In an HFS Safety Technical Group newsletter article, we examined some human factors and safety issues involved in the implementation of intelligent vehicle highway systems (IVHS, Hancock et al., 1991). We focused on driver workload in an operating environment that promises to significantly increase the presentation and availability of information. However, the issue of workload is only one facet of the integration of human capabilities with a more complex technical driving environment (Sheridan, 1991, 1992). Here we discuss problem areas that, when addressed, will lead to a fully functional IVHS system.

**Overload and Underload**

Perhaps the most prominent problem for the human factors researcher and practitioner in the IVHS area is driver overload. The proliferation of potential and actual in-car information is expected to overload the driver’s processing capability and/or distract him or her from the primary task of vehicle control. The study of human factors has shown that periodic operator overload occurs in many different systems. This complicates efforts to enact human-centered automation or, more properly, to develop hybrid human-machine systems (Hancock and Chignell, 1990; Kowalski and Rahimi, 1990). In the realm of IVHS, this projected increase of in-vehicle information—combined with the wide range of individual drivers’ capabilities to deal with such an influx—has devoted the workload question to its current priority. Because our previous report (Hancock et al., 1991) dealt with questions of driver overload, we do not wish to cover the same ground in this article. However, it is important to emphasize one aspect of maladaptive loading that has not received comparable attention in the arena of hybrid systems: work underload.

It is difficult initially to conceive that underload could be an issue in IVHS, given that the general problem of workload seems to be the evaluation and simplification of available information and specification of the appropriate way to convey it. In essence, these questions are centered on context-based information management and interface structure. However, many systems design specifications recommend some degree of automatic vehicle control (Winning, 1988), so what are the driver’s remaining tasks? One might envisage a system in which the destination is literally specified by the driver and dynamic route changes are subject to vehicle-based computer control. In the concept of “platooning” vehicles, an advanced version of the system, the driver’s role defaults to that of system monitor. Studies of intrinsic human capabilities have shown that

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**Election Results**

Results of the election for 1992-93 officers have been tabulated, and the winners are as follows: President-Elect . . . Deborah A. Boxham-Dawes Secretary-Treasurer-Elect . . . David L. Daves Executive Council . . . Robert A. Glass Susan K. Meadows

The name-change ballot determined that HFS will change its name to The Human Factors and Ergonomics Society.
We cannot know how traffic flow patterns will be affected when the number of vehicles with further access to IVHS information increases.

crowded and inconsistent traffic-regulated city, the solution might include the simplification of both information and control. But when the professional long-haul drivers, and for the people who use the traffic as a means of transportation, the danger may increase as well. The development of intelligent interfaces (Hanock and Cigeln, 1990), briefly, the intelligent interface acts as an intermediary between humans and machine, seeking dynamic task allocation strategies that maximize the human's and machine's respective capabilities while maintaining an appropriate and tolerable load on the humans. How such a concept could be applied to the control of an autonomous road vehicle control, whereas the question of pilot control in unmanned and autonomous aircraft systems is of current interest. In this sense, detailed and incident-report road environment, the issue is bound to be of critical concern. Although national and international standardization may provide some form of regulatory infrastructure, the legal and judicial questions of ultimate control may remain a stumbling block for IVHS. However, the situation remains uncertain.

Evolution and Integration of IVHS Technology

A number of demonstration projects are using vehicles that are minimally equipped with on-board computer systems (e.g., Papapeiropoulos et al., 1988; Marzouk, Fujita, and Kohmats, 1990). The vast majority of present-day vehicles possess little or no on-board vehicle information systems. Several vehicles will have the current level of vehicle information systems (e.g., radio and cellular variable message boards), whereas more sophisticated vehicles will have access to a wider range of data bases and other information sources (e.g., global positioning satellites and artificial intelligence vehicle diagnostics). It is perhaps an ambitious goal to implement that the future top-of-the-line vehicle will sweep majestically and impressively down deserted back roads while these less fortunate will be stuck in nightmarish traffic jams. However, is that fantasy destined to be reality?

As developments are made in signage and roadways markings and configurations, the level of IVHS information available to the vehicle in each vehicle will influence the decision-making and response capability of its driver and, by implication, affect the safety of surrounding vehicles. At present we do not know. However, it is clear that some conceptions of IVHS, such as platooning, strongly imply some individual control of each vehicle. (This is true to say that system handling "dump" vehicles could not be developed, but the problem of ingress and egress from the platoon becomes a key research issue.) A related concern is public acceptance of IVHS. We cannot pretend that people will not see the benefits of an evolving IVHS system in which they either significantly or marginally participate with respect to their own vehicle control. The process of acceptance will be determined, but it is clearly a human factors/safety issue.

How Much Will In-Vehicle Navigation Aids Be Used?

Many of the demonstration projects in IVHS-based research concern in-car navigation assistance systems. Such projects have been initiated in the United States (e.g., Florida and California, Ohio, Oregon, and Japan). In these systems, a data base of information about an area is available to the driver and provides route guidance to destinations and amenities (Green, Williams, Theris, and Rachel, 1990; Ikeda, Okawa, and Shimizu, 1991; Noyama, Zoch, and Hidemasa, 1991; Pepp and Parker, 1991). On-line navigational aids guide the driver's decisions as intersections to achieve signposted goals, to such extent that the data structures are static. In more advanced systems, information about current traffic states is provided, and alternative
routes may be used in order to minimize travel time and avoid congestion. In such systems the date structure is dynamic. The full integration and operation of these systems is expected to alleviate the traffic congestion that plagues many urban areas. Such systems will probably be a boon for taxi drivers, package delivery companies, and car rental firms, but what effect will it have on today's drivers? To attempt the question definitively, how much traffic will a better pay for a vehicle that includes a state-of-the-art cruise control system? According to this market segment, we need to know initially what percentage of on-road vehicles are driven by private individuals and what percentage of their travel is to known destinations. Indeed, Rowe and Klander (1947) estimated that three private vehicles constitute 80% of all personal trips. The utility of systems using static informational structures seems marginal.

In this study, IVHS advocates point to potential increases in trip spatial efficiency and the benefits of dynamic informational structures (particularly on-road congestion avoidance). If selecting the closest three Chinese restaurants is seen as a frivolous aim of IVHS, consider how IVHS could reduce stress generating and production-saving highway congestion—surely that is a worthy endeavor.

With respect to dynamic information, IVHS designers will need to know when, where, why, and through what medium commuters and travelers will use traffic congestion and navigational information. Everyday patterns of driving behavior will be intimately linked to city structure, work location, shopping activities, and residence. However, the assumption that all motorists behave as a single, homogeneous group of information consumers is false (Barfield, Haukohl, Spriakakis, and Costant, 1980; Haukohl, Barfield, Webber, and Komatsu, 1980; Spriakakis, Barfield, Komatsu, and Komatsu, 1980). Based on demographics, information, some drivers will be willing to change their departure and arrival times and their routes, even during the trip, whereas others will probably stick to their preplanned plans whatever. The motorists who are willing to adapt according to traffic information will be the target market of advanced traffic information systems. For those drivers who do not use the existing networks of radio, television, and variable message signs for traffic information, future IVHS implementations will probably have relatively little impact.

Large-scale rejection of IVHS technology based on people's stereotyping (Slovic, 1990) and misunderstandings is another concern that must be addressed. An effective management control arm, providing congestion information does not guarantee its use. Hence knowing the proportion of large traffic population that will use advanced traffic information networks will be critical for the success of IVHS.

In-Car Display Conflicts

During a session on IVHS at a recent HFS lunch meeting, an issue was raised concerning the use of voice commands or auditory displays with in-vehicle guidance systems (1. Noy, personal communication, September, 1991). It appears that in certain circumstances a driver will ignore traffic control devices (e.g., a stop sign) and continue on the present route if obeyed, so the in-car message is redundant. The virtual external traffic control devices in an-car computers poses a problem context dependent in-car messaging assumes that the vehicle has a much more thorough knowledge of the external environment than is currently envisaged. The critical research issues concern the use of information presentation and message content that promotes safe interaction with other road users. The addition of cautionary messages such as "proceed when safe to do so" provide necessary clarification of use. However, the interaction among messaging, sensory modality, and the driver's decision making is still problematic. If local rules are always given primary consideration, there could be a decrease in IVHS effectiveness. As aviation display designers have discovered (e.g.. Stokol, Wixon, and Kite, 1991), the medium of usual visual information display has many 'satisficing' solutions. The design process for multiple display systems requires considerable testing to derive a "reasonable" solution.

The critical research issues concern modality of information presentation and message content that promotes safe interaction with other road users.

able operational fit between operator and display (e.g., Pinkers, 1973). Designing an automobile display is fundamentally different from designing an aviation display and the provision of optimal display strategy to a selected group of designers must achieve a fit for the least visually capable. In addition, the incorporation of visual displays require the optimization of the specific information is necessary for each driver in differing conditions. For instance, how often is the speedometer or gas gauge used? This is a question of timing and context—such displays need not be omnipresent. How can auditory and visual displays be presented when the driver needs that information, and how can they be suppressed when their presence might conflict with safe vehicle operation?

Individuals' Differences

How will IVHS be designed to deal with the wide range of driver skill levels? The population of drivers is aging, so is the general population (Transportation Research Board, 1988). The group of older drivers—particularly women aged 75 or older is the fastest-growing segment of road users (McKelvey, Mueck, and Komatsu, 1986). In gerontology the obvious finding is that information processing slows with age and that this effect is magnified as the
complexity of a task increases (Cann, Vrettou, and Hascoët, 1996; Ford, Venutiau, Reynolds, and Hamescu, 1996). How will IVHS adaptively cater to such individuals while also serving the broader public? Put more positively, how can IVHS open driving to an increased percentage of handicapped and disabled drivers?

We posit that the present requirements for vehicle control and traffic control assistance in traffic in-ting will be adjusted to include roadway-based IVHS developments, though vehicular configuration will remain at the discretion of the individual driver. Of course, the eventual prospects of IVHS is the individualization and, potentially, the privatization of the entire driving environment, and the subsequent reduction of problems caused by individual driver differences on the highways of the future.

References


IVHS: Problems and Promises

By Peter A. Hancock and Jeff K. Caird

In part 1 of this article (October 1992), we discussed some of the problem areas that need to be addressed in order to produce a fully functional IVHS system. Among these were overload and underload, vehicle control, IVHS technology evolution and integration, in-vehicle aids and displays, and individual differences. Additional factors are described below.

Traffic Management and Informational Trust

The central tenet of congestion information is that the rational driver, upon hearing of some blockage or slowdown, will immediately begin either self-directed or computer-directed rerouting in order to minimize travel time. Given the potential control capabilities of urban traffic management systems and the plethora of roadway information that should accompany actual implementation, some simple modeling procedure would seem to be sufficient to maximize traffic flow across the system. However, we need to ask how often solutions requiring some form of optimization are successful when human operators are part of the system. These are many issues regarding congestion alleviation, not the least of which is that many current origin-destination models of flow rely on accurate information concerning each specific vehicle; this leaves prediction of flow beyond major freeways highly uncertain. Is the goal of traffic management a top-down strategy to optimize traffic flow at a system level? If so, how much—if at all—does this impede passage of any one vehicle? What happens if and when drivers become aware of this top-down strategy? These are just a few of many questions about trust in the system and in the information it provides.

What happens when the driver misinterprets the current information? Certainly such information merely applies to the entire roadway network, given that the route of traffic flow depends on a person's proximity to the obstruction. It is assuming to be sold of a blockage, only to arrive at the scene and find essentially no slowing. How does such a violation of trust influence a driver's subsequent decision? What if an alternative route is not readily available, and what are the overflow effects on arterials when a freeway's entire flow is diverted into a radically different road network? How often is congestion attributable to standing obstructions, such as inadequate roadway configuration, as opposed to the more ephemeral and unpredictable effects such as accidents, weather, and breakdowns? Although many of these questions also lie in the domain of traffic flow modeling and management, it is the human, nonlinear characteristics and goals of each driver that will dictate the actions of his or her vehicle and, thus, the specifics of flow. Neglect of the human component in this regard will lead to the failure of an intelligent vehicle-highway system (IVHS) to alleviate congestion.

How Far Will We Drive in the Future?

Congestion develops when too many vehicles attempt to occupy the same place at the same time. To alleviate congestion it is generally necessary to reduce the density of vehicles. Platooning, however, is a strategy that actually increases vehicle density. (In a platoon, vehicles follow one another closely—similar to a convoy—in a line of traffic that is controlled externally.) Ingress and egress from platoons and the aggregation that vehicles should be in spatial and temporal proximity, superseding human response capabilities in the event of emergencies, raise important human factors questions.

To compensate for the effects of congestion, motorists may have to work for a while after the morning congestion and take some form of compensation to a centralized location, but this effect of the information age is that physical proximity to the source of the information may be of increasing importance. Given the time frame for the implementation of IVHS,
also on somewhat dubious cases. Some mutual benefit will accrue to those in ecological psychology and in human factors in the development of new and intelligent contracts that help in complex system improvement beyond the IVHS realm.

**Taking the Adaptive System Out of the Loop**

The destruction of human life on our roads is an impossible scientific question and a non-partisan issue. However, the number of accidents that actually occur, compared with the opportunities for them to occur, is relatively small. Many vehicles can navigate to proximity to each other, often on intersecting courses, but actual collisions arise from only a small percentage of the total detections because drivers can generally control their vehicles. This is a manifestation of human behavioral adaptability. One central issue in IVHS is the total or periodic displacement, in part or in whole, of this assent or ameliorated human adaptive facility. For example, the total operation of an automatic controller must exceed human response capability under all operational driving conditions. If some shared control is envisaged, as in hybrid systems, IVHS implementation must ensure that the interaction between human and machine never drops below the response efficiency of the unaided human alone. In essence, we must guard against the premature transfer of control away from the current system that is presentment at adaptive response—the burden being, possibly in no other aspect of life for the nonuniform "average" individual will collaboration with advancing technology play such a key role. As a main point of innovation, IVHS is doubly mandated to do its right.

**What Is at Stake?**

It may seem to readers that the general tone of our comments is parts 1 and 2 of this article has been somewhat critical and negative with respect to IVHS possibilities. However, in part, we wish to balance the argument by presenting an advocacy position for IVHS and the expenditures associated with its development and implementation. To begin, we need only point to the contemporary and anticipated accident record. Approximately 100,000 people are killed every year on U.S. roads alone. For U.S. residents between the ages of 15 and 44 who are in the accident-prone cases is death is a road traffic accident. (However, irreproducible severe injuries caused in traffic accidents, not fatalities, are still present.) Perhaps an additional perspective on these figures may be gained by the fact that a recent edition of 60 Minutes labeled the 2826 deaths of children from gunshot wounds as an epidemic. This number provides dismal evidence of a contemporary social problem, but road accidents continue largely unaddressed in our society. Furthermore, to suggest that these trends are vastly different in any other major behavioral country—on even in developing countries—would be misleading.

As advocates we believe that the most important contribution of IVHS will be to road safety. We hope and expect that IVHS innovations will improve many facets of transportation efficiency, but the pre-emption and amelioration of accidents must form a central focus.

**In-Car Collision Warnings**

If accidents and associated fatalities and injuries are the major problem, then collision warning and avoidance systems are the putative answers. However, it is not known exactly how collision avoidance can be achieved. Again, we are faced with the classic question of driver versus automated control. Should the system inform the driver, or even usurp control? Will an infotainment system be able to devise a potential conflict and devise an avoidance strategy in the time available? What format would such a presumably multimodal message take? How the spectrum of these alarms plays a critical role. Suppression of false alarms appears critical for acceptance. Yet a collision warning might be even more problematic. (However, see Serkin, Kuminowicz, and Kantowitz, 1988.)

Consequently we have sought answers to these concerns. Should we focus on collision detection systems in order to detect conflict situations, or should we employ some sort of general protective envelope approach? Can we individualize alarm systems so that they respond to likely accident conditions in a manner appropriate for the present driver age group? However, the structure and function of a collision avoidance warning system implies some complex, multivariate detection system representing a considerable engineering challenge. Having devised a veridical warning signal, however, its quantization for consumption by various strata of drivers is uniquely a human factors question. It is this arena that promises enhanced safety, though it is also represents the most complex portion of IVHS development.

**Intelligent Transportation Systems**

IVHS is designed to control and manage future roadways into the twenty-first century, but is this enough? The design and conception of an intelligent system dictates that it not only accomplish its own specified goals but also interact with other and become compatible with numerous other interactive systems. For IVHS the obvious interaction is with companion transportation systems, such as rail and air, as well as with service and customer business systems to facilitate improved traffic and environmental efficiency. This parallel and even advanced developments in aviation should not be seen merely as a guide to implementation but as a comprehensive approach to the development of a highly integrated implementation.

An integrative perspective views IVHS not as a singular answer to addressing duged freeways but as an integral part of a greater transportation solution. For example, the underlying system of advanced traffic information systems is that they are theoretically cheaper to design and implement than a major rebuilding of the highway system would be. A balanced glance analysis also considers the expansion and development of highways and other transportation modalities as complementary to IVHS. Under IVHS terms a real-
integration requires resonance throughout the whole system. The future economic survival of an advanced manufacturing society will probably be predicated on such an integrated system, which alone will sustain IVHS development.

In 1991 General Motors estimated that traffic congestion costs the United States up to $93 billion in lost productivity each year. That some form of national IVHS system will be implemented in the near future seems almost a certainty. Comparable efforts in Europe and Japan attest to the need for an advanced, integrated transportation system. The twin goals of facilitating efficiency through congestion alleviation and improving safety through technical advance has strong economic and political appeal. The success of this enterprise is critically dependent on the timely solution to these problems. The failure to resolve such questions may lead to causticness against which the events in Bipol and Chechenya may have been tame.

Calls for Human Factors Participation

This article was begun more than a year ago. Since that time numerous important developments have occurred in the area of IVHS. For example, at the 1992 HFS Annual Meeting, a session devoted to IVHS revealed that the Federal Highway Administration has offered major human factors research contracts in four major areas (see Mast and Peters, 1992, for detailed information). In addition, the National Highway Traffic Safety Administration is exploring numerous issues concerned with collision warning and avoidance as well as IVHS innovations (Howeritz and Dingus, 1992).

It is clear from these collective efforts that human factors is considered as important facet of IVHS. Similar prominence has been given to human factors issues in Minnesota, where the GUIDESTAR program has sought to integrate human aspects of VDS development into each innovative project (e.g., TRAVELINK, Twin Cities, SIGNUS).

One current development illustrating the central position of human factors is the announcement concerning an innovative IVHS architecture (U.S. Department of Transportation, 1992). This call for information makes clear the importance of considering the human in the design of each IVHS component. Human factors input to this project is vital because the integration of human abilities is an important aspect of the design of technical capabilities.

Recent developments worldwide have turned the spotlight on the management of the domestic infrastructure. Success in this area promises great return. The human role in IVHS is vital, as in most large-scale systems, user acceptance is a critical concern. How human abilities are integrated into a technically more complex travel environment is the domain of the human factors profession. We have much to offer here, particularly in transferring our technical skills to allied areas of research. In the past many have lamented the absence of human factors input early in

the system design, and now IVHS appears to provide such an opportunity. We must not fail to grasp it.

Acknowledgments

Many individuals have aired these issues, and it would be misleading to represent them solely as our own. Several of these problems were raised in a session at the 1991 HFS Annual Meeting, and each of the presenters at that session are referenced here. The policy observations of Mast (1991) are given prominence. Tom Sheridan's 1993 work, together with discussions with many colleagues such as Ian Noy, Paul Glotzbach, Mike Schaller, Dick Brown, Rob John, Mike Robinson, Dick Stehr, and Jim Wright, have been most insightful.

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References


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