SUMMARY OF ROADSIDE SAFETY ISSUES

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INTRODUCTION

Although catastrophic accidents involving airliners, ships and trains receive a great deal of media attention, 94 percent of all transportation fatalities occur on roadways and highways.*(1)* These traffic deaths, occurring one or two at a time all over the nation on each day of the year, do not usually receive widespread attention but the cumulative toll is more than 40,000 deaths and more than 3.5 million disabling injuries with a societal cost exceeding $100 billion every year.*(1)*

Thirty years ago more than 50,000 Americans died in traffic accidents.*(2)* Each year from 1966 until 1992, the total number of fatalities dropped such that in 1994, just over 40,000 people were fatally injured in traffic accidents.*(3)* Although this reduction is laudable on its own, the fact that it was made with a concurrent increase in vehicle miles travelled is remarkable. The number of vehicle miles travelled was almost 2.5 times greater in 1992 than it was in 1966. In 1966 5.5 people were fatally injured for every 100 million vehicle miles travelled. In 1992 this rate was 1.8 fatalities per 100 million vehicle miles travelled, less than one third the rate of thirty years ago. If the fatality rate had remained unchanged since 1966, 123,000 people would have died on U.S. roadways in 1992 alone. Ultimately, safety must be measured in terms of lives saved and serious injuries avoided. The statistics above demonstrate that the many efforts at improving highway safety have indeed been effective.

Sustaining this laudable record in highway safety may, however, become more difficult. Some projections suggest that to keep the annual number of highway fatalities at the current number (about 40,000), the fatality rate on **all** roadways will need to be reduced to about 1.4 fatalities per 100,000 vehicle miles travelled. Present-day interstates, the safest highways in the world, had a fatality rate of 1.1 in 1993. It will be very difficult to reduce the system wide fatality rate to this level without significant advances in highway safety.*(1)* Even if it is possible to reduce the system fatality rate to this level, it is unclear whether the deaths of 40,000 citizens is acceptable to our society.

Determining the effectiveness of particular highway safety programs and initiatives, however, is very difficult. There are numerous federal and state agencies with important missions affecting highway safety including Departments of Transportation (state and federal), local law enforcement agencies, citizen groups, professional organizations, automobile manufacturers and the insurance industry. Each of these groups has played a role in making highways safer. One such group is the roadside safety community. Roadside safety professionals have worked behind-the-scenes for more than thirty years using engineering design to improve the safety of roadways. The roadside safety community has traditionally stressed engineering solutions to typical roadside safety problems like designing traversable side slopes, specifying minimum clear zones, and designing roadside safety hardware. The changing highway and legislative environment make it prudent to assess the past accomplishments and future directions of roadside safety research to ensure that the scarce resources available for improving roadside safety can be most effectively used to reduce the number of injuries and deaths resulting from roadside accidents.

The purpose of this meeting was to assemble experts in the area of roadside safety to discuss

- What has been accomplished in the past 30 years in that area of roadside safety,
- What are the major challenges for the future, and
- How the wide variety of organizations with an interest in roadside safety can be mobilized to meet the challenges of the future.

This conference was a follow-on effort to a meeting held in the summer of 1994 in Woods Hole, Massachusetts which resulted in Transportation Research Circular 435, *Roadside Safety Issues.(4)* The conference consisted of fourteen invited presentations from a variety of researchers, policy makers, and practicing engineers. Twelve of the presentations are documented earlier in this Circular. The invited presentations focused on three broad areas:

1. Accomplishments in roadside safety from the perspective of state DOT personnel, the Federal Government, and the research community.

2. The use of new technologies and methods like nonlinear finite element analysis in evaluating roadside hardware, accreditation of crash testing agencies, and emerging Intelligent Transportation Systems (ITS) technologies.

3. The changing vehicle fleet including the increased proportion of light trucks, minivans and multi-purpose vehicles, the possible affects of the Partnership for a New Generation of Vehicles (PNGV) program, and recent crash test experience with full-size pickup trucks.

After receiving the background information provided by the invited papers, participants were divided into the following five discussion and work groups:

A. Development of a strategic plan for roadside safety;

B. Severity indices development;

C. Vehicle fleet characteristics, ITS research needs, driver behavior, accident data collection and analysis research needs;

D. Crash testing and simulation research needs; and

E. In-service evaluation and barrier performance research needs.

Development of a Strategic Plan for Roadside Safety

With the current climate of reduced governmental funding and distributed control over highway programs, it is vital that there be a strategic, multi-organizational approach to improving highway safety in general and roadside safety in particular. All the participants of the roadside safety community need to know how to maximize the effectiveness of their efforts by coordinating and entering partnerships with other groups interested in improving safety. Group A was composed of members of the NCHRP Project 17-13 panel and several guests. They held professionally facilitated discussions to develop statements about the purpose, vision and mission of the group as it relates to improving highways safety.

During the discussions of Group A, it was recognized that highway safety encompasses a very broad range of organizations including

- State and Federal Departments of Transportation,
- Local law enforcement agencies,
- Emergency services providers,
- Citizen action groups,
- Automobile manufacturers, and the
- Insurance industry.

Each of these groups has its own specific areas of expertise and concern which sometimes complement each other and other times work against each other. The primary purpose of a strategic plan for roadside safety is to form a framework to unite all these different organizations in coordinated action for improving the roadside. The group developed the following Vision, Purpose and Mission Statements:

Vision

A highway system where people do not pay with their lives when vehicles inadvertently leave the roadway. In this system, drivers rarely leave the road; but, when they do, the vehicle and roadside work together to minimize harm.

Purpose

To improve highway safety by reducing the frequency and severity of roadside accidents.

Mission Statements

- Mission 1: Build a network of organizations that will be partners in the effort to improve roadside safety research.
- Mission 2: Develop and implement methods to keep vehicles on the roadway.
- Mission 3: Develop and implement methods for minimizing the potential for vehicles striking objects on the roadside.
- Mission 4: Develop and implement methods that minimize the risk of injury when objects are struck on the roadsides.

The discussions held at this meeting are only the first step in developing a roadside safety strategic plan. The group plans to further refine the plan developed at this meeting by defining goals, objectives, action items, and research needs. They also cited the need to begin to broaden the circle of participants to bring other organizations that may not traditionally interacted directly with the roadside safety community.

Severity Indices Development

This discussion group was composed of members of the Task Force on Severity Indices of TRB Committee

A2A04 (Roadside Safety Features). This group was organized to review

- The severity indices used in the ROADSIDE program,
- Severity indices in the new cost effectiveness analysis program being developed in NCHRP Project 22-9,
- The definition of severity indices, and
- Current methodologies used to develop severity indices.

The group identified several areas where additional research is needed. One issue that was discussed was finding methods to more formally link crash test performance and field evaluations to the expected behavior of devices under real-world conditions. Current severity indices have tended to be subjective and there is no specific technique for developing a severity index based on specific crash test performance or real-world experience. Research is needed to provide up-dated indices for cost-benefit programs that are being developed in NCHRP 22-9 (Table 1, Research Need 15). Research is also needed to develop methods that result in more quantifiable measures of severity (Table 1, Research Need 4).

With recent changes in the Federal Motor Vehicle Safety Standards (FMVSS), airbag equipped vehicles are becoming a larger segment of the vehicle population. Airbag sensors installed in vehicles collect information about the accelerations being experienced during the deployment of the airbag. If this data could be collected, it may prove a valuable source of information about the dynamics of real-world collisions. Unfortunately, this information is not readily available to researchers so a study to determine exactly what is retrievable from airbag sensors and how it might be obtained needs to be performed (Table 1, Research Need 6).

One of the most fundamental problems in performing cost-effectiveness analysis for roadside hardware is estimating the number of unreported accidents. Generally, unreported accidents are low severity collisions where the vehicle and driver were able to leave the scene without notifying a law enforcement agency. Such collisions are the "successes" in assessing the effectiveness of the system since they resulted in an accident of such low severity that the occupants could leave the scene. Obtaining better estimates of the number of unreported accidents is vital to performing realistic cost-benefit analyses. Most of the data that is used in current cost-benefit programs date from very old studies that were performed under very limiting conditions. These studies have been extended and generalized well beyond the data that was gathered at the time (Table 1, Research Need 10).

Issues discussed by this group are vital to the development of selection and location criteria that can be used by owner agencies to make decisions about installing and maintaining roadside appurtenances.

Vehicle Fleet Characteristics, ITS Research Needs, Driver Behavior, Accident Data Collection and Analysis Research Needs

This group addressed a wide variety of important topics including

- Vehicle fleet characteristics and trends,
- Vehicle-roadside hardware compatibility,
- Occupant protection technology and its affect on roadside safety hardware,
- Driver behavior and behavior modification,
- Safety opportunities from Intelligent Transportation Systems (ITS) technologies, and
- Improved accident data collection and analysis procedures and technologies.

NCHRP Report 350, published in 1993, recommended a number of changes in crash test and evaluation procedures as well as retaining many of the features of NCHRP Report 230, its predecessor. Past experience has shown that updating test and evaluation procedures is both a lengthy and an iterative process. Several issues need to be re-examined including (1) the compatibility of the current vehicle fleet and roadside hardware, (2) the use of occupant restraint systems in evaluating crash tests, (3) international harmonization of testing procedures, and (4) identifying reasonable worst case impact scenarios (Table 1, Research Need 11). In addition to revising the current recommended procedures, there is a need for the roadside safety community to become proactive rather than reactive. In the past the roadside safety community has reacted to changes in the vehicle fleet and improvements in occupant technology. This has resulted in a long lag between the identification of an emerging trend and the implementation of hardware design to address the trend. There is a need to find methods that allow roadside safety researchers to address potential problems before they show up in accident data (Table 1, Research Need 8).

Historically, the vehicle design and roadside hardware design communities have worked without much interaction. This never was a desirable state of affairs but with the changes in the vehicle fleet it has become impossible to design roadside hardware without considering the design of vehicles. Vehicle-roadside hardware compatibility is an important issue that needs to be examined. Methods need to be that ensure that barrier designs are not made obsolete by rapid changes in vehicle designs (Table 1, Research Need 1).

Roadside hardware has traditionally been designed assuming that the occupant of the impacting vehicle was not using any occupant restraints like seat belts. In decades past when belt usage was relatively low this was a reasonable assumption. Increasing belt use as well as the availability of new active and passive restraint systems suggest that a review of this assumption is warranted. NHTSA studies of airbag equipped vehicles has shown that the types and patterns of injuries in airbag equipped vehicles is different that those found in non-airbag equipped vehicles. Designing hardware only for the unrestrained occupant may be putting the restrained occupant at risk in another injury mode. Designing for the unrestrained occupant may also be too demanding for many difficult impact scenarios (Table 1, Research Need 5).

The Federal Department of Transportation is involved in several major initiatives in developing Intelligent Transportation Systems (ITS). These systems may dramatically change the operating conditions and characteristics on many roadways. There may be important safety implications to ITS technologies that should be considered by roadside designers. One example is the integration of crash avoidance technologies into the vehicle fleet (Table 1, Research Need 14).

In-service evaluation was another area where more research needs to be performed. Methods for performing in-service evaluations need to be developed and owner agencies need to be encouraged to perform these types of studies (Table 1, Research Need 3). There is also a great deal of uncertainty about what type of data needs to be collected. Clinical in-depth accident investigations provide a great deal of information but lack statistical significance. Broadbased statistical studies provide adequate numbers of cases but lack the detail required to determine exactly what happened in the accident.

Crash Testing and Simulation Research Needs

Crash testing has been the principal method for evaluating roadside safety hardware for more than 30 years. The past several years have seen some surprising crash tests, notable those involving full-size pickup trucks striking guardrails.

Vehicles have changed dramatically since the days when the most common roadside hardware was developed. In years past, the vehicle fleet changed relatively slowly and these changes could be accommodated by gradual changes in roadside hardware. Now, however, new types of vehicles are being developed, vehicles that were once "specialty" vehicles now represent a significant part of the vehicle population, and other vehicle types have essentially disappeared. These changes necessitate a re-evaluation of the compatibility between the present day vehicle fleet and the current generation of roadside safety hardware.

One particularly important vehicle is the 2000-kg pickup truck recommended as one of the crash test vehicles in NCHRP Report 350. The performance of this vehicle has been shown to be poor in impacts with a variety of roadside hardware. In addition to being recommended by Report 350, this vehicle is also a popular vehicle and growing portion of the vehicle fleet (Table 1, Research Need 13).

In-Service Evaluation and Barrier Performance Research Needs

The importance of in-service evaluations has been widely recognized by the roadside safety community for more than a decade although in-service evaluations are still relatively uncommon. NCHRP Report 230 was the first evaluation procedure to recommend that formal in-service evaluations be routinely performed. More than a decade later, NCHRP 350 re-emphasized the importance of in-service evaluation.*(5) (6)* The authors of Reports 230 and 350 recognized that without effective in-service evaluations, it was impossible to determine if barriers developed and tested under laboratory conditions performed as expected in the field. Performing research, developing more effective roadside hardware and developing public policy without in-service evaluations has been very difficult. Unfortunately, no accepted procedures or criteria have ever been developed for performing in-service evaluations so they are rarely performed. Today, hundreds of thousands of miles of roadside hardware are installed on the nation's highways and there is only a very limited appreciation for how these devices are performing under real-world operating conditions. This group discussed possible methods and procedures that could be used by the states and other highway agencies to perform in-service evaluations (Table 1, Research Need 2).

CONFERENCE RESULTS

Several of the discussion groups produced research needs statements and the conference attendees ranked the 15 research needs in terms of their importance as shown in Table 1. Each attendee was asked to rank the top five research needs, a score of five for the most important and no score for the least important. The total scores are shown in Table 1 in order of their final ranking.

In can be noted that several different groups independently produced virtually identical research needs statements or closely related ones. This was recognized in the closing session of the conference and suggestions made for combining, modifying, or supplementing the research needs in the final plenary session of the Workshop. After the Workshop these suggestions were used to formulate nine Research Problem Statements. Table 2 summarizes the nine Research Problem Statements and the full text is provided in Appendix A. The individual research needs scores were combined to obtain a ranking of the problem statements. It is important to note that research problem #1 has already been used to prepare a request for proposals for NCHRP Project 22-13 "In-Service Performance of Traffic Barriers." It is expected that this research will be initiated in early 1996.

SUMMARY

A great deal has been accomplished in improving the effectiveness of roadside safety hardware during the past several decades. The always-changing vehicle fleet and highway environment do not allow the roadside safety community the luxury of complacency. There are significant challenges ahead in improving roadside safety. These challenges can only be met by openly discussing difficult issues as they emerge and focusing the efforts all those with an interest in roadside safety on coordinated action.

REFERENCES

1. SCOHTS, "Highway Safety Strategic Plan: 1991-2000," Standing Committee on Highway Traffic Safety, American Association of State Highway and Transportation Officials, Washington, D.C., February, 1990.
2. NHTSA, *Traffic Safety Facts — 1992*, Report DOT-HS-808-022, National Highway Traffic Safety Administration, Washington, D.C., March 1994.
3. E. C. Cerrelli, *1994 Traffic Crashes, Injuries and Fatalities — Preliminary Report*, Report DOT-HS-808-222, National Highway Traffic Safety Administration, Washington, D.C., March 1995.
4. Carney et al, *Roadside Safety Issues*, Transportation Research Circular 436, Transportation Research Board, Washington, D.C., 1995.
5. J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, NCHRP Report 230, Transportation Research Board, Washington, D.C., 1981.
6. H. E. Ross, D. L. Sicking, R. A. Zimmer, and J. D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350, Transportation Research Board, Washington, D.C., 1993.

TABLE 1 RESEARCH NEEDS AND RANKINGS

No.	Score	Group	Research Problem Statement Title
1	30	C	Vehicle and roadside safety hardware compatibility and reconciliation of motor vehicle safety standards and roadside hardware evaluation standards.
2	29	E	In-service performance evaluation of traffic barriers and terminals.
3	27	C	In-service field performance evaluation of roadside hardware.
4	26	B	Accident severity/surrogate measure relationships.
5	24	C	Effect of airbags in roadside safety crashes.
6	22	B	Feasibility of collecting airbag crash sensor data.
7	21	D	Identification of factors causing vehicle rollovers on slopes.
8	20	C	Vehicle and hardware compatibility/2010.
9	17	D	Feasibility of retrofitting existing barrier hardware to meet changes in vehicle fleet.
10	17	B	Extent of unreported accidents.
11	15	C	Update NCHRP Report 350.
12	15	D	Develop an interim revision of NCHRP Report 350.
13	13	D	Development of a crash test matrix for the family of 2,000-kg vehicles.
14	8	C	Assessment of crash avoidance methods through ITS technologies for application to roadside safety features.
15	7	B	Revise severity estimates used in NCHRP 22-9.

TABLE 2 RESEARCH PROBLEM STATEMENTS AND RANKINGS

No.	Score	Research Problem Statement Title
—[1]	56	In-Service Performance Evaluation of Roadside Safety Hardware (combination of research needs 2 and 3).
1	67	Assessment of Means to Improve the Compatibility of Vehicles and Roadside Safety Hardware (combination of research needs 1, 8, and 9).
2	52	Assessment of Updating Needs for the Procedures for the Performance Evaluation of Roadside Safety Features (combination of research needs 11, 12, and 13).
3	46	Effect of Airbags on Roadside Accidents and Potentials for Post-Crash Utilization of Airbag Crash Sensor Data (combination of research needs 5 and 6).
4	33	Development of Accident Severity Indices and Surrogate Relationships (combination of research needs 4 and 15).
5	21	Identification of Factors Causing Vehicle Rollovers on Slopes (research need 7).
6	11	Determination of the Extent of Unreported Accidents (research need 10).
7	8	Assessment of ITS Crash Avoidance Methods for Application to Roadside Safety Features (research need 14).
8	—[2]	Clinical In-Depth Accident Studies.

Notes:

[1] Write-up not included because it was used to formulate the request for proposals for NCHRP Project 22-13, "In-Service Performance of Traffic Barriers."

[2] Late submittal, not rated by workshop participants.