Strategies for Improving Roadside Safety

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While there has been impressive progress to improve highway safety in the U.S. since the 1950s, there are still significant problems to be addressed. Roadside safety is one such problem. It accounts for about one-third of the fatalities and injuries and it has been estimated to impose an $80 billion dollar annual cost on the society. The NCHRP embarked on a comprehensive effort to address this problem in 1994. A distinguished group of professionals was assembled to review the problem, identify possible solutions, and define impediments to resolving the problem. This group determined that all aspects of the problem need to be considered in the search for means to address the problem. They subsequently sought inputs from other professionals knowledgeable about the roadway, driver, and vehicle aspects of the problem. They structured there possible solutions to the roadside safety problem in the form of a strategic plan. This plan is based upon five missions, each having a series of goals and objectives. Specific actions that should be undertaken are identified under each objective. Needs of information or research were listed where additional actions that are believed important have been identified. The outlines many "strategies" that can be undertaken to start addressing the problem now. It also provides a roadmap for efforts to increase awareness of the problem, establish the information resources needed to monitor roadside safety, measures that can keep the vehicle on the roadway, reduce the likely of a crash if a vehicle inadvertently leaves the roadway, and to minimize harm if a roadside object is struck.

INTRODUCTION

There has been a half-century long commitment in the United States to improve all aspects of highway safety. While efforts to improve roadside safety originated in the early years of the automobile, the major impetus in roadside safety began in 1960 with the Stonex's paper "Roadside Design for Safety" (*1*). Prior to that little attention was given to safety of the roadside and run-off-the-road accidents were attributed to "the nut behind the wheel." His paper identified common roadside hazards such as unprotected bridge abutments, blunt guardrail ends, rigid supports for street lights and signs, tree and utility poles, steep side slopes, and unsafe ditch sections. Solutions to these problems have evolved since then, but the problem still exists.

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THE ROADSIDE SAFETY PROBLEM

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. These traffic deaths, occurring one or two at a time all over the nation on each day of the year, do not receive widespread attention but the cumulative toll is more than 40,000 deaths and more than 3.5 million injuries (*2*,*3*). The safety of U.S. highways has improved since the 1950's as a result of efforts on many fronts. The number of highway fatalities has declined from a peak of almost 59,000 in 1969 to slightly less than 42,000 in 1995. The decrease is even more impressive when considered in terms of the great increase (doubling) in the vehicle miles of travel that has occurred resulting in a decrease in the fatality rate (i.e., the number of fatalities per 100 million miles traveled) from 5.5 in 1966 to 1.7 in 1995. This makes U.S. roads the safest of any industrialized nation.

Yet, even with this progress, the safety of travel remains an important concern because the number of fatalities and injuries is still too large. Roadside safety is a major component of the highway safety problem in the Unites States. Analysis of available data indicates that:

- On an average day in 1996, over 110 people were killed and over 6,000 persons sustained disabling injuries in crashes on U.S. highways. These grim statistics become even more startling when you realize that more people lose their lives on the highways each week than lose their lives in airline crashes annually.
- Roadside crashes account for one-third of the total U.S. fatalities each year. Each year, more than 14,000 people are killed and almost 1,000,000 people are injured in roadside crashes in the U.S (*4*).
- Roadside crashes cost society $80 billion per year. Traffic crashes impose a tremendous cost to society in medical costs, worker losses, property damages, and emergency services, in addition to pain and suffering. The annual societal cost of roadside crashes is more than three times the annual governmental expenditures on highways in the U.S. (*5*).
- Crashes with trees account for about 10% of the national fatalities. Approximately 3,500 fatalities and 90,000 severe injuries occur annually as a result of crashes into trees. Approximately 19% of the estimated roadside losses are attributed to tree crashes.
- Crashes with utility poles account for about 5% of the national fatalities. Approximately 1,500 fatalities and 110,000 severe injuries occur annually as a result of vehicle impacts into utility poles. About 14% of the estimated roadside losses are attributed to such crashes.
- Rollovers are the most severe type of roadside crashes. Rollovers occur in only 15% of roadside crashes, but are responsible for more than 25% of all roadside fatalities. Nearly three-quarters of rollovers occur on rural 2-lane roads where right-of-way is limited and lower, older design standards have been used. This

problem is exaggerated because today's hottest selling vehicles, pick-ups, sport utility vehicles, and vans, are more likely to roll.

These facts indicate, that despite dedicated efforts over the past three decades, the roadside safety problem remains a major source of injury, death, and economic loss.

ADDRESSING THE ROADSIDE SAFETY PROBLEM

Highway crashes occur when something goes wrong in the driver-vehicle-roadway system. Each element of this dynamic system has its limitations and is subject to failure as noted below:

- The Driver - Physical and mental limitations affect a driver's performance. Age, intoxication, fatigue, or emotion can affect the driver's ability to perceive a hazard, make decisions, and take action and thereby increase the probability of a crash. In addition, benign non-driving activities such as talking, eating, smoking, or adjusting the radio can distract a driver at an inopportune moment. Most drivers have received only minimal training for the driving task, and very few receive training to control a vehicle in incident situations or when it leaves the roadway. Overconfidence in driving abilities or ignorance of safety hazards can lead to risky behaviors, such as speeding, aggressive driving, inattention, and failure to "buckle-up."
- The Vehicle - A driver's control can be affected by vehicle and roadway conditions. Crashes often occur when the laws of physics overcome the driver's ability to control them as provided by the design and condition of the vehicle. Vehicle design can affect the likelihood of a crash and the severity of injuries resulting from a crash. Vehicles need to be compatible with roadside hardware to maximize the level of safety provided. Emerging technologies are expected to improve safety by providing supplemental information and/or automatic controls on the vehicle.
- The Roadway - Roadway geometry, pavement condition, and traffic control devices affect a driver's ability to maintain vehicle control and stay on the roadway. Ideally, clear areas can be provided along the highway to allow an errant vehicle to come to a safe stop or regain control and return to the roadway. Often, it is difficult to provide clear areas, so roadside safety hardware, such as, median barriers and crash cushions, are provided near hazardous roadside objects to protect the motorist in the event of leaving the roadway. There are many potential roadside hazards and treatments can be expensive, posing a major design challenge.

These elements must work in harmony, if the system is to provide mobility at an acceptable level of safety and a reasonable cost.

EXTERNAL INFLUENCES

Addressing the problem will not be easy due to the ever-changing dimensions of the problem. External factors that must be considered include:

- Changing vehicle fleet characteristics and increasing variance in vehicle size and weight
- Growing volumes of traffic across all periods of the day
- Growing demands by non-vehicle users of the highway
- Continued growth of urbanized areas and limits on right-of-way availability
- Deterioration of the infrastructure
- Increased costs associated with construction, repair, and maintenance of highways
- Aging driver population
- Increased competition for government resources.
- Resistance to highway improvements for environmental reasons.

Further, it must be recognized that the roadside safety problem is distributed over the almost 4 million miles of public roads in the U.S.

A VISION FOR IMPROVED ROADSIDE SAFETY

In an effort to address the roadside safety problem, the National Cooperative Highway Research Program (NCHRP) assembled a distinguished group of experts and charged them with the task of identifying ways to improve roadside safety (*6*). In their deliberations, they formulated a vision - A highway system where drivers rarely leave the road; but when they do, the vehicle and roadside work together to protect vehicle occupants and pedestrians from serious harm. To achieve this vision, the experts outlined five basic missions for transportation agencies:

- Mission 1 - Increase the awareness of roadside safety and support for it. Roadside safety cannot be enhanced until the public, decision makers, and other groups see it as a problem. Significant improvements to roadside safety will require a coordinated effort of transportation agencies, manufacturers, departments of motor vehicles, advocacy groups, and others. Additional funding at the federal, state, and local levels is needed to implement critical improvements and upgrade processes for safety management. Coalitions of government, industry, and civic partners should be formed to promote improved roadside safety.
- Mission 2 - Build and maintain information resources and analysis procedures to support continued improvements in roadside safety. A better understanding of the driver-vehicle-roadway relationship in roadside crashes is needed so that cost-effective remedies can be identified. Improved roadside and roadway inventory systems and better crash data are needed to provide highway designers, safety analysts, decision makers, and researchers with much-needed information. State-of-the-art computer analysis techniques can be used to monitor changing conditions and their influence on roadside crashes, provide better information to decisions makers, and/or simulate crash events. Safety audits, safety management systems, and other techniques can assure that efforts to improve roadside safety are most effective.
- Mission 3 - Keep vehicles from leaving the roadway. Roadside crashes occur when vehicles leave the roadway, as the result of driver error, vehicle failure, highway conditions, traffic situations, or environmental factors. Improved highway designs and better control of traffic operations can minimize the occurrence of events that lead to loss of vehicle control and roadside encroachment. Similarly, improved maintenance of highways and vehicles and innovative vehicle-based systems can help keep drivers on the road. Education, altered insurance regulations, and traffic law enforcement can promote appropriate driver behavior important to staying on the road.
- Mission 4 - Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway. The chances for severe injury or death increase greatly when an errant vehicle overturns or hits a fixed object. Utility poles, trees, steep side slopes, drainage facilities, and roadside hardware are potential hazards found along the roadside. The slopes and configurations of ditches on the roadside should be designed to reduce the

chances of rollover. Hazardous fixed objects should be held to a minimum and protected if they must remain. Vehicles should be designed to increase stability in run-off-the-road situations and driver needed to be educated about the proper actions in such situations.

- Mission 5 - Minimize injuries and fatalities when overturns occur or objects are struck in the roadside. When a vehicle rolls or strikes a fixed object, the risk of injuries can be reduced if the occupants are wearing seat belts and the vehicle has airbags and the vehicle has been designed to be crashworthy. Crash severity can also be reduced by better roadside hardware designs that absorb greater amounts of impact energy assuming that these devices are properly selected, installed, and maintained. Better emergency response after highway crashes can also contribute to reductions in the number of fatalities.

Defining the missions was only the first step in developing the roadside safety strategic plan. For each mission, a set of goals have been defined which indicate the desired outcomes. The five fundamental missions and the associated goals are presented in Table 1. These missions and goals have been further subdivided into objectives, actions, and needs so that the roles of various agents can be highlighted, action agendas formulated, and needs for research identified. A considerable degree of detail has been added to the strategic plan based upon inputs from many professionals with diverse backgrounds resulting from an interactive development process.

TRANSLATING THE VISION INTO ACTIONS

The efforts to identify actions in the strategic plan provided the basis for defining specific activities that could improve roadside safety or to reinforce continuance of current activities that are effective. As the strategic plan is being finalized, lists of action items are being developed for planning, design, construction, operations, maintenance, administrative, enforcement, and driver licensing functions of DOTs. In addition, the strategic plan provides a basis for identifying roles for vehicle designer, roadside hardware manufacturers, and other related disciplines. These allow consideration of the trade-offs between agents to determine where it is most effective to address the problem.

The details provided in the strategic plan provide the basis for further analysis. First, decomposition of the strategic plan also reveals areas where synergy can be achieved through the coordination of actions. It is also possible to isolate all actions that can be directed to specific problems for program development purposes. For example, crashes with trees are known to be a serious problem. By tagging all elements of the plan related to that issue, it is possible to recognize all necessary aspects of a program. The strategic plan also permits interaction analysis to provide the foundations for the establishment of coalitions, linking of activities, and finding places where multiple purposes can be achieved.

The NCHRP effort identified many strategies and actions for addressing roadside safety problems. Some of these actions can be

TABLE 1 Missions and Goals of the Strategic Plan

Missions	Goals
1 - Increase the awareness of roadside safety and support for it.	1-A network of partners. 2-Greater public awareness of the importance of roadside safety. 3-Increased emphasis by partners and better communication between them. 4-Sufficient fiscal resources to address critical needs. 5-Programs to disseminate roadside safety information. 6-Integration of roadside safety into SMS. 7-On-going process for updating the plan.
2 - Build and maintain the information resources and analysis procedures.	1-Improved roadway & roadside inventory data systems. 2-Comprehensive roadway safety information resources. 3-Effective tools and methods for safety analyses. 4-On-going programs to monitor roadside safety.
3 - Keep vehicles from leaving the roadway.	1-Improved highway designs and standards. 2-Improved traffic operating environments. 3-Improved vehicle-based systems to keep driver on the road. 4-Improved driver performance & behavior. 5-Sufficient levels of highway & vehicle maintenance.
4 - Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway.	1-Improved roadway design to reduce vehicle overturning. 2-Improved vehicle designs to increase stability. 3-Reduced numbers of hazardous objects on the roadside. 4-Improved driver performance in run-off-the-road situations
5 - Minimize injuries and fatalities when overturns occur or objects are struck in the roadside.	1-Improved roadside safety hardware. 2-Improved vehicle-roadside compatibility & crashworthiness. 3-Proper selection, design, installation, and maintenance of roadside features. 4-Improved emergency team response. 5-Increased seat belt use and effectiveness.

undertaken immediately, at little cost and others will take time and larger amounts of money to implement. Examples of some important actions are:

- Install shoulder rumble strips to alert drivers - Rumble strips located on the highway shoulder are effective in alerting drowsy or inattentive drivers when their vehicle is drifting off the roadway. These have been effectively installed on some interstate highways, but their potential use extends to rural two lane roads as well.
- Strategically remove or shield trees or utility poles close to the roadway - Pole placement policies need to be re-examined and programs need to be developed to reduce the number of poles on the roadside. Strategies for removing trees in particularly hazardous locations on the roadside (e.g., on the outside of tight curves) are needed to enhance the safety of the traveling public while maintaining the aesthetics of our highways.
- Use public service announcements and citizen initiatives to increase awareness - Impressive reductions in DUI have resulted from citizen initiatives such as MADD and SADD. Similar actions are needed to increase awareness of roadside safety, encourage greater use of seat belts, or discourage excessive speed on curves.
- Improve safety management systems - Transportation agencies need better and more accurate data and tools to manage highway safety. These systems can improve the practices for identifying hazardous locations, link highway features and accident data, assistance in making optimal decisions related to limited resources, and allow monitoring of changing traffic conditions that might increase roadside crashes. While most agencies maintain accident records and highway inventories, there is a need to upgrade, expand, and link this information to increase basic capabilities for safety management on a continuing basis.
- Implement proactive highway maintenance programs - Adequate maintenance will assure that the surface provides the skid resistance necessary to negotiate curves, minimize erratic maneuvers to avoid potholes, and eliminate shoulder drop-offs that can lead to loss of control. Attention should also be given to maintenance of adequate sight lines for the driver.
- Improve driver education programs - Drivers need to learn about the hazards of the roadside and rationale of traffic controls to help them to avoid situations where they could leave the roadway. It is even becoming possible to use simulators to train drivers in maneuvering through unusual situations, such as leaving the roadway.
- Increase speed enforcement at locations with known roadside safety problems - Plan police enforcement activities at or near locations where roadside crashes are known to occur. Use automated enforcement methods when they are available to increase enforcement coverage.
- Promote development of innovative technologies to keep vehicles on the road - Utilize ITS technologies to develop systems that will help drivers stay on the road or avoid hazardous objects or automatically prevent collisions.
- Improve the proficiency of persons responsible for roadside safety - Support safety professionals with a legacy of knowledge, interactive networks for information exchange, national databases, and updated training courses with upgraded delivery systems.
- Improve vehicle design to increase compatibility with roadside hardware - Upgrade vehicle designs to assure compatibility (e.g., establish minimums and maximums for bumper height) in both vehicle-to-hardware and vehicle-to-vehicle crashes.
- Improve hardware design - Develop improved methods for the design and testing of safety hardware including simulation methods. Exploit the properties of new materials in roadside safety hardware and review opportunities for new hardware. Assess the functionality of hardware in field applications.

There is a strong consensus that these and other actions can lead to major reductions in the deaths and injuries that are occurring on the roadside.

SUMMARY AND CONCLUSIONS

The efforts under the NCHRP Project are believed to have laid the groundwork for further efforts and a coordinated approach to improving roadside safety. More effort is needed, particularly to assure that all perspectives are considered and that the most cost-effective options are selected. 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.

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The strategies described in this paper were forged through from the contributions of many professionals over the last three years. Over 3 person-years of time was accumulated in 11 meetings, some having more than 100 participants. In these meetings, the vision, missions, goals, objectives, actions, and needs were incrementally identified and continually refined. The NCHRP Project 17-13 Panel participated in all of these meetings and served to assure that the strategies reflected a comprehensive, unbiased look that the roadside safety problem.

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