INTRODUCTION

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Workshop Chairman

This Circular reports on a committee workshop intended as a critical review of data needs relating to the evaluation of the severity of ran-off-road collisions. The workshop, sponsored by the Transportation Research Board's Committee on Safety Appurtenances, took place in Pacific Grove, California, June 25-26, 1981.

Sound data on the relative hazard of an existing roadside situation and proposed treatments are required in order to use cost-effectiveness techniques to determine the relative payoff of alternatives. A rational life-cycle cost/benefit comparison of alternate safety treatments is also heavily dependent on sound data on the relative severity of collisions with the proposed treatments. The scarcity of such reliable data as viewed from the prospective of the myriad of real-world decisions that must be made has been recognized as the major stumbling block in the effective use of these decision techniques.

This workshop had its origins in internal Federal Highway Administration (FHWA) discussions involving Julie A. Cirillo, Harry W. Taylor and John G. Viner concerning ways of obtaining reliable input severity data. These methods include accident studies (with related data and research design problems), controlled full-scale crash tests (with output in terms of vehicle and roadside feature kinematics and kinetics rather than predicted occupant-injury levels for most studies) and simulation (with necessary input data based on the above studies, thereby incorporating their limitations plus the question of degree of confidence placed on interpolation or extrapolation from the validation cases). It was felt that a workshop focusing on the strengths and weaknesses of these tools would be the most valuable means of assessing current technology in this area.

The Transportation Research Board (TRB) Committee on Safety Appurtenances (A2A04) agreed to sponsor such a workshop. Meeting attendees would include invited technical experts to supplement the technical expertize of TRB Committee A2A04 members in the above areas. The Environmental Factors Section of the American Association for Automotive Medicine (AAAM) provided support and assistance for the planning and conduct of this workshop. A workshop planning committee was established consisting of Forrest M. Council; William W. Hunter; Jarvis D. Michie, Chairman, TRB Committee A2A04, and John G. Viner. King K. Mak and all of the above noted individuals participated in initial workshop planning efforts. Local arrangements were handled by Eric F. and Mrs. Dee Nordlin.

The workshop would focus on knowledge gaps rather than with parts of the system that worked rather well. In so doing, it was hoped that a more meaningful dialogue among the various disciplines represented at the workshop would take place. The goals for the workshop were (a) to engage in a meaningful interdisciplinary dialogue on the impediments to obtaining improved collision severity data and (b) to identify several key problems and suggest solutions.

The technical discussion was divided into two major areas: (a) Physical Testing and Analysis and (b) Field Performance Studies: Evaluation and Data Issues. Each session included invited presentations and group discussions. A review of cost-benefit model algorithms preceded these sessions to set the stage for the specific workshop deliberations.

At the conclusion of these sessions, the four "most important" problem areas identified by the workshop attendees were discussed in subgroups of the attendees. Prior to the workshop, each attendee was asked to provide a statement of "The Most Important Specific Issue Relating to Severity Data." These statements were used as planning guidance for the workshop and are included in Appendix A. At the end of each session, each attendee was asked to list "The Four Most Important Problems Discussed in This Session." The workshop planners used both of these inputs to select the "four most important problems" which were the subject of Session 3, Group Consensus on Key Problems and Recommendations.

The invited presentations and comments by session moderators together with the written summaries of the group consensus statement are in the following sections of this paper.

Part 1: Roadside Appurtenances and the Need for Improved Collision Severity Data

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ISSUES

Increasing fuel costs are prompting a shift to smaller, more fuel-efficient classes of vehicles. In addition, fewer miles of travel are occurring. Coupled with inflation, these events are resulting in fewer revenues available for highway design changes and/or safety improvements. Perhaps more than ever, notions of cost effectiveness and prioritization of programs are assuming more importance. Some current issues include:

1. Are we designing and placing our roadside hardware optimally to maximize benefits and minimize costs?
2. What are the proper effectiveness levels for appurtenances (i.e., how can we quantify how well they work?) for use in cost effectiveness or budget allocation procedures?
3. And as an aside, what vehicles and what crashes will need to be designed for in the future?

Let us momentarily focus on the second question regarding effectiveness levels. We can attempt to answer the effectiveness questions by using three basic methods: (a) field testing of countermeasures (accident and proxy studies), (b) crash testing and (c) simulation. The basic problems relating to field tests are poor study design and poor data. These problems are so intrinsic to many studies that it is difficult to state where we are today in regard to evaluating much of the current hardware. Why is this the case?

PROBLEMS

Many designs have been developed and tried including impact attenuators, breakaway signs, transition guardrail at bridge ends, concrete median barriers, etc. In some cases accident data have been collected and some attempt at an evaluation made, but here the problems begin. Evaluations are often made after the fact, sometimes as an afterthought, as opposed to being built into the entire process. Sometimes the wrong type of data has been collected, such as not specifically examining the types of accidents the design or treatment is specifically supposed to affect. Many of the evaluation designs have been flawed, producing results that are meaningless or that are very hard to interpret.

In this field we have often used before/after designs, most often with no control or comparison group. When this occurs, the results vary widely due to regression to the mean, random fluctuation, etc. And even though it is not an easy task, it is imperative to try to develop some kind of control locations or data. And these should be determined early. Since we generally cannot fund all candidate projects, why not randomly set aside some for comparison purposes? So the first problem is really that of poor evaluations (1). (Numbers in parentheses designate references at the end of Part 1.)

Secondly, there is the problem of information dissemination. Many states are quite capable of setting up and performing evaluations of various devices. Yet many times the results never seem to get past their own people in the design or traffic engineering branches. Publishing the results of evaluations is not a high-priority item in most state highway departments. But it is important that states talk to each other, perhaps through working technical memoranda, short summary reports for remedial treatments or small-scale improvements, or maybe a detailed technical report for major redesign. It is also important that negative as well as positive fundings are reported. One convenient outlet could be FHWA Regional Offices.

NEEDS

All of the above leads to another area--what we need. Basically, for all the many types of roadside or appurtenance designs available, we need to know what works and how well or how poorly. The answers need to be couched in terms of appropriate levels of effectiveness, such as, "the water-filled cushion, when used at high-speed gore areas, reduces fatal accidents by 75 percent, reduces injury accidents by 65 percent and increases property damage only (PDO) accidents by 300 percent" (2). If possible, even further breakdown of the data is desirable, such as by class of roadway, Abbreviated Injury Scale, etc.

We need information for all the various kinds of hazards and accompanying treatments, such as what to do about trees and utility poles, exposed bridge rail end, substandard bridge rail, underpasses and exposed bridge piers, sign supports, etc. Here appropriate questions might be what types of accidents are critical? is it worse to strike a tree or utility pole or guardrail? and what are the relative severities of the various hazards?

We also need to know something about how the various treatments for the various hazards work in relation to each other (i.e., how can we compare appurtenances?) And in this day and age it may not just be a question or a comparison of appurtenances. We may be comparing hardware versus roadway maintenance. What we are addressing is a means of assigning priority to these different elements. If you are talking about roadside safety improvements, the funds today are far from sufficient. The states now seem to be tackling this problem, and most of the approaches tend to involve economic analysis procedures to produce rankings based on concepts like net present worth, benefit cost ratios and integer and dynamic programming.

These economic procedures then lead to some more data needs: for example, knowledge about the number of hazards per some distance of roadway (such as the number of utility poles per mile within 30 ft. of the edge of pavement on rural non-Interstate roadways). In other words, we need exposure data, and this implies an inventory of some sort. Exposure is such a vital concept in regard to evaluation that we need to give it a fair share of attention as it impacts on our severity and methodology concerns. We also need associated cost data (e.g., cost of these utility pole accidents and the cost of a proposed treatment, such as relocating the pole or making it breakaway). Many ideas come into play here, including (a) cost and service lives of various appurtenances (e.g., what does it cost to make a pole breakaway and how does this affect the service life of the pole?); (b) cost of fatal, severe, minor or PDO accidents, and related concerns about whether direct or societal costs should be used. If you then couple these data items with the estimates of effectiveness for the various treatments, then the basis is present for development of some prioritizing or ranking scheme.

ECONOMIC PERSPECTIVES

In many cases, what we are trying to do is calculate a benefit/cost ratio, generally in one of two ways (3):

$$B/C = EUAB/EUAC = PWOB/PWOC$$

where

EUAB = equivalent uniform annual benefits,
EUAC = equivalent uniform annual costs,
PWOB = equivalent present worth of benefits, and
PWOC = equivalent present worth of costs.

In this fashion a project or service life is determined, along with an appropriate interest rate, and present and future costs and benefits are discounted or amortized and reduced to a single number or numbers for calculation purposes. Again, costs may include items like initial capital costs, maintenance costs, salvage values and the like. The benefits may also include many considerations, such as reduced motorist delay, increased confort and convenience, reduced vehicle emissions, etc.; in the safety area, reductions in the frequency and/or severity of accidents over the life of a treatment generally produce the largest benefits and thus gain the most attention. So "how can we determine the real-world accident effectiveness of the design hardware put into place?" is probably the question that most needs an answer if we are to rationally allocate funds among competing needs. Indeed, the consensus is that the lack of this effectiveness data is still our biggest stumbling block to proper prioritizing.

Table 1: Calculation of Accident Benefits

(1) Year	(2) Type	(3) No. of Untreated Accidents	(4) Accident Costs	(5) Untreated Accident Costs	(6) Improve-ment Factor	(7) No. of Treated Accidents	(8) Treated Accident Costs
	Fatal	8	$350,000	$2,800,000	0.50	4	$1,400,000
1	Non-Fatal	152	$ 20,000	$3,040,000	1.14	173	$3,460,000
	PDO	240	$ 900	$ 216,000	1.00	240	$ 216,000
				$6,056,000			$5,076,000
				Accident Benefits = $980,000			
	Fatal	8	$385,000	$3,080,000	0.50	4	$1,540,000
2	Non-Fatal	158	$ 22,000	$3,476,000	1.14	180	$3,960,000
	PDO	250	$ 990	$ 247,500	1.00	250	$ 247,500
				$6,803,500			$5,747,500
				Accident Benefits = $1,056,000			

Let's look at one example of how effectiveness data can be used, or how we might proceed analytically (Table 1). Table 1 shows 2 years of an economic analysis procedure. We are dealing with fatal, non-fatal and PDO accidents. Column 3 gives the number of such untreated accidents. Column 4 then represents the accident costs, and these were based somewhat on the latest National Highway Traffic Safety Administration (NHTSA) figures. Column 5, the untreated accident costs, then results from multiplying Column 3 times Column 4. Column 6 is the improvement factor or the estimate of effectiveness for this particular piece of hardware. In this case, the hardware reduces fatal accidents by 50 percent, increases non-fatal accidents by 14 percent, and produces no change to PDO accidents. Column 7 then is the number of treated accidents that one would expect after this improvement was put into place and results from multiplying Column 3 by Column 6. The treated accident costs, Column 8, then results by multiplying Column 4 times Column 7. The accident benefits of $980,000 represent the difference in the totals of Columns 5 and 8.

In the second year, two assumptions are made. Accidents are assumed to increase by 4 percent, and this is reflected in Column 3 where the numbers increase to 8, 158 and 250 (rounded). We also assume that inflation increases the cost of the accidents by 10 percent, and this is reflected in Column 4. Proceeding with the calculations as in Year 1, the accident benefits then total slightly more than $1 million for this second year. This process is continued until the service life of the improvement is reached. At this point the net present worth can be determined or a benefit/cost ratio may be calculated.

As can be seen from the benefit totals here, any change in the improvement or reduction factors can have a large effect on the benefit calculation. And this is precisely what you see in the literature--a great variety in the determination of how well or how poorly the appurtenance design is working.

Given this line of thinking, there are other ways to proceed that can be shown by other examples. The following formulas appear in the American Association of State Highway and Transportation Officials (AASHTO) traffic barrier guide (4).

$$CT = CI + CD(Cf)(KT) + CM(KT) + COVD(Cf)(KT) - CS(KJ)$$

or, to determine these costs, which are directly incurred by the highway department (or implementing agency), use the equation below:

$$CTD = CI + CD(Cf)(KT) + CM(Kt) - CS(KJ)$$

where

- Cf = collision frequency (accidents per year),
- CI = initial cost (present dollars) of the obstacle,
- CD = average damage cost (present dollars) per accident incurred to the obstacle,
- CM = average maintenance cost (present dollars) per year for the obstacle,
- COVD = average occupant injury and vehicle damage cost (present dollars) per accident,
- CS = estimated salvage value (future dollars) of the obstacle,
- CT = total present worth cost (dollars) associated with the obstacle,
- C = total present worth direct cost (dollars) associated with the obstacle, and
- KT, KJ = economic factors for some current interest rate.

Just as before, the occupant and vehicle damage costs or severities represent our biggest unknown or emphasis point for what we are trying to accomplish in a prioritizing sense.

The final example is a cost-effectiveness model enhanced by Glennon in NCHRP Report 148 (5), which is a probabilistic approach for calculating a hazard index H.

$$H = (V)(PE)(PCE)(PIC)$$

where

H = hazard index or expected number of fatal plus non-fatal injury accidents per year;
V = vehicle exposure;
PE = probability of encroachment;
PCE = probability of a collision, given an encroachment; and
PIC = probability of an injury (fatal or non-fatal), given a collision.

Glennon then calculates the cost-effectiveness ratio defined as the annualized cost for the reduction of one fatal or non-fatal injury accident. Here, data are needed for all the probability terms, because much of this work is based on theory. Indeed, the probability of encroachment is based on the old work by Hutchinson and Kennedy (6).

In models like this, site layout considerations come into play. For example, a pole (breakaway or non-breakaway) is more likely to be struck if closer to the edge of pavement. The same would be true for median barrier placement. Barriers placed close to the pavement yield more hits at shallower angles, while more severe, higher-angle collisions result when distance from the pavement edge is greater. And while such considerations about site layout and impact conditions are important, what we are trying to focus on here are the inherent capabilities or limitations of the appurtenance and the relative severity of the collision.

CONCLUSION

It should be stated that some excellent work has been performed in developing or reviewing procedures for ranking alternatives by the Texas Transportation Institute (7) for FHWA. These methods include incremental benefit/cost techniques with improved algorithm, dynamic programming and inter programming--techniques that lead to optimal budget packages. However, one problem here is that much of the work has focused on fairly meticulous cost calculations (i.e., costs of accidents for various roadway and traffic situations). The accompanying knowledge about treatment effectiveness (frequency or severity reduction) can be stated with nowhere near the same precision. Indeed, the effectiveness factors could be orders of magnitude different.

Thus, we have a good handle on the economic techniques for ranking programs. It is time to develop research methodologies that will produce the needed estimates of effectiveness for our design hardware.

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Part 2: Session 1, Physical Testing and Analysis

Jarvis D. Michie, Southwest Research Institute, Moderator

This session was devoted to seven aspects of roadside hardware development, principally the design, laboratory and crash test evaluation and assessment of the hardware potential. The presenters were asked to critically evaluate a specific area with respect to generating data needed in the benefit/cost analysis procedure. As it was felt that the positive features of the seven areas have been emphasized in previous meetings and in the literature, the presenters were asked to concentrate on limitations. Accordingly, the reader is advised that the following purposely stresses the negative and should not be viewed as a balanced appraisal of highway safety technology.

BASELINE DATA NEEDS

Hayes E. Ross, Jr., Texas Transportation Institute, Texas A&M University

Benefit/cost analyses of roadside safety programs generally involve (a) an estimate of accident frequency and (b) an estimate of the severity of the predicted accidents. In most such analyses these estimates, through no fault of the analyst, are crude and statistically unsound. Data on which reliable predictions can be based are sparse. Numerous variables influence accident frequency and severity, further complicating data needs.

Attempts have been made to develop accident prediction models based on regression techniques utilizing accident data. These have met with little success for the reasons given above. In the absence of accident data bases, researchers have formulated probabilistic models based on observed and/or assumed vehicle encroachment data. Although widely used, the latter technique has relied on very limited encroachment data, and the results obtained are generally suspect.