PROCEEDINGS

INTERNATIONAL SYMPOSIUM ON REAL WORLD CRASH INJURY RESEARCH

11th and 12th June, 1997
Hanover International Hotel, Leicestershire, UK

Hosted by Vehicle Safety Research Centre, Loughborough University

Sponsored by the
Co-operative Crash Injury Study (CCIS) Consortium

The UK Co-operative Crash Injury Study (CCIS):

The UK Co-operative Crash Injury Study (CCIS) is an ongoing programme of research that was set up in 1983 to conduct in-depth investigations into real world car crashes. The aim of the study is to provide government and industry with crash injury data that will assist in the development of regulations and improvements in secondary safety design features to help mitigate injuries to car occupants.

Some 1,600 vehicles are examined each year by teams from the Vehicle Safety Research Centre at Loughborough, Birmingham Accident Research Centre and the Vehicle Inspectorate Executive Agency. The study is managed by the Transport Research Laboratory, and funded by the UK Department of Transport with co-sponsorship from the motor manufacturers listed below.

CCIS funding consortium:

- *Department of Transport*
- *Ford Motor Company Limited*
- *Rover Group Limited*
- *Nissan Motor Company Limited*
- *Toyota Motor Europe*
- *Honda R & D Europe (UK) Limited*

OPPORTUNITIES FOR COLLISION COUNTERMEASURES USING INTELLIGENT TECHNOLOGIES

Dr. Joseph N. Kanianthra
National Highway Traffic Safety Administration
United States Department of Transportation

INTRODUCTION

Within the United States, statistics on vehicular crashes, related fatalities and injuries, and their associated rates per vehicle mile traveled have shown a noticeable decline in recent years [USDOT, 1995]. This has occurred at a time when speed limits and the levels of congestion on the roadways are increasing. While the exact reasons for these improvements in crash statistics are unclear, there is consensus that today's automobiles are designed to provide increased safety to the vehicle occupants. The efforts by the automobile manufacturers to build safer vehicles and the National Highway Traffic Safety Administration's efforts in improving safety through regulations are well known.

It should be noted however, that even with the safety improvements evidenced in the statistics, the number of automobile crashes and related fatalities and injuries are still at unacceptable levels. Much additional effort is needed to address these problems. The problems are multi-faceted, as are the approaches taken to address them. Improved occupant protection, improved braking systems, safer roadway design, better signing, and lighting systems are among the notable attempts to provide the vehicle driver and occupants with a safer driving experience.

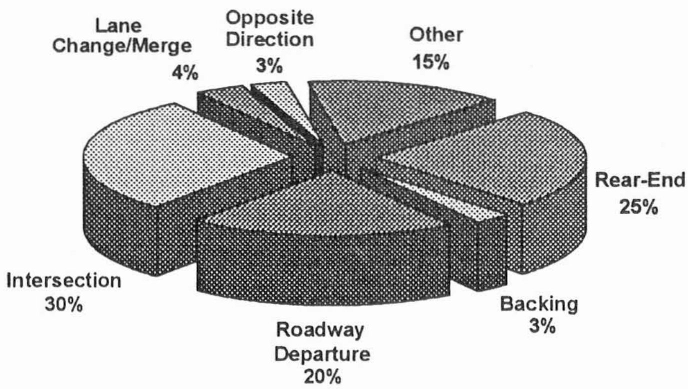
Since 1991, the NHTSA has had a concentrated program to facilitate the development and deployment of effective safety-related collision avoidance systems as part of the Intelligent Transportation Systems (ITS) program within the U. S. Department of Transportation. Research was initiated in developing crash countermeasures (warning or control intervention strategies) that take advantage of existing and developing technologies in the fields of sensors, computers and controls, and displays. The program started with an intensive analysis of safety problems and associated causal factors, in which detailed case studies were conducted to identify problem significance as well as the causal events preceding crashes. These analyses led to the initiation of a number of focused projects to develop and validate specifications for collision avoidance (CA) systems for the more significant collision types.

This paper will discuss the nature of the collision problem and countermeasures suggested by the problem analysis. It will summarize those activities that have been accomplished to date, as well as the major thrusts that are planned during the next 5 years as part of the continuing NHTSA Collision Avoidance Research program. The paper concludes with a discussion of the potential benefits anticipated from a successful program to foster the deployment of effective countermeasure systems/products.

DEFINING AND CATEGORIZING THE SAFETY PROBLEM

Figure 1 [USDOT, 1995] shows the distribution of crash types that provide opportunities for significant safety improvements through the introduction of intelligent technologies into the vehicle. Single vehicle road departure, rear end, and crossing path (intersection) crashes comprise nearly three-fourths of all crashes. The remaining one-fourth includes blind-spot, head-on, and other crash types. Contributing factors such as reduced visibility and driver drowsiness occur across the spectrum of all crash types shown in this figure.

Figure 1. Target Crash Problem Size



A summary of the causal factors for these collision types is shown in Figure 2 [Najm, 1994]. These results are from an extensive study of NHTSA crash files by staff and support contractors at the Volpe National Transportation Systems Center (VNTSC) of the Department of Transportation.

These findings provided an initial basis for the collision avoidance performance specification work that is discussed later in this paper. In addition to the work at VNTSC, each contractor that is working on performance specifications also analyzed crash data files and detailed case studies. This work was done to develop a clearer description of the dynamics of events that preceded specific types of crashes.

Figure 2. Causal Factor Distribution

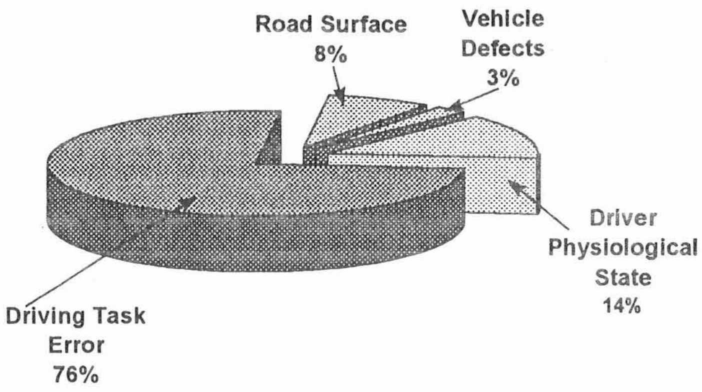


Table 1 is an example of the type of engineering insight that was obtained from these additional studies.

Table 1. Rear-End Collisions Dynamic Situations Matrix (Numbers in table are % of Total)

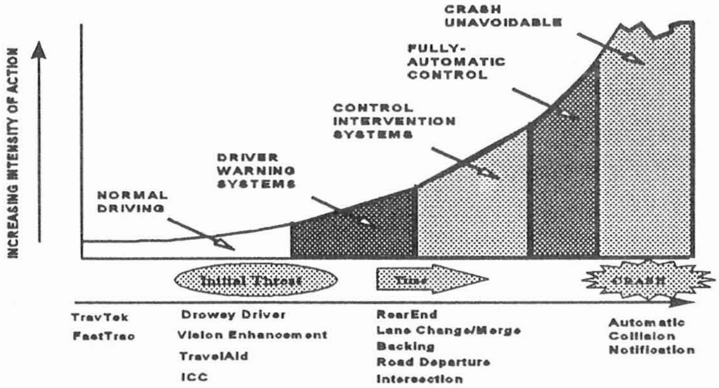
Lead Vehicle	Following Vehicle			SUM
	Accelerating	Constant Velocity	Decelerating	
Stationary	0.54	23.72	0.69	24.95
Constant Velocity	0.74	2.80	0	3.54
Decelerating	0	14.71	0	14.71
Accelerating	0	2.07	0	2.07
Decel & Stationary	0.11	50.05	4.57	54.73
Sum	1.39	93.35	5.26	100

PROBLEM AREAS FOR INTERVENTION STRATEGIES

The approach initially taken in the collision avoidance research program was to 1) establish research priorities based on the magnitude of the identified safety problem, 2) develop intervention strategies based upon analysis of causal factors, and 3) develop and validate collision countermeasure systems and their performance specifications.

Intervention strategies are designed to respond to the level of threat present under the various driving and pre-crash situations. Under normal driving situations and when no imminent threats are present, driving behavior is an "effortless" task requiring very little activity on the part of the driver. On the other hand, when crash risks are present, this effort increases exponentially. Under certain conditions of imminent-threat, information and driving advice is useful to the driver to assist in the normal driving tasks. As the level of threat increases, the CA system will provide tailored responses that are appropriate for the threat level. This will involve responses ranging from advisories and warnings to more timely use of control intervention systems, and finally, to the short-term application of fully automatic control as necessary (either braking and/or steering) under conditions when collisions are imminent and where drivers cannot respond in time to avoid the collision. Figure 3 shows the conceptual framework for the development of collision countermeasure systems.

Figure 3. Intervention Strategies



The above approach to collision avoidance system development gives rise to several specific categories of crash countermeasure systems. Category 1 systems will provide drivers with the driving information and cautionary warning when the potential for a collision exists. Category 2 systems will provide more intense warnings to the driver when the system predicts that a collision is imminent and that immediate action is required by the driver. Category 3 systems will provide warning and control support when the vehicle is on a collision course and where some form of automatic control is required to either avert the collision or to minimize the severity of the crash. The technical complexity of CA systems increases with each category, and the research program seeks to evolve system capabilities from the systems that provide advice and warning to the more complex systems that can also apply short-term vehicle control to avoid a collision.

There are seven safety problem areas that are being addressed through NHTSA's research projects. They are rear-end collisions, road-departure collisions, intersection collisions, lane change and merge collisions, backing collisions, collisions involving drowsy/inattentive drivers, and collisions associated with reduced visibility. All of these except the drowsy/inattentive driver project currently relate to passenger cars.

NHTSA also has separate efforts to improve the safety performance of heavy trucks and a program to speed the emergency medical response to crash victims after a crash has occurred. The latter program involves the development and testing of Automated Collision Notification (ACN) systems, which can transmit information on incident locations as well as other relevant information related to the crash types, their severity and other parameters critical to determining the type and severity of possible injury, to an Emergency Response Center, thereby permitting a rapid and tailored response to the crash scene. Data have shown that actions to expedite the delivery of emergency medical support to crash victims can both increase survival chances and reduce the long-term consequences of injuries.

The seven problem areas are discussed below.

Rear-End Collision Countermeasures

In 1994, there were approximately 1.66 Million police-reported rear-end crashes in the United States. These crashes accounted for more than 920,000 injuries and 1,160 fatalities. The most common causal factor associated with rear-end collisions is driver inattention during the driving task. A second, and overlapping, major causal factor is following too closely. One or both of these factors is present in approximately 90 percent of rear-end crashes. It is estimated that about 50 percent of these crashes could be avoided by collision avoidance systems that sense stopped or moving vehicles in the lane ahead of you, and provide driver warnings and/or speed adjustment control to the vehicle.

To be effective, sensor systems, including detection and threat determination algorithms, must detect objects in the forward field of view, determine range and relative speeds, and determine whether the object is in the countermeasure-equipped vehicle's lane of travel. This requirement includes the need to reject stationary, non-threat objects such as roadside or overhead signs, bridge abutments, etc., and to determine the position of the lane of travel on a curved roadway, a non-trivial task for today's systems. Warnings must be presented to the driver in a timely manner to permit controlled braking or evasive maneuvers.

Road-Departure Collision Countermeasures

Single vehicle road-departure crashes represent the most serious crash problem in the United States, based upon analysis of crash data files. Approximately 1.24 million police-reported crashes of this type occurred in 1994. This number represents about 19 percent of the total crash problem, but more significantly, crashes of this type lead to over 500,000 injuries and 13,000 fatalities, annually. The causes of these crashes are much more varied for this problem category, requiring a variety of intervention strategies. Causes include, but are not limited to, weather/vision problems, driver impairment, and other improper driving behaviors. Development of countermeasures for this problem category presents significant challenges.

The roadway departure countermeasure development project focuses on systems to provide the driver with road-departure warnings and is complemented by projects involving other driver warnings and vision enhancement systems. There are two key components of road-departure countermeasure systems: lateral and longitudinal. The lateral road-departure countermeasure system is designed to prevent run-off-the-road crashes that are primarily caused by driver inattention and driver relinquishing control due to drowsiness or other impairment. In this instance the system detects when the vehicle begins to depart the road. A simpler version would warn the driver when the vehicle has crossed the lane edge onto the shoulder of the road. A more complex system would predict, based upon knowledge of road geometry ahead and vehicle dynamics, that the vehicle will leave the road unless specific and timely actions are taken by the driver.

The longitudinal road-departure countermeasure system addresses crashes caused predominantly by excessive speed on curved roadways and subsequent loss of directional control. This system detects when a vehicle is traveling too fast for the upcoming roadway conditions, and provides warning to the driver. It utilizes vehicle performance data in combination with information about pavement conditions and upcoming roadway geometry to determine maximum safe speed for the vehicle.

Optical vision systems have been examined for their ability to track road or lane edges and to determine road curvature in the forward direction. Another option being examined is the use of enhanced road map data, in an in-vehicle database with positioning systems, to determine road geometry (i.e., curvature and super-elevation).

Intersection Collision Countermeasures

Intersections are among the most dangerous locations on U. S. roads. Approximately 1.95 million crashes occurred at intersections in 1994, causing over 6,700 fatalities and significant numbers of serious injuries. It is more technically challenging to develop countermeasure systems for intersection collisions than for other crash situations. Because of the technical complexity, this problem category is viewed as a longer-term program area, but one with potentially large safety benefits. Three categories of countermeasure systems are being considered at this time: autonomous vehicle-based systems, vehicle-to-vehicle communications systems, and systems that involve vehicle interactions with specially equipped highway infrastructure at intersections.

Lane Change and Merge Collision Countermeasures

Lane change and merge crashes accounted for approximately 244,000 crashes in the United States in 1994 and resulted in about 225 fatalities and numerous injuries. They occur most frequently on metropolitan arterials and secondary roads. While the consequences of these crashes are generally less severe than in some of the other categories, and the total numbers of such crashes are small, the public perception of the enormity of the problem is high. Therefore, countermeasures are expected not only to improve safety, but also to meet with public acceptance, which could lead to reduced congestion on the roadways as well.

Early systems are expected to provide the driver with increased awareness of the presence of vehicles in adjacent lanes. These systems will warn the driver that it may be unsafe to change lanes. This warning would occur during the decision phase of a lane-change, before the driver has initiated the lane-change maneuver. Subsequent systems will require more sophisticated sensing and processing capabilities to determine the relative lateral position and velocity of vehicles in adjacent lanes prior to and during the lane-change maneuver. These systems would warn the driver of potential risks under a much wider array of conditions. A variety of sensors, including acoustic, laser, and radar systems have been evaluated for performance and applicability to solve this safety problem.

Backing Collision Countermeasures
Analysis of backing crash scenarios reveals two distinct subtypes - "encroachment" and "crossing path" crashes. Encroachment backing crashes involve vehicles moving at slow closing speeds striking pedestrians, objects, or other stationary or slowly moving vehicles. In contrast, crossing path backing crashes generally involve vehicles moving at higher closing speeds. A typical scenario involves a vehicle backing out of a driveway and striking or being struck by another faster moving vehicle. Approximately 57 percent of all backing crashes are crossing path crashes; the remaining 43 percent are encroachment crashes. About 90 percent of drivers involved in backing crashes (drivers of the backing vehicles) were unaware of the presence of other vehicles or objects in their path. While the total number of injuries and fatalities for this crash type are relatively small, NHTSA research has developed countermeasure systems which are ready for testing and deployment and thus relevant for addressing the safety problem identified in these types of crashes.

Drowsy Driver Warning Systems
NHTSA General Estimates System (GES) statistics for 1992 indicate that over 100,000 crashes are caused annually by driver drowsiness or fatigue. Data from the 1992 Fatal Analysis Reporting System (FARS) indicate that drowsiness/fatigue was a factor in crashes in which over 1400 fatalities occurred. At least 80 truck-related fatalities occur annually due to driver fatigue. The initial focus of this program area is on the commercial trucking segment for four key reasons; the extensive night driving in commercial operations, the need to minimize fatigue-related crashes among the professional driver population, the high cost of commercial vehicle crashes, and the relative affordability and cost-benefits of countermeasure systems for high-value heavy trucks. Ultimately, drowsy driver monitoring systems should be available at a low costs in both heavy trucks, as well as passenger vehicles.

Systems currently under consideration for addressing the driver drowsiness problem rely on sensing two primary features of driver performance. One feature is lane tracking and maintenance, i.e., how well the vehicle stays within lane demarcations. The second feature is eye and eyelid movements. Additional indicators of driver performance include erratic steering wheel motions, head movement, and lateral acceleration. The drowsy driver program is oriented toward identifying effective combinations of detection devices, development of drowsiness detection algorithms, and selection of best detection and warning devices for implementation.

Reduced Visibility Collision Countermeasures

Approximately 42 percent of all crashes and 58 percent of fatal crashes occur at night or during other degraded visibility conditions, according to NHTSA crash statistics. This translates into approximately 2.8 million annual police-reported crashes, including 23,000 fatal crashes for which reduced visibility may be a contributing factor.

Clearly, a number of inter-related factors contribute to the high crash rate at night, including alcohol, fatigue, and reduced visibility. A recent analysis of FARS cases suggests that reduced visibility is a major factor in night-time crashes involving pedestrians and pedacyclists.

Driver vision enhancement systems attempt to provide the driver with an augmented view of the forward scene. These systems fall into two primary categories: those that depend upon natural or infrastructure-based illumination, and those that depend upon additional illumination from the vehicle. Infrastructure-based systems use reflective materials on pavement and road signs and other fixed roadside objects to provide an enhanced view of the driving environment. Vehicle-based systems use a suite of sensors and equipment to improve the view of the driving scene through an in-vehicle display.

Tests on prototype in-vehicle vision enhancement systems to answer outstanding questions regarding the linkage between visibility and safety, as well as concerns regarding system performance and user acceptance, are currently underway. The implementation of cost-effective vision enhancement systems for passenger vehicles presents significant technical challenges. These include selecting sensor technologies that can work effectively under a variety of environmental conditions (fog, snow, rain, etc.), with sufficient sensitivity to detect a range of objects in the vehicle's forward field of view, and which also provide other information to the driver. Another challenge associated with the use of vision enhancement technology is the difficulty in registering the sensed image with the driver's visual image of the roadway.

ACCOMPLISHMENTS DURING THE PAST 5 YEARS

During the first phase of our research, NHTSA has developed a detailed understanding of highway safety problems and has built the foundation for on-going research, development, and evaluation of collision avoidance systems during the past 5 years. Extensive analyses of crash data were performed to define collision problem areas and causal factors. Based upon these and other considerations, such as related human factors research activities, projects were initiated to develop and validate performance specifications for countermeasure systems. These cross-cutting projects are discussed below.

Development of Research Tools
Progress was made in the development of new research tools--namely efforts to design and build the Variable Dynamics Test Vehicle (VDTV) and the National Advanced Driving Simulator (NADS) scheduled to come on-line by 1999. The design for the Data Acquisition System for Crash Avoidance Research (DASCAR) was completed and initial driver behavior data collection activities are already underway.

Collision Avoidance Knowledge Base
The research program has established an extensive collision avoidance knowledge base. This is a key element in NHTSA's continuing efforts to facilitate deployment of cost-effective crash countermeasure systems. A number of joint efforts with motor vehicle industry partners to collect data and assess the performance of critical countermeasure technologies have been completed or are nearing completion. In addition, NHTSA has initiated operational tests to examine the capabilities and benefits of Intelligent Cruise Control (ICC) and Automated Collision Notification (ACN) systems. Operational tests involving in-vehicle navigation systems were also conducted during the first phase of crash avoidance research, with NHTSA taking an active role in the evaluation of the safety performance of these systems. The evaluation focused specifically on the presentation of navigation, route guidance, and relevant traffic information to the driver and on comparison of the effectiveness and safety impacts of various information presentation modes [SAIC, 1996].

Collision Avoidance System Specifications
Preliminary performance specifications covering the sensing, processing, and driver interface functional elements have been developed for the collision countermeasure systems. These specifications were developed initially through analysis of data from NHTSA crashes files, causal analyses activities, and data generated from driving simulators, and are refined and updated based on results from technology studies, simulator studies, test vehicle projects, and operational test activities. First generation specifications have been developed and are being validated through prototype and/or field testing.

Driver Behavior and Performance Consideration
For each of the collision mitigation concepts described above, additional research projects addressing human-vehicle interaction and related problems are carried out. Generally these projects address issues that are germane to several collision avoidance problem areas. This research also supports the development of performance specifications for the driver/vehicle interface for the various countermeasures.

Initial guidelines have been established for the presentation of safety warnings to the driver. Research is continuing to determine what cues (e.g., visual, audible, displacement, speed, feel, or pedal feedback) drivers use to make decisions regarding vehicle control inputs (such as braking, steering, or throttle) in crash-imminent situations. Other research projects have been conducted to identify drivers' requirements for direct and indirect visibility, to determine optimum location of displays for lane change/merge systems, and to determine the viability of head-up displays (HUD) as a means of communicating information to drivers. This research is used to define the optimum driver/vehicle interface for ITS collision avoidance systems.

Recognizing that new technologies have the potential to increase driver workload and distraction, NHTSA has developed a workload evaluation protocol that can be used to assess the potential of any in-vehicle system to create excessive workload, thereby degrading safety.

Facilitating Introduction of Promising Technologies

In order to realize the goals of the NHTSA collision avoidance program, the department must take steps to encourage industry to make countermeasure systems widely available, at a reasonable cost, and with improved performance to maximize the number of cars equipped with the safety systems. NHTSA has embarked on a program that emphasizes outreach and cooperative activities with the automotive industry, to reach the goal of achieving increased safety on the nation's highways. One element of this approach is to develop and make available to interested parties a substantial knowledge database regarding collision intervention strategies. The database includes, among other things, safety problem definitions and results of research into crash causal factors, information on intervention approaches, research findings on collision avoidance application of technologies, and, where appropriate, the results of prototype and operational testing undertaken to validate design approaches, determine system performance potential, and understand user performance and acceptance issues.

NEXT STEPS (1997-2002)

At this stage, the NHTSA collision avoidance research program has developed a basic understanding of crash causal factors, identified promising intervention strategies, and developed preliminary specifications for crash countermeasure approaches. In many cases prototype systems have been developed for use in field and operational testing. Design and development of supporting research tools have progressed to the point where many are available to be employed in the continuing research and testing program.

Application of Research Tools

During the next phase of the NHTSA Crash Avoidance Program, the research tools (i.e., simulators, test vehicles, and in-vehicle data collection suites), will provide significantly enhanced capabilities for analyzing and evaluating technical performance of CA countermeasures and estimating their real-world safety benefits. Proof-of-concept demonstration activities and integration of several collision countermeasures, along with other information systems, are considered critical elements of the program and will be expanded to include operational test and demonstration activities working in cooperation with private automotive industry partners.

Integration of Collision Avoidance Systems
Another significant element of the continuing research program will be the effort to integrate selected collision avoidance systems with each other and with other in-vehicle technologies, such as data bases and navigation and information systems. These integration efforts will demonstrate the feasibility of multiple collision avoidance systems enhancing safety and, at the same time, provide synergism of performance of system elements, including sensors, processors, and driver interfaces (displays) that ultimately will lead to increased system capabilities. This effort will lead to the development of functionally integrated demonstration vehicles, which will be used to explain and demonstrate that collision avoidance systems are within the realm of practicality. The vehicles will be used mainly for estimating real-world effectiveness of safety systems and for demonstrations and focus groups to better understand driver acceptance issues. Results from use of the vehicles will provide the basis for understanding driver acceptance issues and the inter-operability of systems/technologies addressing more than one collision avoidance problem area. NHTSA intends to develop an integrated collision avoidance demonstration vehicle by the year 2003.

Facilitate Introduction of Crash Countermeasure Systems
Other on-going ITS efforts within NHTSA and the Federal Highway Administration, including driver/vehicle interface systems and other information systems, and the introduction of commercial vehicle productivity enhancements to heavy trucks, are expected to lead to early introduction of in-vehicle systems that can be exploited to reduce the overall cost of first generation CA systems. NHTSA will maintain an awareness of these activities to determine where complementary development efforts may be justified. On-going consensus-based standards development activities and the establishment of requirements and standards for in-vehicle data bus capabilities within the overall ITS activities in the department are also considered complementary to the CA research program. NHTSA will also continue to monitor CA technology and product development efforts within other countries, and where appropriate, support the coordination of efforts leading to the development, test, and evaluation and subsequent fielding of effective CA products.

ASSESSMENT OF PROGRAM BENEFITS

The reduction of collisions, fatalities, collision severity, and injuries will be the ultimate measures of success of this program. In addition to these primary safety benefits, several other benefits will accrue from these improvements in safety performance. For example, a reduction in injuries from motor vehicle collisions will have a direct impact on the cost of health care. The cost of these injuries and related lost productivity and property damage in the United States alone is more than $150 billion per year. Any reduction in these injuries would result in a proportional reduction in direct economic costs. Also, the reduction of congestion caused by crashes will yield increased transportation system efficiency.

Safety benefits are highly dependent upon the levels of system capability and user acceptance that are ultimately achieved by market-ready products. Initial estimates of systems effectiveness and their safety benefits were derived from simulation studies and experimental data. Improved benefit estimates will result from use of the Data Acquisition System for Crash Avoidance Research (DASCAR), the System for Assessing the Vehicle Motion Environment (SAVME), additional simulator studies and vehicle tests. A more complete level of understanding of the benefits to be derived from potential CA systems will be obtained after operational tests are conducted to thoroughly examine driver/system interactions and to assess the performance of each system under a variety of real world operating conditions.

Current estimates of potential benefits to be derived from the implementation and deployment of selected countermeasure systems are discussed below. The benefits that might be associated with effective crash avoidance systems include reduction in the number and severity of crashes, crash-related fatalities and injuries, property damage losses, and crash-caused traffic delays that lead to lost work, wages, or productivity. Additional benefits might include reduced driver stress, increased driver comfort and satisfaction, and increased highway throughput. A recent study [NHTSA, 1996] provides preliminary estimates of safety benefits for several crash avoidance systems, in terms of the number of crashes that might be avoided. The study used preliminary experimental data as the basis for estimating the probability of a collision when driving without the assistance of a collision avoidance system and the corresponding probability when driving with a collision avoidance system. These estimates are combined with other information about the target collisions, the use of countermeasures, and market penetration of collision avoidance systems to estimate benefits.

The system effectiveness and the number of crashes avoided are given below for three crash countermeasure systems. A significant number of assumptions have been made in the conduct of the preliminary benefits study and the reader is cautioned to interpret the results below within the context of these assumptions, as presented in the referenced report. The results of this preliminary study are presented in Table 2.

Table 2. Crash Reduction Effectiveness Summary

CAS	Function	Target Crash Size*	Crash Type	Empirical Data**	Percentage Effectiveness for Target Crash	Crashes Avoided*
Rear-End Collision, Driver Warning	Provides warnings if headway to a lead vehicle presents a potentially dangerous situation.	1547 K	Rear -End	Brake reaction times - U. Iowa Following time gaps - U. Iowa	51	791 K
Lane Change/ Merge Crash Avoidance	Provides alerts/warnings if adjacent vehicles are in left/right blind spot, or otherwise adjacent with host vehicle.	190 K	Lane Change/ Merge	Driver and system performance data - NHTSA/VRTC	47	90 K
Road Departure Counter-measures	Recommends safe speed when vehicle is traveling too fast for upcoming roadway curvature. Warns driver when likelihood of vehicle departing the road exceeds a threshold.	458 K	Single Vehicle Road Departure	Data extrapolation -U. Iowa Crash avoidance rates - U. Iowa	65	297 K

* Police-reported crashes according to 1994 GES.

** Additional data were extrapolated from other human factors and highway traffic studies conducted in driving simulators or on road tests.

It must be noted that the study deals with crash statistics associated with police-reported crashes, although data show that unreported crashes may exceed those that are reported in certain categories. It should also be noted that the results of this study are based upon numerous estimates and assumptions regarding driver and system performance and the market penetration of these systems. In general, the methodology for estimating the overall benefits to be derived from a specific crash countermeasure was to 1), determine the numbers and types of crashes that are addressed by the countermeasure, (i.e., the relevant crashes, a subset of police-reported crashes), 2), use limited field and simulator studies, in addition to modeling and simulation, to estimate the effectiveness of the countermeasure in avoiding crashes, and 3), determine the overall estimated benefit (in terms of crashes avoided) as a product of countermeasure system effectiveness and the number of relevant crashes (size of the crash category). For this initial effort, the system reliability was assumed to be one for all scenarios, and market penetration for the countermeasure system was assumed to be 100 percent.

The Rear-End Crash Driver Warning System is applicable to "lead vehicle decelerating" and "lead vehicle not moving" rear-end pre-crash scenarios. Both scenarios were analyzed under dry and wet/icy roadway surface conditions. Computer simulations were used to estimate the system effectiveness. Subject to the various assumptions of the study, the effectiveness of the rear-end collision driver warning system is estimated at 42 percent in the "lead vehicle decelerating" target pre-crash scenario and at 75 percent in the "lead vehicle not moving" target pre-crash scenario. Overall, the effectiveness of this system is estimated to be 51 percent of its target crashes.

The Lane Change/Merge Crash Avoidance System supports driver tasks during lane change maneuvers. These maneuvers involve the decision phase, where the driver gathers information about obstacles to decide whether or not to start the lane change, and the execution phase, where the host vehicle begins the lateral motion to the destination lane. The crash record indicates that lane change crash-involved drivers were largely unaware of the obstacle in the adjacent lane. Lane change collision avoidance systems considered here have the potential to warn the driver during the decision phase and prevent the unsafe maneuver. Estimates of the percentages of crashes avoided for lane change target collisions varied dramatically. However, study participants estimate a decrease for relevant (target) lane change collisions of 47 percent, or about 90,000 crashes annually.

The Road-Departure Countermeasure System addressed two separate crash conditions: lateral and longitudinal road-departure. The lateral road-departure system is applicable to two pre-crash scenarios based on driver "relinquished steering control" and "inattention" causal factors. These scenarios address drowsy and/or inattentive drivers under a variety of roadway geometry and environmental conditions. The longitudinal road-departure countermeasure system is applicable to two pre-crash scenarios based on "excessive speed" and "loss of directional control" causal factors. The combined effectiveness of the road-departure systems were estimated to be 65 percent of relevant police-reported single vehicle road departure crashes, resulting in about 297,000 crashes avoided.

NHTSA has estimated the 1994 economic costs of motor vehicle crashes to be $150.5 billion [Blincoe, 1996]. This cost represents the lifetime costs of 40,676 fatalities, 5.2 million non-fatal injuries, and 27 million damaged vehicles. These estimates are based on both police-reported and unreported crashes. Estimates include the direct value of goods and services which must be purchased as a result of motor vehicle crashes. They include medical care, legal services, workplace costs, vocational rehabilitation, emergency services, vehicle repair services, and insurance administration costs. In addition, economic costs include the value of both household and workplace productivity lost due to death or injury, and the value of travel delays to non-involved motorists. Other intangible costs are not included in these estimates, although they may ultimately influence decisions regarding "willingness to pay" for countermeasure systems. The analysis was performed to reflect a hypothetical year, when all vehicles in the fleet are equipped with the collision avoidance systems, but results are stated in terms of 1994 equivalent dollar values. Based upon the effectiveness estimates derived for each collision avoidance system, the annual economic benefits for the three systems described above would be roughly $25.6 billion in 1994 dollars. As noted, these benefits include only savings from crashes that would be prevented by the three selected crash countermeasure systems. They do not account for any system effects in reducing the severity of injuries in non-preventable crashes, which might also be anticipated.

Table 3 summarizes the economic benefits of each collision avoidance system type when individual system effectiveness values are applied to the total costs of crashes. These cost figures assume there are no substantial cost disbenefits associated with the deployment and operations of these collision avoidance systems.

Table 3. Annual Economic Benefits of CAS

Collision Avoidance Systems	Effective Rate %	Economic Cost-Savings (1994 $ in Billions)	
		Crash Cost	Saving
Rear-End	47.7	35.4	16.9
Lane Change/Merge	37.0	3.5	1.3
Single Vehicle Road Departure	24.0	30.7	7.4
Total			25.6

SUMMARY

The NHTSA collision avoidance research program has made substantial progress in developing an understanding of the predominant crash causes and of potential countermeasure approaches. Research tools have been developed and are beginning to be applied to further the efforts aimed at crash prevention. Performance specification projects have defined preliminary specifications for countermeasure systems. Technology assessments have been completed for many of the countermeasure systems, and system prototyping is underway. For several countermeasure systems, such as rear-end, road-departure, and lane change/merge collision avoidance systems, planning is underway to conduct field and operational testing of promising prototype systems. The testing program involves efforts to obtain quantitative information regarding system performance, system usability and user acceptance, as well as better estimates regarding the potential benefits of these systems. Other critical elements of the ongoing program include 1) efforts to safely and effectively integrate collision avoidance systems with each other and with other ITS systems and features that are beginning to appear in vehicles and 2) efforts to reduce the costs of technologies that are considered critical to the development of effective collision avoidance systems. Many of these efforts will be completed within the next 6 years and should facilitate the introduction of collision avoidance products to the consumer market.

REFERENCES

Leasure, W.A., Jr. and Burgett, A., *"NHTSA's IVHS Collision Avoidance Research Program: Strategic Plan and Status Update,"* Paper No. 94 S3 O 01, *The Proceedings of the 14th International Technical Conference on Enhanced Safety of Vehicles,* Munich, Germany, 1994.

Najm, Wassim, et. al., *"Comparative Assessment of Crash Casual Factors and IVHS Countermeasures," The Proceedings of the IVHS America Annual Meeting,* Atlanta, Georgia, 1994.

Najm, Wassim, et. al., *"Synthesis Report: Examination of Target Vehicular Crashes and Potential ITS Countermeasures,"* 1995 DOT-HS-808 263.

ITS America Workshop *"Peer Review of the NHTSA Program,"* Baltimore, Maryland, 1995.

ITS America and U.S. Department of Transportation, *"National ITS Program Plan - Intelligent Transportation Systems,"* ITS America, 1995.

U.S. Department of Transportation, *"Transportation Statistics Annual Report 1995,"* Bureau of Transportation Statistics, pg. 52-57.

Blincoe, L.J., *"The Economic Cost of Motor Vehicle Crashes 1994,"* 1996 DOT-HS-808 425.

Burgett, A., *"Status Update of NHTSA's ITS Collision Avoidance Research Program,"* Paper No. 96-52-O-09, *The Proceedings of the 15th International Technical Conference on Enhanced Safety of Vehicles,* Melbourne, Australia, 1996.

NHTSA Benefits Estimate Working Group, *"Preliminary Assessment of Crash Avoidance Systems Benefits,"* 1996.

Science Application International Corporation (SAIC), *"TravTek Evaluation Safety Study,"* Federal Highway Administration Contract Number DTFH61-91-C-00106, Publication No. FHWA-RD-95-188, 1996.

U.S. Department of Transportation, *"NHTSA ITS Strategic Plan for 1997-2002,"* 1997.