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# Driver Interfaces for Vehicles of the Future and Usability Roadblocks to Their Introduction

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## Abstract

Driver information systems that are likely to see more widespread implementation in future vehicles include: cellular phones, adaptive cruise control, navigation, package/cargo and vehicle tracking, and night vision systems. To interact with those systems, use of menu-based architectures and speech input/output will increase.

In projecting what might appear in future products, the key considerations are usefulness, usability, and cost. To achieve the desired levels of usability for these interfaces, more research is needed to provide (1) basic models of driving and related baseline data, along with a greater understanding of the workload of driving; (2) application-specific data on most of the new systems; (3) safety data on their actual use; and (4) low-cost usability assessment tools. More work also needs to be done to disseminate human factors knowledge to suppliers and to educate them in iterative design and the use of driver interface prototyping tools.

## Introduction

The purpose of this paper is to identify driver information systems that are likely to appear in future vehicles and how usability issues are likely to affect the introduction of these systems. It must be emphasized that the author of this paper is a usability specialist, not a futurist, a perspective that colors this paper. The author's view is that usefulness, usability, and cost are the primary factors that determine which driver information systems are popular with the driving public. Further, classical engineering/technology considerations are often secondary, especially over the long term. While this may seem to be a shock to engineers, history shows otherwise.

## What systems, proposed in the past, have not been a market success?

### Electronic Clusters

There was a major industry push in the early 1980s to replace mechanical and electromechanical clusters with all-electronic clusters, employing liquid crystal display (LCD), vacuum fluorescent (VF), or light emitting diode (LED) technology. While the electronic content of clusters has grown, the primary displays are still electromechanical. The technology has not radically changed due to cost (electro-mechanical displays have been cheaper) and usability (the electronic displays can be more difficult to read and lack smooth pointer movement).

### Head-Up Displays (HUDs)

Several manufacturers have sold products with head-up displays, citing their advantage in reducing glance times to displays such as the speedometer. However, the reduction in reading times is not sizable, and, because the speedometer glance frequency is relatively low when compared with the road scene and mirrors, the performance benefits have not been overwhelming. Consequently, few drivers have purchased HUDs as an option. While manufacturers are continuing to make inroads in reducing HUD cost and making them brighter for daytime viewing, HUDs will not become a popular item until an application is found that requires frequent glances (navigation) or very short glance times (collision warning).

### Speech

Discussion continues on the use of speech-operated controls and speech output in motor vehicles. The primary advantage of the auditory modality is minimizing eyes-off-the-road time, providing an alternative to visual displays and manual controls. To date, there are few systems that are sufficiently complex to make using manual input/visual output a challenge to drivers.

At one time, some Chrysler products had voice warnings, such as,"Your door is ajar." (But a door is a door, not a jar.) The author believes that customer acceptance of that interface was poor, and customer impressions have become generalized to create a barrier against automotive speech interfaces.

## What systems could become more prevalent in the future?

One of the best sources for predictions of the future is the most recent Michigan Delphi forecast of the automotive industry (Cole and Londal, 1996) produced by the Office for the Study of Automotive Transportation of the University of Michigan Transportation Research Institute (UMTRI). (See also Crone, 1995.) In the Delphi method, experts individually participate in repeated rounds of questioning, with feedback from the entire group being provided for all but the first round. The technology panel consisted of 120 technology experts (most at fairly high levels in their organizations--CEOs, presidents, vice presidents, directors, chief engineers, etc.). In response to a question concerning vehicles produced in North America having intelligent transportation systems (ITS), the installation rates shown in Table 1 were predicted for the year 2005.

Table 1. Production Percentages for ITS by 2005

| System | Median Response (%) | Interquartile Range (%) |
|---|---|---|
| Adaptive cruise control | 10 | 5/24 |
| Collision warning | 5 | 3/20 |
| Automatic toll collection | 6 | 2/20 |
| Navigation | 10 | 5/20 |
| In-vehicle message | 10 | 5/20 |

Elsewhere in the current Delphi study, other electronic/electrical features having associated human elements are discussed. Most features, such as drive-by-wire, expert system diagnostics, and voice systems, are predicted to have low installation rates. Only 5 percent of all vehicles are predicted to have factory-installed cellular phones by the year 2000, and 10 percent by 2005.

Secondary indicators of what might be in future vehicles come from assessments of which systems provide benefits, in terms of reducing accidents, improving traffic flow, and making driving more pleasant (Green, Serafin, Williams, and Paelke, 1991). For that analysis, the systems that were likely to offer the greatest benefit were driver information systems that warned drivers of congestion and special hazards.

The author's personal predictions are similar to those of the current Delphi study. The number 1 growth item will be cellular phones, mostly as aftermarket products. Phones provide a means for readily obtaining assistance, a great comfort to those driving alone. In addition, cellular phones allow people to make more efficient use of scarce personal time by conducting business while driving.

The number 2 feature to see near term growth is adaptive/intelligent cruise control, particularly in the U.S., where varying congestion levels on expressways are suited to its application. Conventional cruise systems make driving on expressways more pleasant, but, as one drives from outlying areas into cities, it is necessary to repeatedly switch the system on and off to drive safely. The sensor (most likely a scanning laser), currently quite expensive, will soon be a moderate cost item. A system of this type has recently been introduced by Mitsubishi for the Diamante sold in Japan, and other manufacturers are poised to offer systems in Europe.

Number 3 in growth in the U.S. will be navigation systems, with the first market being rental cars and emergency vehicles. It will take several years for drivers to experience navigation systems in rental vehicles, to appreciate their advantages, and to build demand. Navigation systems are fairly expensive and likely to be a discretionary purchase. Navigation systems are very popular in Japan (Treece, 1996). For some deluxe models, they are a factory-installed option on a majority of the vehicles sold.

Number 4 in growth will be menu-based driver interfaces. Proposals for them have been around for some time (Green, 1979), but only in recent years has the feature content in vehicles grown to the point where there is not enough room for dedicated controls and displays (Farber, 1992).

Number 5 in growth will be dispatching and tracking systems for trucks, and intelligent packages/cargo that assist in tracking. While this area is not as glamorous as developments relating to passenger cars, its economic impact could be quite large because of the large volume of freight that is moved by truck.

Number 6 in growth will be speech technology. Speech technology could be a solution to the problem of vehicle-driver communication. There are already pieces of this technology in place (speech-operated cellular phones, for example), and further piecemeal introduction of systems (such as speech-operated entertainment systems) is likely to occur before entire interior systems are speech operated. Speech operation is also a possibility for navigation systems, where complexity and unit cost can justify the development of a new interface method. The negative customer experiences described earlier are a major stumbling block.

Number 7 in growth will be night vision systems. These systems have great potential for reducing accidents, but because they substantially alter the visual aspects of a highly visual task, namely driving, it will be some time before they are introduced.

### What are impediments to their successful introduction?

The author sees five areas in which there are deficiencies: (1) models of driving, (2) application-specific data for ITS systems, (3) safety data on cellular phones and other new systems, (4) usability assessment tools, and (5) human factors expertise within the suppliers. Each of those impediments is considered separately.

There has not been a great deal of thought given to general human factors issues relating to the introduction of new automotive technology. The most comprehensive summary appears in the ITS-America Human Factors Research Plan (Intelligent Transportation Society of America, 1995), with a short summary of some aspects appearing in Green (1996). The major, long term problem to be faced is the fundamental lack of understanding of how people drive, and, in particular, mathematical models of such driving (Impediment 1). While good models of steering exist, fully validated models of the complete task ensemble--steering, visual search, use of secondary controls, and so forth--do not exist. Such information could serve as a basis for predictions of driving workload.

In some sense, this lack of models of driving is analogous to trying to build a bridge by trial and error, without equations to predict the load on bridge members. Beyond basic design, there is a need for comparative evaluations. Will a particular new technology affect driving? Will driving be safer or less safe, and will new systems be easy to use?

For example, baseline data on lane variance as a function of the type of road being driven, traffic, speed, weather, time of day, etc. could be extremely useful. Then, if a test of some interface was conducted on a particular type of road, there would be existing baseline data for comparison. Furthermore, knowing the natural amount of variation in the real world, one could assess if the difference, even if detectable, had any practical impact. Without such information, establishing safety and usability standards is quite difficult.

The Federal Highway Administration is now sponsoring a study to develop a model of driving. While that effort is a good start, the necessary knowledge will be available only after multiple investigators in multiple projects have independently developed models as called for in the ITS plan.

Beyond the general data on driving, product-specific information is needed (Impediment 2). For phones, navigation systems, intelligent cruise control, and night vision systems there are research efforts underway. But there is likely to be a shortfall of knowledge for menu-based interfaces and voice interfaces, so work directed to those interface styles is needed. However, even in areas receiving study, there are still major gaps. For example, during recent ISO deliberations there was considerable discussion of how much deceleration intelligent cruise systems should be capable of providing. The concern was that as the vehicle becomes more capable (throttle only versus downshifting versus minimal braking versus locked wheel braking) the driver becomes disconnected with the driving situation, less able to intervene in an emergency, and less informed about when to intervene. Instances where drivers might have access to several vehicles on particular days with differing levels of automation in their cruise systems further complicates matters.

There is also a need for much better safety data on cellular phones and other new systems (Impediment 3). While all of the details are not yet available, a one month survey by the National Police Agency in Japan found that of the 62,000 injury-related accidents in June of this year, 129 were "mainly caused" by the use of car phones (Tsuda, 1996). Data on phone-related accidents are difficult to obtain in the U.S., as phone use (or use of other new technologies) is not recorded on standard accident forms developed by the states or the federal government. Systems to methodically collect and analyze accident data for these products are needed. Cellular phone safety is likely to serve as a landmark for product liability claims against many types of advanced systems (navigation, intelligent cruise control, etc.).

An area needing additional focus (and funding) is the lack of usability assessment tools (Impediment 4). At UMTRI, the author and his colleagues have focused on the development of an instrumented car (Sweet and Green, 1993) and a driving simulator (MacAdam, Reed, and Green, 1993) for human factors tests. Many engineers overlook the fact that one needs not only good data collection tools, but also software to reduce and analyze the reams of data gathered. Even though tremendous effort has been put into keeping costs down, simulators and instrumented vehicles are far from off-the-shelf items. For example, the typical automotive industry driving simulator costs between $2,000,000 and $3,000,000 and requires several people to operate. Therefore, a typical study costs several hundred thousand dollars, too much for typical engineering tests. If driving simulators are to see more routine and widespread use in engineering, their cost needs to be reduced significantly. Some have said that the highly regarded GM simulator facility in Warren was mothballed for reasons of cost effectiveness.

ITS device implementation may be delayed due to the lack of human factors knowledge, expertise, and experience, especially within the automotive suppliers (Impediment 5). This includes not only limitations in data, but those related to the design process, in particular the use of interface prototyping tools (Green, Boreczky, and Kim, 1990; Green and Olson, 1996), and the integration of small sample usability tests with iterative design. This process is generally not taught in university programs, especially in psychology, the background of about half of the practicing human factors specialists. This shortfall is likely to be overcome by the use of human factors consultants by suppliers. Internal knowledge could be established by supplier attendance at the Michigan Human Factors Engineering Short Course (Pew and Green, 1996).

Thus, the author argues for continuing ITS-related research initiatives, in particular for both basic research and for knowledge specific to applications. It is important for manufacturers and suppliers to realize that it will take many years to acquire a basic understanding of these topics, and data collection initiatives cannot start concurrently with product development. Further, there needs to be a realization that knowledge gathering must continue well after the first model has been fielded. As technology and applications change, the supporting knowledge base needs continuing development. As a parallel, motor vehicles have had internal combustion engines since the turn of the century, but no one would assert that enough is known about thermodynamics, combustion behavior, or engine materials so that research on those topics should cease. Likewise, as ITS products are implemented, work on gathering knowledge to improve them should continue. Failure to continue and expand research on driver interfaces means that the long term prognosis for ITS will be similar to that for electronic displays and HUDs: interesting ideas that sometimes appear in products, but do not radically alter the customer experience, enhance mobility, or make driving safer.

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