DEVELOPMENTS IN COOPERATIVE INTELLIGENT VEHICLE-HIGHWAY SYSTEMS AND HUMAN FACTORS IMPLICATIONS

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Summary: Cooperative vehicle-highway systems offer the potential to enhance the effectiveness of active vehicle safety systems which have entered the marketplace for light vehicles and heavy commercial vehicles. *Cooperative intelligent vehicle-highway systems (CIVHS)* offer an improved level of overall functionality. These systems are *cooperative* in that the vehicles can receive information from the roadway and respond appropriately, and vehicles can detect and report hazards to the roadway, for dissemination to other travelers. The systems are *intelligent* in that the ultimate response is determined by algorithms which weigh multiple parametersse. This paper describes the results of a study to collect information on the various forms of cooperative IVHS worldwide, and assess R&D activities, deployment issues, standards development, and government policies. An extensive set of parameters which may pass between the vehicle and its external environment are listed. Potential human factors implications are identified, resulting from the emergence of these driver assistance systems into the marketplace.

INTRODUCTION

Cooperative vehicle-highway systems offer the potential to enhance the effectiveness of active vehicle safety systems which have entered the marketplace for light vehicles and heavy commercial vehicles. Currently on the market are adaptive cruise control (ACC), forward collision warning, side collision warning, and lane departure warning systems -- all of which rely on vehicle-based sensors to perceive the surrounding environment and detect dangerous situations.

These *autonomous* vehicle-based safety systems, while generally effective, have limitations based on the laws of physics -- they can't see around blind curves, for instance. At the same time, autonomous infrastructure systems can and have been deployed, which detect hazards in real-time and advise drivers via (typically) changeable message signs. Such infrastructure systems suffer from the limitation that they can only influence drivers who choose to pay attention to them; even then, a safe outcome depends completely on the driver making appropriate and timely decisions.

Cooperative intelligent vehicle-highway systems (CIVHS) offer an improved level of overall functionality by bridging this gap. These systems are *cooperative* in that the vehicles can receive information from the roadway and respond appropriately, and vehicles can detect and report hazards to the roadway, for dissemination to other travelers. The systems are *intelligent* in that the ultimate response is determined by algorithms which weigh multiple parameters, rather than a pre-programmed response.

This paper describes the results of a study, the first of its kind as far as is known, to collect information on the various forms of cooperative IVHS worldwide, and assess R&D activities, deployment issues, standards development, and government policies to gain a sense for the future of such systems. Activities to develop these results included information gathering and contacts with experts and policy-makers in government, the private sector, and academia (the full report is available at www.IVsource.net). Based on the study, potential human factors implications are identified, resulting from the emergence of these driver assistance systems into the marketplace.

APPLICATION AREAS

General applications of CIVHS are in the areas of safety, traffic flow, and navigation. Safety CIVHS systems encompass crash avoidance (pedestrians, vehicles, road departure), enhanced driver awareness, and safety compliance. Applications for traffic flow include micro-dynamic speed control (providing vernier control of speed to individual vehicles in a traffic stream, in order to smooth traffic and optimize flow), automatic gap adjustments (enabling / permitting ACC systems to reduce headway below one second, based on highway monitoring of traffic and environmental conditions), traffic signal response assist, road use status, and automated vehicle operation. For navigation, vehicles can collect mapping data to refine digital map databases and provide these corrections in real time to a central database manager; updates can also be delivered to vehicles.

SIGNIFICANT PROGRAMS WORLDWIDE

Europe

In Europe, research supported by the European Commission is providing a major impetus to developments in intelligent vehicle-highway systems through Fifth Framework program.

Several national-level programs are ongoing, as well. In France, advanced forms of CIVHS are being envisioned within the La Route Automatisee program, for automated guidance and management of traffic flows in the twenty year timeframe. As part of the Dutch Ministry's Advanced Vehicle Guidance program, pilots are under development for Lane Departure Warning Systems (LDWS), External Speed Assistant, and Autonomous Speed Assistant; the pilots would run from 2002 - 2007. Sweden is taking a worldwide lead in evaluation of the benefits of Intelligent Speed Adaptation. In England, the U.K. Highways Agency is active in several areas. Vision 2030 aims to identify a longer term vision for inter-urban transport, using the approach of transferring control of the vehicles from the driver to an infrastructure-linked control system to optimize operation and manage access. Already deployed is the Road Traffic Advisor system, which provides two-way vehicle-roadside communications across a 350 km test site from London to Wales. Additionally, External Vehicle Speed Control is being investigated.

Asia

In Japan, "Assistance for Safe Driving" is one of nine areas in the overall ITS program. Since 1991, the Japanese Ministry of Transportation has sponsored the Advanced Safety Vehicle (ASV) program, and the Ministry of Construction established the Advanced Cruise-Assist Highway System Research Association (AHSRA) in 1996. Through these activities, the Japanese have established a significant program in CIVHS and are a worldwide leader in developing and testing such systems for active crash countermeasures. Development of both "autonomous" and "cooperative" systems are a key aspect of Japan's approach to road safety. CIVHS are the domain of AHSRA, whose program focuses on vehicle-highway cooperative systems to maximize safety -- hazards that can't be sensed effectively from the vehicle are detected by roadside equipment, which relays key information to vehicles to perform the necessary maneuvers to keep the ride safe. Seven user services have been defined as the central focus of the Japanese program, called SmartCruise 21.

In Korea, the Korea Highway Corporation acts as the key implementer for government highway system plans. Korea completed a National ITS Master Plan recently, which includes basic ITS elements and also development of an "advanced highway system." The advanced highway system incorporates "safe driving" functions which include both autonomous vehicle-based systems and cooperative road-vehicle interfacing for both warning and control.

North America

The U.S. Department of Transportation has focused their activities on near-term safety systems with the establishment of the Intelligent Vehicle Initiative (IVI) program in 1998. A small part of the IVI program focuses on cooperative infrastructure through the Infrastructure Consortium, which currently is working on intersection collision countermeasures. The US Federal Highway Administration is also examining curve warning systems using cooperative approaches.

California is the leading advocate in the U.S. for CIVHS research -- they participate in the Infrastructure Consortium and lead the Cooperative Vehicle-Highway Automation Systems (CVHAS) eleven-state pooled fund research project. The CVHAS is pursuing research in cooperative vehicle-highway systems. California is planning a major demonstration of cooperative systems in 2003.

PERSPECTIVES AND TRENDS

Perspectives on the potential for vehicle-highway cooperative systems were collected from a variety of stakeholders worldwide, in the public sector, private sector, and academia. These have been consolidated and highlights are offered in the full report. Several functions and approaches repeatedly arose in discussions, for which an overview is provided here.

User Services

Functions of strong interest are:

- Enhanced ACC -- The provision of environmental, traffic, and roadway information not detectable by the vehicle, allowing the on-board system to adjust operation parameters as appropriate. This function was seen as long-term by those who envisioned external information coming only from an extensive set of infrastructure sensors (see below for nearer-term alternatives).

- Intelligent Speed Adaptation -- Systems which provide a haptic feedback in the throttle pedal and also provide dynamic speed settings based on conditions
- Intersection Collision Avoidance -- Systems which detect immediate hazards and provide information directly to the driver/vehicle are of high interest. Some feel that infrastructure-only systems are sufficient; others feel that only cooperative vehicle-roadway systems will be effective.

With regard to gathering safety-related data external to the vehicle, the direct approach is infrastructure-based sensors; however, many felt that ubiquitous infrastructure sensing was too expensive to deploy and maintain. Therefore, the "floating car" data collection approach is of interest and offers to provide data without the need for extensive infrastructure sensing. With the floating car approach, DSRC, toll tags, telematics data streams, or electronic licence plates enable the vehicle to provide information on roadway issues just encountered and receive information on the roadway ahead, in concert with a data dissemination system. Digital maps can also be updated in this way. <u>A key point to note is that vehicles can be designed to receive external information, regardless of the means of data collection.</u> To stimulate market availability of communications to the vehicle, multi-functional uses can be defined, such as advertising, roadside information, traffic information, and hazard notification.

Standards

Lack of technical standards was noted by many as a key deployment barrier. (Standards development for Enhanced ACC has recently been initiated.) In discussions regarding standards development for CIVHS, several points were prominent:

- Standards must focus on defining the "what" -- parameters and types of information that will flow between vehicles and the external world -- but not on "how" that data will flow.
- Standardization of particular designs or products must be avoided.
- In standardizing on parameters, avoid being too prescriptive.
- Standards must be well formulated and very clear for liability reasons.
- Now is a good time to be in discussion of CIVHS systems, in the opinion of many. Some feel it is too early for standards setting, while others point to situations where standards setting has started too late to really benefit the industry. Typically, standards activities begin after a sufficient body of experience exists for working systems, having reached a reasonable level of system maturity.

Many spoke of the need for infrastructure agencies to become actively involved in the standards process, as CIVHS requires some degree of joint development by vehicle manufacturers and road authorities. Infrastructure agencies are typically very focused on highway standards but have had little involvement historically in vehicle-oriented standards.

As one commentator put it, "the highway agencies must become champions" of these systems to achieve progress. This because traffic flow and safety are central to the mission of infrastructure operators. If we are lucky, the vehicle and/or telematics industry may deliver forms of CIVHS – but they will do so only if the business case is solid and therefore our society cannot depend on this as the only route. The leadership role falls squarely in the laps of the infrastructure operators.

EXTERNAL PARAMETERS FOR ENHANCED VEHICLE OPERATION

A table was developed in the full report which details several levels of parametric information which may pass between vehicles and their environment. Ten categories of parameters were identified, with over 50 sub-parameters. The categories are as follows:

- Obstacle in projected path of vehicle
- Speed advice
- Gap advice
- Environmental condition
- Road condition
- Road geometry
- Road use status
- Automated vehicle operation
- Traffic control devices
- Messages from the host vehicle

HUMAN FACTORS IMPLICATIONS

Fundamentally, CIVHS are driver assistance systems. However, as for all driver assist systems (cooperative or autonomous), drivers must adapt successfully to a shared-control paradigm. This may not be so difficult – today's Anti-Lock Braking systems and Traction Control are also shared control functions.

Systems must be designed so that drivers either a) understand what the system is doing, or b) the system operation is transparent. Re b), in the case of a cooperative merge system (in which the host vehicle requests adjacent vehicles to create a gap), the driver would simply notice convenient gaps "showing up" when he/she seeks to merge, and need not understand the underlying communications and negotiations conducted automatically by the vehicles.

For CIVHS supporting improved traffic flow, it is expected that driver participation in having their vehicle's speed automatically controlled would be voluntary. This introduces user issues, perceptions, and the possible use of incentives. If, for instance, a lane is designated which provides external speed control, will drivers opt to give up some speed control in exchange for traveling in a smoothly flowing lane (and avoiding congested lanes)?

At minimum, in the ideal case, data passing to and from vehicles will enable a much higher level of *awareness* for drivers, as to unusual or hazardous conditions ahead. This will enable them to take appropriate action upstream, so that emergency maneuvers are less likely to be required.

CONCLUSIONS

Looking globally, the Japanese are leading in testing and deployment of CIVHS for crash countermeasures, while the Europeans have the strongest focus on Intelligent Speed Adaptation. Work on intersection collision countermeasures dominates CIVHS work in the U.S.

CIVHS discussions become sidetracked with an assumption that extensive deployment of infrastructure sensing is a necessary component of such systems. The many complexities of infrastructure sensing and communications represent a huge challenge for many (but not all) countries. Because the alternative exists of data provided by floating car approaches, consideration of CIVHS can productively proceed without "solving" the infrastructure deployment issue, leaving this to individual agencies to decide.

For CIVHS to proceed from concept to reality, infrastructure agencies must become more active, particularly in ongoing standards discussions.

Human factors implications include adaptation to shared control, voluntary relinquishment of control for perceived benefits, and assimilating information regarding upstream road conditions.

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REFERENCES

1. Final Report: Cooperative Intelligent Vehicle-Highway Systems: *Status of Activities Worldwide, Stakeholder Perspectives, and Major Trends;* published by Richard Bishop Consulting, 23 March 2001. Available via download from IVsource.net.