness standpoint. With all other factors known, we then solved for the average accident cost associated with the slope. This dollar value was equated to a severity index based on the aforementioned Pennsylvania-specific figures, and the height of the slope Pennsylvania-specific figures, and the height of the slope was calculated from the formula shown below.

$$\log SI = 0.556 + 0.160 \log h + 0.324 \log s$$

A microcomputer program made the job fairly easy. The result was the set of embankment warranting criteria for ADT shown here.

Slope	More than 5,000	751- 5000	400- 750	Less than 400
1 ½ :1	4[a]	6	9	17
2:1	8	10	16	31
2 ½ :1	12	16	25	49

[a] In feet

You will note that the 2,000 ADT figure is not included. This particular ADT yielded values very similar to those found at the 5,000 figure, so the two were combined into a single listing. Three observations immediately come to mind as you review our findings:

1. As ADT decreases, reduced accident frequency permits greater slope height.
2. As the rate of slope decreases, the reduced severity associated with it permits greater slope height.
3. The greater the length of slope, the greater the slope height.

Further work by the task force resulted in a number of significant recommendations.

1. The height of weak post guide rail should be reduced to 30 inches for all new construction.
2. The height of strongpost guide rail should be reduced to 27 inches, and rub rail should be eliminated, for all new construction.
3. The standard bridge protection should be reduced to a minimum length of 50 feet. This previously had been 125 feet.
4. The minimum length of guide rail in advance of an obstruction should be reduce to 50 feet.
5. Each District Engineer retains the option of providing guide rail treatment at locations with a previous accident history of the potential for accidents, at locations where personal safety would be compromised, and in socially sensitive areas.
6. Undoubtedly, the most significant finding of the task force, is that the chart be adopted as Pennsylvania's guide rail warranting criteria for slopes.

Based on these recommendations, we conservatively estimate that the Pennsylvania Department of Transportation can save over $5 million per year in guide rail installation and maintenance costs. We estimate the annual cost to remove unwarranted guide rail at $1.8 million over each of the next four years, leaving a net savings of $3.4 million per year.

It was our further recommendation that these monies be plowed back into the guide rail improvement program, to enable the Department to upgrade substandard guide rail which will still be required under the new criteria. An annual program to systematically upgrade substandard guide rail in accordance with these criteria can produce savings in terms of improved highway safety, reduced tort liability, and decreased maintenance needs. As a first step, each District has been asked to include projects to upgrade guide rail protection of bridge parapets as part of their annual highway safety efforts.

These recommendations were presented to top management, which enthusiastically endorsed them and forwarded them to the Federal Highway Administration for their approval. After a period of approximately 3 months, we received word from FHWA that they likewise concurred with the concept and approved the warranting criteria as presented.

We have printed and distributed these revisions, and our District designers have incorporated the revised criteria into projects to be constructed in 1986. We think these criteria present a logical, cost-effective means of dealing with the problems associated with too much outdated guide rail and guard fence, while at the same time recognizing our responsibility to provide for safe highway environment for our motoring public. The effects of limited highway budgets, make this cost-effectiveness approach the only sensible means of dealing with this challenge. In Pennsylvania, we like to think it will keep us out of some very big holes.

Legal Considerations Based on Benefit-Cost Analysis

By: Jack Sollis, Oregon Department of Transportation

The legal authorities addressing considerations of policies based on benefit-cost analysis are extremely skimpy. I have run a computer search for any tort claims cases in which a benefit-cost analysis was used and have not been able to find any in the United States.

Absent any cases that give you any direction, the only thing left to do is to resort to common sense.

In the cost benefit analysis the cost of course is determined by the construction cost and the cost of preliminary engineering, preparing the plans, right of way purchase, etc. The benefit is derived by determining a monetary equivalent to the benefit to the public because of the reduction in accidents that it is estimated will not occur if the improvement is made.

The National Safety Council publishes figures on the cost of fatalities, injury and property damage yearly. This is the basis for the monetary value of the benefit. In using the benefit-cost analysis the same common sense approach must be used as is required in all formulas, that is to have the right ingredients in the formula. You can't "fudge" on the construction costs and the benefit to the public in order to come up with a figure high enough to put the project on the top of the list. You also can not "fudge" with the figures on either side to put the project on the bottom of the list.

It is important that the cost figures be updated to take care of inflation or deflation, whichever may occur; and the figures used to compute the benefits be updated annually on the basis of figures supplied by the National Safety Council. The only admonition I can give here is - don't play around with the figures in order to have your result come out to a greater one, so that the project is on the list merely because somebody thinks it ought to be there.

I think it is extremely important that we have been unable to find any cases on this matter. Therefore, it indicates that it is not a matter that the plaintiff's attorneys are using in bringing tort suits against highway divisions. However, that is not to say such tort suits will not happen in the future and that some bright young attorney may conceive a way to bring the benefit-cost analysis into a case to the detriment of the public body. I have no doubt that the benefit-cost analysis has been brought up and discussed in tort claim cases but it has never become a key factor that has been subject to discussion of review upon appeal. It is probably of more importance to defending a action, or non-action, based on cost benefit; and bringing that action under discretionary function immunity.

One of the things that is very important in using the benefit-cost analysis, in case you do ever end up in court, is being able to explain it in language that is understandable to a layman. Many times it is helpful to have charts and other diagrams that will help the jury understand what you are talking about. Sometimes a slide show might even be worthwhile. It is always important to be a little innovative in your defense tactics in order to bring across to the jury clearly what you are trying to explain. Many times it is the inability to explain a particular theory or a particular method of calculating the priority of highway safety projects that may get a public body in trouble.

I realize that this has not been a brilliant exposition on benefit-cost analysis. B-C analysis does not lend itself to that type of discussion, because it has not yet become a controversial issue.

In closing all I can say is that in applying the factors that are used in the benefit-cost analysis the biggest item is the use of common sense in applying the elements and being able to explain those elements in simple direct language that can be understood by laymen.

PART 3 WORKSHOP SUMMARIES AND RECOMMENDATIONS
Summary of the Workshop Groups

Background

The afternoon of day one and all of day two were devoted to Workshop Groups on several issues related to benefit-cost analysis. The Workshops were divided into two basic topics:

- Problems, Solutions and Needed Research Related to Development of B-C Methodologies and
- Problems, Solutions and Needed Research Related to Application of B-C Methodologies.

Figure 4 lists the individual discussion topics within each broad category.

The objective of the Workshops was to provide an informal forum to discuss these issues. The Workshops resulted in a very interesting and productive exchange of ideas. The participants discussed their experience in using B-C analysis and presented ideas on how their utility to the highway safety community might be improved. Each Workshop Group generated specific recommendations based on the discussion among its participants.

Workshop Recommendations

The following discussion presents the more significant recommendations and observations which were generated by the Workshop Groups, including recommendations for research. They are categorized according to the major topics which were addressed by the Workshops, as shown in Figure 4. This report in subsequent sections presents the discussion topics and full reports from the Workshop Group Leaders.

Development of B-C Methodologies, Topic A

1. Complexity. There was a consensus view that the existing B-C methodologies are too difficult for the average user. There is a recognition that the model itself is necessarily complex, but its application can be significantly simplified. The Workshop Groups recommended that the B-C model needs to be adjustable at the central office level of a user agency so that agency-specific data can be incorporated. Therefore, a B-C model should be developed at the national level which has the desired flexibility and user-friendly features.

2. Probability of Impact (Encroachment vs. Accident). Establishing the probability of impact is crucial to the accuracy of B-C analysis. The Workshop Groups concluded that the encroachment method is superior to the accident data method to predict the probability of a roadside impact. Therefore, the Groups recommended that future research concentrate on improving and validating the encroachment model approach for impact probability.

3. Real-World Impact Conditions. Real-world impacts involve a multitude of vehicular characteristics. These include tracking, speed, angle of impact and lateral extent of encroachment. The lack of confidence in our understanding of this phenomena is recognized as a major deficiency in the validity of B-C analysis. Therefore, the Workshop Groups recommended that future research should be encouraged to improve the safety community's understanding of real-world impact conditions. This would involve some combination of accident reconstruction, evaluating the existing crash test matrix for safety features, and in-service performance evaluation of safety features.

4. Impact Severity. In B-C analysis, it is necessary to estimate the impact severity to assign various probabilities of fatal injury and PDO occurrences. However, there is a recognition that this is one of the more significant deficiencies within the methodologies. Therefore, the Workshop Groups recommended that research be performed to better determine the severity of impacts with roadside features. The objectives of this research would be to conduct an extensive investigation in order to:

   a. Identify the list of roadside hazards for which an impact severity is needed;
   b. Document the existing bank of data on impact severity;
   c. Develop strategies for the best method of estimating impact severity, such as crash tests, computer simulations, and accident reconstruction; and
   d. Implement the strategies.

5. Societal Costs. These include the cost of a death, injury, property damage, and indirect costs, for example, insurance administration. The determination of societal costs, especially the cost of a fatal injury, will have a major affect on the outputs of a B-C model. In addition, there are currently a wide range of values used by

various agencies and organizations throughout the nation. Therefore, the Workshops recommended that future research should seek to determine societal costs which can be accepted on a widespread basis and can be incorporated into B-C models. The objectives of this research would be to:

a. Determine what entity should select the societal costs for B-C analysis, for example, at the national level or at an individual state level, or some other variation;

b. Determine which societal costs should be reflected in the B-C analysis; and

c. Determine which approach should be used for the cost of a human life, such as human capital, and willingness to pay.

d. Determine what dollar values should be used for the selected societal costs.

6. Validation of B-C Analysis. Validation is needed to establish the accuracy and credibility of B-C analysis. This will help ensure their acceptance within the highway safety community. The Workshop participants recognized that this has received insufficient attention in the past. Therefore, a recommendation emerged to address this problem on a major, comprehensive scale. The approach is to conduct an in-depth, long-term field study of roadside safety to collect data for B-C analysis. The study could be conducted via the selection of several highway segments which are representative of various highway conditions, such as urban or rural, functional classification, traffic volumes, design speeds, terrain, and roadside environment. Each highway segment may range in length from 10 to 30 miles. A research team would closely monitor the roadside for unintentional encroachments, for example, downed roadside appurtenances, wheel tracks. The monitoring would likely take place for several years. Police accident reports could be supplemented by in-depth accident reconstruction. The data gained from these extensive field study could add immeasurably to the understanding of roadside safety and could provide valuable input data to B-C analysis.

Application of B-C Methodologies, Topic B

1. Context. B-C analysis could be presented in national publications as either an optional tool or as the primary method of making roadside safety decisions. The overwhelming consensus view of the Workshop participants was that a B-C analysis should be an optional tool to be used at the discretion of the user agency.

2. Minimum Roadside Safety Criteria. If B-C analysis becomes a major tool in the future for roadside safety, there may still be a need to establish threshold criteria for many features. Some candidates include clear zones, barrier flare rates, and dynamic deflection. The consensus view of the Workshop Groups was that there will be a need for these threshold criteria regardless of the future emphasis on B-C analysis.

3. B-C Analysis for Barrier Details. The type of barrier and barrier layout details, such as length of need, and flare rate could be determined by B-C analysis. Within certain limitations, the consensus view of the Workshop was that this is a practical application of B-C analysis. However, actual field conditions may dictate superseding the recommendations from the B-C model.

4. Upgrading Roadside Safety. The future highway program will likely be dominated by work on existing highways. This environment presents special and difficult challenges to upgrading roadside safety. The Workshop Groups concluded that B-C analysis could be a useful tool in deciding what improvements should or should not be made to the roadside. However, it was recommended that the roadside safety criteria within the B-C model should be less demanding for 3R projects than for new construction or reconstruction projects.

5. Selected Speed. When using a B-C analysis, the selected speed will have a significant influence on the impact severity. However, the selection of the most appropriate speed for a given set of highway conditions is not clear-cut, especially on 3R projects. The Workshop recommended that the proper speed input data be determined based on studies of speed distribution of impacts with roadside hazards. The distribution would vary with highway functional class and urban or rural location.

6. Flexibility of User Agency. If a B-C model gains widespread use in the future, the level of flexibility allowed for the user agency needs to be addressed. The assumptions and data within the model will drive the roadside safety decisions, and these will likely be the source of legitimate debate within the safety community. The Workshop Groups concluded that, if a user agency has well documented data, it should be allowed to use these data within the model.

7. Tort Liability Implications. Depending upon the nationwide context of B-C methodologies, the tort liability implications could become a serious issue. The Workshop Groups concluded that the key legal defense mechanism is a supportable technical basis, good documentation and adherence to the adopted criteria. This suggests that transportation agencies can successfully avoid tort liability problems, even if they elect not to use nationwide B-C analysis.

8. User Application. Ultimately, the success of applying B-C analysis depend upon the individuals who will

make roadside safety decisions with the outputs. The Workshop Groups concluded that there may be a high level of resistance to the use of B-C models. One suggested way of softening the resistance is to provide charts and nomographs to the users rather than requiring the direct use of a computer program to generate outputs. The participants also concluded that the use of the model by maintenance personnel is unlikely.

9. Transition Phase. In the future if a B-C model is proposed as the best means of making roadside safety decisions, the transition phase should be carefully planned. The most significant recommendation from the Workshop Groups was the need for an extensive trial-testing period before any official position is adopted. The *Highway Capacity Manual* experience, with its interim publications and resulting major revisions, was cited as a good example of how the application B-C analysis may be phased in.

10. Computer Software. The Workshop Groups deliberated on several issues related to the availability and use of computer software for the B-C model. The more important conclusions included:

a. Charts and nomographs should be used on a project-by-project basis.

b. The software documentation should allow easy manipulation so that user agencies can input their own data.

c. The availability of a comprehensive User's Manual is very important.

d. An extensive training program will be necessary.

FIGURE 4 WORKSHOP RECOMMENDATIONS

Topic A: Development of B-C Methodologies

1. Are the widely used and proposed B-C analysis procedures too complex?

2. What is the preferred method of estimating the probability that an object or feature will be struck at a given location during a given period of time? How can data be gathered to support the preferred method(s)?

3. What can be done to improve our knowledge of performance of safety features for real-world impact conditions.

4. What can be done to improve our knowledge of impact severity?

5. How should societal costs be assessed?

6. How can the B-C analysis procedures be validated?

Topic B: Application of B-C Methodologies

1. What is the proper context of a B-C analysis to make roadside safety decisions?

2. Assume that a B-C approach sill be the lead in making roadside safety decisions. Should this be supplemented with a set of minimum, inviolable criteria for barrier warrants and layout details, regardless of the results of a B-C analysis?

3. Once a barrier is determined to be warranted, should a B-C analysis be used to select the type of barrier system for installation? Should it be used to determine the most cost-effective layout details for installation? How should actual field conditions be reflected in the analysis?

4. How should a B-C model be used for up-grading roadside safety on existing highways?

5. What speed should be used when applying the B-C model?

6. What flexibility should be provided the user agencies for selecting different values within the B-C model or for revising the model itself?

7. What might the tort liability implications be with the use of a B-C methodology for roadside safety decisions?

8. What can reasonably be expected from the individuals who will be applying the B-C model on a project-level basis?

9. Assuming that the B-C model is adopted, how should the transition phase be handled?

10. How should the implementation and use of the computer software be handled?

PART 4 APPENDIXES FOR WORKSHOP MATERIALS

Appendix I

Problems, Solutions, and Needed Research Related to Development of B-C Methodologies (Agenda Item V, Topic A)

Discussion Topic 1

Are the widely used, and proposed, B-C analysis procedures too complex?

Discussion

While the widely used B-C analysis procedures are rational and based on sound principles, their formulation is based on relatively complex mathematical or probabilistic models, or both. A relatively high level of expertise and experience is needed to ensure their proper use. Further, they generally suffer from a sparsity of supportive input data. This requires that assumptions and simplifications be made, which in turn diminish the method's credibility. As will be discussed in the workshop, there is an acute need for improved encroachment data, accident data, impact severity data, and performance data for safety features.

Until the needed data are collected, should we consider a more simplified approach to evaluating safety alternatives? If so, how should the approaches be formulated? If these simplified approaches rely heavily on subjective reasoning, are we better off using the more complex methods, albeit there's a shortage of input data?

Discussion Topic 2

What is the preferred method of estimating the probability that an object or feature will be struck at a given location during a given period of time? How can data be gathered to support the preferred methods?

Discussion

Two basic methods have been used for this purpose: the encroachment-probability (EP) approach and the accident data (AD) approach. In the EP approach, encroachment data (rates and lateral extent of movement) are used in conjunction with a description of the object's geometry and offset to estimate the probability that an object will be struck. In the AD approach, accident data are used to develop the probability relationships, and these relationships may be relatively simple or complex. Some of the positive and negative aspects of the methods are as follows:

Positive Aspects

Encroachment-Probability Model

- Logical, systematic way of evaluating roadside safety alternatives;
- Only alternative in the absence of good accident data; and
- Used to develop general policies, such as barrier warrants on a state-wide basis.

Accident Data Model

- Based on real-world accident histories,
- Large volume of data, and
- Data will continue to be collected.

Negative Aspects

Encroachment-Probability Model

- Difficult to separate intentional encroachments from unintentional encroachments,
- Encroachment speeds cannot be ascertained from pure encroachment data,
- Difficult to detect encroachments on paved shoulders,
- Difficult to differentiate vehicle types for a given set of encroachments
- Encroachment data costly to collect,
- Encroachment rates dependent on a multitude of variables, and
- A number of assumptions are made regarding the nature of encroachments and the probability of an accident given an encroachment.

Accident Data Model

- Accident studies are always retrospective in nature;

- Reliability of police-level data is marginal at best;
- Cannot account for unreported accidents; and
- Accident data are not meaningful without exposure data, and exposure data is not generally collected.

Accident Data Model

- Problems arise from an incompatibility of accident records from state to state,
- Accident rates dependent on a multitude of variables, and
- Random nature of accidents requires a relatively long data gathering period.

It can be seen that neither method has a clear advantage over the other. It may be desirable to use the best of each method in a combined approach.

Discussion Topic 3

What can be done to improve our knowledge of the performance of safety features for real-world impact conditions?

Discussion

Impacts with safety features occur over a spectrum of conditions, such as encroachment speed and angle, vehicular attitude, size of vehicle, occupant restraint, etc. In a B-C analysis, one has to estimate the consequences (probability of occupant injury, damage to vehicle, damage to safety feature) of the spectrum of impacts predicted to occur over the analysis period. To date only a very limited data base exists from which these estimates can be made. The primary source of performance data has been through full-scale crash tests. However, most tests have been conducted within a very narrow spectrum of impact conditions. For example, most longitudinal barriers have been tested only at 60 mph and at either a 15 degree or a 25 degree encroachment angle. Test conditions are also ideal, for example, the vehicle strikes the barrier in a tracking mode (not spinning) on level terrain. Further, the test may not indicate how close the barrier was to failure (limit of performance). Computer simulation data have also provided limited insight on the performance of safety features. These programs have limitations, and a relatively high level of expertise and experience are needed to insure their proper use. Accident data has been used to a limited extent also to evaluate safety feature performance. To be meaningful, however, the data gathering plan must be carefully designed to acquire the appropriate data. Further, the data must be gathered and analyzed by trained personnel. It is preferable that the accident be reconstructed to accurately define impact conditions, a costly task.

Discussion Topic 4

What can be done to improve our knowledge of impact severity?

Discussion

B-C analysis are very sensitive to the assigned impact severities, underscoring the importance of proper severity values. Generally, impact severity is defined in terms of occupant injury probability, which is in turn defined in terms of societal costs.

The severity of impact with roadside features such as barriers, signs, luminarie supports, etc., can be approximated from crash tests or computer simulations. A major limitation of these approaches is the absence of a reliable linkage between vehicular or dummy response and the probability of injury had there been an occupant in the vehicle. Crash test data are also limited in terms of impact conditions (vehicle speed, encroachment angle, vehicle attitude, vehicle size, etc.).

Impact severity can also be approximated directly form real-world accidents, without the linkage problem. In-depth studies at TTI have related accident severities (from volumes of accident data) to societal costs. The accuracy of this approach obviously depends on the reliability of the data base. Unfortunately, reliable descriptions of impact conditions, (speed, angle, vehicle attitude) the feature impacted, and geometric features in the impact area are usually not available in accident reports. It is preferable that the accident be reconstructed to determine impact conditions. This would provide the linkage needed in crash test data. Accident reconstruction, however, is an expensive and time-consuming process.

Discussion Topic 5

How should societal costs be assessed?

Discussion

This is perhaps the most debated and controversial factor in B-C analysis since it requires that a value be place on human life. Values chosen for a B-C analysis will have a significant influence on the end result.

Various methods have been used to arrive at the value of a life. It seems that each federal agency involved in B-C studies has its own method and values, with considerable difference between the upper and lower values. In the past, the human capitol approach was commonly used to assess life values. This method computes the present value of one's expected lifetime earnings. In a recent study a TTI, this approach was expanded to include direct costs, such as damage to the vehicle and facility, and indirect costs, such as accident investigation and insurance administration. Another method receiving national attention is the willingness to pay approach, whereby the value of life is measured by the payments one would willingly make to reduce a given risk.

Questions to be addressed in the workshop are

1. Is there a preferred method of assessment?
2. Should there be a national set of values for all transportation agencies, or would it be more appropriate for each agency to establish their own values?
3. What are legal implication of answers to numbers one and number two.

Discussion Topic 6

How can the B-C analysis procedures be validated?

Discussion

Measures are needed to establish the accuracy, and credibility, of the B-C analysis procedures. This will involve direct comparisons of projected versus actual accident frequency and accident severity. The process could be structured to validate elements of the B-C procedure or the complete model. For example, a potential method to evaluate predicted encroachment rates and accident frequency would involve the monitoring of maintenance records of features such as light poles or crash cushions. The feature should be one whose damage to impact is detectable and requires maintenance work for most impacts, to minimize the unreported accident problem. With a record of the frequency of impacts and site conditions, such as traffic volume, offset, and pole spacing, comparison can be made with the projected frequency. In fact, this technique could be used to improve and expand encroachment data bases. Cost to conduct studies of this type would probably not be prohibitive.

Comparisons of projected versus actual impact conditions and impact severity would be more difficult to make. Accident reconstruction via appropriate techniques is probably the best way to determine impact conditions. It may be possible to compare the average severity of all projected impacts with the average severity of all recorded accidents, making some adjustments for the unreported accidents.

SUMMARY OF GROUP I DISCUSSIONS

***Group Leader*: Jarvis Michie**
***Other Group Members*: Richard Adams, Gordon Alison, Bill Bishop, Duane Christensen, Harold Cooner, Donald Lund, Frank McFarland, Frank Page, Ken Shearin, and Charles Wilson**

Topic 4

What can be done to improve our knowledge of impact severity?

Summary of Discussion

It is recognized that impact severity is an important element of a B-C procedure. That is, we need to know the consequences of a vehicle collision or interaction with a roadside feature in terms of injury risk and damage. To date, the primary source of collision severity data are police level accident reports.

Three shortcomings of police accident reports cast major doubt as to the validity of the resulting severity indices. First, only a fraction of vehicle collisions with roadside features are reported due to the fact that many motorists are uninjured and the vehicle can be driven form the scene. The percentage of drive-aways varies with type of feature and impact conditions. Thus, by using only reported accidents, which are generally more severe that the total, average consequences are overstated and the severity indices are exaggerated.

A second concern is the oversimplification of accident events. In many cases, a vehicle may strike several features in sequence with the occupant injury occurring during any one impact yet assigned to the first item struck. Recent findings indicate that secondary impacts that occur sometimes at lesser speeds and angles may be subjecting occupants to the highest risk. Accordingly, analysts in reviewing police level accident data should be aware of the secondary impacts on occupant injury.

Finally, a third concern is the lack of consistency of terminology of highway features and in important collision details, such as vehicle attitude, speed and angle. Police accident reports many times give collision conditions that are rough estimates at best.

One discussion group recognized the temporal nature of severity indices which may be subject to change due to changes in, vehicle size and design, speed limits, drinking and drug laws, seat belt laws, and vehicle equipment, such as anti-lock brakes.

Solution

Because current accident investigation and reporting techniques are inadequate, it is apparent that a new approach is necessary to develop impact severity indices. The most promising technique would be to select a limited number of representative highway sections that may range from 10 to 30 miles in length and to characterize each segment for geometrics and traffic conditions. The roadside would be periodically monitored for evidence of inadvertent encroachments and other sub-accident reporting collision damage, such as down poles and supports, guardrail dents, and crash cushion deformation. Police accident reports would be supplemented with in-depth investigation by specially trained teams and the data collected would be compared to the highway photolog and damage repair reports. It is noted that with carefully documented exposure data, such as vehicle traffic volume and roadside feature density and offset, probability of collision occurrence can be studied simultaneously from the monitored segments.

It is recognized that the proposed solution involves a major effort by many state highway agencies and will extend over a minimum period of 5 to 10 years. It will require a closely coordinated effort at the local level among state maintenance personnel, police investigators and teams of accident investigators to adequately monitor a single road segment. A national team or agency will be required to standardize monitoring techniques and procedures at these road segments, in order that the data can be assembled and the findings analyzed.

Although the road segment safety monitoring system (RSSMS) would be established primarily to acquire input data for benefit-cost models, the system could be easily broadened at minimum effort and cost to serve as test beds for other types of highway research.

Needed Research

Because of the national scope and importance of this effort, it appears reasonable that the effort be pursued and funded by a broad base of state highway agencies. A pooled-funds, Highway Planning and Research study appears to be a suitable approach. A budget for a 5-segment program might range from $200,000 to $500,000 per year with each participating state contributing $10,000- $25,000 per year. Being a new effort, a three-stage program is envisioned. Stage 1 would involve a $25,000- $50,000 research planning study in which a single-road segment is selected and the process is evaluated. Finally, Stage 3 would be the full implementation of RSSMS.

Topic 5

How should societal costs be assessed?

Summary of Discussion

The pros and cons of several techniques and methods for calculating societal costs were discussed. However, it was opined that the critical issue is that a consensus approach be developed and adopted by the highway community. The acceptance of the concept of societal costs is more important than the actual monetary values that are eventually established. Without the general acceptance of the concept of societal costs, the effectiveness of benefit-cost analysis will be nil regardless of any precision in calculating risks.

Solution

Accordingly, it is recommended that a high-visibility research project be funded to establish the most acceptable method of determining societal costs and that this effort be conducted in a deliberate process that promotes input and discussion and that will eventually lead to a general consensus.

Needed Research

To initiate the effort in a timely manner, a two-step approach is suggested. In step one, a synthesis study by NCHRP or TRB, or both is proposed to document current societal cost-thinking among state and federal highway agencies, and independent and private organizations.

In step two, a NCHRP-type project is recommended to examine all facets of societal costs, including legal, and to develop recommended societal values. To assist the contractor, a special blue ribbon panel would be established. Also, as a part of this effort, a symposium would be planned to stimulate active discussion and critique.

Ideally, the final product of the project would receive the active endorsement of AASHTO and DOT.

Topic 6

How can the B-C analysis procedures be validated?

Summary of Discussion

It was recognized that an overall B-C analysis procedure cannot be validated against a known yardstick in the way theoretical formulations are compared to experimental findings. However, it was agreed that risk prediction part of the procedure can be validated against accident experience. Risk prediction is the combined probability of frequency and severity of highway collisions.

Solution

A solution would be to separate out the cost part of the B-C model and to validate the precision of the collision frequency and severity indicators.

As a first step, a sensitivity study should be performed on the parameters to identify the more critical elements and the necessary accuracy of field data to be collected.

To be able to validate the risk prediction model, a comprehensive highway exposure environment and detailed accident data base are needed. Specifically, a highway segment must be fully detailed as to geometrics, roadside profile, hazard density and factors that may affect inadvertent vehicle roadside encroachments. Also, the traffic must be characterized as to makeup, for example, trucks, large cars, small cars, motorcycles, etc., operating speed, and profile of occupants. It is noted that the test segment may be representative of either obsolete or current roadside safety technology. Based on these specific input data, a prediction of the number and severity of roadside collisions will be made. For comparison, actual accidents will be carefully investigated and documented.

Needed Research

As a part of the pooled-fund HPR research effort suggested for Topic 4, data for this validation could be acquired simultaneously. Possibly, the same data could be used for both efforts.

SUMMARY OF GROUP II DISCUSSIONS

***Group Leader*: King Mak**
***Other Group Members*: James Bryden, Arthur Dinitz, Don Gripne, James Hatton, Michael McFall, Charles Reed, George Ring, Edward Tye, and Charles Whittle**

Topic 1

Are the widely used, and proposed, B-C analysis procedures too complex?

Summary of Discussion

The B-C model is necessarily complex to account for the large number of parameters that need to be considered. Over-simplification of the model would likely lead to erroneous answers.

Despite the complexity of the formulation of the model, it must be simple to use or its utility would be severely limited.

The use of the B-C analysis should be restricted to headquarters' level. For district or field level, warrants or application criteria summarized in tables or nomographs would be provided.

B-C analysis is also useful as a pre-decision document, showing the reasoning behind ceratin decisions for future references.

Needed Research

Develop a single framework or methodology for B-C analysis at the national level that has sufficient flexibility to allow for inputs by the individual states to account for local conditions.

Conduct sensitivity analysis on the model parameters and develop appropriate default (average) values as well as ranges of values for use by the states.

Topic 2

What is the preferred method of estimating the probability that an object or feature will be struck at a given location during a given period of time? How can data be gathered to support the preferred methods?

Summary of Discussion

The encroachment approach is preferred over the accident data approach for B-C analysis. There are too many problems associated with accident data, such as unreported accidents, poor quality of data, regression to the mean effect for high accident locations, lack of exposure data, and so on.

Accident data could be used to fill in the gaps in the state-of-the-knowledge in the encroachment model.

The encroachment model needs to be validated with accident data or other surrogate measures.

Needed Research

Develop more detailed guidelines for conducting in-service performance evaluation to complement the NCHRP 230 guidelines.

Develop a program to gather and analyze clinically in-depth accident data on a sample of severe or fatal accidents involving roadside hardware or features.

Conduct a study to compare and evaluate the crash test matrix versus real-world impact conditions.

SUMMARY OF GROUP III DISCUSSIONS

***Group Leader*: Bill Hunter**
***Other Group Members*: Ronald Canner, C.P. Damon, Owen Denman, John Grant, William Marley, Hayes Ross, Dominique Vulin, Bob Walters, and David Weaver**

Topic 4

What can be done to improve our knowledge of impact severity?

Summary of Discussion

As a point of departure, the group noted that an entire summer meeting of our committee was held at Asilomar, California about five years ago to discuss impact severity concepts. Good knowledge of impact severities is necessary because this accident outcome is instrumental in developing accident cost information.

There remains a need for more information on ways to link crash test data on the vehicle and the resulting probability of injury to occupants. Southwest Research Institute has completed some research in this regard on an FHWA contract to update NCHRP *Report 230*: *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*. Recent findings describe methods for converting non-standard data acquisition procedures to *Report 230* guidelines, calculating the occupant risk factor when vehicle accelerations are known, and estimating the occupant risk factor when only the gross barrier and vehicle behavior are known. These methods could be used to examine crash test results, calculate the occupant risk, and then compare outputs to real-world impacts. State-level accident reconstruction teams might also provide case data.

Discussion then centered on what the NASS system can provide to the knowledge of impact severity. In particular, the Longitudinal Barrier Special Study (LBSS) conducted for FHWA has produced a data file covering more that 600 cases. This file should provide good accident reconstruction data for barrier crashes, but little has appeared in the literature based on these data. Real-world barrier crashes show much deviation from crash tests in regard to, whether the vehicles are tracking at impact, the angle and orientation of the vehicle, and the actual sequence of events, such as striking another vehicle and then the barrier. This should be kept in mind as crash testing and simulation strategies are designed. We recommended a rigorous analysis of the LBSS crashes and subsequent reporting of the results.

Beyond the LBSS discussion, recommended research centered on the suggestion of using the recent New York State methods, where maintenance forces helped identify barrier crashes which were followed up with accident reports to fill selected gaps in knowledge. For example, FHWA could focus on selective studies (e.g., guardrail face impacts, bridge rail impacts) and choose candidate states to supply the data. If detailed speed and angle of impact are needed, then consideration could be given to assembling accident reconstruction teams by contracting with firms in the private sector. The idea is to spread the collection of needed information among states and across several years, if necessary, to develop a large data base. Funding possibilities include, 402 evaluation funds from the FHWA side, a pooled-fund HPR study, and FHWA post construction monies.

This discussion topic was ranked as our top priority.

Topic 5

How should societal costs be assessed?

Summary of Discussion

The assembled group contained no economists nor any members from states that routinely use B-C procedures to compile rankings of preferred projects. Thus, we felt our knowledge was somewhat limited in regard to the subject. As a result, the discussion was of a philosophical type with little emphasis on proposed solutions or recommended research.

A brief survey of the group revealed that, of the states represented, practically all used National Safety Council costs or some derivative of these as the basis for their societal costs. In regard to the value of a life, most costs were in the $200,000- $300,000 range. This was also true for the representative from France. There was recognition that the willingness to pay concept was assuming more importance in societal cost determination.

The discussion then centered around the philosophical question of whether B-C ratios were to be used to select individual projects or develop warrants, as proposed in the new Barrier Guide, or whether the B-C concept was more likely to be used for overall project rankings. If B-

C ratios really will be used to develop warrants for hardware, then the issue of societal cost becomes much more important. This is also true of safety and non-safety issues being compared together, because large societal costs pertaining to accidents could bias the results in favor of the safety procedures.

The overall consensus was that states need flexibility in making project decisions. Some have advanced B-C tools in place and would most likely want to continue to use these, substituting their own societal costs values, perhaps, with some limits on the possible ranges.

If FHWA recommends specific societal cost values, the development should be documented, as well as the percentage breakdown of direct and indirect costs. It is felt that the courts would examine these values closely in developing award amounts.

This topic was our third priority.

Topic 6

How can the B-C analysis procedures be validated?

Summary of Discussion

Rather than a question of the techniques used to calculate a B-C ratio, incremental B-C ratio, etc., this topic more properly concerns the validation of input values used in the process. Insofar as accident data are concerned, this could mean follow-up investigations to determine if a design treatment, for example, performed as expected. Were the projected accident benefits obtained? Was an actual B-C ratio calculated to determine the project's worth?

The state DOT members present were surveyed to determine if follow-up investigations were made with any regularity. It was determined that Oregon examines hazard elimination projects, but not much else. Although some variability exists from project to project, the predicted versus actual accident benefits match reasonably well. In North Carolina, the Traffic Engineering Branch develops data to track project effectiveness, but more in line with the regular before and after reporting procedures required by FHWA. For all states represented, it appeared that few after-the-fact B-C ratios are ever calculated. Thus, from the accident data side of B-C techniques, the weakest input links are the estimates of program effectiveness.

From the encroachment side of the B-C methodology, accurate projections of encroachment rates or frequencies are necessary as model inputs. It was noted that attempts at instrumentation of objects like guardrail have not proven fruitful.

Given the large guardrail accident data base now available for New York State, a recommended research endeavor is to apply existing encroachment models to data like that from New York, to determine if the real impacts yield what would be expected form the encroachment model. In other words, use the available maintenance and accident records to determine if the models can accurately predict encroachment rates. It was also felt that some of the utility pole data bases, such as the Zegeer and Mak studies, could also be checked.

Such an approach would enable a check of the inputs or assumptions used in the development of the new Barrier Guide, where accurate estimates of encroachments by road type, design speed, etc., are vital. Such validation will likely be necessary to sell this approach.

This topic represented our second priority.

SUMMARY OF GROUP IV DISCUSSIONS

***Group Leader*: John Carney**
***Other Group Members*: Julie Cirillo, Linn Ferguson, Robert Mannel, Robert Murphy, Charles Sanders, Louis Schultz, Dean Sicking, Flory Tamanini, and Walter Witt**

Topic 1

Are the widely used, and proposed, B-C analysis procedures too complex?

Summary of Discussion

Most existing Benefit-Cost procedures are too hard to use. It is possible to develop easy-to-use computer programs (user-friendly) without sacrificing the sophistication of the B-C model. It is not necessary for every user to understand every detail of the model. The program should be menu-driven. To tailor the general program to a specifics state's use, someone at the central level, who understands the program, must decide on the values of some of the input data; e.g., general policy decisions could be made on accident cost figures and installation costs. The user would input things like ADT, offset distance, vehicle mix, and speed distribution. There should be default values that could be used at the option of the user. In other words, the general program could be customized to reduce the input required of the user. Improved data is certainly required, but a user-friendly program can be developed now and be made more accurate as more useful data becomes available. Such user-friendly programs should be developed as soon as possible.

Topic 2

What is the preferred method of estimating the probability that an object or feature will be struck at a given location during a given period of time? How can data be gathered to support the preferred methods?

Summary of Discussion

Although an accident data model can be used in high accident locations, it is not feasible to use this approach for every hazardous location. Encroachment probability modeling can be employed on a general basis and is therefore preferred. A nationwide effort is required to gather this encroachment data. Existing data are very sparse. FHWA has spent $800,000 over 4½ years and has came up with very little useful information. Accurate encroachment data is extremely important to the development of an accurate B-C program. However, state DOT personnel are not aware of this need and would be unwilling to take part in an encroachment data collection effort at the present time. AASHTO should champion this data collection effort, through its Subcommittee on Design, define the facilities to be monitored (visually), and coordinate an effort on a national level. It is critical to build a huge data base of encroachment data. How many states would cooperate? Sensitivity analysis should be performed on B-C programs to determine the importance of accurate encroachment data to program output. It may still be possible to rank some projects using conservative encroachment data until more accurate information becomes available.

Topic 3

What can be done to improve our knowledge of the performance of safety features for real-world impact conditions?

Summary of Discussion

The answer is accident reconstruction. There is an ongoing longitudinal barrier impact data collection effort underway, which has been funded at $400,000-$600,000 per year for three years. Two years of data have been analyzed at a cost of $2000- $3000 per accident. Safety appurtenances, when properly installed, are doing a fine job. However, there is a real problem with improper installations. State DOT's are responsible for proper training and control of maintenance personnel in this regard. This is difficult because of the high turnover rate. Another source of data is Experimental Demonstration projects program which requires that accidents be documented. However, many states are not motivated to send in this information or even get involved in the program. For financial reasons, we question the need for a more sophisticated set of crash guidelines at this time. Most real-world accidents occur at speeds of less than 60 mph and this counterbalances, somewhat, the problems associated with such things as non-tracking vehicles, and non-level and curved terrain. We recommend continued funding for accident reconstruction.

Appendix II
Problems, Solutions and Needed Research Related to Application of B-C Methodologies (Agenda Item VIII, Topic B)

Discussion Topic 1

What is the proper context of a B-C analysis to make roadside safety decisions?

Discussion

For the past several decades, the decision to install a barrier has been based on the answer to the following question: Which represents the greater danger to the travelling public — a roadside barrier or the roadside hazard? Over the years, roadside safety professionals have developed and refined their approach to answering this question. The 1977 AASHTO *Guide for Selecting, Locating and Designing Traffic Barriers* (Barrier Guide) presents barrier warrants based on clear zone criteria and an evaluation of the relative severity between barrier and hazard (equal severity boundary). These criteria are meant to be combined with engineering judgment for application.

Most agree that the roadside safety problem is a serious national concern which the highway industry must address. Most agree that highway agencies need a sound, rational basis to make roadside safety decisions. However, the relative severity approach has created problems for the highway profession. Many believe it has led to an unnecessary proliferation of roadside barriers with a resulting inefficient allocation of scarce highway funds. Barrier repair needs have also created a burden on highway maintenance resources. In addition, many believe that the current decision-making environment unfairly exposes highway agencies to tort liability losses. If a roadside hazard exists and if it is not shielded by a barrier, then the highway agency is often held liable for the consequences of an accident. Many highway agencies contend that a common sense evaluation of the overall roadside safety problem makes it obvious that it is not reasonable or even possible to correct all roadside hazards or to shield them with a barrier.

The alternative is to make roadside safety decisions by use of an economic analysis which compares the monetary benefits and costs of the available treatments. This allows a highway agency to allocate its funds cost effectively for roadside safety. From an application perspective, the context of the B-C analysis is important. Two approaches are

1. The cost-effective analysis in the Barrier Guide (Chapter VII) is presented as a supplement to the relative severity criteria. The designer may use this approach to conduct a more refined assessment of the most cost-effective treatment for any site. The options include remove the hazard, reduce the severity of the hazard, install a barrier or do nothing. There is no obligation on the part of the highway agency to use this cost-effective analysis.
2. The B-C methodology could be used exclusively to make roadside safety decisions based on the specific site characteristics. Theoretically, This would eliminate the need to establish a separate set of clear zone criteria or establish equal severity boundaries, for example, for fill slopes. This approach is being considered for the new Roadside Design Guide under development.

Which approach is best? Is there another and perhaps better context for a B-C analysis?

Discussion Topic 2

Assume that a B-C approach will be the lead in making roadside safety decisions. Should this be supplemented with a set of minimum, inviolable criteria for barrier warrants and layout details, regardless of the results of a B-C analysis?

Discussion

Some candidates for minimum roadside safety criteria might include:

1. A barrier must be provided when a body of water is "x" distance or less from the travel lane and is "y" or more deep.
2. A barrier must be provided for a fill slope which is "x" distance or less form the travel lane, has "y" or more height and is "z:1" or steeper.
3. Minimum clear zone criteria could be established for various roadside conditions.
4. The length of need for a barrier must be long enough to fulfill some minimum objective, for example, 15 degrees form the back of the obstacle.
5. The clear distance between the back of the barrier and a fixed object must meet a minimum objective, such as the dynamic deflection for the design speed, 25 degree angle of impact and a full-size passenger car.

6. Maximum barrier flare rates could be established for various design speeds.
7. All gore areas at freeway exits must be free of hazards.
8. No barrier can be less than "y" inches in height.
9. Only crashworthy end sections will be allowed.

If minimum criteria are established, a different set of criteria could be developed for each functional class or design speed.

Discussion Topic 3

Once a barrier is determined to be warranted, should a B-C analysis be used to select the type of barrier system for installation? Should it be used to determine the most cost-effective layout details for installation? How should actual field conditions be reflected in the analysis?

Discussion

The proposed approach for the new Roadside Design Guide will use the B-C methodology to identify the minimum barrier performance level (PL) for a given site. Within a PL range there may be several barrier systems which meet the performance requirements of that PL. These barrier systems may vary substantially in their initial cost, repair cost after impact, useful service life, routine maintenance cost and severity potential to occupants. In addition, site characteristics may affect the selection of a system, such as available deflection distance, even within the same PL. Conceivably, a B-C analysis could be used to select the most cost-effective barrier system for a given site. Does this appear to be a practical application of a B-C methodology? Would it be better to give each user agency total discretion on selecting the barrier system, assuming it meets or exceeds the PL requirements of the site?

The B-C methodology could also be used to determine the barrier layout. These details can add appreciably to the cost of the system; on the other hand, the barrier layout affects the safety of the installation. The details of barrier layout include:

1. Length of need,
2. Flare rates,
3. Available deflection distance to hazards,
4. Slopes in front of barrier,
5. Barrier location relative to curbs,
6. Lateral placement from travel lane, and
7. Treating barrier end by flaring back into a cut slope.

Some aspects of using the B-C model to determine the barrier layout must be addressed in the development of the model. To determine the most cost-effective length of need, for example, requires some knowledge of the nature of run-off-the-road vehicles. From an application perspective, the following approaches could be considered:

1. For any barrier installation, the B-C model could assume that the criteria for barrier layout are fixed. The model would also have to assume the unit costs for complying with the layout criteria. For example, the length of need would be determined based on an accepted equation and based on unit costs of barrier length. The cost-effectiveness of installing the barrier would automatically reflect the cost of a proper barrier layout. Are field conditions sufficiently uniform to accept the use of an assumed barrier layout and average costs within the B-C model?
2. The B-C model could be developed to compare the incremental safety benefits with the incremental costs. For example, when evaluating the barrier length of need, the additional cost of providing an extra foot of barrier could be assumed to be constant. However, the incremental safety benefit for the additional barrier length may drop as the barrier is lengthened. Therefore, there may be a most cost-effective length of need for a given barrier installation. Does this appear to be a practical refinement to determining the details of barrier layout?
3. Some or all of the details for barrier layout could be considered input data on a case-by-case basis. This would increase the required effort by the user, but it would allow the user to incorporate the impacts of actual field conditions. For example, providing an acceptable barrier flare may be prohibitively expensive at a site because of the need to flatten the slope in front of the barrier. Does this appear to be a practical approach to determining a barrier layout? would it place an unreasonable burden on the user of the B-C model?

Discussion Topic 4

How should a B-C model be used for upgrading roadside safety on existing highways?

Discussion

The majority of the future highway program will likely be 3R-type projects on existing highways. The preceding discussion topics were directed toward roadside safety decisions on new construction and reconstruction projects. Most of the considerations within these topics will also apply to 3R projects. However, upgrading roadside safety on existing highways will involve special considerations when applying a B-C model. For example, some details of many existing barrier installations will have deficiencies. Correcting these deficiencies will provide a safer installation, but at some cost. Typical deficiencies might include:

1. Barrier height too low;
2. Uncrashworthy end treatment;
3. Inadequate length of need;
4. Inadequate clear space for dynamic deflection;
5. Flare rates too steep;
6. Slopes leading up to barrier too steep;
7. No blockouts;
8. Hardware and other design deficiencies, such as washers, bolts, footing, direction of beam overlap, and BCT flares;
9. Barrier radii too sharp at, such as driveways; and
10. Barrier-to-barrier transitions not acceptable.

It may be practical to use a B-C approach to decide if these deficiencies should be corrected. However, for some deficiencies, the proper position may be to correct the deficiency, regardless of the costs and benefits, for example, an inadequate flare on a BCT.

It would seem that using a B-C model to evaluate barrier warrants would be equally applicable to 3R projects as it is to new construction and reconstruction projects. However, there will likely be at least one major difference. On new construction and reconstruction, the B-C model can be used to evaluate the cost effectiveness of removing or reducing the hazard to eliminate the need for a barrier. Many 3R projects are designed within very restrictive right-of-way and financial constraints. The option of removing or reducing the hazard is less likely to be available.

Discussion Topic 5

What speed should be used when applying the B-C model?

Discussion

Vehicular speed has a significant impact on roadside safety. This will be reflected in the B-C model. Therefore, the user of the methodology must select a design speed. For new construction, it may be appropriate to use the design speed recommendations from the AASHTO Green Book. However, even this leaves the designer with considerable flexibility. For example, an urban freeway may have a design speed of 50 to 70 mph. One could also argue that, even if the design speed is 70 mph, the posted limit, 55 mph, should be used for roadside safety decisions. This, in turn, can be challenged on the basis of the nationwide violation of the 55-mph speed limit.

For improvements on existing highways, the selection of the appropriate design speed is less clear. For 3R or 4R freeway and non-freeway projects, a variety of approaches have been used to select project design speed. These include:

1. The design speed for new construction;
2. The average running speed (ARS), determined by spot-speed measurements in the field;
3. The field-measured ARS plus 10 percent;
4. The 85th percentile speed, determined by spot-speed field measurements; and
5. At a minimum, the legal and posted speed limit.

The simplest approach for use of the B-C model would be to decide that the design speed for using the model will be the same as the overall design speed for the highway project. The alternative would be to identify the required method to determine the design speed for use of the B-C model.

Discussion Topic 6

What flexibility should be provided the user agencies for selecting different values within the B-C model or for revising the model itself?

Discussion

The assumptions and use of data within the B-C model will determine how roadside safety decisions are made. In the development of a national B-C model, many assumptions will be made which will be intended to reflect average nationwide values, such as cost of a PDO, cost of a barrier system, and barrier repair costs. In addition, considerable subjectivity will be involved in deciding which research results to use and how to use these research results, for example, encroachment probability, and nature of a run-off-the-road accident. In particular, the selection of the B-C ration will be quite subjective and may have widely varying affects from state to state and from locale to locale. These issues will be discussed during Day one.

For the Day two discussion, the topic of user agency flexibility should be discussed. The use of nationwide data may lead to too many dollars invested in roadside safety for one area of the nation and too few dollars for another area. In addition, highway safety professionals will legitimately debate the assumptions within the model. Some factors to consider are:

1. It may be determined that some of the assumptions cannot be revised, such as the cost of a fatal, the treatment of barrier length of need, and the selection of the B-C ratio.

2. Recommended values could be presented, and each user agency could be allowed to select its own values. Acceptable ranges of values may also be presented. These could be supplemented with a set of factors which must be considered when selecting values.

3. It may be necessary to establish a review, evaluation and approval process for revising and values or assumptions within the national B-C model.

4. The level at which the flexibility can be allowed will need to be decided. For example, it could be required that, once a State highway agency selects a B-C model, it must apply to all public roads within the State.

Discussion Topic 7

What might the tort liability implications be with the use of a B-C methodology for roadside safety decisions?

Discussion

The discussion on this topic depends upon the first potential discussion topic. If the B-C model is used to determine roadside safety criteria, then it would likely have large implications on tort liability. If the B-C model is used to supplement roadside safety criteria based on other considerations, such as clear zones, and equal severity boundaries, then its tort liability implications may become less clear.

Another aspect of the tort liability issue merits discussion. For geometric design the accepted bible is *A Policy on Geometric Design of Highways and Streets* (Green Book). Many believe that, if the geometric design meets the criteria in the Green Book, the highway agency will not lose a liability case based on a design deficiency. In other words, the validity of the criteria within the Green Book itself cannot be successfully challenged.

Concerning this potential discussion topic, these issues are pertinent:

1. In studying the history of roadside safety and tort liability, have the courts generally held that, if the roadside design is consistent with nationally adopted criteria, for example, Barrier Guide, the highway agency cannot be held liable?

2. If the answer to number one is yes, the following questions result:

a. Can the highway agency assume that the correct application of the B-C model will protect itself from liability? In other words, will it be difficult if not impossible for a plaintiff to challenge the underlying assumptions within the model itself?

b. Will the incorrect application of the B-C model automatically expose a highway agency to tort liability losses?

c. The highway agency may consciously take an action contrary to the results of the B-C model, based on what it believes are good, valid reasons. Will it still be exposed to tort liability losses?

3. User agencies may be allowed to change the values or the assumptions within the B-C model. If so, how will this affect the tort liability implications within the jurisdiction? How important might the review and approval process (as suggested in Discussion Topic 6) be to the tort liability issue?

Discussion Topic 8

What can reasonably be expected from the individuals who will be applying the B-C model on a project-level basis?

Discussion

Ultimately, the success of applying the B-C model will lie with the individuals who will make roadside safety decisions from site to site and from project to project. It is worthwhile to discuss what can reasonably be expected form these individuals. Based on the consensus view of the Workshop attendees, the following should be considered relative to the users of the B-C model:

1. What has been the success to date on the correct application of roadside safety criteria?

2. What is the predicted success on the correct application of the B-C methodology? Is it likely to be better or worse than the experience to date?

3. Would the success rate be better with charts or nomographs as design aids, or with the use of a computer program to calculate the answers?

4. Will the use of the B-C approach most likely increase or decrease the time spent making roadside safety decisions as compared to the time spent today? If the time will be increased, will this cause problems?

5. Regardless of the accuracy and comprehensiveness of the B-C model, this will not eliminate the role of

judgment in its application. Will the users have a sufficient foundation to use sound judgment when applying the B-C model?

6. At what level should the B-C analysis be directed? Should it be for designers in the main office or in the districts? Should maintenance personnel be able to use the model to perform their roadside safety responsibilities? Should highway agencies seriously consider establishing a group of experts who will make all roadside safety decisions on all projects and for maintenance by using the B-C model?

Discussion Topic 9

Assuming that the B-C model is adopted, how should the transition phase be handled?

Discussion

If the B-C model is adopted for roadside safety, this will represent a significant change form how roadside safety decisions are made today. This indicates that the transition phase should be carefully planned. Some factors to consider include:

1. The transition may warrant an extensive training program. The details of the program should be discussed.
2. An effective date of application should be established. This might be set as, for example, one year beyond the distribution date of the new Roadside Design Guide.
3. How to handle pipeline projects may pose an additional problem for highway agencies.
4. It may be warranted to consider a long-term transition phase, perhaps 5-10 years. The workshop attendees could discuss how to gradually convert from today's decision-making environment to an environment where a B-C model is the dominant tool.

Discussion Topic 10

How should the implementation and use of the computer software be handled?

Discussion

Computer software will be developed for the B-C model. From an application perspective, the following should be considered:

1. On a project-by-project basis, the B-C model can be used to make roadside safety decisions by either:

   a. Providing charts or nomographs for solutions,
   b. Using the computer directly on each project,and
   c. Providing the option of either "a" or "b."

   Which approach would be best?

2. A comprehensive, easy-to-understand User's Manual should be prepared.
3. An extensive training program will be necessary to ensure the successful use of the computerized B-C model.
4. The highway agencies may be allowed to revise the data or assumptions, or both, within the B-C model. Therefore, the software documentation should allow easy manipulation of the computer program. In addition, the highway agencies should be able to assume that a standard statistical modeling package will be used in the development of the computer software. The computerized model should also be in a modular format.
5. It may be relevant to specifically consider the potential areas of flexibility, such as the encroachment probability model, cost of a fatal, and barrier system cost, and to discuss the mechanical process of revising the national B-C model within the available computer software.

SUMMARY OF GROUP I DISCUSSIONS

***Group Leader*: Harold Cooner**
***Other Group Members*: Richard Adams, Gordon Alison, Bill Bishop, Duane Christensen, Donald Lund, Frank McFarland, Jarvis Michie, Frank Page, Ken Shearin, and Charles Wilson**

Topic 6

What flexibility should be provided the user agencies for selecting different values within the B-C model or revising the model itself?

Summary of Discussion

Topic 6, as well as other topics that were assigned, were somewhat difficult for this particular group to discuss in depth, due to a lack of general or specific knowledge regarding the proposed Roadside Design Guide and the B-C methodology. Seven state transportation agencies were represented in the discussion group, and none of these participants had been previously enlightened regarding the proposed content of the guide nor the relationships upon which a B-C methodology would be founded. Each state representative expressed a desire to know more about the guide and B-C methodology development, and questioned the appropriateness of the work being done by a small group without greater involvement by the research community and ultimate users. The consultant and research members of the group, or both were familiar with past roadside studies and had a better understanding and concept of the likely approach, content, and so on, of future tools for roadside design.

The group felt that B-C model usage itself should be optional. For those who choose to use the model, ceratin values, such as cost of a safety feature, would need to be supplied by the user. Little or no flexibility would be anticipated in basic relationships and values, such as encroachment rates, and the dollar values of life and serious injury. A range of values might be appropriate. Should length of need of barrier be incorporated into the B-C methodology, a desire was expressed to override this portion of the model and utilize local practices.

Topic 7

What might the tort liability implication be with the use of a B-C methodology for roadside safety decisions?

The consensus on tort matters was that transportation agencies needed established procedures, methodologies, guidelines, policies, etc., and needed to follow these and document the decision-making process whenever circumstances resulted in deviation from usual practice. The specific guidelines used, such as the 1977 Barrier Guide, new method, state guidelines, etc., were deemed of no real consequence as long as they have an adequate technical basis.

Certain potential litigation problems were identified in using a B-C methodology. First, can the methodology be explained in layman's terms for a jury's understanding? Second, if the user does not have full knowledge of the assumptions and relationships within the model, testimony could be discredited.

Topic 8

What can reasonably be expected from the individuals who will be applying the B-C model on a project level basis?

Based on experience with the 1977 Barrier Guide, it can be expected that the states would prefer trial usage and testing before fully evaluating the appropriateness of using new techniques for design

In many states, planwork is decentralized. Although in these instances, there may be a handful of central office personnel who have through knowledge of a B-C model, most of the roadside design work itself is performed by technicians and engineers who have a multitude of other duties and tasks. For these circumstances, design aids in summary form — charts, figures, rules of thumb, and so on — would be extremely valuable. It is conceivable that there may be several sets of design aids, one for safety improvement projects, one for 3R projects, one for freeways, and so forth. Usage of a B-C model by maintenance personnel was not foreseen.

Topic 9

Assuming the B-C methodology is adopted, how should the transition phase be handled?

Trial usage for 2 to 5 years prior to adoption would be beneficial. A parallel was drawn with new methodologies for the updated *Highway Capacity Manual* (HCM). In this case, interim methods were published in Transportation Research Circular 212 and users gained experience, suggested changes, etc., before HCM publication 1985, as TRB Special Report 209. A trial usage period would also provide users the capability to finish design work underway without changing the basis of design during midstream of plan development.

Topic 10

How should implementation and use of the computer software be handled?

The provision of design aids, (e.g., charts, and figures) as well as computer software was deemed desirable.

Provision of a users manual, small classes, and intensive training of experts in the states, were envisioned. The development of video tapes would be helpful for widespread training purposes. Concern was expressed over software maintenance and how enhancements would be ranked, developed, and distributed.

SUMMARY OF GROUP II DISCUSSIONS

***Group Leader*: Edward Tye**
***Other Group Members*: James Bryden, Arthur Dinitz, Don Gripne, James Hatton, King Mak, Michael McFall, Charles Reed, George Ring, and Charles Whittle**

General Discussion

The group engaged in a general discussion which broadly addressed the issue of the application of B-C methodologies. The proceeding paragraphs present the key items in the discussion.

Panel members felt that the wording of several discussion topics implied an authoritarian approach to the use of the proposed B-C model. As a result, most of the state representatives were concerned that the model would be imposed on a project-by-project or even an item-by-item basis. After additional input and discussion, it was determined that the model would be used by states at the headquarters level to establish warrants and guidelines for roadside safety features. It could be used for individual situations as needed. Those states that had input data based on their own experience would use it while states lacking the ability to provide their own data would be furnished a range of values to be used for input.

A primary factor in the preceding concern was the opinion by researchers that the B-C model should be a precision product considering as many variables as possible. On the other hand, state representatives felt that the model should be as simple as possible; otherwise, a complex B-C model would see little use. It was noted several times that the B-C model be validated before it is released for general use.

None of the group members were aware of a situation where benefit-cost procedures became an issue in a tort action. However, most members felt that proper use of B-C procedures to set priorities for safety-related projects could be a distinct benefit in the defense of such a case.

Group members felt that the implementation of a B-C model would be subject to administrative decision. To facilitate the decision-making process, managers and administrators should be introduced to the benefits of using a B-C model. The actual users should receive training in the use of the model. This would include both the proposed personal computer and mainframe versions of the model.

Topic 1

What is the proper context of a B-C analysis to make roadside safety decisions?

Solutions

The B-C analysis should be used by the states to develop tables, charts and graphs for warranting procedures. It should be used as a tool to make policy decisions affecting programs and standards. It may be used to make decisions about special problems that occur.

Needed Research

Data needs to be gathered to develop the B-C model and eventually validate it.

Topic 6

What flexibility should be provided the user agencies for selecting different values within the B-C model or for revising the model itself?

Solutions

States that have their own documented input data should be allowed to use it. States that do not have their own data should be given a range of selected values to choose from.

Needed Research

Develop regional values to fit into B-C model frameworks for those states without the capability to generate their own data.

Topic 7

What might the tort liability implication be with the use of a B-C methodology for roadside safety decisions?

Solutions

B-C procedures used to set priorities for projects can be a good defense mechanism.

Topic 8

What can reasonably be expected from the individuals who will be applying the B-C model on a project-level basis?

Solutions

Project level B-C use should be limited to charts and nomographs generated form the B-C model.

Needed Research

A follow-up study to see if and how the B-C model is being used. Note: As worded, the consensus response to the topic was extreme resistance!

Topic 9

Assuming the B-C model is adopted, how should the transition phase be handled?
Solutions

Potential users should receive training. Managers and administrators should be educated about the B-C model as these are the people who will be making the decision on whether or not the model will be used.

Topic 10

How should the implementation and use of the computer software be handled?

Solutions

The B-C model should be used to develop charts or nomographs to make safety decisions. The model should not be used on a project or item-by-item basis unless there is a real need. States should be allowed to input their own background data. The proposed users manual should contain tutorial or example problems.

Needed Research

A follow-up study should be performed to identify the extent of use of the model and any unreported problems.

SUMMARY OF GROUP IV DISCUSSIONS

***Group Leader*: Robert Murphy**
***Other Group Members*: John Carney, Julie Cirillo, Linn Ferguson, Robert Mannel, Charles Sanders, Louis Schultz, Dean Sicking, Flory Tamanini, and Walter Witt**

Topic 1

What is the proper context of a B-C analysis to make roadside safety decisions?

Summary of Discussion

Use of the relative severity approach to roadside safety design has led to proliferation of guardrail along our roadsides. Whether installation of guardrail in some of these instances has been in the best interest of public safety or the best use of public safety funds is questionable. Use of B-C analysis procedure is seen as a more rational way of making important roadside safety decisions and is considered preferable to the relative severity approach.

The primary role of B-C analysis in making roadside safety decisions is in the establishment of broad policies to cover the majority of situations. Those decisions are best handled by individual states at the main office or headquarters level. Such decisions relate to maximum height of fill without guardrail for various fill slope ratios, width of clear zone, etc. Policy decisions established at headquarters would form the basis of roadside safety design at the District level, and designers could supplement those criteria with B-C analysis of site-specific problems.

Although it is observed that main office personnel must be thoroughly familiar with B-C procedures and the establishment of overall state policy, District personnel must also be well-versed in the B-C methodology so that they will make competent project level decisions. Engineering judgement will still play an important part in the process. Too rigid a policy could result in poor design decisions. An example is, a 15 foot clear zone with a vertical drop-off into a deep quarry 16 feet form the edge of pavement. Although beyond the theoretical area of interest for roadside safety treatment, engineering judgment would call for site-specific B-C analysis and possibly, dependent upon site conditions, protection in any case.

There is a question whether, with the adoption of a B-C analysis procedure, the idea of a uniform clear zone on a given project should be abandoned. Although a case can be made for analyzing clear zones throughout the project and varying it as determined by B-C analysis, doing so at the project level by designers is liable to result in inconsistent design from squad to squad and from district to district, due to variations in degree of understanding and application of B-C procedures. Clear zones are probably best established as policy guidelines at the Main Office level, with project variations when justified by B-C procedures.

An additional, important use for B-C analysis procedures is in the relative ranking of safety improvements. Use of such a procedure is often deemed to be an agency's best defense in tort liability cases involving safety hazards not yet corrected. Quite obviously, this use of B-C analysis will ensure that public funds are being utilized so as to obtain maximum benefit in the treatment of roadside safety problems.

Topic 2

Assume that a B-C approach will be the lead in making roadside safety decisions. Should this be supplemented with a set of minimum, inviolable criteria for barrier warrants and layout details, regardless of the results of a B-C analysis?

Summary of Discussion

Because of the unlikelihood that designers at the District level will be intimately knowledgeable of the B-C procedure and would apply those procedures uniformly, establishment of basic roadside safety design criteria at a high level is important. Doing so, will provide for basic consistency and credibility in the design process statewide. It is desirable that different design criteria be provided for new design and for 3R project design.

On spot improvement projects, and design decisions should be reasonable, considering local conditions where, for instance, adjacent sections of highway are not scheduled for improvement in the foreseeable future. In such cases, as well as other special instances, basic criteria would not be inviolable. Inviolable is too strong a term here. Basic criteria should be viewed as generally applicable unless analysis indicates otherwise.

The question of whether, and to what extent, barrier design should be subjected to the B-C process was discussed. Whereas certain aspects of barrier design, such as layout geometrics and dimensions, might be appropriately analyzed using B-C procedures, many features of the barrier, such as hardware types and sizes, barrier height, allowable end treatment details, and maximum flare rate, are performance related and determined or verified through crash testing. Such features must be considered as inviolable or standard characteristics of the system and should not be subjected to B-C analysis at the state level.

Topic 3

Once a barrier is determined to be warranted, should a B-C analysis be used to select the type of barrier system for installation? Should it be used to determine the most cost-effective layout details for installation? How should actual field conditions be reflected in the analysis?

Summary of Discussion

Use of the B-C model should allow a state to determine the most cost-effective barrier for use in a given situation. Alternatives to be analyzed must be up to the individual state, which may wish to limit the list of acceptable barrier types to be considered. Limitation on acceptable barriers may be universal (statewide) or determined by local conditions. Some states currently limit allowable barrier types statewide to minimize replacement parts inventories, for aesthetic reasons, or to respond to other statewide policy decisions. Reasons a state may wish to limit alternatives for barrier selection may be cost, aesthetes, or environmental conditions. Those types of decisions must be retained at the state level. Once the list of allowable barriers for a given performance level has been determined, however, use of the B-C model will ensure that the public is getting the best buy for their money.

Layout geometrics and dimensions are legitimate uses for B-C analysis. Hardware design and many other barrier system characteristics are determined during development and testing to achieve a given performance level and should not be altered by states without successful crash testing of the modified design before use.

It is desirable that the B-C model allow for consideration of actual field conditions in the vicinity of the barrier or hazard. Data input by the user would describe grades, cross slopes, barrier height, curb location, and other characteristics which would affect the vehicular path, speed and attitude. Creation of a B-C model which assumes ideal conditions for all situations is unrealistic and could result in suboptimal decisions.

Topic 4

How should a B-C model be used for upgrading roadside safety on existing highways?

Summary of Discussion

The B-C model should be used primarily to develop global criteria to be applied to most 3R projects. Individual site-specific problems may then be analyzed on a case-by-case basis by design engineers at the project level. Because lower standards generally apply to 3R projects, roadside safety criteria can be expected to be less demanding than would be the case with new construction projects.

It is noted that present use of B-C analysis or cost-effectiveness procedures varies considerably from state to state. Whereas some states routinely use B-C analysis to determine what safety enhancements to fund, others simply upgrade based on arbitrary criteria, such as is it substandard, then it needs replacement. As with 3R guidelines themselves, because of the needs of individual states and the variety of individuals making decisions, uniformity of 3R-related safety criteria nationwide is not expected. Individual states will most likely arrive at a variety of 3R safety criteria guidelines through negotiation with local FHWA officials.

Using the B-C procedures on 3R projects requires frequent assessment of the cost of the status quo. This often means trying to assign a severity index to any one of a large number of existing barrier types of other existing hazards. The fact that severity indices have not been determined for many of these objects makes use of the B-C procedures somewhat more arbitrary than is desired. Because the B-C procedure is very sensitive to the severity index chosen, realistic choices for severity indices are extremely important.

It is recognized that the severity indices appearing in the 1977 Barrier Guide are somewhat arbitrary themselves, being a mean of the best guesses of a number of individuals familiar with hazards and their relationship to accident severity. However, establishment of severity indices for a greater number of hazards, even done by this method, creates greater consistency in the B-C process, and more credibility in the method than if individual states were all coming up with their own values. A high priority need, therefore, is to develop more information on severity levels to assist B-C analysis and decision-making at the state level.

Topic 5

What speed should be used when applying the B-C model?

Summary of Discussion

Selection of the proper speed to use in the B-C process is very important, because speed affects the severity index and the outcome of the process is very sensitive to the severity index. It is desired, therefore, that the speed used in the analysis approximate as closely as possible the actual speeds of vehicles leaving the highway in uncontrolled encroachments.

Studies of accident data and associated speeds of features indicate that the speeds are generally lower than either the design or the operating speeds of the highway sections in question. Use of a speed distribution based on those values as a basis for safety analysis will result in more frequent, and actually unjustified, use of traffic barriers, since severity of accidents with unprotected hazards will be thereby inflated. Because speed distributions based on accident analysis consider only reported accidents, and unreported accidents can be considered to occur at generally lower speeds use of accident analysis to determine speeds for the B-C model will inflate the number of protective installations as well. Unfortunately, analysis of reported accidents is perhaps as close as we'll get to the real values, because there's simply no way to get information on the unreported ones.

Data exists to support development of speed distributions based on reported accidents for a variety of highway types. A number of studies have been done, and there is reportedly good correlation among the results of the various studies. These and similar studies should be analyzed to develop speed distributions for a variety of highway classifications. Those values should be built into the model and should not normally be modified by the user. The user will select the proper speed distribu tion simply by putting in the appropriate functional class for the highway under analysis.

Final Comments

Major needs determined in the discussion of the above topics may be summarized and ranked as follows:

1. A larger data base of severity indices is needed by the states to support cost-effectiveness of B-C analysis of safety alternatives. This is especially important in 3R projects, where a wide variety of existing features, not commonly encountered in new construction project design, confounds those attempting to assign reasonable severity indices. Because the severity index is so important to the B-C analysis outcome, selection of appropriate values is critical.
2. Speed distributions based on accident data need to be derived for use in the B-C model. Those distributions should be built into the model and should be automatically selected by the user when he inputs the highway functional classification.

One final comment is that, if the new B-C model is ever to be widely used, it must be very easy to use. Experience in a number of states indicates that unless computer programs are used frequently, engineers and technicians tend to easily forget how to use them. Experience also indicates that the Cost Effectiveness procedure of the 1977 Barrier Guide is not often used in many states, and future use of a new B-C model can be expected to be used relatively infrequently as well. If users are to feel at all comfortable about dusting off the B-C program for infrequent use, the computer program will have to be able to guide the user, step by step, through the process. Liberal use of optional help screens is encouraged. On-screen documentation and assistance will be much more useful and instructive than a printed manual.