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Strategic Plan for Improving Roadside Safety

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CHAPTER 1

INTRODUCTION

There is a four decade-long commitment in the United States to highway safety. In the United States, highway safety is considered a societal responsibility shared by government, industry, public interest groups, and highway users. Our society's commitment to safety reflects its compassion for individuals, even when those individuals do not behave responsibly. This societal commitment to safety does not eliminate the individual's responsibility for driving and behaving in a safe manner, but it does obligate all those involved in the building, operating, and maintaining of vehicles and roadways to make a concerted effort to protect the users of our nation's roadways.

As a result of this commitment, highway safety has improved greatly. Traffic fatalities in the US peaked at 53,543 in 1969 and dropped 27% to a recent low of 39,250 in 1992. Since 1993 annual fatalities have remained relatively constant, fluctuating between 40,150 and 42,065. The fatality rate, measured in fatalities per 100 million vehicle-miles of travel (100 MVMT), has improved more dramatically. Since 1966 when the rate was 5.5 fatalities per 100 MVMT, it has dropped 72% to an estimated 1.5 in 1999.

Even with the great strides that have been made in safety still every 6 days more people are killed on US highways than are killed annually on airlines around the world. On an average day, 113 persons are killed and nearly 9,000 are injured in US highway crashes. This gruesome statistic is equivalent to a crash of a 747 every three days plus 3,200,000 injuries per year resulting in annual societal cost of over 100 billion dollars. Traffic crashes happen every day in every state and are so common that most people ignore them until a friend or relative is involved. Statistics predict that, in a lifetime, 1 out of 2 people will be killed or injured in a traffic crash. Additional efforts are needed

to improve highway safety and reduce the number of people being killed and injured on US highways.

THE ROADSIDE SAFETY PROBLEM

Each year roadside crashes cost society an estimated $110 billion, killing approximately 15,000 people and injuring another 1,000,000. Many of these crashes involve single vehicles that run off the highway and either overturn or crash into a fixed object such as a tree or pole.

Fatalities related to roadside crashes peaked in 1980 at 20,352, which represented 40% of the 51,091 people killed in US highway crashes and 49% of motorists killed (excluding pedestrians and pedal cyclists). By 1997 roadside-related fatalities had dropped 27% to 14,940, representing 36% of highway fatalities and 42% of motorists killed.

Despite dedicated efforts over the past three decades, the roadside safety problem remains a major problem. The ever-changing characteristics of the vehicle fleet, driver population, traffic conditions, and highway environment make improving roadside safety a difficult task. Addressing the remaining roadside safety problems may represent an even greater challenge than previously faced in improving highway safety.

ADDRESSING THE PROBLEM

Highway crashes occur when something goes wrong. It could be a mechanical failure, roadway deficiency, driver error, medical emergency, or a combination of these factors. Addressing the roadside safety problem requires that all elements of the roadside-vehicle-driver system be considered. This system is always in a state of flux as a result of changing traffic, roadway, and environmental conditions. Each element of the system has its limitations and is subject to failure.

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

The importance of the roadside safety problem has been recognized by different organizations including the Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), National Highway Traffic Safety Administration (NHTSA), Transportation Research Board (TRB), Roadway Safety Foundation, Insurance Institute for Highway Safety, and others. The need for coordination of activities was recognized by AASHTO, and in 1995 the National Cooperative Highway Research Program (NCHRP) initiated Project 17-13, "Strategic Plan for Improving Roadside Safety."

NCHRP PROJECT 17-13

The impetus for a strategic plan emerged from the current climate of reduced governmental funding and distributed control over highway programs. For progress to be made in roadside safety, it is vital that there be a strategic, multi-organizational approach to improving highway safety in general and roadside safety in particular. All members of the roadside safety community need to work together to maximize the effectiveness of their coordinated efforts through the formation of strategic partnerships.

The initial objective was to develop a consensus plan for future research activities in roadside safety. The plan was intended to identify the gaps in current knowledge and define the scope and priorities for research activities believed necessary to address them. It became apparent that focusing strictly on research needs would not be sufficient to address the problem. Consequently, a comprehensive approach was pursued to define all strategies that could lead to improvements in roadside safety. This approach required the involvement of highway designers,

vehicle manufacturers, roadside safety hardware developers, law enforcement personnel, safety advocates, academics, and others.

A panel of fifteen prominent roadside safety experts from state DOTs, FHWA, NHTSA, universities, safety hardware and vehicle manufacturers, and a safety advocacy group was formed to develop the strategic plan. A number of multi-day meetings were held from 1995 to 1997 with many additional people participating at times in the plan development. This process produced a strategic plan with 5 missions, 25 goals, 78 objectives, and 359 action items all directed toward achieving the following 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.**

ORGANIZATION OF THE REPORT

This report summarizes the results of the 6-year effort to develop a strategic plan for improving roadside safety in the United States. The outline below shows the organization of the report.

Chapter	Topic
2	The Roadside Safety Problem
3	Roadside Safety Programs
4	Roadside Safety Issues
5	Strategic Plan Development
6	Action Plans for Improving Roadside Safety

GETTING STARTED

Now that the strategic plan has been completed, the next step is to identify the "champion" who will assemble and lead the roadside safety coalition. FHWA, AASHTO, and NHTSA need to work together to engage the appropriate organization or groups to accept this responsibility.

CHAPTER 2

THE ROADSIDE SAFETY PROBLEM

The vision of the creators of the strategic plan to improve roadside safety is to have ***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.** Before a plan can be developed to reach this desired state, a clearer understanding of the roadside safety problem is needed.

Roadside crashes are very rare events when considered from the viewpoint of an individual traveler. For a given trip of 25 miles, the probability of a driver being involved in an injury-producing roadside crash is approximately one in 100,000. Drivers do not expect to be involved in roadside crashes, and most of the time they are correct in this assumption. However, in a country where drivers travel over 2,500,000,000,000 miles per year even very rare events can become major problems when considered in the aggregate.

Roadside crashes are rare because for the most part our highway system is very safe. Something has to go wrong with the driver, vehicle, or roadway before a roadside crash can occur. Each of these components is subject to failure, and thus the highways, vehicles and drivers must have built-in safety features to compensate for these failures that inevitably will occur. The types of errors most likely to cause roadside crashes and the societal costs associated with roadside crashes must be identified before cost-effective strategies can be developed to improve roadside safety.

A comprehensive analysis of roadside crashes by Viner (*1*) estimated societal costs of reported 1985 U.S. roadside crashes to be $65 billion in1988 dollars. Inflating these values to current dollars and current roadside crash levels produces a current estimate of $110 billion (2000

dollars) for the annual societal cost of roadside crashes. These losses are equivalent to $1,600 per year for an average family of 4 persons.

MOST HARMFUL EVENT IN ROADSIDE CRASHES

Table 1 shows the distribution of 1985 roadside crashes by most harmful event (MHE). Overturn, tree & shrubbery, and pole and post are clearly the three most critical events in roadside crashes. These types of crashes are the most severe roadside crashes accounting for 66% of the societal costs, 72% of fatalities, 61% of injuries, and 43% of property-damage-only (PDO) crashes.

The second tier of roadside crashes involves a highway feature as the MHE. Embankment, longitudinal barrier, bridge rail, bridge end, bridge pier, and ditch are responsible for 21% of the societal costs, 16% of fatalities, 27% of injuries, and 24% of PDO crashes. The other seven types of roadside crash shown in Table 1 represent the remaining 13% of the societal costs, 12% of fatalities, 12% of injuries, and 33% of PDO crashes.

A comparison of the distribution of 1997 FARS (*2*) roadside crash fatalities to Viner's 1985 crashes is shown in Table 2. The most harmful event was unknown for 790 of the 1997 crashes and "adjusted" total were computed using the first harmful event as a surrogate for MHE. The 1985 to 1997 change in the proportion of crashes represented by each type of roadside crash is shown for the unadjusted and adjusted values. Little change has occurred in the distribution except for overturn crashes and pole and post crashes. Overturn is now responsible for two-fifths of roadside fatalities compared to one-third in 1985. Pole and post crashes now account for one-ninth of roadside fatalities compared to one-seventh in 1985. The decrease in the number of pole and post-related crashes is encouraging, but the large increase in overturn crashes is very disturbing.

A study performed by McGinnis (*3*) examined longitudinal trends in fatal roadside crashes to see how various driver, vehicle, and roadway factors relate to run-off-road crash rates. Data from FARS, the National Personal Transportation Studies (NPTS), and the Federal Highway Administration's Highway Statistics publications were used to analyze crashes occurring from 1975 through 1997. Although fatal crashes represent only a small percentage of highway crashes, they do command a lot of attention because of their severity and associated large societal costs.

RUN-OFF-ROAD FATAL CRASHES 1975 TO 1997

Fatal Run-off-road (ROR) crashes peaked in 1980 when 19,852 people were killed in 18,174 ROR primary crashes. Run-off-road primary crashes are composed primarily of single-vehicle crashes that occur off the roadway. Another 500 people were killed in ROR secondary crashes, multi-vehicle crashes in which the first harmful event is not on the roadside, but the most harmful event is hitting an object on the roadside. In 1980 ROR crashes accounted for 40% of the 51,091 people killed in motor vehicle crashes.

Luckily, highway safety in the United States has been improving. By 1997 total fatalities associated with motor vehicle crashes dropped to 35,693, a savings of 15,398 lives (a reduction of 30%) over a period when vehicle-miles of travel increased by 67%. ROR fatalities in 1997 dropped to 14,940, a savings of 5,410 lives (26.5%) from the peak levels of 1980, but their proportion of total fatalities increased to 42%. Had ROR fatalities reduced at the same rate as non-run-off-road (NROR) fatalities (32.5%), an additional 1,200 lives would have been saved in 1997 compared to 1980.

Appendix B contains a detailed analysis of fatal crashes that occurred in the US between 1975 and 1997. Longitudinal trends in roadside crashes were analyzed to see how driver

characteristics such as gender, age, and alcohol usage relate to ROR crashes. Run-off-road (ROR) crash rates, adjusted for driving exposure, have decreased 40% for male and female drivers since peaking in 1980. The greatest improvement has occurred at night on rural and urban, non-interstate highways.

Young drivers, male drivers, drivers over 70, utility vehicles, rollovers, and alcohol pose special challenges for roadside safety improvements efforts. Male drivers have higher ROR crash rates than females even after adjusting for driving exposure. Males 20 to 24 have ROR crash rates 3.3 times females of the same age. Using ROR crash rates for female drivers 40 to 49 as a base, ROR rates for teenage males are 20 times as high and for teenage females 9 times as high. For drivers 70 and older, these ratios are 4.5 for males and 4.0 for females. Alcohol involvement in ROR crashes is nearly 50% for male drivers 20 to 39 and is over 50% for all drivers during dark conditions. From 1975 to 1997 the number of utility vehicles involved in ROR crashes increased nearly 600%. Seventy percent of fatal ROR crashes with utility vehicles involve a rollover. Rollovers rates for vans and pickups involved in fatal ROR crashes are nearly 5 times those for non-ROR crashes. See Appendix B for details of this analysis.

CHAPTER 3

ROADSIDE SAFETY PROGRAMS

In the United States, highway safety is considered a societal responsibility shared by government, industry, public interest groups, and highway users. Our society's commitment to safety reflects its compassion for individuals, even when those individuals do not behave responsibly. This societal commitment to safety does not eliminate the individual's responsibility for driving and behaving in a safe manner, but it does require that all those involved in building, operating and maintaining vehicles and roadways make a concerted effort to protect the users of our nation's roadways.

CHRONOLOGY OF ROADSIDE SAFETY CONCERNS AND DEVELOPMENTS

Since the early years of the automobile there have been efforts to improve roadside safety. Examples can be seen in old film footage of vehicle manufacturers' testing of vehicles for rollover and in the highway design standards of the early 1930's which included provisions for traffic barriers and clear roadside areas.

Ross (4) suggests that the major impetus for roadside safety began in 1960 with Stonex's article, "Roadside Design for Safety," (5) published in the Highway Research Board's Proceedings. Prior to this time little attention was given to roadside safety because run-off-the-road crashes were attributed to "the nut behind the wheel." Stonex's paper identified common roadside hazards such as blunt guardrail ends, rigid supports for street lights and signs, trees and utility poles, steep side slopes, and unsafe ditch sections and offered potential solutions to these problems. Subsequent to this publication significant improvements in roadside safety have occurred as a result of governmental and private sector actions.

Improving roadside safety requires a multifaceted approach, and over the last four decades developments in legislation, design guidelines, testing procedures, roadside safety products, and modeling techniques have combined to make today's highway roadsides much safer. Many of these improvements are the results of research conducted and sponsored by governmental agencies, safety advocacy groups, vehicle manufacturers, roadside hardware manufacturers, and universities.

Notable milestones in roadside safety since 1960 have been compiled by Ross (4) and others and are summarized in Appendix C. The milestones are grouped by category (legislation, highway design guidelines and warrants, testing procedures, product developments, modeling developments, vehicle design, and roadside safety research) and listed in chronological order by decade.

CURRENT ROADSIDE SAFETY PRECEPTS

Roadside safety practices have evolved over the years. Today's approach to roadside safety is to:

1) keep the vehicle on the roadway,
2) remove, remedy, or shield roadside hazards for those vehicles that do leave the roadway, and
3) minimize injury to occupants of vehicles that collide with roadside hazards.

Each of these aims requires a specific strategy that considers the three components of the problem: the roadway/roadside, the vehicle, and the driver.

Keep the vehicle on the roadway

Obviously if it were possible to keep all vehicles on the roadway at all times there would be no roadside safety problem. Unfortunately, the complexities of the roadway-vehicle-driver

relationship are such that achieving one hundred percent success in keeping vehicles on the roadway is not feasible with current technology. However, current practices are able to prevent most roadside encroachments so that roadside crashes are in many respects rare events.

Roadway/Roadside Design

Improvements in geometric design standards established by the interstate highway program have reduced roadside encroachments by providing more consistent and safer horizontal and vertical alignments. Many of these standards have been applied to new non-interstate roadway designs.

Design enhancements directed specifically toward reducing roadside encroachments include rumble strips, roadway and lane delineation (including raised pavement markings), improved signage, and better lighting. More attention given to highway maintenance has also been important in reducing roadside encroachments: quick repair of potholes, pavement edge drop-offs, and slippery pavement surfaces are examples.

Problems do exist even on highways built and maintained to the highest standards. Greater congestion on highways has increased the number of roadside encroachments that arise from inter-vehicle actions resulting from aggressive drivers, inattentive drivers, and traffic slowdowns. Higher operating speeds and increased numbers of work zones have exacerbated these problems.

A significant number of run-off-road crashes occur on secondary roadways, many of which were built 40 or more years ago using design standards no longer considered appropriate. These roads pose special problems for drivers who are accustomed to driving on highways built to modern-day standards.

Vehicle Technology

Improvements in vehicle headlights and braking systems have helped drivers avoid run-off-road crashes. Brighter and better-focussed halogen headlights illuminate the roadside better giving drivers improved information for vehicle guidance. Anti-lock brakes, now available on most vehicles, allow steering to occur during emergency braking operations giving drivers a chance to avoid leaving the roadway.

Vehicle manufacturers have started the development of lane sensing systems that will be able to alert drivers when they inadvertently go off course. The lifting of the precision constraints on the Global Positioning System (GPS) by the Department of Defense will create opportunities for using GPS to alert drivers about to encroach on the roadside. Night vision enhancement, a military technology, is being explored as a means of providing guidance assistance to drivers during dark and low visibility situations.

Driver Programs

Young inexperienced drivers and intoxicated drivers are the two types of drivers most prone to having run-off-road crashes. Public awareness programs about drinking and driving promoted by organizations such as MADD and SADD have been successful in making drinking and driving less socially acceptable. The decrease in drunk driving has helped reduce the number of roadside crashes, but a large percentage of roadside crashes still involve impaired drivers.

Many states have implemented graduated licensing programs for their young drivers that put special restrictions on teenage drivers as far as nighttime driving, the number of people riding with them, and the amount of driver training required to obtain an unrestricted license. Most programs also contain a zero-tolerance clause to encourage young drivers to avoid drinking alcohol or using

drugs. Youths arrested for illegal use of alcohol or drugs, even if not driving, are subject to license suspension or revocation. These programs are a step in the right direction, but young drivers still have the highest risk of having a roadside crash.

Remove, remedy, or shield roadside hazards for those vehicles that do leave the roadway

Forgiving Roadside

Knowing that it is inevitable that some vehicles will encroach on the roadside, highway designers have tried to make the roadside as forgiving as possible within physical and fiscal constraints. The term "forgiving roadside" is thought to have originated in the 60's. K. A. Stonex, Paul Skeels, and others at the General Motors Proving Ground recognized the need for clear zones and were effective in promoting this concept with highway engineers.

A forgiving roadside is free of obstacles that could cause serious injuries to occupants of errant vehicles. When possible, a relatively flat, unobstructed roadside recovery area should be provided; and when these conditions cannot be provided, hazardous features in the recovery area should be made breakaway or shielded with appropriate barriers.

A clear zone was first recommended in the 1967 AASHO Yellow Book. (6) The width of 30 feet was based primarily on General Motors Proving Ground studies of the lateral extent of movement of vehicles inadvertently leaving their test track. In 1977, AASHTO's *Guide for Selecting, Locating, and Designing Traffic Barriers* (*7*) refined the clear zone concept to consider factors such as side slope, operating speed, traffic volume, and horizontal curvature to determine the appropriate width for a particular location. Today's clear zone guidelines are still based on the 1977 AASHTO barrier guide.

Surprisingly little information is available on the frequency, angle, and length of roadside encroachments making it difficult to establish relationships between clear zone width and safety. Without this information it is difficult to develop clear zone guidelines that consider both the benefits and costs of providing wider recovery areas.

NCHRP Project 17-11, Recovery-Area Distance Relationships for Highway Roadsides, is expected to develop new guidelines for determining safe and cost-effective recovery areas. These guidelines will consider facility service level, traffic operating conditions, roadway alignment, roadside conditions, right-of-way cost, hazard locations, and the potential benefits from reducing the number and severity of roadside crashes.

Utility poles and trees are common roadside hazards, but currently there is no national policy that addresses the removal of hazardous trees and utility poles from the roadside. Laws governing the placement of utility poles in public highway rights-of-way vary from state to state and some times from municipality to municipality. Millions of utility poles located adjacent to roadways pose danger to motorists, but utility companies have not been eager to remove their poles from the roadside. Removing trees from the roadside often conflicts with the desire of many people to have landscaped highways that blend with their surroundings.

Roadside Barriers

Longitudinal roadside barriers have been used for over 50 years to shield roadside hazards from motorists. Steel and concrete are the common materials used in these barriers that are typically located adjacent and parallel to the roadway. Steel rails with a W-shaped cross-section or thrie beam cross-section, box beams, and wire ropes have been the most common steel systems. Either “strong” posts or “weak” posts support these systems. Concrete barriers with various cross-sections known as the New Jersey shape, F-shape, and constant slope are used throughout the US.

Barriers are categorized as rigid (concrete barriers), semi-rigid (strong-post and box-beam systems), or flexible (weak-post w-beam and cable systems). Rigid systems deflect little when hit and consequently do not absorb energy from the impacting vehicle. Vehicles are redirected from the barrier, often back into the flow of traffic. The maximum deflections of semi-rigid barriers are usually under 1m, and they do absorb some of the crashing vehicle's energy during vehicle redirection. Flexible barriers are the most forgiving to the vehicles because they absorb energy as the barrier "stretches" during impact. These barriers, however, have large deflections (2m to 4m) and can be used only when the clear space behind the barrier is sufficient to accommodate the barrier deflection.

The design and testing of roadside barriers has become increasingly sophisticated over the years. Today all barriers must be crash tested to prove their crashworthiness before they can be installed. Sophisticated finite element analysis may be used to optimize barrier designs by simulating crash tests on a computer. Once the design works well in the simulation, it can then be subjected to the more expensive full-scale crash tests. Crash test requirements and procedures are described below.

Minimize injury to occupants of vehicles that collide with roadside hazards

Protecting vehicle occupants from serious injuries resulting from crashes into roadside hazards can be accomplished by enhancing the safety features of the vehicle and by decreasing the danger of the roadside obstacles. The highway infrastructure includes many potential roadside hazards such as drainage structures, bridge supports, traffic control devices, signs, embankments, ditches, and longitudinal barriers.

Designing Crashworthy Roadside Hardware

Optimally, roadside hardware should be designed so occupants of errant vehicles striking the hardware are not injured severely. To accomplish this goal guidelines for full-scale crash tests that determine the crashworthiness of roadside hardware have been developed and refined over the past 30 years.

Evolution of US Roadside Hardware Crash Test Guidelines (8)

Initial test guidelines applied only to longitudinal barriers, and the test results were evaluated subjectively. It was realized that vehicular accelerations were indicators of occupant risks, and efforts were made to minimize accelerations. In early breakaway support development, change in vehicular momentum was used as an indicator of occupant risk. Subsequently it was realized that change in vehicular velocity was a better indicator of occupant risk since it was not dependent on the vehicle's mass.

In the late 60's and early 70's, an acceleration severity index (ASI) was adopted for use in evaluating vehicular response to encroachments onto roadside geometric features such as ditches, embankments, and median crossovers. It was an interaction relationship involving the ratios of average vehicular accelerations in the x, y, and z directions to tolerable accelerations in those directions. Although this approach was abandoned by US researchers many years ago, some European countries still use it to evaluate tests of various roadside features. In fact, the ASI will be included in test standards for "road restraint systems" by the Committee on European Normalization (CEN).

NCHRP Report 153 (9), published in 1974, contained state of the art test and evaluation guidelines for longitudinal barriers, crash cushions, and breakaway features. Impact severity of

longitudinal barriers was evaluated by limiting values of vehicular acceleration in the longitudinal and lateral directions. Direct, head-on impacts with crash cushions were evaluated by limiting acceleration in the longitudinal direction computed over the stopping distance.

NCHRP Report 230 (10), published in 1980, updated Report 153. Among other things, it revised completely the occupant risk evaluation criteria by introducing the "flail space model." It represented the occupant as an unrestrained lumped mass, free to flail in the vehicular x-y plane, within a given "occupant compartment." The velocity at which the occupant struck the compartment and the ridedown accelerations subsequent to contact were measures of occupant risk.

NCHRP Report 350 (11), published in 1993, updated Report 230. Although some changes were made in the "structural adequacy" and the "vehicle trajectory" evaluation criteria, only minor changes were made to the occupant risk criteria, and the basic flail space model was retained. Other revisions to Report 350 included changes in test vehicles, changes in the impact conditions and number of tests required to evaluate a feature, adoption of the "test level" concept, inclusion of test guidelines for additional features, and adoption of the International System (SI) of units. While Report 350 does require testing under a variety of impact conditions, these “standard” conditions do not represent the full range of conditions that can be found in the field.

Both Reports 230 and 350 pointed out that field evaluation was the final and perhaps the most important step in the evaluation of a feature. Both reports provided guidelines by which a feature could be field evaluated. However, to a large extent, field evaluation remains the weak link in the assessment of a feature's performance and suitability for use. Notable exceptions are the field studies the New York DOT conducted on many of its barrier systems, studies by the Kentucky DOT on end treatments, studies by California DOT on median barrier performance, studies by Texas DOT on end treatments, studies by FHWA on selected safety features, and in-service performance

studies conducted by Malcolm Ray et al as part of NCHRP Project 22-13, In-Service Evaluation of Traffic Barriers. Proprietary systems are often closely monitored by their suppliers/manufacturers, especially during the period of their initial use. Problems that arise in proprietary systems are usually corrected quickly, and changes to improve performance and reduce costs are incorporated.

The FHWA has also played a key role in the evaluation and implementation of new safety features. FHWA has served as an arbiter in establishing acceptability and operational status of new features to be used on federal-aid highways. An assessment is made based on design details, specifications, and crash test results. State highway agencies typically rely heavily on this assessment to determine which safety features to use on their highways.

Design of a roadside safety feature is an arduous process. Most safety features are highly non-linear structural systems, usually supported by highly non-linear soils, being struck by speeding, highly non-linear vehicles. Furthermore, the design should be aesthetically pleasing, meet environmental requisites, have a long design life, require minimal maintenance, and not cost too much.

Computer simulation programs have provided insight and served as design tools in recent years. As the sophistication of the software and the power of the hardware increase, computer simulation programs are better able to predict behavior and failure modes observed in crash tests. However, until computer simulations are able to reproduce the results of full-scale crash tests, crash testing, with all its limitations, remains the ultimate proof of a feature's acceptability.

Evolution of Vehicle Design

The improvements in highway safety seen over the last four decades could not have been achieved without the evolution of vehicle design to provide greater safety. The creation of the

National Highway Traffic Safety Administration (NHTSA) in 1970 and their subsequent promulgation of vehicle safety standards have reduced the consequences of all crashes including those on the roadside.

Improved in-vehicle occupant protection systems such as energy-absorbing interior features, head restraints, seat belts, frontal air bags and side airbags are helping to reduce the severity of injuries in motor vehicle crashes. Auto manufacturers, aware now that safety sells, are working hard to develop improved safety features for their vehicles.

Driver Programs

Rollovers in roadside crashes are common and are associated with increased risk of serious injury or death. Being secured by a seat belt during a rollover greatly increases the chances of surviving the crash without serious injury. Primary seat belt laws have been successful in getting more motorists to buckle up; however, many states still have not passed the necessary legislation to allow full enforcement of seatbelt laws. Public awareness campaigns when coupled with enforcement programs have also had some success in increasing seat belt usage, which contributes to reductions in injury severity in all types of roadside crashes.

Recent publicity about air bags injuring children and small women have increased motorist's awareness of the safety aspects of air bags and the need to place child car seats in the proper location. Hopefully drivers concerned about the safety of air bags will adjust their seating positions rather than disconnect their air bag system.

CHAPTER 4

ROADSIDE SAFETY ISSUES

Efforts over the past four decades to improve roadside safety have had a dramatic impact on the number of roadside crashes and injuries. These accomplishments have been achieved through dedicated endeavors by nearly every segment of the highway transportation industry. While these efforts are commendable the problem has not been solved. The programs, resources, and collective wisdom of the various constituents of the highway transportation community need to be brought together and used to formulate a unified strategic plan for improving roadside safety.

This chapter discusses the issues that need to be resolved if roadside safety is to be improved significantly during the first decade of the 21st century. The issues are organized by topic (awareness, funding, legislation, and technology) and by sector (agency and public-private). Because of the importance of research needs and issues, they are discussed separately in Chapter 7.

AWARENESS OF THE ROADSIDE SAFETY PROBLEM

The media is extremely effective is raising the public's awareness of issues; and without media coverage, getting the public's attention is very difficult. A crash of a commercial airliner is surely to attract widespread media coverage, and within hours the entire nation is aware of the tragedy that has occurred. The recent problem with Firestone tires on sports utility vehicles captured the attention of the media, and within days the nation was aware of the problem and congressional hearings were held to investigate the problem.

Each of these examples involves a failure in the transportation system that caused the death of a number of persons. However, roadside crashes kill just as many people each week of

each year. But, media coverage of this carnage is limited to spots on the local news and articles in local newspapers. Occasionally a particularly disastrous crash involving multiple fatalities or someone of notoriety (e.g., Princess Diana) may attract state or national media attention, but this coverage is short-lived and soon forgotten by the public.

If roadside safety is to be improved markedly, the public must be aware that the problem exists, and they must want the problem solved. Precious governmental resources will not be appropriated to solve a problem that is not recognized as a problem by the majority of the population. Getting the public interested in solving the roadside safety problem must be a major tenet of the strategic plan.

Legislative leaders at the federal, state, and local levels need to be aware of the magnitude of the roadside safety problems so that legislation can be adopted to provide the policy and funding support needed to improve roadside safety. Governmental agency leaders need to understand their role in establishing programs and policies that insure cost-effective use of safety funds to improve roadside safety. The general consciousness of the public to roadside safety needs to be raised so that driving behavior can be modified in ways that improve highway safety. Once everyone is aware of the gravity of the roadside safety problem, developing and implementing solutions will be much easier.

FUNDING

One would think that a national problem that is responsible for societal losses of over $100 billion each year would be at the top of the list for Congressional funding. Unfortunately, roadside safety has not been a high priority.

Long-term funding commitments are needed to solve the roadside safety problem, and these funds will need to come from a variety of sources including federal, state, and local governments as well as from the private sector. Funding issues include:

- Should roadside safety be funded on its own (similar to highway-railroad grade crossing safety) or as a component of a general highway safety program?
- Should roadside safety be funded through dedicated revenue sources, e.g., designated portion of fuel tax revenues, vehicle registration fees, or traffic fines, or should it be funded through annual appropriations?
- Should the federal government provide the major part of the funding or should the states and local governments provide it?
- What role should private sector groups (e.g., the National Safety Council, Automobile Association of America, insurance companies, and health care providers) have in funding roadside safety improvements?
- What should be the appropriate roles of the FHWA, AASHTO/NCHRP, state DOTs, and the private sector in funding roadside safety research?
- What role do motor vehicle manufacturers have in providing funding to improve roadside safety through R & D efforts to improve vehicle crashworthiness, in-vehicle encroachment warning systems, dynamic vehicle stabilizers to prevent rollover, etc.?

LEGISLATION

Legislation at the federal, state, and local levels will be needed to provide the funding, policies, programs, and standards necessary to improve roadside safety. Governmental agencies and police forces must have sufficient resources to carryout and enforce the various legislative

mandates. The following are some of the legislative issues associated with roadside safety improvements:

- Should federal legislation be passed to mandate seat belt usage and enforcement of the law?
- Should federal motor vehicle safety standards ensure that passenger vehicle designs are compatible with roadside safety hardware?
- Should federal motor vehicle safety standards include requirements for vehicle stability?
- Should federal crashworthiness standards be upgraded to make vehicles safer for occupants in roadside crashes?
- Should federal legislation be passed to require state DOTs to establish and maintain highway safety management systems?
- Should graduated licensing programs be expanded to require specific training to help young (and aging) drivers be better prepared to avoid running off the road?
- Should driver license renewals (particularly for the elderly) be subject to periodic vision and driving ability tests?
- Should legislative action be taken to encourage or require utility companies to remove poles that are roadside hazards?
- What legislative actions can be taken to discourage aggressive driving?

TECHNOLOGY

Crash Test Guidelines

As discussed in the previous chapter the guidelines for testing the crashworthiness of roadside safety hardware have evolved over the last 40 years. The current guidelines are

contained in NCHRP Report 350, published in 1993. These guidelines cover the test facility, test article, test vehicles, test conditions, and evaluation criteria for longitudinal barriers, terminals, crash cushions, support structures, work zone traffic control devices, breakaway utility poles, and truck-mounted attenuators.

A major change from the previous guidelines was the substitution of a 2,000-kg pickup truck for the 4,500-lb passenger car in the crash tests evaluating structural adequacy. This change has proved to be a challenge to hardware manufacturers because of the higher center-of-gravity and greater instability of the pickup truck as compared to the passenger car.

The NCHRP Report 350 guidelines have been the focus of discussions at the 1999 and 2000 summer meetings of TRB Committee A2A04, Roadside Safety Features. NCHRP Project 22-14, Improvement of Procedures for the Safety-Performance Evaluation of Roadside Features, initiated in 1997 and to be completed in 2001, will provide recommended modifications to the Report 350 guidelines. Some of the testing issues are:

- Should test vehicles at the extremes of the weight range (2,000-kg pick-up truck and 700-kg car) continued to be used or should vehicles more representative of the vehicle fleet be used?
- Is the 2,000-kg pickup truck the correct vehicle to use for the structural adequacy tests?
- Should the 700-kg vehicle be eliminated from the test matrices since it is no longer a commonly used vehicle in the US?
- Should the 820C vehicle be changed because of its disappearance from the vehicle fleet?
- Should a mid-sized vehicle be added because of its large representation in the vehicle fleet?
- Should the soil conditions in the tests be controlled better, be more representative of actual field conditions, be worst case, or be standardized?

- Should test speeds be increased from the current maximum of 100 kph to levels more consistent with today's freeway speeds?
- Should impact angle/speed conditions be changed to be more representative of the majority of roadside crashes?

Role of Computer Simulation

Simulation is a modern analytical technique that can be used to understand the expected performance of vehicular and roadside safety hardware. Nonlinear finite element analysis allows a detailed study of impact reactions and associated forces to predict the severity of roadside collisions helping designers formulate more effective designs. Once a finite element model of a vehicle or roadside safety appurtenance (e.g., barrier, crash cushion, small sign support) has been developed, the performance impacts of design changes can be examined quickly and with confidence.

Another significant advantage of using finite element simulations is the ability to explore impact situations that are difficult or impossible to test. For example, there is no convenient method for performing full-scale tests with non-tracking vehicles crashing sideways into roadside features. Computer simulation can provide a way to explore this important scenario. Simulation also provides a cost-effective way to identify the critical impact point (CIP) for a particular hardware design. NCHRP Report 350 guidelines require that certain impacts occur at the CIP. Thus, simulation allows hardware developers to limit expensive full-scale crash testing to the most promising design alternatives.

Issues related to the use of simulation include:

- Are the results of computer simulations good enough to replace full-scale crash tests?

- Should simulations be required in addition to full-scale crash tests to predict the outcome of conditions not covered by full-scale tests?
- What validation procedures should be used to check the results of simulations?
- Should vehicular manufacturers be required to develop and provide finite element models of their vehicles for roadside hardware evaluation?

AGENCY ISSUES

A variety of agencies have roles in roadside safety as regulators, designers, builders, maintainers, operators, overseers, and enforcers of the highway system and its rules. A successful strategic plan must ensure that each of these agencies understands its responsibility, how to carryout its role, and how to coordinate with the other agencies working to improve roadside safety.

State departments of transportation have major roles in roadside safety since they are typically the agencies that design, construct, and maintain the primary highways. Even in states where the DOTs have direct responsibility for relatively small proportions of the entire roadway network, they usually influence the design and maintenance standards used by the local jurisdictions.

Technological advancements and consumer behavioral patterns in the 90s have had a major impact on roadside safety. Major changes in the vehicle mix on the highways prompted Congress to mandate in the 1991 ISTEA legislation that roadside hardware be designed to accommodate the increased use of pickups, vans, and sport/utility motor vehicles. The FHWA in response to Congress adopted new crash test guidelines (NCHRP Report 350) for roadside hardware that use a 2000-kg pickup truck instead of the 4500-lb passenger car used previously to

test the structural integrity of roadside hardware. Manufacturers have responded by using new technologies to provide a plethora of new roadside hardware that meet the upgraded standards.

Selection of Roadside Treatments

Roadside safety hardware has a very long service life, far longer than a typical vehicle. As a result much of the hardware on the highway system is antiquated according to today's standards. Given the changes that occurred in the 1990s, highway agencies are now facing serious issues related to the selection and use of roadside safety hardware.

- Should DOTs try to minimize the number of different types of roadside hardware in their repertoire to minimize training and inventory costs and reduce the risk of improperly installed or maintained hardware? Or
- Should DOTs try to select the best-suited roadside hardware device for each project to maximize the potential safety benefits by making use of the latest technology available?
- How do DOTs determine when older roadside hardware should be upgraded to current standards?
- What effect will litigation have on actual use of different performance-based systems?
- How do DOTs determine if a longitudinal barrier installation is preferable to an upgrading of the roadside, e.g., flattening side slopes, removing roadside hazards, etc.?

Performance-Level Concept

Research has developed the performance-level concept for the application of roadside safety hardware. Under this concept hardware is selected to accommodate the amount and type of traffic that is expected on a road. A high-volume, high-speed roadway needs roadside safety hardware with high performance ratings while low volume rural roads can be accommodated

with lower performance hardware. While this approach is intuitively attractive, it is not easy to implement.

NCHRP Report 350 provides guidelines for evaluation of safety hardware for up to six test (performance) levels. However, it provides no warrants or guidelines to establish highway conditions appropriate for the test levels. To date most hardware has been designed to meet test level 3, the minimum level required for the National Highway System.

- Should roadside safety hardware be developed for each of the six test levels specified in NCHRP 350?
- Do the benefits of having six different performance levels for roadside hardware exceed the costs associated with developing, designing, installing, and maintaining the different hardware?
- What guidelines should be used to match test levels to specific highway categories?

Installation and Maintenance

During the 1990s many highway agencies went through reorganization and downsizing loosing many of their experienced engineers to retirement. At the opening of the 21st century these agencies are operating with lean staffs and tight budgets. Greater emphasis is placed on reducing on-going expenses such as maintenance and repair of roadside hardware, and more design and maintenance jobs are being done by private contractors. These changes raise additional roadside safety issues.

- Should rigid concrete barriers be used more often than flexible or semi-flexible barriers by agencies that have limited resources to repair the barriers when hit? Or

- Should more forgiving barriers be used when sufficient behind-barrier clear zones exist and life-cycle costs are less?
- How do DOTs determine appropriate maintenance standards for the "timely" repair of roadside hardware damaged in a crash?
- What is the role of highway safety audits in roadside safety? When, where, how, and by whom should they be used?

Proper installation of safety features is critical to good performance. For example, the BCT has been one of the most widely used safety features and one that often has been installed improperly. Frequently it has been installed without the recommended flare and end offset, and the consequences have been alarmingly injurious. Installation problems are generally proportional to the degree of design complexity. Thus by keeping designs simple and using readily available standard parts, correct installations of roadside hardware should be easier to achieve.

Repairing and maintaining roadside hardware can also create problems for highway agencies. Often contractors familiar with the hardware do the initial installation, but repair of the hardware is the responsibility of the highway agency. The agency maintenance personnel may not be properly trained and may not understand the potential consequences of incorrect repairs.

- How can highway agencies insure that their maintenance personnel are prepared to maintain the growing number of different and more complex roadside safety devices?
- Should agencies contract with hardware manufacturers for repair services?
- Should agencies avoid safety devices that are too complex to be repaired by their maintenance crews?

Crash Data

The quality of crash data has been a persistent problem in roadside safety research making it difficult to develop models for predicting highway safety. Collecting high-quality crash data relevant to specific roadside problems is very expensive, and relying on low-cost, high-volume police-level crash data severely restricts the detail of analysis that can be done. Police-level data is prone to errors and omissions, but new technology may provide quality improvements. Use of portable computers, global positioning system (GPS), and other data acquisition technologies will allow officers to input location data and crash information quickly and more accurately.

Police officers at crash scenes typically perform many functions, most of which are more important and more urgent than filling out crash reports. Terminology familiar to roadside safety researchers may be foreign to police officers causing confusion in recording and interpreting crash details. The crash severity level used by state DOTs to determine "reportable" and "non-reportable" crashes vary, making state-to-state comparisons problematic. National crash databases such as FHWA's Highway Safety Information System and NHTSA's FARS suffer from these same data quality/consistency problems.

Crash test data issues include:

- How should exposure and roadway/roadside inventory data be linked to crash data?
- Are police-level crash reports accurate enough to use in roadside safety research?
- What data should police officers collect at crash scenes?
- Do the benefits of providing police with new data acquisition technologies exceed the costs?

- Should specially trained and equipped crash investigators be used to collect data on a statistically significant sample of crashes?
- Are there alternative ways to collect the roadside crash data needed for research?

International Cooperation and Harmonization

Considerable progress has been made in international cooperation and harmonization relative to roadside safety. The European community was represented on the advisory panel for NCHRP Project 22-7, in which Report 350 was prepared. US representatives attend and participate as observers in CEN technical working groups responsible for writing test standards for road safety systems. Further, TRB subcommittee A2A04(2), International Research Activities, has been active and successful in promoting technology exchanges in the roadside safety area and in promoting harmonization of impact performance guidelines/standards internationally.

However, there are technical barriers to trade that need to be resolved:

- Should crash test results from non-US testing laboratories be used to certify products for use in the US?
- What standards and inspection procedures should be used to certify non-US testing laboratories?

PUBLIC-PRIVATE ISSUES

Public-private issues involve at least one public agency and one private entity. The private entities can be vehicle or hardware manufacturers, utility companies, health care providers, insurance companies, private individuals, or other non-government organizations. The public agencies can be transportation providers, regulators, elected officials, or legislators.

Accommodating a Changing Vehicle Fleet

Roadside safety features need to accommodate a continually changing vehicle fleet. Changing vehicle dimensions and characteristics can lead to dangerous situations when newer vehicles are incompatible with older roadside hardware. The breakaway cable terminal (BCT) provides a cautionary illustration. When the testing of the terminal was done originally (1972 through 1980) the then current guidelines (NCHRP Report 153) used a 1020-kg passenger vehicle for the small test vehicle. The oil embargo of 1973 quickly caused automobile manufacturers to introduce smaller cars, and by 1978 820-kg vehicles like the Honda Civic and the Volkswagen Rabbit were common. Soon thereafter researchers began to observe problems when these newer, smaller vehicles collided with BCTs. The lower mass of these vehicles was insufficient to "trigger" the BCT crash energy absorbing mechanisms and as a consequence increased the risk of severe injury to the occupants.

Unfortunately, little interchange of information occurs between automobile manufacturers and roadside hardware manufacturers. This lack of coordination is due in part to competitive pressures within the automobile industry and to concerns about possible litigation and anti-trust problems. As a result, the roadside safety community has been forced to react to automotive changes, sometimes long after the changes have become widespread in the vehicle fleet.

A current concern is the "light truck" class of vehicles, which includes vans, mini-vans, pick-up trucks, and sports utility vehicles (SUVs). These vehicles, which now represent approximately half of all new passenger car purchases, have higher centers-of-gravity, different bumper configurations and body structures, and other features that influence the effectiveness of existing roadside safety hardware. Some of the commonly used barrier systems, such as the

strong-post w-beam guardrail with steel blockouts, have failed to pass crash tests involving the 2,000-kg pickup truck.

The on-going need for the roadside safety community to operate in a “catch-up” mode compromises safety and wastes valuable resources. Some of the issues related to this problem include:

- Should vehicle manufacturers be require to meet federal standards on bumper height, vehicle stability, and other vehicle parameters that affect the compatibility of vehicles with existing roadside safety hardware?
- Should DOTs be required to update older safety features that are incompatible with the current fleet of vehicles? If so, what guidelines should be used to determine when the number of incompatible vehicles reaches the critical point?
- Should a joint automobile manufacturers-roadside hardware manufacturers group be formed to develop voluntary guidelines for designs of new vehicles and safety hardware?

Utility Poles Adjacent to Roadways

Utility companies commonly use highway rights-of-way for the poles carrying their transmission lines. Most states grant utility companies the legal right to use highway rights-of-way although the extent (and limitations) of these rights vary from state to state.

Providing utilities to residents is a necessity; however, the death of 1,500 motorists each year resulting from crashes into utility poles is a tragedy. In general, utility companies have been non-responsive to requests to improve roadside safety by installing crashworthy poles, moving poles farther away from the roadway, or by putting their lines underground. Furthermore, utility

companies have been known to replace poles destroyed by vehicle crashes with stronger, even more dangerous poles.

Many issues need to be resolved before the utility pole problem can be solved. Some of these issues include:

- Should utility companies be held liable for poles located dangerously close to roadways?
- Should transportation agencies have the authority to require utility companies to remove hazardous poles?
- Should utility companies be required to pay for the movement of their hazardously located poles?
- What factors should be considered in developing policies for removing poles from the roadside?
- What criteria should be used to determine when poles should be removed and when longitudinal barriers should shield them?
- What clear zone widths should be provided for different combinations of highway characteristics (traffic volume, speed, and functional category)?

Trees Adjacent to Roadways

Trees located adjacent to roadways are potentially lethal hazards to errant motorists and can reduce visibility on curves and at intersections. Trees also provide beauty to the roadside and can act as buffers between roadways and adjacent land uses. Removing trees from the roadside may increase safety but also may invoke protests from neighbors, motorists, and environmental groups.

Some highway agencies have instituted policies of removing trees involved in serious crashes. Other highway agencies have programs to beautify roadsides and medians by planting trees and shrubs. Removing all trees out of harms way for all highways is not feasible given the millions (or perhaps billions) of trees involved, but continuing to allow over 3,000 fatalities each year from tree crashes is not an attractive alternative either. NCHRP Project 17-18 (3), AASHTO Safety Plan Implementation Guide, will include strategies on tree-related collision reduction and other ROR collisions.

Developing a rational approach to dealing with trees on the roadside involves many issues and tradeoffs. However, trees are major roadside safety hazards that have to be addressed by the strategic plan. Some of the important issues related to trees include:

- What factors should be considered in developing policies for removing trees from the roadside?
- What criteria should be used to determine when trees should be removed and when longitudinal barriers should shield them?
- What combinations of highway characteristics (traffic volume, speed, functional category) and land uses are appropriate for retaining trees on the roadside?
- What clear zone widths should be provided for different highway-land use combinations?
- Should attractive, crashworthy substitutes for trees be developed?
- Should owners of trees on private land outside of the legal right-of-way be liable for crashes into their trees?
- Should highway agencies have the right to condemn trees located outside of the legal right-of-way?

Motor Vehicle Event Data Recorders

Many airbag-equipped cars are equipped with data recorders that capture valuable data before, during, and after the vehicle's airbag is deployed in a crash. The data varies from manufacturer to manufacturer, but most collect at least information on vehicle speed and deceleration for several seconds before and after air bag deployment. These data, as well as other information on brake usage, driver actions, and vehicle behavior, could provide a wealth of information currently unavailable to safety researchers.

Access to the data from these event recorders involves many legal issues including data ownership, driver liability, and privacy issues. The vehicle manufacturers are working with NHTSA to develop workable agreements that may make some of these data available for research purposes.

Issues related to event data recorders include:

- Should event data recorders be required in all motor vehicles as they are for commercial aircraft?
- Should event data recorders be required in all commercial motor vehicles?
- Should the data elements collected in automobile event recorders be standardized for the auto industry?
- Should crash investigators have access to these data on a confidential basis?
- Should these data be obtainable by subpoena for legal purposes?

CHAPTER 5

STRATEGIC PLAN DEVELOPMENT

The roadside safety problem has been recognized by different organizations including the Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO), National Highway Traffic Safety Administration (NHTSA), Transportation Research Board (TRB), Roadway Safety Foundation, Insurance Institute for Highway Safety, and others. The impetus for a strategic plan emerged from the climate of reduced governmental funding and distributed control over highway programs. For progress to be made in roadside safety there has to be a strategic, multi-organizational approach that involves all members of the roadside safety community working together to maximize the effectiveness of their coordinated efforts through the formation of strategic partnerships.

PLAN DEVELOPMENT

AASHTO recognized the need for coordination of activities, and in 1995 NCHRP Project 17-13 was initiated to develop a strategic, multi-faceted, multi-organizational approach to improving roadside safety. To develop the plan a panel of fifteen prominent professionals was formed representing four state DOTs, FHWA, NHTSA, four universities, a vehicle manufacturer, a safety hardware manufacturer, and a safety advocacy group.

The panel's first meeting occurred in May 1995, and at that meeting a decision was made to expand the project's original scope from developing a plan for roadside safety research to developing a plan for improving roadside safety. For years TRB Committee A2A04 had developed statements of research needs for roadside safety and much of the research had been or was being conducted. However, the results of these research efforts were not always making it

to the highway agencies where they could be used to improve roadside safety. Solving the roadside safety problem requires a coordinated effort involving all of the stakeholders, not just the research community.

In mid-summer 1995, the panel, with the aid of a professional facilitator, developed its first draft of a strategic plan for roadside safety. In this intense and at times frustrating 3-day process, panel members freely expressed their thoughts and ideas which were displayed on numerous flip charts. Panel members examined the external environment affecting roadside safety noting significant trends, events, and features. Potential partners and stakeholders were identified as were their needs and wants. Thoughtfully, this myriad of wisdom contributed by panel members was distilled into statements of the vision, purpose, missions, and goals of the strategic plan.

This panel meeting was held in concurrence with the summer meeting of TRB Committee A2A04 at which 12 invited papers on various aspects of roadside safety were presented by noted experts. At the conclusion of the meeting the panel presented its initial ideas to the group of approximately 100 roadside safety stakeholders. In preparation for the beginning of NCHRP project 17-13, the previous summer meeting (1994) of Committee A2A04 laid the groundwork for the strategic plan by including six invited papers and four breakout session on topics specifically related to the development of the plan. The papers and breakout session summaries from the 1994 (Woods Hole, MA) and 1995 (Irvine, CA) summer meetings of TRB Committee A2A04 are contained in Transportation Research Circular Numbers 416 and 435, respectively.

After making several refinements to the initial draft of the strategic plan, the panel again held a meeting together with the summer meeting of Committee A2A04 in Park City, Utah in

August 1996. At this meeting the 4th draft of the plan was presented and reviewed by the 110 attendees. Two sets of breakout sessions were used to assess the completeness and feasibility of the individual elements of each of the plan's five missions. Additional sessions examined topics related to implementation of the plan, i.e., identifying the champion and advocates, building community support, integrating the roadside into management systems, applying new technologies, and assessing the roadside's role in overall highway safety. Consultants were used to record and summarize the discussions within each breakout session. The 5th draft of the strategic plan incorporated the results of the 1996 summer meeting.

The panel produced the 6th draft of the strategic plan for improving roadside safety in late 1996 and the final draft in 1997. These rewrites made minor organizational changes to version 5 and edited the plan for consistency in word usage and form. The complete text of the final version of the plan is contained in Appendix A.

THE PLAN

The roadside safety strategic plan provides a comprehensive, coordinated approach to reducing roadside crashes and their associated societal costs. It contains 5 missions, 25 goals, 78 objectives, and 359 action items, 221 of which are research-oriented.

The Vision underlying the plan is:

> 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 protect vehicle occupants and pedestrians.

Missions

To achieve this vision, five targeted missions were identified. Each mission is a focused group of efforts needed to improve roadside safety. The set of five missions addresses the full realm of endeavors needed to solve the roadside safety problem.

Mission 1 establishes a coalition, heightens public awareness, and obtains financial resources. **Mission 2** obtains needed information resources, conducts general research, and disseminates the results so that the last three missions, the "meat" of the plan, can be accomplished. **Mission 3** keeps the vehicles on the roadway by improving highway design, traffic operations, highway and vehicle maintenance, vehicle-based driver-aid systems, and driver behavior. **Mission 4** keeps vehicles from overturning or hitting fixed objects by improving roadside geometrics, improving vehicle stability, removing hazardous objects from the roadside, and improving driver performance. **Mission 5** minimizes injuries and fatalities by making optimum use of roadside safety features, improving vehicle crashworthiness, increasing seat belt usage, and improving emergency team responsiveness.

Mission 1 - Increase the awareness of roadside safety and support for it.

Roadside safety cannot be enhanced until people see it as a problem. Significant improvements to roadside safety require a coordinated effort of the many involved organizations, manufacturers, and stakeholders. Increased safety funding is needed to implement the initiatives of the strategic plan. A coalition of governmental, industrial, institutional and civic partners will be formed to work toward the improvement of roadside safety. Through public information campaigns the general public, decision makers, and special interest groups will be made aware of the roadside safety problem so that support for safety funding at the federal, state, and local levels can be generated.

Mission 2 - Build and maintain information resources and analysis procedures to support continued improvement of roadside safety.

A better understanding of the driver-vehicle-roadway relationship associated with roadside accidents is needed so that more cost-effective remedies can be perfected. Less expensive methods for insuring the compatibility between roadside hardware and the increasingly diverse vehicle population are required. Improved roadside and roadway inventory systems based on a common location referencing system will be created to provide sufficient roadside safety information to researchers, designers, and decision makers. State-of-the-art computers and analysis techniques will be used to study roadside crashes and simulate hardware crash tests. Safety audits and other techniques will be conducted to identify hazardous roadside locations.

Mission 3 - Keep vehicles from leaving the roadway.

Roadside crashes occur when vehicles leave the roadway. Loss of vehicle control can be the result of driver errors, driver incapacities, vehicle failures, highway conditions, traffic situations, or environmental factors. Consistent and improved highway designs and better control of traffic operations will be used to reduce the occurrences of events that contribute to loss of vehicle control and roadside encroachment. Improved maintenance of highways and vehicles will reduce the chance of loss of vehicle control. Innovative vehicle-based systems that help keep drivers on the road will be developed. Driver behavior will be enhanced through education, training, legislation, and traffic law enforcement.

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 to roadside encroachers. Roadside geometry will be improved to reduce the chances of rollover. Hazardous fixed obstacles in the roadside will be removed or modified where possible. Improved vehicle designs that increase vehicle stability in run-off-the-road situations will be developed. And driver performance will be improved through education and training.

Mission 5 - Minimize injuries and fatalities when overturns occur or objects are struck in the roadside.

When overturns occur or fixed objects are struck, the severity of injuries is particularly grave if occupants are unbelted. Increased use of seat belts will be promoted through advertising, training, legislation, and enforcement. Air bags and padded vehicles interiors are effective, but new safety advancements in vehicle design are possible. Better roadside hardware designs and improved vehicle crashworthiness will be developed. The selection, design, installation, and maintenance of roadside safety features will be optimized. Better emergency team responsiveness for highway accidents will be achieved.

Goals

Defining the missions is only the first step in developing a roadside safety strategic plan. Under each mission is a set of goals that describe the desired outcomes of each mission (Table 3).

Objectives

For each goal there are several objectives that describe the various tasks that must be accomplished to realize the goal. For example, achieving Goal 3.1 (see below) requires a change in how highway designs are produced. First, the relationships between highway designs and roadside accidents must be understood so that the design tools needed to improve highway design can be developed (Obj. 3.1.1). Once these tools have been developed, design policies and guidelines must be modified to take advantage of the new techniques (Obj. 3.1.2). Finally, the highway designers must be trained so that they are aware of the impacts of their designs on roadway safety and are capable of incorporating the new procedures into their work (Obj. 3.1.3).

Goal 3.1 - Improved highway designs that reduce the probability of vehicles leaving the roadway

> **Objective 3.1.1 -** Develop the tools to allow highway designers to incorporate safety into the design process
>
> **Objective 3.1.2 -** Enhance design policies & guidelines to include safety considerations
>
> **Objective 3.1.3 -** Enhance the highway designer's understanding of the effects of highway design on roadway safety

Actions

Each objective has several action items that refer to explicit activities or research needed to achieve the objective. An action item is usually specific enough that it could be accomplished with a single research project or management directive. For example, Objective 3.1.1 has five action items (see below). Action 3.1.1.1 addresses the basic research needed to understand the

relationships between highway geometric design and roadside safety. Action 3.1.1.2 seeks to find ways to implement a desired quality -- designs that are consistent with driver expectations. Action 3.1.1.3 addresses the need to be able to identify designs that could be hazardous so that they can be fixed before they are built. Action items 3.1.1.4 and 3.1.1.5 suggest specific techniques that should be useful in carrying out Objective 3.1.1. The action items are not necessarily all-inclusive, but they do provide definitive projects that if carried out move us closer to the attainment of the stated objective.

Objective 3.1.1 - Develop the tools to allow highway designers to incorporate safety into the design process.

Action 3.1.1.1 - Develop a better understanding of the effects of highway geometric design on roadside safety (e.g., sight distance, superelevation, curvature, etc.)

Action 3.1.1.2 - Develop techniques to promote consistent designs that conform to driver expectancy

Action 3.1.1.3 - Develop improved hazard identification tools to identify potentially hazardous roadside designs and features on all roadways including local roads

Action 3.1.1.4 - Investigate the use of safety audits in the roadway design process

Action 3.1.1.5 - Develop uses of 3- and 4-dimensional visualization technologies to improve the design of highways

APPLICATIONS OF THE PLAN

The details provided in the strategic plan represent the ideas and thoughts of the nearly 200 roadside safety professionals who have participated in the preparation of the plan. While insufficient in its present form to solve completely the roadside safety problem, the plan does set the stage for the initiation of a unified effort to improve roadside safety.

The next chapter discusses the development and use of action plans based on the information contained in the plan. These plans identify the individual actions that can be directed toward solving specific aspects of the roadside safety problem.

CHAPTER 6

ACTION PLANS FOR IMPROVING ROADSIDE SAFETY

The strategic planning process has identified over 350 action items that can be done to improve roadside safety. These items must be organized in ways that will allow the various "partners" to recognize their roles in solving the roadside safety problem. From these organized lists of action items specific strategies for each partner can be developed.

CLASSIFICATION OF ACTION ITEMS

Each action item in the plan was tagged with up to three different sectors, functional areas, physical elements, and issues. The sectors (transportation agencies, roadside safety hardware manufacturers, vehicle manufacturers, safety advocacy groups, regulatory and enforcement agencies, legislative bodies, and the roadside strategic plan champion) are the organizations/agencies/industries best suited to accomplish the action item. Sectors that have a vested interest in the results of a particular action item were also associated with the action item.

Functional areas (administrative, design, education and public information, information management, law enforcement, maintenance, planning, research, safety management, and traffic operations) are the disciplines or bureaus within the organizations that would most likely be responsible for the action item. The functional areas listed above are not necessarily mutually exclusive nor are they applicable for all organizations involved in roadside safety. The action items can be tagged with additional functional areas and/or consolidated to match the organizational structure of specific partners.

Physical elements (driver, vehicle, highway, roadside, and crashes) are the physical components of the roadside safety problem that an action affects or analyzes. These elements can be subdivided into small components (e.g., guardrails, embankments, drainage facilities, etc. for roadside) and other elements could be added (e.g., vehicle occupants, highway maintenance personnel, emergency response units, etc.).

Issues (rollovers, trees, utility poles, young drivers, etc.) are specific known “problems” or “needs” that might want to be addressed. Each partner will have its own list of issues that it wants to address.

ACTION PLANS

A spreadsheet was used to classify the action items by sector, functional area, physical element, issue, and by combinations of these four classification groupings. Several “action plans” are shown in Appendix D to demonstrate how the large list of action items can be targeted for the interests of the various strategic partners. An action plan for the issue of tree crashes is shown in Table 4 as an example.

Each action item’s mission (M), goal (G), objective (O), and action (A) numbers are given as a reference to the overall plan contained in Appendix A. Within each sector-functional area-physical element-issue cell the action items are arranged by the priority [high (H), moderate (M), low (L)] established by the panel for each of the plan’s objectives. Within each priority group the action items are arranged numerically by their mission-goal-objective-action numbers. Actions items associated with more than one member of a classification group are duplicated as needed so that each cell is complete.

Sectors

Action plans for vehicle manufacturers and safety advocacy groups are shown in Tables D-1 and D-2, respectively, in Appendix D. Action items are classified by functional area for each of these sectors. As might be expected design activities dominate the plan for the vehicle manufacturers while the public information and educational activities cell has the largest number of activities for the safety advocacy groups. These action plans provide the starting point for the development of strategic plans for these two sectors.

Action plans for transportation agencies and hardware manufacturers are in Tables D-9 and D-10 in Appendix D. These are the two sectors most involved in solving the roadside safety problem, and the numbers of action items included in their plans are quite large.

Functional Areas

Each of the sector action plans is subdivided by functional area, but there is benefit in viewing all of the action items associated with a particular functional area. These action plans show the combined efforts of all of the sectors that deal with functional areas such as law enforcement, research, design, etc.

Tables D-3, D-4, and D-5 show action plans for maintenance, education and public information, and law enforcement, respectively. These plans, if desired, could be subdivided by sector to show how the activities are assigned among the various strategic partners.

Physical Elements

Actions to improve roadside safety can also be stratified by the physical elements that are a part of the roadside safety problem. The four obvious components are drivers, vehicles, roadways, and roadsides. However, there are other more specific elements that might be of

interest to the partners such as construction workers, police officers, SUVs, pickups, rural 2-lane highways, interstate highways, guardrails, and sign posts. The possibilities are limitless.

Action plans for two physical elements are presented as examples. Table D-6 shows action items directed toward drivers and Table D-7 shows all action items dealing with roadside crashes.

Issues

Research has identified a number of key issues that are associated with the roadside safety problem. These issues include trees and poles in the roadside, insufficient clear zones, antiquated or poorly design roadside hardware, pavement drop-offs, substandard highway alignment, SUVs, teenaged drivers, alcohol-impaired drivers, to name just a few.

Tables D-8 and 4 show the action items that are directed toward the issues of rollovers and tree crashes, two of the more serious roadside safety issues. The items in these tables provide the basis for establishing specific strategies for attaching each of these problems.

USING THE ACTION PLANS

The action plans provided in this chapter provide the starting point for developing strategic initiatives. A first attempt at establishing priorities for the proposed individual actions has been made by using the priorities established for each objective by the NCHRP 17-13 panel in a roundtable discussion. However, additional work is needed to extract from these action plans cost-effective strategies to solve the roadside safety problem.

For each action item the costs and benefits of implementation need to be estimated. A time frame for carrying out the action as well as an estimate of the likelihood of success is needed. Once this information is known the action items can be sorted according to their

anticipated cost-effectiveness. Action items that seem to offer the potential for large benefits-to-cost ratios can be studied in more detail so that a plan for implementing the action can be developed.

In developing the strategic initiatives, the probability of obtaining needed resources and public support must be assessed. Certain action items may have very high benefit/cost ratios but may not be "popular" actions for funding and implementation.

Coordination between the strategic partners is important to insure that resources are not wasted through duplicated efforts and that maximum benefit is derived from partnerships. Solving the problem of roadside safety will take a well-planned, highly coordinated effort comprised of numerous targeted action plans.

CHAPTER 7

ROADSIDE SAFETY RESEARCH NEEDS

The first step in solving a problem is to understand the problem, its causes and possible solutions. Roadside crashes have occurred throughout the history of highways yet there are still many aspects of the problem that are not understood clearly. Cost-effective solutions to the roadside safety problem require a better understanding of interrelationships between the roadway, the vehicle, the driver, the roadside, and the vehicle occupant.

The Federal Highway Administration, the American Association of State and Highway Transportation Officials, the states, the Transportation Research Board, and others have undertaken a variety of research activities directed toward improving roadside safety. These efforts have included analyzing crash trends, formulating improved analysis procedures, developing better hardware, and promoting better understanding of the crash environment. Maintaining the current level of safety in the face of increased travel demand, lighter vehicles, and strained public funding resources will require a bold strategic plan that coordinates the efforts of all agencies involved and maximizes the effectiveness of future research and development efforts.

The findings of previous research efforts have contributed greatly to the improvements in roadside safety that have been accomplished over the last 40 years. However, there are still many aspects of the roadside safety problem that are not understood clearly, and future research is needed to answer the many remaining questions. Examples of some of the more important data needs are given below.

DATA AND RESEARCH NEEDS

Very little empirical data on roadside encroachments exists, and the data that are available are old and of questionable quality. Fundamental information is needed on the frequency of encroachments, the speed and angle of the vehicle when leaving the roadway, and the path and extent of the encroachment. The relationship of these encroachment parameters to basic highway characteristics such as daily traffic volumes, highway operating speeds, highway classification, roadway alignment, and roadside design is also unknown but must be understood if meaningful countermeasures are to be developed.

Very few studies have linked highway crash data with traffic, roadway, and roadside characteristics. Without these linkages it is not possible to analyze the relationships between traffic, roadway, and roadside characteristics and crash frequency and severity. These data are expensive and difficult to obtain, but are needed before cost-effectiveness models for roadside safety can be developed.

The processes of locating, selecting, and installing roadside safety hardware continue to be important areas for research. Locating specific sites for roadside safety enhancements is a challenge because of the huge size of the highway system and the lack of data and analytical tools to identify and prioritize hazardous locations. Over the last two decades hardware manufacturers have developed many new safety devices for the roadside, and selecting the optimum treatment for a particular site has become a formidable task for the highway designer. Many of these newer devices have incorporated new technologies to achieve higher levels of safety. The greater complexity of these systems increases the likelihood of installation errors that could potentially transform a "safety" device into a roadside "hazard." Thus, if the technological advances in roadside safety hardware are to be used cost-effectively to improve

roadside safety, additional research is needed to refine the procedures for locating, selecting, and installing hardware.

Tremendous advancements have been made in computer technology which have led to good progress in the development of intelligent transportation systems (ITS). Applications of these new technologies for in-vehicle warning devices and occupant protection systems hold great promise for making quantum jumps in roadside safety. Additional developments in communication systems when coupled with computer advancements offer wonderful opportunities for in-roadway systems that can communicate with in-vehicle systems to help the driver navigate safely through an increasingly congested highway system. But, without research, the potential benefit of these technological developments to roadside safety will not be realized.

RESEARCH PLAN

During the development of the strategic plan, 221 action items having a research component were identified. The term "research" is defined broadly to include both knowledge transfer and implementation efforts. The individual research action items have been associated with the appropriate missions and goals within the strategic plan and are presented below.

Mission 1 - Increase the awareness of roadside safety and support for it

The research actions (Table 5) required to achieve the goals of mission 1 are related primarily to the development of public information materials to increase awareness of the roadside safety problem and to the development of a funding program to finance roadside safety improvements. Additional research is needed to create and manage an effective coalition that will ensure on-going improvements in roadside safety.

Mission 2 – Build and maintain information resources and analysis procedures necessary to support continued improvement of roadside safety

Mission 2 is designed to accomplish much of the research (Table 6) required to carryout the strategic plan. Each of the goals of this mission are directed toward filling important holes in our current understanding of the roadside safety problem.

Mission 3 – Keep vehicles from leaving the roadway

Mission 3 strives to keep the vehicle on the roadway and if achieved fully would eliminate roadside crashes entirely. Mission 3 research (Table 7) is aimed at improving the design, maintenance, and operation of highways, developing better vehicles, and creating improved drivers.

Mission 4 – Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway

If the involved vehicle in a roadside encroachment rolls over or strikes a roadside object, the chances of severe injury or death for the occupants increase greatly. Mission 4 research (Table 8) seeks to improve the understanding of the vehicle-roadside interactions that cause rollovers so that vehicle designs, roadside designs, and driver performance can be improved to reduce or eliminate rollovers. Research is also directed toward finding feasible and cost-effective programs to remove hazardous fixed objects from the roadside.

Mission 5 – Minimize injuries and fatalities when overturns occur or objects are struck in the roadside

Realizing that it is impossible to eliminate roadside crashes completely by achieving fully the goals of missions 3 and 4, mission 5 seeks ways to minimize the harm that occurs when a

vehicle overturns or strikes a fixed object in the roadside. Mission 5 research (Table 9) is focused on providing crashworthy roadside appurtenances, enhanced occupant protection systems in vehicles, increased seat belt usage by occupants, and improved medical treatment for the injured.

RESEARCH ACTION PLANS

Research action plans have been assembled for the roadside safety sectors. Table E-1 in Appendix E includes action plans for safety advocacy groups, the roadside safety strategic plan champion, hardware manufacturers, regulatory and enforcement agencies, transportation agencies, and vehicle manufacturers. For each roadside safety sector, the research action items are shown by functional areas.

CHAPTER 8

IMPLEMENTATION OF THE STRATEGIC PLAN

The success of the strategic plan for roadside safety will depend in large part on the efforts expended by the many anticipated participants. An important function of the plan is to form the framework needed to unite the different organizations and people so that their actions will be coordinated as they strive together to improve roadside safety.

POTENTIAL PARTICIPANTS

Highway safety affects the entire population in one way or another. Improving the safety of highways involves a very broad range of organizations comprised of people with diverse backgrounds and divergent viewpoints and agenda. Sometimes these groups have complementary goals and other times they have contradictory goals.

During the creation of the strategic plan, the groups that are known stakeholders in roadside safety were identified. Each of these groups, as shown in Table 10, is a potential participant in the strategic plan.

IMPLEMENTATION PROCESS

The proposed process for implementing the strategic plan is described in the first two missions of the plan. Each of these missions can be seen as a phase in the implementation process. The first phase (Mission 1) establishes a coalition, heightens public awareness, and obtains financial resources. The second phase (Mission 2) obtains needed information resources, conducts general research, and disseminates the results of the research. These two phases provide the financial and informational resources needed to accomplish the safety-enhancing

missions of the plan (Mission 3, 4, and 5). It is anticipated that all five missions will be carried out simultaneously rather than sequentially.

Phase 1

The first step in Phase 1 is the establishment of a coalition of governmental, industrial, institutional and civic partners that will work toward the improvement of roadside safety. It can be accomplished by proceeding as follows:

1. Identify a lead organization to champion the creation of the coalition,
2. Create a steering committee to guide and oversee the operation of the coalition,
3. Recruit coalition members from those groups that can have an impact on improving roadside safety (key partners) and those groups potentially affected by the plan (stakeholders),
4. Encourage partners to take responsibility for implementing specific aspects of the strategic plan, and
5. Establish ongoing communication to and among the network of partners.

Next it is necessary to create a heightened public awareness of the importance of roadside safety. The two components of this awareness campaign are:

1. Inform elected officials, the public, the environmental community, utility companies, law enforcement organizations, metropolitan planning organizations (MPO's), grassroots organizations, and news media about the importance of roadside safety programs, and
2. Inform the public about specific roadside safety issues that they can influence.

A crucial requirement of the implementation process is to obtain sufficient financial resources to address roadside safety needs at the federal, state and local levels. Steps to develop the funding program include:

1. Develop estimates of funding needs for roadside safety and establish priorities for using the funds,
2. Identify potential funding sources for roadside safety,
3. Establish roadside safety items as fundable elements via line items in federal and state budgets,
4. Identify opportunities for funding roadside safety projects and research from pooled-funds and cooperative agreements among coalition partners, and
5. Provide roadside safety information to meet the needs of decision-makers at state and local levels.

To maintain the interest within the coalition and to guarantee continuing funding there should be ongoing programs to disseminate roadside safety information to practitioners, researchers, decision makers, and the public. Objectives of the dissemination program should include:

1. Improve the proficiency of practitioners responsible for roadside safety,
2. Enhance the exchange of roadside safety information between federal, state, local and private partners,
3. Exchange safety technologies and innovative approaches between domestic partners and international colleagues,

4. Provide roadside safety information to meet the needs of decision makers at state and local levels, and

5. Provide roadside safety information to the public.

An ongoing process for updating the roadside safety strategic plan and for prioritizing research needs must be established early in the implementation process. New developments in technology, new discoveries from research, adjustments in the vehicle mix, modifications in driver behavior, and shifts in societal priorities are a few of the changes that could necessitate updates to the strategic plan. The ongoing modification process should include at least the following tasks:

1. Develop a system for periodically updating the Strategic Plan,

2. Identify and prioritize research needs for AASHTO, FHWA, and others, and

3. Revise priorities to reflect new knowledge and the changing features of the vehicle fleet, driver population and other factors.

During the first phase of the implementation process the framework of the organization is established and the resources are obtained. In the second phase, the data and analytical resources needed to develop solutions to the roadside safety problem must be obtained.

Phase 2

The initial task of the second phase of the implementation process is to create improved roadside and roadway inventory systems that are based on a common location referencing system. These systems will make it possible for the various members of the roadside safety coalition to share and compare data. Specifically the coalition needs to:

1. Establish a common location referencing system to integrate all databases,
2. Improve roadway/roadside inventory databases, and
3. Improve traffic operations data.

Valid data pertinent to the various roadside safety issues are required before meaningful solutions can be developed. Needed are comprehensive roadside safety information resources including crash data, in-service evaluations, funding sources, research results, training programs, tort claims, highway inventories, traffic data and vehicle sensor data. To begin the process of obtaining these data the coalition needs to:

1. Create a framework for the establishment of cooperative agreements to develop needed information resources,
2. Improve highway crash databases, and
3. Investigate and monitor the effectiveness of roadside treatments to increase the amount of information available on in-service evaluations of roadside safety hardware.

The data described above will provide the fuel for the numerous research studies needed to comprehend the roadside safety problem well enough to be able to develop feasible, cost-effective solutions. State-of-the-art methodologies and tools for analyzing and simulating roadside crashes and crash tests are required to improve the understanding of fundamental relationships between safety, roadside features such as clear zones, side slopes, and roadside hardware and traffic factors. Steps to accomplish this goal include:

1. Develop a database on vehicle dynamics in roadside crashes,

2. Develop and utilize finite element analysis techniques to model vehicle-roadside safety device interactions,
3. Utilize vehicle dynamics models to investigate rollover issues and pre- and post-impact scenarios, and
4. Examine existing Federal Motor Vehicle Safety Standards (FMVSS) for linkages to roadside appurtenance performances.

The US highway system is expansive and diverse. Solving the roadside problem will involve using treatments tailored to specific sites and conditions. The repertoire of potential treatments will be large, and the number of potential sites is huge. Thus, ongoing programs to conduct safety analyses and identify hazardous roadside locations must be established to:

1. Identify hazardous or potentially hazardous roadside locations,
2. Analyze problem roadside locations to determine the causes of crashes, and
3. Select alternative treatments using cost-effectiveness techniques.

The successful implementation of the strategic plan for improving roadside safety will have to take advantage of available opportunities and circumvent any obstacles that could potentially constrain the effectiveness of the plan. Identifying these constraints and opportunities early is an important step in the implementation process.

CONSTRAINTS AND CHALLENGES

Implementing a plan as ambitious as this one requires a carefully planned strategy to meet and overcome the numerous challenges and constraints the coalition must face. Listed

below by category (institutional, political, social, technical, and economic) are some of these known obstacles.

Institutional

- The coalition needs a strong champion to lead the implementation of the strategic plan.
- Potential partners in the coalition may have competing institutional goals that could cause conflicts within the coalition.
- Potential partners may have legal or institutional constraints that forbid them from certain coalition activities, e.g., lobbying for funding (government agencies and non-profit organizations), sharing data (anti-trust concerns), etc.

Political

- The national trend is away from big government, and solving roadside safety problems through governmental agencies may be difficult.
- Funding for FHWA research projects, previously a source for roadside safety research has been reduced.
- Fuel prices are at or near record highs making new fuel taxes an unpopular source of funding for the plan.
- Many of the roads most in need of roadside treatments are under the control of local governments who have the least amount of resources available to address the needs.
- Politicians have been reluctant to enact primary seat belt laws that would have a positive effect on seat belt usage, a major contributor to occupant safety in roadside crashes.

Social

- The majority of the general public is not aware of the seriousness of the roadside safety problem.
- Americans are in love with SUVs and pickup trucks, two vehicle types known to have major roadside safety problems.

Technical

- The driver/vehicle/roadway/roadside relationship is very complex making modeling of the relationship difficult and expensive.
- Roadside encroachments at an individual location are rare events making data collection for research purposes difficult and expensive.

Economic

- The research efforts required to solve the various roadside safety problems are extensive and expensive.
- The number of locations where roadway/roadside treatments are needed is limitless making the remedial costs extremely high.

OPPORTUNITIES

While the list of constraints and challenges is long, there are many opportunities that can be capitalized on to help in the implementation of the plan. Recent technological advancements provide many of these opportunities.

Institutional

- Many of the key coalition partners (FHWA, AASHTO, NHTSA, Roadway Safety Foundation) have already recognized the seriousness of the highway safety problem and have developed their own strategic plans to help solve roadside safety problems.
- AASHTO through NCHRP has funded the creation of this strategic plan providing an excellent starting point for the coalition.
- Communication technologies (web pages, e-mail, video conferencing, etc.) make it quite easy to communicate between and among coalition partners and the general public.

Political

- Safety is a popular topic for politicians.
- Congress has consistently provided funding for highway safety initiatives.
- The Department of Defense has recently expanded the availability of Global Positioning System (GPS) data for civilian purposes opening opportunities for vehicle control and encroachment warning devices.
- Many states have implemented graduated licensing programs for young drivers that contain increased driver training requirements and restrictions on nighttime driving among teenagers, the highest roadside crash risk group.

Social

- Public awareness of the dangers of median crossover crashes and rollovers is increasing.

- Citizen safety advocacy groups such as MADD and SADD provide excellent models for new organizations directed toward different aspects of the roadside safety problem, e.g., teenaged drivers, elderly drivers, aggressive drivers, vehicle stability, roadside hazards, etc.

Technical

- The widespread access to the Internet provides numerous opportunities for communicating roadside safety information to the public, to legislators, to regulators, and to the coalition partners.

- Computer advances in hardware and software make it feasible to develop simulation programs for roadside safety research, roadway/roadside design, and driver training.

- Intelligent transportation system (ITS) developments are providing numerous new opportunities for improving the safety of roadways, roadsides, vehicles, and motor vehicle occupants.

Economic

- The recent strength of the US economy has produced record budgetary surpluses at the federal and state levels that may provide funding opportunities.

- The relative wealth of the general populace allows discretionary spending for safety-enhancing options in automobiles.

IMPLEMENTATION ACTION PLAN

The action items in the first two missions of the strategic plan provide detailed guidance for the implementation of the plan. These items (Table F-1 in Appendix F) have been arranged

by functional areas for the three sectors most involved in plan implementation: roadside safety strategic plan champion, safety advocacy groups, and transportation agencies.

The most important step in moving the Strategic Plan for Improving Roadside Safety forward is to identify the organization that will be the roadside safety “champion”. NCHRP and the Transportation Research Board are not in a position to make this designation. The decision on who will carry this plan forward is the responsibility of FHWA, AASHTO, and NHTSA. These groups need to meet soon to make this decision so that the work of the over 200 safety professionals who contributed to the development of this plan will not be for naught.

Table 1: 1985 Roadside Crashes by Most Harmful Event (Viner)

	Societal Cost (Millions 1988 $)			Fatalities			Injuries			Property-Damage-		
Most Harmful	**Amount**	**% of loss**	**Rank**	**Number**	**%**	**Rank**	**Number**	**%**	**Rank**	**Number**	**%**	**Rank**
Overturn	17,786	27.5%	1	4,820	33.2%	1	134,000	20.9%	1	32,000	10.0%	3
Tree &	12,809	19.8%	2	3,512	24.2%	2	104,000	16.2%	3	38,000	11.9%	2
Pole & Post	12,140	18.8%	3	2,052	14.1%	3	151,000	23.5%	2	69,000	21.6%	1
Embankment	6,004	9.3%	4	668	4.6%	5	95,000	14.8%	4	18,000	5.6%	8
Longitudinal	3,335	5.2%	5	718	4.9%	4	34,000	5.3%	5	28,000	8.8%	5
Bridge rail, end,	2,247	3.5%	6	562	3.9%	6	19,000	3.0%	8	14,000	4.4%	11
Ditch	1,932	3.0%	7	353	2.4%	8	23,000	3.6%	6	16,000	5.0%	10
Other Fixed	1,782	2.8%	8	298	2.1%	11	22,000	3.4%	7	32,000	10.0%	4
Fence & wall	1,572	2.4%	9	351	2.4%	9	15,000	2.3%	10	23,000	7.2%	7
Culvert	1,514	2.3%	10	302	2.1%	10	17,000	2.6%	9	4,000	1.3%	12
Curb	1,078	1.7%	11	193	1.3%	12	13,000	2.0%	11	24,000	7.5%	6
Immersion	946	1.5%	12	394	2.7%	7						
Building	884	1.4%	13	174	1.2%	13	10,000	1.6%	12	4,000	1.3%	13
Non-	551	0.9%	14	121	0.8%	14	5,000	0.8%	13	18,000	5.6%	9
Total	**64,580**	**100%**		**14,518**	**100%**		**642,000**	**100%**		**320,000**	**100%**	

Table 2: 1997 Roadside Fatal Crashes (FARS)

	Fatalities		Change	Adjusted Fatalities			Change
Most Harmful Event	**Number**	**%**	**From 1985**	**Unknown**	**Total**	**%**	**From 1985**
Overturn	5,377	41.4%	8.2%	57	5,434	39.4%	6.2%
Tree & Shrubbery	3,374	26.0%	1.8%	9	3,383	24.5%	0.3%
Pole & Post	1,398	10.8%	-3.4%	116	1,514	11.0%	-3.2%
Embankment	419	3.2%	-1.4%	7	426	3.1%	-1.5%
Longitudinal Barrier	537	4.1%	-0.8%	327	864	6.3%	1.3%
Bridge rail, end, pier	317	2.4%	-1.4%	65	382	2.8%	-1.1%
Ditch	223	1.7%	-0.7%	4	227	1.6%	-0.8%
Other Fixed Object	160	1.2%	-0.8%	25	185	1.3%	-0.7%
Fence & wall	231	1.8%	-0.6%	10	241	1.7%	-0.7%
Culvert	232	1.8%	-0.3%	13	245	1.8%	-0.3%
Curb	48	0.4%	-1.0%	104	152	1.1%	-0.2%
Immersion	234	1.8%	-0.9%		234	1.7%	-1.0%
Building	155	1.2%	0.0%	9	164	1.2%	0.0%
Non-Collision*	23	0.2%	1.4%	2	25	0.2%	-0.7%
Fire & Explosion	192	1.5%			192		
Non-Fixed Objects	81	0.6%		38	119		
Unknown	790			4	4		
Total	**13,791**	**100%**	**0.0%**	**790**	**13,791**	**100%**	**0.0%**

Table 3 Missions & Goals

Missions	Goals
1 Increase the awareness of roadside safety and support for it.	1 A coalition of governmental, industrial, institutional and civic partners that will work toward the improvement of roadside safety 2 A heightened awareness of the importance of roadside safety by the public 3 Increased emphasis on roadside safety by partners and stakeholders and better communications between them 4 Sufficient financial resources 5 On-going dissemination programs 6 A roadside safety component in all DOT safety management systems 7 On-going process for updating the strategic plan
2 Build and maintain the information resources and analysis procedures to support improvement of roadside safety.	1 Improved roadside and roadway databases 2 Sufficient roadside safety information resources on crashes, in-service projects, research results, ... 3 State-of-the-art methodologies for analysis and simulations of crashes and crash tests 4 On-going programs to conduct safety analyses and identify hazardous roadside locations
3 Keep vehicles from leaving the roadway.	1 Improved highway designs that reduce the probability of vehicles leaving the roadway 2 Improved traffic operating environment that reduces the occurrences of roadside encroachments 3 Sufficient maintenance of highways and vehicles to reduce the probability of loss of vehicle control 4 Improved vehicle-based systems that keep drivers on the road 5 Improved driver performance and behavior
4 Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway.	1 Improved roadway geometrics and roadside designs that reduce the probability of overturns 2 Improved vehicle designs that increase stability 3 Improved roadsides that reduce the number of collisions with hazardous objects 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 Optimum use of roadside safety features in relation to their selection, design, installation & maintenance 2 Improved roadside safety hardware 3 Improved vehicle compatibility and crashworthiness 4 Increased seat belt use and effectiveness and enhanced occupant protection systems 5 Improved emergency team responsiveness for highway crashes

Table 4 Action Items Directed Toward Trees

Action # M	G	O	A	Priority	Description of Action
					Roadside Safety Hardware Manufacturers
5	2	4	5	H	Develop energy absorbing devices for trees and rigid poles.
					Transportation Agencies
2	3	3	10	H	Use finite element analysis to explore the effects of airbags on vehicle occupants in roadside collisions.
2	3	3	11	H	Utilize available occupant models to estimate severity of injury in simulated crashes and crash tests.
3	2	2	2	H	Develop guidelines for enhancing the conspicuity of roadside hazards and fixed objects (poles, trees, etc.).
4	3	1	1	H	Identify and remove hazardous trees on and off the right-of-way (R/W).
4	3	1	2	H	Establish a policy - if a tree is hit, remove it.
4	3	1	3	H	Determine appropriate trade-offs to reduce the number of trees in the R/W.
4	3	1	4	H	Develop techniques to deal with obstructions on private property outside of the highway R/W.
4	3	1	5	H	Develop alternatives for trees that keep environmentalists happy and motorists safe.
4	3	1	6	H	Analyze vehicle/tree interactions to determine when tree size becomes hazardous.
4	3	1	7	H	Educate the public about the hazards of trees close to the roadway.
5	2	4	5	H	Develop energy absorbing devices for trees and rigid poles.
					Vehicle Manufacturers
2	3	3	10	H	Use finite element analysis to explore the effects of airbags on vehicle occupants in roadside collisions.

Table 5 Research Needs for Mission 1

Mission 1 – Increase the awareness of roadside safety and support for it	
Research Subject	**Research Needs**
Awareness of roadside safety (RS)	• Develop public information materials on RS • Develop position papers on RS issues • Develop press releases on RS
Financial resources to address RS	• Develop estimates of funding needs for RS • Identify potential funding sources for RS • Develop materials for legislative briefings and testimony
Proficiency of RS practitioners	• Develop training materials for designers, installers & maintainers of RS hardware • Establish a clearinghouse for RS information
Safety Management System RS module	• Review RS components of existing SMSs • Develop model RS module for SMSs • Develop decision support tools for RS module
Updating the RS strategic plan	• Develop a system for updating the strategic plan • Develop a system for prioritizing the action items in the plan

Table 6 Research Needs for Mission 2

Mission 2 – Build and maintain information resources and analysis procedures necessary to support continued improvement of roadside safety	
Research Subject	**Research Needs**
Roadway/roadside inventory databases	• Develop common location referencing system • Develop model roadway/roadside inventory database • Develop compatible traffic operations database
Highway crash databases	• Establish standardized requirements for crash data • Develop methods for police officers to record crash locations • Develop procedures to increase accuracy of crash data • Develop a database for "unreported" roadside impacts • Obtain data on vehicle roadside encroachments trajectories
In-service evaluations of RS hardware	• Develop procedures for in-service performance evaluations • Conduct post-crash performance evaluations of RS hardware • Conduct in-service quality evaluations of installation and maintenance of RS hardware
Fundamental relationships between safety and roadside features	• Develop techniques to estimate run-off-road encroachment rates as functions of road type, alignment, grade, traffic, … • Develop techniques to estimate occupant injury severity • Develop models to predict the impact on RS of changes in highway conditions or policies
Vehicle dynamics database	• Develop policies and procedures for using data from vehicle event data recorders associated with airbag deployment
Finite element analyses (FEA) of vehicle-roadside interactions	• Develop or obtain FE models for standard test vehicles • Develop models of widely-used roadside hardware • Develop behavior models for soils and hardware materials • Develop modeling techniques for rolling tires and vehicle suspension systems • Use FEA to test the sensitivity of RS hardware effectiveness to installation and maintenance errors • Develop validation procedures for FE models • Use FEA to determine effects of airbag usage on RS injuries • Develop methods to estimate occupant injuries using FEA
Identifying and prioritizing locations	• Develop methods for identifying hazardous roadside sites • Develop methods for identifying hazardous work zones • Develop causal models for roadside crashes • Develop methods for selecting cost-effective roadway-roadside countermeasures

Table 7 Research Needs for Mission 3

Mission 3 – Keep vehicles from leaving the roadway	
Research Subject	**Research Needs**
Safety enhancement tools for highway designers	• Determine the effects of geometric design on RS • Develop design techniques that meet driver expectations • Develop safety audit techniques to identify RS problems • Develop uses of 3- and 4- dimensional visualization technologies for highway design • Develop RS enhancing design guidelines that consider highway class, current vehicle fleet, traffic conditions, economics, aesthetics, and other pertinent factors • Develop training materials and programs that emphasize the relationships between highway design and RS
Improved traffic operations that reduce roadside encroachments	• Develop guidelines for the use of rumble strips • Develop guidelines for sight lines at intersections and curves • Study the impact of traffic control devices on ROR crashes • Study the effects of bicycles & pedestrians on ROR crashes • Develop guidelines for enhancing the conspicuity of RS objects • Develop improved delineation, signing, and lighting systems • Develop improved guidelines for traffic control devices
Improved highway and vehicle maintenance to reduce vehicle control loss	• Develop guidelines for highway maintenance to enhance RS • Identify vehicle failure mechanisms that cause control loss • Recommend changes to state vehicle inspection programs that will enhance RS • Study the effects of long work zones on driver behavior
Improved vehicle-based systems to keep drivers on the road	• Develop vehicular lateral guidance systems • Develop guidelines for in-vehicle information systems • Develop systems to enhance driver nighttime visibility • Develop safety effective driver monitoring systems • Develop impending rollover warning systems
Improved driver performance and behavior	• Develop educational materials to improve driver behavior • Identify driver behaviors that lead to loss of control and roadside encroachments • Develop model driver education programs • Develop remedial driver training programs • Develop improved graduated licensing programs • Determine the effect of vision tests on highway safety • Develop speed enforcement strategies that improve RS • Develop enforcement strategies to reduce impaired driving • Determine the effect on RS of multiple traffic offenders

Table 8 Research Needs for Mission 4

Mission 4 – Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway	
Research Subject	**Research Needs**
Improved roadway and roadside designs that reduce the probability of overturns	• Determine the relationship between vehicle characteristics and vehicle overturning for various side slope • Develop computer models of slope/vehicle interaction • Develop computer models of vehicle interactions with curbs, drainage facilities, vegetation, etc. • Develop design guidelines for curbs, slopes, and drainage features so vehicles can traverse them without overturning • Develop methods to prevent slope and ditch erosion • Develop design strategies to prevent pavement drop-offs • Develop guidelines for maintaining clear zones • Develop slow-growth vegetation species for roadsides
Improved vehicle designs that increase vehicle stability in ROR situations	• Develop vehicles that are more stable in ROR situations • Develop technologies that improve vehicle stability when rollover is impending • Determine the effects of tire condition on vehicle stability • Determine the feasibility of establishing vehicle-stability requirements, warnings, or regulations • Compare the cost-effectiveness of improving vehicle stability versus improving roadside traversability
Improved roadside treatments that reduce hazards collisions with roadside	• Determine when tree size becomes hazardous • Develop guidelines for dealing with natural obstructions occurring within and adjacent to the highway right-of-way • Develop guidelines for placement of highway appurtenances in the highway right-of-way • Develop model utility permit policies
Improved roadside treatments that reduce collisions with roadside hazards	• Develop programs to get utility companies to relocate poles • Develop guidelines for the removal of misplaced highway appurtenances • Evaluate guardrail performance on slopes and develop design guidelines • Evaluate the adequacy of guardrail runout length guidelines • Evaluate the adequacy of clear zone requirements • Develop conspicuity guidelines for roadside appurtenances
Improved driver performance in ROR situations	• Identify typical driver responses to ROR situations • Develop a list of correct driver responses for ROR scenarios • Develop ROR simulation programs for driver training

Table 9 Research Needs for Mission 5

Mission 5 – Minimize injuries and fatalities when overturns occur or objects are struck in the roadside	
Research Subject	**Research Needs**
Improved methods for selecting roadside safety hardware	• Develop standards for traversable side slopes • Develop warrants for roadside hardware performance levels • Develop warrants for selecting guardrail terminals • Develop warrants for clear zones behind roadside barriers • Develop warrants for work zone safety features
Roadside maintenance management systems	• Develop programs to train roadside hardware maintainers • Develop methods to identify hardware needing maintenance • Develop equipment to automate hardware repairs
Validity of current crash testing procedures	• Assess the field relevance of crash test impact specifications, occupant risk criteria, and non-tracking impacts • Assess the importance of post-impact vehicle trajectories and soil conditions and post installation methods • Assess the effects of higher speed limits on test criteria • Assess the effects of airbags, occupant restraints, and anthropomorphic test devices on testing procedures • Develop improved crash testing procedures
Improved roadside safety hardware	• Develop roadside hardware for a range of test levels • Develop roadside hardware suitable for side impacts • Develop roadside hardware that is easy to construct & repair • Develop energy absorbing devices for trees and poles
Compatibility between vehicles and roadside safety hardware	• Determine which vehicle and barrier features need to be controlled to ensure vehicle/barrier compatibility • Determine the range of bumper heights compatible with existing roadside hardware • Develop procedures to test the performance of vehicles in side impacts with narrow roadside objects
Vehicle rollovers	• Develop systems that reduce door openings in rollovers • Develop vehicles with non-crushable occupant “safe zones” • Develop occupant restraint systems effective in rollovers
Increased seat belt usage	• Develop enforcement programs to increase seat belt usage • Develop education programs to encourage seat belt usage
Improved emergency team responsiveness	• Develop automatic crash signaling devices for vehicles and roadside hardware to alert emergency response teams • Develop methods to transmit vehicle and occupant data to trauma units to assist in treating the injured

Table 10 Potential Participants - Strategic Plan for Improving Roadside Safety

Legislative bodies	Emergency services providers
Elected officials	Universities and research organizations
Transportation agencies	Automobile manufacturers
Regulatory agencies	Roadside hardware manufacturers
Law enforcement agencies	Insurance companies
Safety advocacy groups	Utility companies
Citizen action groups	Trial lawyers
Health providers	News media

APPENDIX A

THE STRATEGIC PLAN FOR IMPROVING ROADSIDE SAFETY

Mission, Goals, Objectives, and Actions

Goals - statements of desired outcomes under each mission

Objectives - specific aspects of a goal which can be measured to determine the degree to which a goal is met

Actions - Activities that can be taken by one or more entities to satisfy an objective

Mission 1 - Increase the awareness of roadside safety and support for it.

Goal 1.1 A coalition of governmental, industrial, institutional and civic partners that will work toward the improvement of roadside safety.

Objective 1.1.1 Identify a lead organization to champion the creation of the coalition.

Action 1.1.1.1 Compile a list of possible lead organizations.

Action 1.1.1.2 Assemble representatives of potential lead organizations for a discussion of the roadside safety strategic plan.

Action 1.1.1.3 Involve the representatives in a process to identify the best organization to lead the implementation of the strategic plan.

Objective 1.1.2 Create a steering committee to guide and oversee the operation of the coalition.

Action 1.1.2.1 Solicit steering committee volunteers from the meeting of potential lead organizations.

Action 1.1.2.2 Identify key partners and stakeholders who should be represented on the steering committee and contact them about participating on the committee.

Action 1.1.2.3 Convene the initial steering committee and have the group suggest possible additional members.

Objective 1.1.3 Recruit coalition members from those groups that can have an impact on improving roadside safety (key partners) and those groups potentially affected by the plan (stakeholders).

Action 1.1.3.1 Develop a comprehensive list of key partners and stakeholders and the organizations or individuals that can most effectively reach them. Groups and constituencies could include: Auto clubs, health care professional societies, emergency medical services personnel, senior groups - AARP, MADD, law enforcement personnel, utilities, environmental groups, safety-concerned groups, auto insurance, federal, state and local governments.

Action 1.1.3.2 Send letters of invitation with personal follow-ups. The key is to show potential partners what is in it for them.

Objective 1.1.4 Encourage partners to take responsibility for implementing specific aspects of the strategic plan.

Action 1.1.4.1 Identify and support “champions” in each partner organization to promote the aspects of roadside safety relevant to their interests.

Action 1.1.4.2 Find additional “champions” for aspects of the plan not covered by the partner organizations.

Objective 1.1.5 Establish on-going communication to and among the network of partners.

Action 1.1.5.1 Create an Internet home page for the coalition.

Action 1.1.5.2 Create newsletters, legislative alerts, brochures, and a fax hotline.

Action 1.1.5.3 Establish a regular flow of information on the latest research, legislation, and policy developments.

Goal 1.2 A heightened awareness of the importance of roadside safety by the public including citizens, decision makers, and special interest groups (e.g., environmentalists, utility companies, MPO’s, and grassroots organizations).

Objective 1.2.1 Inform elected officials, the public, the environmental community, utility companies, law enforcement organizations, MPO's, grassroots organizations, and news media about the importance of roadside safety programs.

Action 1.2.1.1 Develop and identify briefing material and technical assistance for these diverse groups--a package of brochures, videos etc. that groups can send to members with their logo.

Action 1.2.1.2 Identify current positions of these groups and their justification for these positions to develop materials tailored to their interests.

Action 1.2.1.3 Develop "canned" public awareness materials and programs on roadside safety for others to personalize and distribute.

Action 1.2.1.4 Work with coalition partners and stakeholders to include roadside safety issues on the agendas of on-going meetings, symposia, and workshops to create awareness of roadside safety problem and ways to implement countermeasures.

Action 1.2.1.5 Conduct with coalition members joint meetings, forums, and workshops to highlight roadside safety issues.

Action 1.2.1.6 Develop an instructional video on roadside safety for use in roll call training sessions.

Action 1.2.1.7 Develop a roadside safety team to speak at roll call training sessions.

Objective 1.2.2 Inform the public about specific roadside safety issues that they can influence.

Action 1.2.2.1 Encourage mass media coverage of roadside safety issues and countermeasures through partners.

Action 1.2.2.2 Develop campaigns to increase driver and public awareness of specific roadside safety issues, e.g., work with post offices to inform rural mailboxes owners of the hazard of certain types of mailboxes.

Action 1.2.2.3 Identify and emulate previous successful public service announcement (PSA) campaigns regarding seat belts, smoking, prevention of forest fires, etc.

Action 1.2.2.4 Provide generic, copy-ready materials for printing and use in media promotion.

Goal 1.3 Increased emphasis on roadside safety by partners and stakeholders and better communications between them.

Objective 1.3.1 Establish and maintain communication networks between partners and stakeholders.

Objective 1.3.2 Promote roadside safety activities by partners and stakeholders.

Goal 1.4 Sufficient financial resources to address roadside safety needs at the federal, state and local levels.

Objective 1.4.1 Develop estimates of funding needs for roadside safety and establish priorities for using the funds.

Action 1.4.1.1 Work with coalition partners to make estimates of the funding needed to finance the roadside safety program.

Action 1.4.1.2 Develop and communicate information on the societal costs of neglecting roadside safety and the benefits of addressing it.

Action 1.4.1.3 Establish a procedure within the coalition to set priorities for roadside safety projects, initiatives, and research.

Objective 1.4.2 Identify potential funding sources for roadside safety.

Action 1.4.2.1 Provide a database to match partners with resources and alternative funding mechanisms.

Action 1.4.2.2 Identify experts who can assist partners with grant requests.

Action 1.4.2.3 Identify approaches for funding from public sources.

Action 1.4.2.4 Identify approaches for funding from the private sector.

Action 1.4.2.5 Develop white papers and briefing materials describing the funding process and resources available to finance roadside safety.

Objective 1.4.3 Establish roadside safety items as fundable elements via line items in federal and state budgets.

Action 1.4.3.1 Develop and communicate legislative issues that partners can support to promote the cause of roadside safety.

Action 1.4.3.2 Prepare briefing material, talking points and videos for legislative briefings and testimony.

Action 1.4.3.3 Assist partners in developing good working relationships with safety staff of key Congressional and state legislative committees.

Objective 1.4.4 Identify opportunities for funding roadside safety projects and research from pooled-funds and cooperative agreements among coalition partners.

Action 1.4.4.1 Use cooperative agreements to fund joint initiatives with key partners and stake holders.

Action 1.4.4.2 Use established programs such as NCHRP to fund roadside safety research projects.

Objective 1.4.5 Provide roadside safety information to meet the needs of decision makers at state and local levels.

Goal 1.5 On-going programs to disseminate roadside safety information to practitioners, researchers, decision makers, and the public.

Objective 1.5.1 Improve the proficiency of practitioners responsible for roadside safety.

Action 1.5.1.1 Develop and maintain basic information on the roadside safety problems in a format usable by practitioners, i.e., designers, installers, maintainers.

Action 1.5.1.2 Develop and conduct training courses to insure that practitioners understand basic concepts of roadside safety.

Action 1.5.1.3 Conduct research on behavioral modification training to increase sense of importance and accountability for good installation and maintenance practices.

Action 1.5.1.4 Develop techniques for effective targeting of training programs.

Action 1.5.1.5 Develop methods to aid practitioners in roadside safety functions, e.g., IHSDM.

Action 1.5.1.6 Establish pervasive, interactive networks available to the practitioner which share information on national and international experience, standards, and procedures--the state of the art of roadside safety.

Action 1.5.1.7 Develop feedback loops to insure that developed information can lead to improved guidelines and designs (installers/maintainers to designers).

Action 1.5.1.8 Promote technology transfer through demonstration projects, pilot installations and in-service evaluations.

Objective1.5.2 Enhance the exchange of roadside safety information between federal, state, local and private partners.

Action 1.5.2.1 Establish a national clearinghouse for roadside safety information.

Action 1.5.2.2 Use the Internet to facilitate the sharing of information.

Action 1.5.2.3 Encourage professional societies to promote roadside safety in their activities.

Action 1.5.2.4 Identify stakeholder groups' publications and have articles on roadside safety and countermeasures published in these periodicals.

Action 1.5.2.5 Work with highway agencies, health providers, law enforcement officials and insurance companies to gather existing information relevant to roadside safety.

Action 1.5.2.6 Analyze, identify and communicate key roadside safety problems revealed in these data.

Action 1.5.2.7 Promote development of mechanisms for state and local agencies to utilize data resources that focus on local roadside safety issues.

Action 1.5.2.8 Develop and disseminate roadside safety materials designed for use by county and city engineers.

Objective1.5.3 Exchange safety technologies and innovative approaches between domestic partners and international colleagues.

Action 1.5.3.1 Identify mechanisms to work with domestic and international groups to share technology and innovations, e.g., IRF, IBTTA, etc.

Action 1.5.3.2 Conduct international conferences and seminars on roadside safety.

Objective 1.5.4 Provide roadside safety information to meet the needs of decision makers at state and local levels.

Action 1.5.4.1 Create an executive information system to provide access to roadside safety information.

Action 1.5.4.2 Develop mechanisms to provide information concerning the cost implications and injury benefits of roadside safety actions (e.g., tort claim losses, roadside harm information).

Action 1.5.4.3 Develop feedback loops from the practitioners to the decision makers to insure that developed information can affect policy and program development.

Objective 1.5.5 Provide roadside safety information to the public.

Action 1.5.5.1 Use the results of in-service evaluations to develop communication pieces appropriate for a broad audience - public officials, MPO's, private sector companies, law enforcement etc.

Action 1.5.5.2 Develop and communicate information on the societal costs of neglecting roadside safety and the benefits of addressing it

Goal 1.6 A roadside safety component in all DOT safety management systems.

Objective 1.6.1 Develop a model roadside component for Safety Management Systems SMS).

Action 1.6.1.1 Assess the handling of roadside safety information in current SMS courses and materials developed by the National Highway Institute.

Action 1.6.1.2 Modify these materials as necessary.

Action 1.6.1.3 Develop data-driven decision support tools to accompany the roadside component of the SMS.

Objective 1.6.2 Improve coordination and planning of all aspects of roadside safety within all states and local agencies.

Action 1.6.2.1 Identify a state/federal-funded Safety Engineer in each state to coordinate roadside safety activities.

Action 1.6.2.2 Designate state/federal-funded Safety Engineers to assist local governments with their roadside safety programs.

Goal 1.7 On-going process for updating the roadside safety strategic plan and for prioritizing research needs.

Objective 1.7.1 Develop a system for periodically updating the Strategic Plan.

Action 1.7.1.1 Convene the NCHRP 17-13 panel to review the Plan components and after four years, the use of the Plan.

Action 1.7.1.2 Establish a systematic process for reviewing progress and updating the Plan.

Objective 1.7.2 Identify and prioritize research needs for AASHTO, FHWA, and others.

Action 1.7.2.1 Develop a data-driven methodology for prioritizing research needs.

Action 1.7.2.2 Distribute research priorities to all possible funding agencies.

Objective 1.7.3 Revise priorities to reflect new knowledge and the changing features of the vehicle fleet, driver population and other factors.

Action 1.7.3.1 Aggregate specific trend data on demographics and vehicle characteristics.

Action 1.7.3.2 Develop one or more mechanisms for revising program priorities.

Action 1.7.3.3 Develop feedback loops between the research community and the coalition members as a means for revising priorities.

Mission 2 - Build and maintain information resources and analysis procedures necessary to support continued improvement of roadside safety.

Goal 2.1 Improved roadside and roadway inventory systems based on a common location referencing system.

Objective 2.1.1 Establish a common location referencing system to integrate all databases.

Action 2.1.1.1 Investigate referencing systems currently being used with safety databases and determine the feasibility of establishing a common referencing system.

Action 2.1.1.2 Investigate the feasibility of using new information technologies to establish a common referencing system.

Action 2.1.1.3 Select the appropriate referencing system(s) to be used for database integration.

Action 2.1.1.4 Establish and maintain reference markers in the field to support the location reference system.

Action 2.1.1.5 Monitor improvements in GIS/GPS and Intelligent Transportation Systems (ITS) to keep the roadside safety database referencing system current and compatible with other transportation information systems.

Objective 2.1.2 Improve roadway/roadside inventory databases.

Action 2.1.2.1 Develop model roadway/roadside inventory databases for use by state DOT's and by local highway agencies which include data on cross-section, alignment, pavement conditions, sight distance, traffic control devices, roadside hardware, side slopes, etc.

Action 2.1.2.2 Provide incentives for state and local highway agencies to create (or enhance) roadway inventory databases.

Action 2.1.2.3 Expand the HSIS system to include more roadside data.

Action 2.1.2.4 Create/improve/maintain databases on construction zones.

Action 2.1.2.5 Create/improve/maintain databases on roadside maintenance activities (e.g., guardrail and crash cushion maintenance).

Objective 2.1.3 Improve traffic operations data.

Action 2.1.3.1 Improve and expand operating traffic speed information.

Action 2.1.3.2 Investigate methods to improve vehicle classification information.

Action 2.1.3.3 Improve information on counts by vehicle classifications (e.g., truck types) so it can be matched with crash characteristics (e.g., time of day, functional class).

Action 2.1.3.4 Establish links to national databases (e.g., HPMS) to provide traffic adjustment factors, trend information, and other relevant information.

Action 2.1.3.5 Capture information from surveillance networks (e.g., ITS for congestion data).

Goal 2.2 Comprehensive roadside safety information resources including crash data, in-service evaluations, funding sources, research results, training programs, tort claims, highway inventories, traffic data and vehicle sensor data.

Objective 2.2.1 Create a framework for the establishment of cooperative agreements to develop needed information resources.

Action 2.2.1.1 Identify information resources needed.

Action 2.2.1.2 Investigate the structures of existing cooperative agreements used by agencies for other purposes as possible frameworks for roadside safety agreements.

Action 2.2.1.3 Work with two or three potential "cooperative" partners to develop a model cooperative agreement.

Objective 2.2.2 Improve highway crash databases.

Action 2.2.2.1 Incorporate the goals and actions of the "National Agenda for Improving Highway Information Systems" by reference and actively support attainment of the National Agenda goals.

Action 2.2.2.2 Establish standardized data requirements to facilitate performance comparisons across the nation (e.g., NGA, CADRE).

Action 2.2.2.3 Improve identification of crash location by investigating officers (e.g., through use of on-board locational devices).

Action 2.2.2.4 Include data related to sequence of events and/or most harmful event on crash reports.

Action 2.2.2.5 Improve accuracy/consistency of roadside object definitions for police use.

Action 2.2.2.6 Work with the National Safety Council's (NSC) traffic records division and the law enforcement community to include workable, but effective, roadside hazard elements on police crash report forms.

Action 2.2.2.7 Include "threshold" data in databases so that comparisons can be made across jurisdictions and time.

Action 2.2.2.8 Develop a database of unreported roadside impacts to support research on impact severity (e.g., maintenance data, inventory of vehicle contacts, insurance data).

Action 2.2.2.9 Obtain improved data on vehicle trajectories in roadside encroachment crashes for use in designing and interpreting computer simulation studies as well as in roadside benefit-cost models.

Action 2.2.2.10 Capture and monitor information from citizen reports.

Action 2.2.2.11 Request generic information from insurance companies on PDO crashes.

Action 2.2.2.12 Explore feasibility of in-depth crash databases for specific roadside issues.

Action 2.2.2.13 Develop "smart computers" to automate data collection efforts and location accuracy.

Action 2.2.2.14 Improve feedback/coordination between engineers and police.

Action 2.2.2.15 Identify "successes" resulting from good police crash reports and communicate to law enforcement leaders and patrolmen via their trade periodicals.

Objective 2.2.3 Investigate and monitor the effectiveness of roadside treatments to increase the amount of information available on in-service evaluations of roadside safety hardware.

Action 2.2.3.1 Develop a framework for in-service evaluations that is based on sound scientific methods and includes data needed to evaluate facility effectiveness, life-cycle costs, and maintenance requirements.

Action 2.2.3.2 Develop a priority-based plan for monitoring the effectiveness of various types of roadside treatments.

Action 2.2.3.3 Conduct in-service evaluations of roadside treatments to monitor the quality of installation and maintenance.

Action 2.2.3.4 Conduct post-crash performance analyses of roadside safety hardware.

Action 2.2.3.5 Conduct carefully controlled, post-implementation evaluations of roadside safety improvement projects and programs.

Goal 2.3 State-of-the-art methodologies and tools for analyses of crashes and simulations of roadside crashes and crash tests.

Objective 2.3.1 Improve the understanding of fundamental relationships between safety, roadside features such as clear zones, side slopes, and roadside hardware and traffic factors.

Action 2.3.1.1 Develop improved techniques for crash-based studies.

Action 2.3.1.2 Develop techniques to estimate run-off-road encroachment rates as functions of road type, alignment, grade and other variables.

Action 2.3.1.3 Develop improved estimates of occupant injury severity in run-off-road crashes (e.g., by angle, speed of impact, age of occupant) and develop linkages with medical databases (CODES).

Action 2.3.1.4 Develop predictive models to study the impacts of changes in conditions (e.g., traffic volumes, land use) or policy (e.g., speed limit changes, zoning, illumination) on roadside safety.

Objective 2.3.2 Develop a database on vehicle dynamics in roadside crashes.

Action 2.3.2.1 Develop policies and procedures to allow collection of information from on-board air-bag data recorders.

Action 2.3.2.2 Develop links between this database and crash analysis models and databases.

Objective 2.3.3 Develop and utilize finite element analyses techniques to model vehicle-roadside safety device interactions.

Action 2.3.3.1 Develop vehicle models of standard test vehicles.

Action 2.3.3.2 Obtain vehicle models from vehicle manufacturers or manufacturer trade associations.

Action 2.3.3.3 Develop models of widely-used roadside hardware.

Action 2.3.3.4 Develop material failure models for timber.

Action 2.3.3.5 Develop material behavioral models and modeling techniques for analyzing reinforced concrete roadside hardware.

Action 2.3.3.6 Develop material behavioral models for soils that include the effects of compaction, moisture content, and soil type.

Action 2.3.3.7 Develop modeling techniques to account for the effects of rolling tires and vehicle suspension systems.

Action 2.3.3.8 Develop validation techniques for roadside hardware and vehicle models.

Action 2.3.3.9 Use finite element analysis to explore the importance of test repeatability and the sensitivity of roadside hardware to installation and maintenance errors.

Action 2.3.3.10 Use finite element analysis to explore the effects of airbags on vehicle occupants in roadside collisions.

Action 2.3.3.11 Utilize available occupant models to estimate severity of injury in simulated crashes and crash tests.

Action 2.3.3.12 Examine the effects of various vehicle improvements in protecting occupants in off-road rollovers.

Action 2.3.3.13 Explore the expected performance of roadside hardware in impacts with future generations of motor vehicles.

Action 2.3.3.14 Establish a forum for communication between vehicle and roadside hardware modelers.

Objective 2.3.4 Utilize vehicle dynamics models to investigate rollover issues and pre- and post-impact scenarios.

Action 2.3.4.1 Use simulation tools to assess the impact of all typical roadside conditions.

Action 2.3.4.2 Use vehicle dynamics models to explore the interaction between vehicle suspension characteristics, inertial properties, slope characteristics, and other factors to understand rollover better.

Action 2.3.4.3 Develop methods of including tire/soil interaction for off-road traversals that can be used in vehicle dynamics programs.

Objective 2.3.5 Examine existing Federal Motor Vehicle Safety Standards (FMVSS) for linkages to roadside appurtenance performances.

Action 2.3.5.1 Establish a mechanism for sharing crash test data between vehicle manufacturers, roadside hardware manufacturers, NHTSA, FHWA and other organizations.

Action 2.3.5.2 Examine possible linkages between vehicle compliance tests (FMVSS tests) and roadside safety hardware testing.

Action 2.3.5.3 Establish standardized data analysis procedures and methods for certifying compliance of testing agencies.

Action 2.3.5.4 Perform out-reach activities to involve more vehicle manufacturers in the roadside safety hardware community.

Goal 2.4 On-going programs to conduct safety analyses and identify hazardous roadside locations.

Objective 2.4.1 Identify hazardous or potentially hazardous roadside locations.

Action 2.4.1.1 Develop improved procedures for identifying and prioritizing locations (e.g., linking crash data, inventory information and maintenance records).

Action 2.4.1.2 Explore the possible use of encroachment models or other methods to identify potentially hazardous locations (i.e., over long sections or entire routes).

Action 2.4.1.3 Identify hazardous roadside locations by monitoring crash data and changes in crash data over time.

Action 2.4.1.4 Develop procedures for identifying hazardous construction/maintenance work zones.

Objective 2.4.2 Analyze problem roadside locations to determine the causes of crashes.

Action 2.4.2.1 Develop causal models to study the influences of roadside, roadway, traffic, vehicle, environment, and driver characteristics on crash occurrence.

Action 2.4.2.2 Upgrade collision diagramming procedures to provide better information on roadside crashes.

Action 2.4.2.3 Develop improved diagnostic techniques (e.g., use of tort claims data and diagnostic teams).

Action 2.4.2.4 Increase the use of road safety audits.

Objective 2.4.3 Select alternative treatments using cost-effectiveness techniques.

Action 2.4.3.1 Define driver, vehicle, or roadway/roadside countermeasures for addressing each identified problem.

Action 2.4.3.2 Define and use societal costs that are consistent with those used in other national harm-reduction programs.

Action 2.4.3.3 Use cost-effectiveness and risk assessment techniques to select treatments.

Mission 3 - Keep vehicles from leaving the roadway.

Goal 3.1 Improved highway designs that reduce the probability of vehicles leaving the roadway.

Objective 3.1.1 Develop the tools to allow highway designers to incorporate safety into the design process.

- Action 3.1.1.1 Develop a better understanding of the effects of highway geometric design on roadside safety (e.g., sight distance, superelevation, curvature).
- Action 3.1.1.2 Develop techniques to promote consistent designs that conform to driver expectancy.
- Action 3.1.1.3 Develop improved hazard identification tools to identify potentially hazardous roadside designs and features on all roadways including local roads.
- Action 3.1.1.4 Investigate the use of safety audits in the roadway design process.
- Action 3.1.1.5 Develop uses of 3- and 4-dimensional visualization technologies to improve the design of highways.

Objective 3.1.2 Enhance design policies and guidelines to include safety considerations.

- Action 3.1.2.1 Develop specific design guidelines for identifiable functional highway classes that consider the interrelationships among highway function, design, operations, economics and safety.
- Action 3.1.2.2 Update design policies to recognize current vehicle fleet characteristics and operating speeds.
- Action 3.1.2.3 Develop guidelines for making tradeoffs between safety and other project considerations (aesthetics, historic, etc.).
- Action 3.1.2.4 Integrate new safety design tools and policies into existing roadway design software systems.
- Action 3.1.2.5 Establish a process for periodic review and updating of design documents to reflect new knowledge and research.

Objective 3.1.3 Enhance the highway designer's understanding of the effects of highway design on roadside safety, in particular, the importance of consistency in highway design in aiding drivers to maintain vehicle control.

- Action 3.1.3.1 Develop training materials for roadway designers, installers, and maintainers that emphasize the relationships between roadway design and safety with emphasis on 3R/4R and similar projects.
- Action 3.1.3.2 Develop training programs targeted for inexperienced engineers at the federal, state, and local levels and for consultants and design reviewers.
- Action 3.1.3.3 Develop and maintain continuing education requirements and materials for experienced engineers.
- Action 3.1.3.4 Encourage faculty to upgrade university programs to include consideration of roadway/roadside safety issues.

Goal 3.2. Improved traffic operating environment that reduces the occurrences of events contributing to loss of vehicle control and roadside encroachment.

Objective 3.2.1 Manage operating conditions to reduce the probability of out-of-control vehicles.

Action 3.2.1.1 Implement effective speed management strategies.

Action 3.2.1.2 Improve real-time information to drivers about adverse weather conditions, major incidents and potential run-of-the-road hazards.

Action 3.2.1.3 Retrofit the rural freeway system with rumble strips.

Action 3.2.1.4 Develop guidelines (considering bicycle needs) for use of rumble strips and edge-line rumble markings for all highway types.

Action 3.2.1.5 Develop guidelines for improving sight lines for safer operations (intersections, curves).

Action 3.2.1.6 Develop mathematical models of encroachment that include the effects of roadway geometry, function class and traffic mix.

Action 3.2.1.7 Study the impacts of traffic control devices on the potential for vehicles to run off the road.

Action 3.2.1.8 Study the effects of bicycles and pedestrians on vehicles' leaving the roadway.

Action 3.2.1.9 Train designers to look for operational situations that could cause a motorist to leave the roadway.

Objective 3.2.2 Improve signing, lighting, and delineation of the roadway to aid drivers' ability to stay on the road.

Action 3.2.2.1 Reassess advance warnings for speed reduction in light of increased speed limits.

Action 3.2.2.2 Develop guidelines for enhancing the conspicuity of roadside hazards and fixed objects (poles, trees, etc.).

Action 3.2.2.3 Develop improved delineation, signing and lighting systems for all conditions, including severe weather.

Action 3.2.2.4 Develop guidelines for the deployment of roadway lighting.

Action 3.2.2.5 Develop improved guidelines for deploying traffic control devices to warn of driver expectancy violations.

Action 3.2.2.6 Develop design and control guidelines for multilane highways that minimize the driver's need to change lanes.

Action 3.2.2.7 Develop improved traffic operations systems to reduce the hazard of animals on the roadway.

Goal 3.3. Sufficient maintenance of highways and vehicles to reduce the probability of loss of vehicle control.

Objective 3.3.1 Maintain roadway elements adequately to minimize run-off-the-road crashes.

Action 3.3.1.1 Develop guidelines for low-cost maintenance improvements on low-volume roads to reduce run-off-the-road crashes.

Action 3.3.1.2 Correct pavement surfaces likely to result in wet-weather, run-off-the-road crashes.

Action 3.3.1.3 Repair promptly road surface defects which may cause erratic maneuvers.

Action 3.3.1.4 Maintain pavement/shoulder edges to minimize hazardous drop-offs.

Action 3.3.1.5 Remove promptly roadway debris.

Action 3.3.1.6 Maintain drainage facilities adequately to minimize occurrences of water on the road surface.

Action 3.3.1.7 Maintain signing and delineation systems.

Action 3.3.1.8 Maintain roadside foliage to preserve clear sight lines.

Action 3.3.1.9 Sensitize maintenance workers to the safety importance of details in the maintenance of traffic control devices.

Objective 3.3.2 Maintain vehicles adequately to minimize malfunctions which result in run-off-the-road crashes.

Action 3.3.2.1 Identify vehicle failure mechanisms that result in loss of control and determine corrective strategies.

Action 3.3.2.2 Re-evaluate state vehicle inspection programs and incorporate needed corrective strategies into programs (e.g., headlamp aiming).

Action 3.3.2.3 Educate drivers of the risks associated with these vehicular malfunctions.

Objective 3.3.3 Minimize the number and durations of work zones.

Action 3.3.3.1 Minimize work zone duration by minimizing maintenance time.

Action 3.3.3.2 Coordinate maintenance operations of various agencies by location.

Action 3.3.3.3 Consider alternative strategies to work zones such as road closure.

Action 3.3.3.4 Use rumble strips before work zones to alert drivers of the work zone.

Action 3.3.3.5 Maintain positive separation between work zone and traveling motorists.

Action 3.3.3.6 Remove signs when work zones are not in effect to improve credibility.

Action 3.3.3.7 Promote driver training on how to deal with work zones.

Action 3.3.3.8 Study the effects of long work zones on drivers and ways to help drivers cope.

Action 3.3.3.9 Develop designs that have low maintenance requirements.

Goal 3.4 Improved vehicle-based systems that help keep drivers on the road.

Objective 3.4.1 Develop reliable vehicular lateral guidance systems.

Action 3.4.1.1 Develop vehicle-based roadway departure warning systems

Action 3.4.1.2 Assess the infrastructure requirements of proposed systems.

Objective 3.4.2. Develop vehicle systems to improve driver performance.

Action 3.4.2.1 Delineate vehicles for better nighttime conspicuity.

Action 3.4.2.2 Monitor ITS developments with respect to roadside safety implications (e.g., intelligent cruise control).

Action 3.4.2.3 Develop guidelines to ensure consistency of messages and presentation format for in-vehicle information systems.

Action 3.4.2.4 Develop technologies to enhance driver visibility during nighttime and adverse conditions (e.g., head lamp designs, ultraviolet head lamps, etc.)

Action 3.4.2.5 Develop safety effective driver monitoring systems.

Action 3.4.2.6 Develop systems to warn drivers of impending rollover.

Goal 3.5 Improved driver performance and behavior.

Objective 3.5.1 Change driver behaviors that contribute to run-off-the-road crashes.

Action 3.5.1.1 Develop effective educational materials and dissemination techniques to improve driver behavior (e.g., public service announcements on rules of road).

Action 3.5.1.2 Target specific driver groups and behaviors for behavioral modification techniques.

Action 3.5.1.3 Promote more education on the correct use of anti-lock braking systems.

Action 3.5.1.4 Study and identify driver behaviors and characteristics that contribute to loss of vehicle control and encroachment of the roadside.

Objective 3.5.2 Support legislative and policy activities to improve driver behavior.

Action 3.5.2.1 Enact primary seat belt laws.

Action 3.5.2.2 Enact administrative license revocation for impaired driving violations.

Action 3.5.2.3 Enact lower blood-alcohol concentration (BAC) thresholds for all drivers, and zero-tolerance for under-21 drivers.

Action 3.5.2.4 Enact legislative changes to allow automated traffic law enforcement.

Action 3.5.2.5 Develop model driver education programs.

Action 3.5.2.6 Develop effective remedial training programs to improve driver performance.

Action 3.5.2.7 Develop effective graduated licensing policies for younger and older drivers.

Action 3.5.2.8 Determine if vision screening tests (both initial and renewal) will reduce highway crashes.

Objective 3.5.3 Enforce traffic laws to reduce run-off-the-road crashes.

Action 3.5.3.1 Develop speed enforcement strategies that encourage safer driving behavior.

Action 3.5.3.2 Develop enforcement strategies that reduce impaired driving.

Action 3.5.3.3 Determine the effect of multiple traffic offenders on run-off-the-road crashes and develop appropriate remedial programs.

Mission 4 - Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway.

Goal 4.1 Improved roadway geometrics and roadside designs that reduce the probability of overturns for the variety of vehicles using the road.

Objective 4.1.1 Develop design standards for curbs, gutters, slopes and ditches that allow errant vehicles to traverse these features without overturning.

Action 4.1.1.1 Review and synthesize existing research on the interactions between vehicles (characteristics and speed) and slope angle and height, soil conditions, and ditch configurations.

Action 4.1.1.2 Determine the relationship between vehicle characteristics (e.g., track width, center-of-gravity height, etc.) and vehicle overturning for various side slopes.

Action 4.1.1.3 Develop and validate dynamic computer models of slope/vehicle interaction (tire/soil and bumper/soil interaction).

Action 4.1.1.4 Develop and validate dynamic computer models of vehicle interactions with curbs, gutters, vegetation, etc.).

Action 4.1.1.5 Investigate the trajectories of vehicles leaving the roadway under tracking and skidding conditions.

Action 4.1.1 6 Investigate driver behavior and reactions in "loss-of-control" situations.

Action 4.1.1.7 Identify performance characteristics of current vehicle fleet.

Action 4.1.1.8 Develop slope break point guidelines appropriate for current vehicle fleet and speeds.

Action 4.1.1.9 Establish inspection programs to insure that slopes are constructed smoothly.

Objective 4.1.2 Develop effective drainage techniques that result in more traversable roadsides.

Action 4.1.2.1 Remove drainage features from clear zones when cost effective.

Action 4.1.2.2 Develop strategies to improve the traversability of drainage facilities.

Action 4.1.2.3 Develop concepts to prevent erosion of slopes and ditches.

Objective 4.1.3 Develop design strategies to reduce pavement drop-offs.

Action 4.1.3.1 Develop models for soil-curb/tire interactions to study pavement drop-off reactions.

Action 4.1.3.2 Determine allowable drop off configurations.

Action 4.1.3.3 Develop longitudinal drainage concepts that eliminate erosion problems that lead to pavement drop-offs.

Action 4.1.3.4 Develop guidelines for pavement overlays to reduce pavement drop-offs.

Objective 4.1.4 Maintain roadside clear zones.

Action 4.1.4.1 Develop maintenance guidelines for roadside slopes and drainage structures.

Action 4.1.4.2 Mow/trim/spray roadside vegetation on a regular basis.

Action 4.1.4.3 Remove debris from roadside.

Action 4.1.4.4 Familiarize maintenance workers with the safety importance of roadside maintenance.

Action 4.1.4.5 Develop slow-growth, low-maintenance vegetation options for the roadside.

Goal 4.2 Improved vehicle designs that increase vehicle stability in run-off-the-road situations.

Objective 4.2.1 Develop improved vehicle stability relative to roadside terrain features.

Action 4.2.1.1 Investigate the ride and handling characteristics of current vehicles.

Action 4.2.1.2 Explore vehicle technologies that would vary the suspension system stiffness or shift the vehicle center of gravity during an impending overturn situation.

Action 4.2.1.3 Determine the effect of tire condition on vehicle stability.

Action 4.2.1.4 Compare the cost-effectiveness of improving the vehicle fleet vs. creating or improving clear zones.

Objective 4.2.2 Discourage consumers from purchasing vehicles that tend to be unstable.

Action 4.2.2.1 Compare the relative stability of vehicles.

Action 4.2.2.2 Disseminate information on vehicle stability to the general population.

Action 4.2.2.3 Determine the feasibility of establishing vehicle-stability requirements, warnings, or regulations.

Goal 4.3 Improved roadside treatments that reduce the number of collisions with hazardous objects along the roadside.

Objective 4.3.1 Develop guidelines for dealing with natural obstructions (trees, rocks, water courses, etc.) occurring within and adjacent to the highway right-of-way.

Action 4.3.1.1 Identify and remove hazardous trees on and off the right-of-way (R/W).

Action 4.3.1.2 Establish a policy - if a tree is hit, remove it.

Action 4.3.1.3 Determine appropriate trade-offs to reduce the number of trees in the R/W.

Action 4.3.1.4 Develop techniques to deal with obstructions on private property outside of the highway R/W.

Action 4.3.1.5 Develop alternatives for trees that keep environmentalists happy and motorists safe.

Action 4.3.1.6 Analyze vehicle/tree interactions to determine when tree size becomes hazardous.

Action 4.3.1.7 Educate the public about the hazards of trees close to the roadway.

Objective 4.3.2 Develop design guidelines (based on highway classification/ADT/speed, etc.) for placement of highway appurtenances in the highway right-of-way.

Action 4.3.2.1 Identify current utility placement practices of highway agencies, utility companies, and PUCs

Action 4.3.2.2 Develop model utility permit polices.

Action 4.3.2.3 Develop incentive programs for utility companies to relocate poles.

Action 4.3.2.4 Develop guidelines for removal of misplaced guardrail and other appurtenances.

Action 4.3.2.5 Train local highway personnel how to install roadside hardware properly.

Action 4.3.2.6 Evaluate guardrail performance when placed on slopes to determine if it is safe to locate them on slopes away from the pavement edge.

Action 4.3.2.7 Evaluate adequacy of current guardrail runout length requirements considering clear zone sizes.

Objective 4.3.3 Provide adequate highway clear zones.

Action 4.3.3.1 Investigate clear zone requirements considering speed, traffic, facility type, geometry, land availability, and other factors.

Action 4.3.3.2 Purchase or reserve adequate R/W.

Action 4.3.3.3 Establish model ordinances for R/W controls relative to plantings.

Objective 4.3.4 Improve conspicuity of roadside appurtenances.

Action 4.3.4.1 Determine conspicuity requirements.

Action 4.3.4.2 Develop guidelines to meet the conspicuity needs.

Goal 4.4 Improved driver performance in run-off-the-road situations.

Objective 4.4.1 Identify proper driver responses.

Action 4.4.1.1 Identify typical driver population responses under different run-off-the-road situations.

Action 4.4.1.2 Develop a list of correct driver responses for various run-off-the-road scenarios.

Objective 4.4.2 Implement driver education programs.

Action 4.4.2.1 Develop run-off-the-road simulation programs for driver training.

Action 4.4.2.2 Use TV public service announcements to promote the importance of seat belt usage and to inform drivers of proper actions to take when their car leaves the roadway.

Action 4.4.2.3 Use 402 funds to implement highway safety driver education programs.

Action 4.3.2.4 Use state licensing programs to inform drivers of proper driving techniques.

Mission 5 - Minimize injuries and fatalities when overturns occur or objects are struck in the roadside.

Goal 5.1 Optimum use of roadside safety features in relation to their selection, design, installation and maintenance.

Objective 5.1.1 Improve methods for selecting roadside safety hardware.

- Action 5.1.1.1 Update warrant criteria to reflect current knowledge of roadside crashes and hardware performance.
- Action 5.1.1.2 Develop specific definitions for "traversable" and "non-traversable" side slopes.
- Action 5.1.1.3 Develop warrants for a range of roadside hardware performance levels.
- Action 5.1.1.4 Develop warrants for energy-absorbing versus gating guardrail terminals.
- Action 5.1.1.5 Develop warrants for straight versus flared guardrail terminals.
- Action 5.1.1.6 Develop warrants that link clear zones with specific roadside hardware.
- Action 5.1.1.7 Develop warrants for work-zone safety features.
- Action 5.1.1.8 Maintain a readily available source of crash certification information.
- Action 5.1.1.9 Monitor high-crash locations to determine if higher performance hardware is warranted.

Objective 5.1.2 Provide training for personnel involved in the design, construction, and maintenance of roadside safety features.

- Action 5.1.2.1 Identify highway agencies with innovative and effective methods of ensuring that roadside hardware is installed and maintained properly.
- Action 5.1.2.2 Develop training materials for personnel involved in the design, installation, maintenance and inspection of roadside hardware.
- Action 5.1.2.3 Develop stand-alone video tapes that stress the importance of proper installation and maintenance of roadside hardware.
- Action 5.1.2.4 Expand accessibility to roadside hardware training and establish a dependable distributor for roadside hardware training materials.
- Action 5.1.2.5 Explore ways to encourage local and state highway agencies to take advantage of training opportunities.
- Action 5.1.2.6 Require the inclusion of training materials with all new roadside safety hardware delivered to highway agencies.
- Action 5.1.2.7 Identify a roadside safety hardware "point-person" in each state DOT as a part of its safety management system.
- Action 5.1.2.8 Establish state-level contractor certification programs for the installation, maintenance and inspection of roadside safety hardware.

Objective 5.1.3 Implement roadside maintenance management systems to assure prompt repair and appropriate periodic maintenance of roadside safety features.

- Action 5.1.3.1 Develop systems for the public to report roadside hardware repair needs.

Action 5.1.3.2 Use roadside safety audits to identify safety improvement possibilities.

Action 5.1.3.3 Incorporate in-service evaluation and crash data monitoring as a part of safety management systems.

Action 5.1.3.4 Develop equipment to automate roadside hardware repair functions.

Action 5.1.3.5 Utilize maintenance equipment effectively to minimize the time and cost for safety hardware repair or replacement.

Action 5.1.3.6 Include in original roadside hardware bid specifications provisions for spares of commonly-damaged parts.

Goal 5.2 Improved roadside safety hardware.

Objective 5.2.1 Assess the validity of current crash testing procedures

Action 5.2.1.1 Assess the field relevance of current full-scale test impact conditions.

Action 5.2.1.2 Assess the relevancy of the "occupant risk" criteria with respect to real-world crash experience.

Action 5.2.1.3 Assess the importance and field relevancy of non-tracking impacts and the feasibility of addressing such impacts in roadside hardware test procedures.

Action 5.2.1.4 Assess the importance of the post-impact trajectories of redirected vehicles.

Action 5.2.1.5 Assess the importance of soil conditions and post installation methods on guardrail and guardrail terminal performance.

Action 5.2.1.6 Assess the effects of higher speed limits on full-scale testing procedures.

Action 5.2.1.7 Assess the effects of airbags on full-scale testing procedures.

Action 5.2.1.8 Assess the use of restrained occupants in full-scale crash tests.

Action 5.2.1.9 Assess the utility and effectiveness of using anthropomorphic test devices and dummy-based injury measures for evaluating roadside hardware crash tests.

Action 5.2.1.10 Assess the real-world importance of changing from Report 230 to Report 350.

Objective 5.2.2 Develop targets of performance and improved testing procedures.

Action 5.2.2.1 Develop methods to account for and address the sensitivity and repeatability of roadside hardware crash tests.

Action 5.2.2.2 Develop guidelines for site geometry for crash tests of guardrails, crash cushions, and guardrail terminals.

Action 5.2.2.3 Develop specific definitions of acceptable test vehicles for inclusion in roadside hardware test procedures.

Action 5.2.2.4 Develop new methods for evaluating the risk of occupant harm in roadside hardware crash tests.

Action 5.2.2.5 Develop test and evaluation criteria for side impact crash tests with roadside hardware.

Action 5.2.2.6 Develop field-relevant, quantifiable guidelines on allowable floor-pan/firewall deformation in roadside hardware crash tests.

Action 5.2.2.7 Assess the possibility of including maintenance issues in the performance evaluation of roadside hardware.

Action 5.2.2.8 Assess the possibility of including environmental factors in the performance evaluation of roadside hardware.

Action 5.2.2.9 Continue efforts at standardizing and harmonizing international roadside hardware crash test procedures and evaluation criteria.

Objective 5.2.3 Analyze performance of existing hardware against target and identify performance deficiencies.

Action 5.2.3.1 Assess the real-world importance of proper guardrail terminal installation.

Action 5.2.3.2 Increase the amount of information included in roadside hardware crash test reports.

Action 5.2.3.3 Develop methods for informing roadside hardware users about their performance limits.

Objective 5.2.4 Develop improved hardware or new hardware.

Action 5.2.4.1 Develop roadside hardware for a broader range of test levels.

Action 5.2.4.2 Develop generic guardrail terminals.

Action 5.2.4.3 Develop guardrail terminals that perform acceptably in side impact collisions.

Action 5.2.4.4 Develop roadside hardware that is easier to construct and maintain

Action 5.2.4.5 Develop energy absorbing devices for trees and rigid poles.

Action 5.2.4.6 Determine if the government should develop new roadside hardware.

Action 5.2.4.7 Use new and innovative materials in roadside hardware.

Action 5.2.4.8 Encourage the use of standard hardware components in roadside hardware.

Objective 5.2.5 Validate & implement improvements.

Action 5.2.5.1 Develop procedures for performing in-service evaluations.

Action 5.2.5.2 Explore legislative methods for specifying that a percentage of SPR funds be used for in-service evaluations.

Action 5.2.5.3 Assess methods to include the results of in-service evaluations in the over-all evaluation of roadside hardware.

Action 5.2.5.4 Establish a national in-service evaluation clearinghouse for information on real-world experience with roadside hardware.

Goal 5.3 Improved vehicle compatibility and crashworthiness relative to roadside features.

Objective 5.3.1 Improve the compatibility between vehicles and roadside safety hardware.

Action 5.3.1.1 Determine the typical range of bumper heights and compare to the typical range of roadside hardware effective heights. Assess the importance of changing bumper and/or barrier heights.

Action 5.3.1.2 Determine which vehicle and barrier features need to be controlled to assure compatibility between the vehicle and barrier.

Action 5.3.1.3 Explore the performance of a variety of vehicle types in roadside hardware crash tests.

Action 5.3.1.4 Develop test procedures to evaluate the performance of vehicles in side impact collisions with narrow roadside objects and determine whether improvements are feasible and cost effective.

Action 5.3.1.5 Assess the effect of future vehicle fleet changes on roadside hardware performance.

Action 5.3.1.6 Assemble all the stakeholders involved in bumper height issues including vehicle manufacturers, NHTSA, FHWA, state law makers and roadside hardware developers to try to minimize bumper height related inconsistencies.

Objective 5.3.2 Reduce vehicle roll-overs or provide protection for such events.

Action 5.3.2.1 Minimize conditions which cause roadside rollovers.

Action 5.3.2.2 Develop systems that reduce door openings in rollovers to reduce the chance of occupant ejection.

Action 5.3.2.3 Develop vehicle systems that reduce the level of roof crush in rollovers.

Action 5.3.2.4 Develop vehicle structures with a non-crushable "safe zone" for occupant protection inside vehicles.

Action 5.3.2.5 Determine the importance of specific suspension components in off-road vehicle rollovers.

Action 5.3.2.6 Develop occupant restraint devices that are effective in protecting occupants in off-road rollovers.

Action 5.3.2.7 Use advanced glazing systems to reduce the chance of occupant ejection during rollovers.

Action 5.3.2.8 Improve seat belt performance to reduce the chance of occupant ejection during rollovers.

Goal 5.4 Increased seat belt usage and effectiveness and enhanced occupant protection systems.

Objective 5.4.1 Promote enforcement of occupant restraint laws.

Action 5.4.1.1 Educate law enforcement personnel on the importance of enforcing occupant restraint and child restraint laws.

Action 5.4.1.2 Encourage enforcement of occupant restraint and child restraint laws.

Action 5.4.1.3 Encourage insurance carriers to promote seat belt use through premium credits or penalties.

Action 5.4.1.4 Identify champions in each state to promote enforcement campaigns.

Objective 5.4.2 Improve the effectiveness of in-vehicle occupant restraint systems.

Action 5.4.2.1 Investigate alternative materials for restraint systems to reduce impact forces on occupants.

Action 5.4.2.2 Educate consumers on the proper use of occupant restraints.

Action 5.4.2.3 Modify FMVSS 213 to allow CRS attachment development.

Objective 5.4.3 Promote education regarding the use of seat belts and other occupant restraint systems.

Action 5.4.3.1 Educate the public on the importance of using seat belts in conjunction with airbags.

Action 5.4.3.2 Educate the public on the importance for older drivers to use seat belts.

Action 5.4.3.3 Develop partnerships between national, state, and other organizations to promote correct use of restraint systems.

Goal 5.5 Improved emergency team responsiveness for highway crashes.

Objective 5.5.1 Develop automatic crash signaling devices for vehicles and hardware to identify "compelling" injuries and serious crashes.

Action 5.5.1.1 Identify "clinical" and "vehicle" information that can be used by emergency response teams to assess remotely the seriousness of the crash.

Action 5.5.1.2 Develop methods to transmit vehicle and occupant data to emergency trauma units to allow them to make better triage decisions.

Objective 5.5.2 Use uniform communications notification systems.

Action 5.5.2.1 Encourage FCC to develop a standard protocol for transmitting crash information to police, trauma centers and highway agencies.

Action 5.5.2.2 Investigate the use of cellular phones and standard emergency response numbers to provide notification to emergency response units.

APPENDIX B

RUN-OFF-ROAD FATAL CRASHES 1975 TO 1997 (*3*)

This appendix is available upon request from the NCHRP.

APPENDIX C

MILESTONES IN ROADSIDE SAFETY SINCE 1960

This appendix is available upon request from the NCHRP.

APPENDIX D

ACTION PLANS FOR IMPROVING ROADSIDE SAFETY

This appendix is available upon request from the NCHRP.

APPENDIX E

RESEARCH ACTION ITEMS

This appendix is available upon request from the NCHRP.

APPENDIX F

ACTION ITEMS DIRECTED TOWARD IMPLEMENTING THE STRATEGIC PLAN

This appendix is available upon request from the NCHRP.

APPENDIX G

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