Concerns About Use of Severity Indexes in Roadside Safety Evaluations

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Severity indexes, which serve as indicators of the expected injury consequences of a crash, are an integral part of the analysis of proposed roadside safety improvements. Although research since the 1960s has sought to quantify severity indexes for a range of object types and impact conditions, wide variations remain in the values from which analysts may choose when performing cost-effectiveness evaluations. To clarify the current state of the practice in understanding and using severity indexes, a survey of state highway agencies was conducted. Among the 11 primary parameters used in the AASHTO roadside safety analysis model, respondents expressed the least level of confidence in severity indexes; indeed, more than 70 percent indicated that they encountered problems in selecting and justifying these values. Numerous respondents asserted a need for the validation of the severity indexes used in the model. General support was expressed for the inclusion of more object types and impact conditions in tabulations of severity indexes, although opinions were divided on the merits of providing a range of severity indexes as opposed to specific values. Survey results also supported the need for continued development of the roadside safety method, better documentation of the procedures, user-friendly computer programs, and additional training.

During the past 30 years significant progress has been made in reducing the number of highway fatalities that occur in run-off-the-road accidents. Improvements are most evident on Interstate freeways, where obstacle-free roadsides and the judicious use of barrier systems provide a restrained motorist in an errant vehicle a good chance of surviving an excursion onto the roadside. Similar treatments have been effective on arterial, collector, and even local roads, but the expense of implementing corrective action has limited the extent of improvements on these facilities.

As part of the economic evaluation of alternative roadside safety improvements, the analyst compares the incremental benefits resulting from a treatment with the additional costs required to build and maintain it. In these cases the expected benefits arise from a reduction in the frequency or severity of collisions with roadside obstacles. A critical element in the projection of benefits is the severity of those crashes that are expected to occur with and without a particular treatment. These benefits are currently estimated in a multistep process that relies in part on severity indexes.

Alternative definitions have been suggested, but most early researchers defined severity indexes on a scale of 0 to 1; for specific objects the severity index represented the proportion of reported accidents that resulted in a fatality or injury. Although there were points of agreement, results from studies often differed, possibly because of variations in object design and placement, impact speed, vehicle characteristics, and similar factors. By the mid-1970s a refined procedure and an enlarged scale of 0 (no damage) to 10 (fatality) were used to describe severity. Some indexes were based more on professional judgment and expert opinion than on the results of accident studies and were inherently difficult or impossible to validate by traditional methods. During the past 15 years, serious efforts have been made to develop justifiable severity indexes by both traditional and innovative techniques, including expert opinion, analyses of large accident data bases, in-depth studies of particular objects, evaluation of vehicle damage, application of accident cost models, simulation, and the results of crash testing. In most cases these studies have increased the level of understanding of severity indexes, although the perplexing variations in values recommended by different studies have not been eliminated. The development of severity indexes continues today with a number of ongoing initiatives that may help clarify some of the long-standing concerns.

The evolution of severity indexes is partially evidenced by a comparison of the values for a sample of objects from a 1974 NCHRP report (*1*) with 1991 values given by FHWA (*2*). The older values, calculated on a scale of from 0 to 1, represented the average proportion of reported accidents that resulted in a fatality or injury. The more recent data from FHWA are expressed on a scale of from 0 to 10, but they are based more on judgment than on actual accident data. They also include a much greater range of object types and impact speeds. A sample of severity indexes from the NCHRP report is compared with similar objects evaluated by FHWA for a 97-km/hr (60-mph) design in Table 1. Although the values clearly differ, the general pattern of more severe objects remains relatively consistent.

Despite continual improvements in severity indexes during the past three decades, inconsistencies and difficulties remain. Questions exist about many factors such as the roles of impact angle and speed, whether accident data can yield accurate severity indexes, whether average severity indexes are appropriate for circumstances of individual accidents, and whether users have an adequate understanding of such indexes. Highway safety managers are aware of these problems, and major efforts are under way by FHWA and NCHRP to improve severity indexes. One such NCHRP project was conducted by the authors to prepare a report on severity indexes.

Throughout the history of severity indexes, it has been assumed that roadside safety analysts understood the concept and possessed sufficient judgment to choose appropriate severity indexes for cost-effectiveness determinations. Unfortunately, this has not always been the case, since highway agency safety analysts, public works managers, and others have not always kept abreast of the relevant technical developments. By the early 1990s FHWA had invested extensive efforts in the development and promulgation of severity indexes, but the degree of understanding among users and the extent of use for off-road accident analyses varied considerably.

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TABLE 1 Comparison of Severity Indexes, 1974 Versus 1991

Object	NCHRP 148[a]	FHWA[b]
Sign Support		
Breakaway	0.22	1.7
Rigid (steel)	0.53	5.3
Luminaire Support		
Breakaway	0.22	2.8
Rigid	0.53	5.5
Guardrail Face	0.33	3.6
Tree (medium-size)	0.50	5.5
Embankment		
6:1 slope	0.22	2.6
3:1 slope	0.53	4.0
Utility Pole	0.53	5.5
Bridge Pier	0.70	5.5

[a] Represents the portion of accidents resulting in a fatality or injury.
[b] Represents the average severity, on a scale of 0-10, for 97 km/h (60 mph) design.

PURPOSE OF THIS PAPER

The understanding and use of severity indexes by design and safety personnel are examined in this paper. It is based on a survey conducted as part of an NCHRP project. A questionnaire distributed to state highway and transportation departments identified several areas in which these agencies were experiencing difficulty in evaluating alternative roadside safety improvements. Several findings from this survey could affect future research on severity indexes and roadside safety cost-effectiveness procedures.

SURVEY OF STATE HIGHWAY AGENCIES

The technical literature, supplemented by information from recent telephone interviews with recognized experts in the applied and research communities, confirms that numerous research teams have examined various aspects of the severity index issue. The most recent AASHTO standards for roadside safety design (*3*) incorporate inputs from multiple contributors and provide a limited set of severity indexes as a function of speed, object type, and impact point. However, qualified observers have expressed concern regarding the validity of the severity indexes cited in current AASHTO procedures and have noted the sensitivity of the economic analyses of roadside safety improvements to rather small changes in assumed severity indexes, especially at the upper end of the severity scale. The expanded level of detail in the more recent supplemental information on severity indexes (*2*) may have partially offset these concerns, although interviews with severity index users conducted as part of this study provide ample evidence that neither researchers nor practitioners are comfortable with the current values.

In an effort to determine if and how the individual state highway and transportation departments had resolved their concerns, a survey was developed and distributed to safety and traffic engineers in these agencies. The survey, which was intentionally kept short to encourage responses, was distributed in August 1992. It was sent to prominent, upper-level highway and traffic engineers at each agency, and those who had not responded were recontacted in October. Overall, individuals representing 38 states (76 percent) responded to the survey; although input from the remaining states would have been welcome, there is no reason to believe that additional responses would have affected the primary findings from the survey. In some cases the original recipient of the survey passed it along to others in the organization who worked more closely with the day-to-day task of assessing roadside safety. These people may be in a better position to address the technical issues raised by the survey, although they may lack the background to respond to policy issues. In about 10 cases answers given in the survey required further clarification; respondents were contacted by telephone and were asked to expand on their replies.

The following sections indicate the questions presented on the survey and summarize the responses. Not every respondent provided a reply to each question, so responses do not always total to 38.

Resources for Roadside Safety Analysis

The respondents were first asked what resources the "agency routinely use(s) to assist with roadside safety analyses." The 1989 AASHTO *Roadside Design Guide* (*3*) was reportedly the most widely used resource, with 32 (84 percent) of the respondents indicating that they use it. In addition, respondents from 13 states (34 percent) reported that they used other technical references, including the 1977 AASHTO Barrier Guide (*4*), the *Supplemental Information for Use with the ROADSIDE Computer Program* (*2*), and locally developed design or traffic engineering manuals.

The ROADSIDE computer program was cited as a resource by 15 (39 percent) respondents. This statistic probably overstates the program's use, however, since many of the affirmative responses were accompanied by qualifiers such as "occasionally," "not routinely," or "optional." The limited use of the ROADSIDE computer program is somewhat surprising, since it clearly simplifies the computational aspects, especially when multiple alternatives are being considered. Twelve states use other computer software in their roadside safety analyses. On the basis of comments provided by the respondents and several follow-up telephone interviews, many of the software packages were developed in-house to satisfy particular conditions. For example, some were developed to select projects for the federal-aid safety program. Other agencies reported using specialized software to analyze accident records, and two used special software to calculate the length of need for guardrails.

Several survey responses offered alternative methods for the identification of problem locations and the development of corrective actions. These are typically designed to reflect local characteristics. For example, Indiana has developed its own *Roadside Design Guide* (*5*), combining elements of AASHTO's publication (*3*), Indiana Department of Transportation (DOT) clear zone policy, and the severity indexes in FHWA's supplemental information (*2*). However, Indiana DOT used existing data and made several assumptions to estimate the severity indexes for certain proprietary guardrail end treatments. The Indiana guide will be limited to applications for new, non-Interstate construction and resurfacing, restoration, and rehabilitation (RRR) work.

Nevada DOT developed and uses a personal computer Basic program called Potential, which calculates hazard indexes for roadside features (*6*). The program helps Nevada DOT perform "what-if" analyses for proposed treatments based on the design and operating features of the road. Nevada does not use the ROADSIDE computer program but rather relies on AASHTO's 1977 Barrier Guide (*4*).

Parameter Selection

Survey respondents who indicated that they use the *Roadside Design Guide* (*3*) or ROADSIDE software (*2*) in conducting evaluations and making decisions regarding roadside safety were asked if they "have problems in selecting or justifying values for 11 parameters" necessary for applying these procedures. This question was potentially the most fruitful in the survey, since it addresses the serviceability of the most commonly used resources for evaluation and decision making related to roadside safety.

The items enumerated in this question represent the minimum data requirements (or assumptions) an analyst needs to conduct roadside safety evaluations using the AASHTO methodology. Several of the data parameters (e.g., roadway gradient and traffic volume) are clearly within the purview of the highway agency; if the agency does not have the information, it cannot expect to find it in secondary sources. On the other hand there are few highway agencies that routinely develop several other parameters (e.g., encroachment rates and angles) required in the model. Regardless of the source of the information, the question sought to establish the ease with which the respondent could obtain justifiable values for these parameters and the respondent's confidence in the selected values.

Of the respondents from 33 agencies that reported using either the *Roadside Design Guide* (*3*) or the ROADSIDE computer program (*2*), between 28 and 31 rated each of the parameters; the last two columns in Table 2 indicate the percentage of respondents encountering difficulty in selecting or justifying parameter values while performing roadside safety analyses.

As expected, the responses reflect a high level of confidence in the site-specific parameters such as roadway alignment, traffic volume, and object dimensions and placement. This was not true for other types of parameters. As suggested by Figure 1, about 40 percent of the respondents encounter problems in establishing the encroachment rate and lateral extent either often or occasionally. More than half experienced difficulty with values for the angle of encroachment and the cost of a single-vehicle run-off-road accident. Figure 1 clearly demonstrates that highway agencies have the least degree of confidence in severity indexes for fixed-object impacts. More than 70 percent of the respondents report difficulty in selecting and justifying these values. The severity index and accident costs, two of the most problematic parameters, are believed by most knowledgeable analysts to have the most significant effect on the outcome of a roadside safety analysis.

Solutions

Respondents citing problems with quantifying key parameters were then asked "what would be required to reduce or eliminate these problems and improve your confidence in assessing the safety effectiveness of roadside improvements." The 24 states that responded to this question offered a variety of suggestions, but by far the most common, given by 12 (50 percent) of those responding, dealt with severity indexes. Representative comments called for a "well-documented set of severity indexes" for a "wider variety of objects." Some respondents expressed their general frustration with the apparent subjectivity of the values presented in the *Roadside Design Guide* (*3*) by calling for better field data, not only for severity indexes but also for encroachment parameters and accident costs.

Two respondents expressed dissatisfaction with the substantial amount of engineering judgment required by the current methods of roadside safety analysis. Conversely, others believed that the rigidity of the *Roadside Design Guide* (*3*) and ROADSIDE software (*2*) stifled their exercise of engineering judgment. "Informed engineering judgment" is a fundamental component of the profession. What differentiates the informed, educated opinion of an engineer from the guess of a typical citizen is a readily available, credible, and comprehensive set of evidence that the engineer can apply to the problem at hand. Survey responses indicate that many engineers believe that this necessary informational base is missing or inadequate in the case of severity indexes.

Questions of this type permitted the responding engineers to mention issues that have created recent difficulties for them. Isolated points mentioned by one or two persons who make significant use of the AASHTO procedures could reflect real problems and might lend themselves to simple correction. Responses in this category include:

- Clarify the proper use of design versus operating speed,
- Provide for traffic volumes greater than 20,000,
- Give more information on encroachment angle-runout length relationship, and
- Include data on barrier repair costs.

Severity Indexes

Appendix A of the AASHTO *Roadside Design Guide* (*3*) provides a limited set of severity indexes as a function of object type, impact

TABLE 2 Respondents Experiencing Problems in Selecting Parameters

Encounter Problems With:	Rarely	Occasionally	Often
Design Traffic Volume	90%	7%	3%
Roadway Curvature	90%	3%	7%
Roadway Gradient	93%	0%	7%
Design Speed	77%	19%	3%
Baseline Encroachment Rate	61%	21%	18%
Encroachment Angle	45%	28%	28%
Hazard Offset	79%	21%	0%
Dimensions of the Hazard	83%	17%	0%
Lateral Extent of Encroachment	62%	28%	10%
Severity Indices	27%	30%	43%
Expected Accident Costs	47%	23%	30%

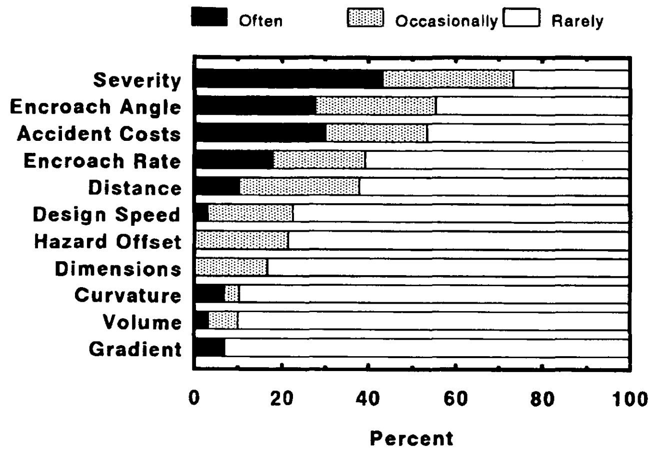

FIGURE 1 Respondents encountering problems in roadside safety analysis.

location, and design speed. The survey asked whether the respondents use this information, whether they are highly confident in the information, and whether they have developed alternate information in which they have greater confidence.

In contrast to the respondents from 33 states that had previously indicated that they used the *Roadside Design Guide* (*3*) or ROADSIDE software (*2*), only 15 of the 36 respondents (42 percent) to this question claimed to use the severity index information in Appendix A of the *Roadside Design Guide*. The states have little confidence in the quality of the severity index information; only 5 of the 27 respondents (19 percent) indicated a high degree of confidence.

Only 23 percent of the respondents indicated that they had developed information on severity indexes that they believed was more reliable than the *Roadside Design Guide*. On the basis of supplemental comments provided by the states, it appears that most had not actually developed alternate values for severity indexes; rather, they were aware of or were using alternate severity indexes, such as those contained in FHWA's supplemental information.

Pennsylvania was the only responding state to describe internal efforts to develop alternative severity index information. Pennsylvania DOT uses its accident record system together with assumed unit costs of crashes (ranging from $1,994 for property damage only to $1,259,544 for a fatal crash) to estimate the average cost of impacts with nine different object types in both urban and rural areas. Although the unit costs have not been revised recently, average crash costs are updated annually to reflect the actual severities of reported crashes. The resultant costs, which serve as surrogates for severity, were formerly used in benefit-cost analyses; Pennsylvania DOT only implemented treatments with a benefit-cost ratio of >2. Pennsylvania now emphasizes safety improvements along corridors according to problem locations identified by cluster parameters [e.g., five hit tree accidents per 0.3 km (0.2 mi) per year]; corridors with multiple accident clusters are reviewed in the field by safety engineers.

Desired Revisions

Anticipating that there might be some level of dissatisfaction with existing severity indexes, the survey asked "what specific revisions are needed to make fixed-object severity indexes more useful in the analysis of roadside safety improvements." Although the responses to this question were highly varied, the central theme of the most common request was for severity indexes to encompass a more extensive set of objects. Several respondents mentioned specific objects, including trees by diameter, different barrier designs, and the combined effects of embankment height and slope.

Related topics of interest included more information on severity indexes as a function of speed, angle of impact, and the roadside slope between the traveled way and a rigid object. Several respondents volunteered that the greater number of objects included in the FHWA supplemental information was quite helpful, although it still had significant gaps.

The lack of severity index credibility evident in replies to the previous question was also obvious in these responses, in which the need for reliable, justifiable values that reflect real-world conditions was mentioned by several respondents. The concept of using a more scientific approach to determining severity indexes and carefully explaining the process and the results to the end user was also recommended by several respondents. Numerous individuals believed that the whole methodology in the *Roadside Design Guide* (*3*) needs to be better explained.

Divergent opinions were offered on the issue of providing discrete severity indexes versus a range of values. One respondent argued convincingly that the presentation of single severity indexes, as in Table A.3 of the *Roadside Design Guide* (*3*), gives a designer the false impression that severity indexes are absolute. Another respondent contends that ranges of values, as given in FHWA's supplemental information, create an undue burden for the typical user who has insufficient expertise to make a choice among the severity indexes in a range. These differences of opinion are simply diverse perspectives on how well (or poorly) the AASHTO guidelines accommodate "informed engineering judgment."

Four additional recommendations were offered by several respondents. These suggestions appear to deserve consideration in any effort to enhance either the roadside safety analysis procedures or parameters.

- The existing process is too vague. Two competent engineers using the AASHTO methodology and the FHWA supplemental information to evaluate a particular situation can arrive at dramatically different results.
- The *Roadside Design Guide* (*3*) should be clearer on the proper method for evaluating multiple roadside obstacles at a location.
- Application of the roadside safety evaluation procedures over an extended section of highway is extremely time-consuming.
- A tabulation of cost-effective treatments as a function of design speeds would be a useful addition.

Alternative Tabulations

The survey asked if respondents are "aware of any severity index tabulations for roadside obstacles that could be used to supplement or corroborate those presented in the AASHTO *Roadside Design Guide*" (*3*). Those responding affirmatively were asked to indicate the source of the information.

Of the 37 responses to this question, 13 (35 percent) indicated an awareness of supplemental severity index information. Most of these identified FHWA's *Supplemental Information for Use with the ROADSIDE Computer Program* (*2*), but it was clear that some respondents were not aware of the most recent version of this document. Other respondents mentioned a computer program developed by the University of Kansas, some research results from Vanderbilt University, the New York DOT accident reduction factors, and AASHTO's 1977 Barrier Guide (*4*). One state noted that its own accident records included cost and casualty information that could be used for this purpose.

Ongoing Studies

Information was solicited about any ongoing projects or studies that are attempting to improve the understanding, usefulness, or quality of roadside severity index information. Only three of the respondents indicated an awareness of such activities; they referred to some research at Vanderbilt University and NCHRP Projects 22-8 and 22-9.

Carney is directing research at Vanderbilt University toward the use of comprehensive federal traffic accident data systems. Data from the Fatal Accident Reporting System (FARS) and the National Accident Sampling System (NASS) are being used for these efforts. The FARS and NASS data are being subjected to multiple statistical treatments in an attempt to develop more meaningful severity indexes.

NCHRP Project 22-8 (*7*), on the evaluation of performance-level selection criteria for bridge railings, included a detailed examination of the Benefit-Cost Analysis Program (BCAP), a computer program (*8*) developed to facilitate the evaluation of alternative roadside safety improvements. As its name suggests, BCAP compares an improvement's incremental benefits accruing to road users with the additional costs for construction and maintenance incurred by the highway agency (*9*). NCHRP Project 22-8 researchers analyzed 4,552 accidents involving Texas bridges for the period from 1988 to 1990 (*10*) and found that the proportion of severe to fatal (percent A + K) injury accidents differed markedly among vehicles retained on the bridges, those that went through the bridge railings, and those that went over the bridge railings. The study was unable to establish the reasons for the difference in severity between vaulting and penetration.

Mak at the Texas Transportation Institute and Sicking at the University of Nebraska are currently conducting NCHRP Project 22-9 to develop improved microcomputer software for cost-effectiveness analysis procedures. The proposed software is intended for two primary uses:

- To access alternate roadside safety treatments for either point locations or sections of roadway, and
- To develop warrants and guidelines, including those which consider the performance levels of safety features.

At the time that the survey was undertaken, Mak was also conducting an FHWA project to develop techniques and plans for future accident research studies to improve benefit–cost models (such as the models being developed in NCHRP Project 22-9). The now-completed study examined the potential for the development of severity indexes through the collection of in-depth accident data.

Although only three ongoing projects were mentioned by respondents, they are prominent examples of the types of research efforts necessary to significantly improve current severity index values. An additional study by Council at the University of North Carolina is developing techniques to account for items such as the effects of airbags and unreported accidents. The work is especially timely since the adoption of new technologies, such as airbags, could make current severity indexes obsolete.

New Research Suggestions

The next question challenged respondents to identify potential improvements to existing resources. Specifically, they were asked, "If you were given the authority to define the next major research project addressing the weaknesses of existing severity index and/or roadside safety information, what would be the primary focus of the research?" Finally, they were asked for any other comments or suggestions related to severity indexes, roadside safety, establishing priorities, or cost-effective treatments.

The responses to both questions tended to offer suggestions in which additional improvements could be made in the roadside safety analysis process. Some of the respondents' interests require research for their resolution, whereas others might be resolved through administrative or educational initiatives.

Five respondents suggested that the primary focus of a new research project should be verification of projected severity indexes, preferably through an evaluation of actual improvements that were selected on the basis of the *Roadside Design Guide* (*3*) methods. The skepticism expressed by many could potentially be resolved through a validation project. Four respondents recommended efforts to simplify the analysis methods. A similar number of respondents proposed studies to develop severity indexes for objects that are not included in the current guidelines. Two states suggested that the primary need was to establish more credible information on encroachment rates and angles, whereas two others believed that improved accident cost estimates should be a priority topic. Other issues recommended for additional study included methods and data for speeds of less than 64 km/hr (40 mph), determination of cost-effective clear roadside widths, and the redirection capabilities of back slopes.

Although it was not a research topic, several states mentioned a need to improve the user interface and operation of the ROADSIDE computer program (*2*). In addition, some respondents expressed concern that engineers within their agencies did not have a good understanding of the factors associated with roadside safety; the simplicity of the ROADSIDE program could lead the unwary to erroneous conclusions. In other words, in the absence of "informed engineering judgment," ROADSIDE simply allows the analyst to make mistakes faster.

Summary

Responses of state traffic and highway safety engineers to the survey described here provide a reasonably representative picture of the roadside safety analysis methods used by highway agencies. Survey responses indicate that AASHTO's 1989 *Roadside Design Guide* (*3*) and the companion ROADSIDE computer program (*2*) are the authoritative, most commonly used technical references on roadside safety issues. Respondents expressed relatively high degrees of confidence in the values of those analysis parameters, such as traffic volume and roadway alignment, that they can readily determine for their own road systems. On the other hand they expressed concerns about those parameters that are not specific to a particular study site; prime examples include severity indexes, roadside encroachment characteristics, and accident costs. The responses from the extended population of practitioners, who attempt to implement research recommendations on a daily basis, may differ from the perceptions of researchers, who may be more familiar with the technical difficulties involved in developing severity index values.

CONCLUSIONS

In spite of previous studies to define, develop, and test severity indexes, the present research found that the severity index has not reached a mature stage of development. Currently, the most widely used values for severity indexes are those presented in the *Roadside Design Guide* (*3*) along with those in the *Supplemental Information for Use with the ROADSIDE Computer Program* (*2*). The developers of these indexes based them on expert opinion tempered with an understanding of general accident study methodologies and results. To date no research effort has confirmed these severity index values as accurate, authoritative, or representative of crashes that actually occur on U.S. roadsides. Despite some shortcomings, the AASHTO procedures, together with supplemental information developed by FHWA, represent the best guidance available today; they should certainly be used as a starting point for the beginning user.

Although local engineers and consultants also conduct roadside safety analyses, state highway safety analysts and designers are the most frequent users of severity indexes. National survey results show that these individuals have greater problems with severity indexes than with any other aspect of roadside cost-effectiveness studies. In addition, their responses indicated uncertainty, and in some cases confusion and frustration, about cost-effectiveness studies and the ROADSIDE computer model. Clearly, there is a need for improvement in the understanding and use of these safety tools.

The survey found that state highway safety analysts and designers had an extremely difficult time selecting and justifying their choice of severity indexes, accident costs, and encroachment parameters. When roadside safety calculations produce nonintuitive results or support treatments with excessive costs, the skeptical analyst may simply be inclined to blame severity indexes or other parameters that are difficult or impossible to validate.

Despite concerns with severity index accuracy, there was considerable sentiment among survey respondents for an expanded severity index list. As long as severity indexes are not tied directly to crash experience, it should be possible to incorporate additional objects, different object designs, other speeds, and similar parameters into such a list.

The findings of this project offer several important opportunities for additional research. First, it is obvious that many users of current roadside safety evaluation methods lack confidence in the results of their analyses; an effort is needed to correct any deficiencies and bolster the confidence of the users. Second, the inventory of objects and conditions included in a list of severity indexes should be expanded and annotated to facilitate proper analysis, especially by those with limited engineering experience. Third, the software commonly employed to simplify the analyses should be made more user friendly; modifications should also limit the opportunity for serious errors due to the unwary acceptance of default values within the program. Fourth, the levels of understanding of roadside cost-effectiveness methodology vary considerably with the training and experience of the analyst; consequently, there is a real need for expanded training in this area, especially for young engineers.

Finally, a major effort is required to significantly improve the quality and accuracy of severity indexes. The endeavor must be comprehensive in terms of the obstacles and conditions addressed and must recognize the dynamic aspects of both vehicle and roadway technologies that will continue to influence crash severity. The optimal method for undertaking this type of study is not certain. A meaningful study based on accident and roadway data would require extensive, high-quality data bases and would need to account for unreported accidents. Alternative study procedures employing some of the innovative techniques used on a smaller scale in several recent studies might provide a better opportunity for resolving the severity index dilemma.

ACKNOWLEDGMENTS

Materials in this paper were developed during preparation of TRB's NCHRP Project 20-5, Synthesis Topic 23-09. The authors gratefully acknowledge the contributions of the state highway agency personnel who participated in the survey of understanding and use of severity indexes for cost-effectiveness determinations for off-road accidents.

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