2000-01-COO8

Crashes Induced by Driver Information Systems and What Can Be Done to Reduce Them

Paul Green
University of Michigan Transportation Research Institute (UMTRI)

Copyright © 2000 Society of Automotive Engineers, Inc.

ABSTRACT

Future in-vehicle information systems may overload drivers, compromising driving safety and product usability. Suggestions of overload appear in (1) statistics from Japan, the United States, and Kuwait for mobile phone-related crashes, (2) statistics from Japan for navigation system-related crashes, and (3) human performance data. From most to least frequent, tasks associated with crashes were receiving a call, dialing, talking (on a phone), looking at a (navigation) display and operating an interface (for navigation). To optimize driver performance for future interfaces, developers should comply with design guidelines (JAMA, SAE J2364), work more closely with human factors experts, expand usability testing, and implement workload managers.

INTRODUCTION

Over the last few years there have been numerous changes in motor vehicles. In the U.S. market, the product mixture has shifted from predominantly passenger cars to a mixture in which light trucks, minivans, and sport-utility vehicles predominate. This change has occurred in parallel with numerous advances in technology, providing vehicles with greater reliability, lower emissions, and more performance, for approximately the same cost. As significant as these changes are, the fundamental nature of driving is unchanged.

Looking towards the future, the author's colleagues at Nissan refer to the transition from automobiles to infomobiles. As systems such as adaptive cruise control (ACC), navigation, mobile phones, traffic information, web access, email, and automatic lane control (ALC) see expanded use in the vehicle fleet, driving will change from a real-time control task to telematics management. The implications of these changes for vehicle safety and usability, and more generally, the driving process, have received insufficient attention in the research literature and in public discussions.

In part, this is due to the source of these innovations. Motor vehicle manufacturers are well aware of the connections between usability, safety, and product liability. Critical topics include post crash fires, air bag deployment, door latch failures in crashes, and other matters. To a lesser degree, some suppliers of safety-related components (e.g., brake parts, air bags, etc.) may also have been exposed to legal actions.

According to the National Safety Council, 999,000 traffic-related deaths occurred worldwide in 1990 (National Safety Council, 1999). Each year, about 42,000 people are killed in motor vehicle crashes in the U.S. (U.S. Department of Transportation, 1999) and about 12,000 in Japan (Nissan, 1999). In the office environment familiar to computer and electronics manufacturers (the new developers of driver information systems), the major health concerns are carpal tunnel syndrome from typing and, back and neck problems from prolonged sitting. The author is not aware of anyone who has died as a result of using a computer in a normal manner, yet deaths are common from "normal use" of motor vehicles. Hence, the computer and electronics manufacturers have had little experience with the safety concerns so central to motor vehicle design. Caution on their part is imperative.

In view of these concerns, this paper answers 3 questions concerning the safety of driver interfaces for in-vehicle information systems:

1. Has driver use of existing information systems led to crashes?
2. Which tasks lead to crashes?
3. How can driver interfaces be designed to minimize crash risk?

QUESTION 1: HAS DRIVER USE OF EXISTING INFORMATION SYSTEMS LED TO CRASHES?

The most compelling evidence of safety concerns comes from crash statistics. No crash statistics exist for Intelligent Transportation System (ITS) devices for the U.S. or Europe. However, the Japanese National Police Agency Traffic Planning Department collects such data for mobile phones and navigation systems, the only ITS devices in production in quantity. That data is solely available on the Japanese version of their web site (www.npa.go.jp), not the English version, although translated copies are available (Nissan, 1999). (See also Green, 1999c.) Following are sample narratives from two crash investigations in which a mobile phone was identified as a causal factor, an association that seems reasonable given the information provided.

Driver is seriously injured as she receives a call to her cell phone.

A female driver was driving with her friend as a passenger. As she was signaling to turn left at the intersection, the cell phone placed on her left rang. As she picked up the phone with her left hand, her friend called for her attention. The driver took the phone off her ear and looked ahead. As she sees a woman on a bicycle crossing the intersection, she could not avoid hitting the woman on a bicycle. The right front side of the vehicle hit the left side of the bicycle. The woman on the bicycle suffered an injury that required 1 month for complete recovery, including a broken rib.

Driver checking his mail on his cell phone crosses the center line.

A man driving a passenger car noticed incoming mail indicated on his cell phone, which was placed on the driver's seat. As his attention is diverted to the phone, he realizes that he was crossing the centerline by the light from a car turning onto the man's direction. The driver was unable to avoid the oncoming car, hitting its side. The driver of the oncoming car suffered injury on his head. His female passenger also suffered injury.

Table 1 provides crash statistics from the National Police Agency for 1997-1999 (up to November, 1999). The number of mobile-phone related deaths per year in Japan is in the mid 20s and the number of navigation-induced crashes is about 2. To put these deaths in perspective, in Japan there were 9640 driving-related deaths in 1997, 9211 in 1998, and 9005 in 1999 (for the entire year). At the time these data were collected, using a mobile phone in a moving vehicle was legal in Japan. In contrast, there were many restrictions to the design of navigation systems to promote safety, though as discussed later in this article, those restrictions were not always applied to aftermarket navigation products. For both products, there was a steady increase in market penetration over time. For example, the cumulative numbers of navigation systems in Japan were 2.4 million, 3.5 million, and 4.7 million by the end of October in 1997, 1998, and 1999 respectively. Finally, although the number of deaths in some instances is a single digit value, the pattern of 1 death for every 100 injuries seems consistent.

Table 1. Cell Phone and Navigation System-Related Crashes in Japan

Year	Cell Phones		Navigation Systems	
	Injuries	Deaths	Injuries	Deaths
1997	2,095	20	117	1
1998	2,397	28	131	2
1999	2,418	24	205	2

Violanti and Marshall (1996) compared 100 randomly selected U.S. drivers involved in a crash over the last 2 years with another 100 who were not involved. Although the number of mobile phone users in the sample was small, the results indicated a risk ratio of 5.6:1 for drivers who talk more than 50 minutes per month on cellular phones.

Probably the most often-cited study of mobile phone use is Redelmeier and Tibshirani (1997). They examined data for almost 700 drivers who were mobile phones users and were involved in motor-vehicle crashes that resulted in substantial property damage. Each driver's mobile phone records for the day of the crash and the previous week were examined. Redelmeier and Tibshirani reported the risk of a crash was 4.3 times greater when a mobile phone was used than when it was not. Interestingly, hands-free units had a greater, though not significant, risk ratio than hand-held units (5.9:1 versus 3.9:1).

Additional evidence comes from the Koushki, Ali, and Al-Saleh (1999) study of mobile phone use in Kuwait. They surveyed 2,000 drivers, 73 percent of whom had a mobile phone. Figure 1 shows the relationship between the number of calls per trip and the number of crashes involving damage and injuries per driver since owning a mobile phone. Notice that the difference between no

calls and 1 call per trip is over a factor of 3 for injuries and 4 for crashes involving damage; the likelihood of both types of crashes continues to increase as call frequency increases. The risk ratios for a single call per trip are consistent with the results of Violanti and Marshall (1996) and Redelmeier and Tibshirani (1997).

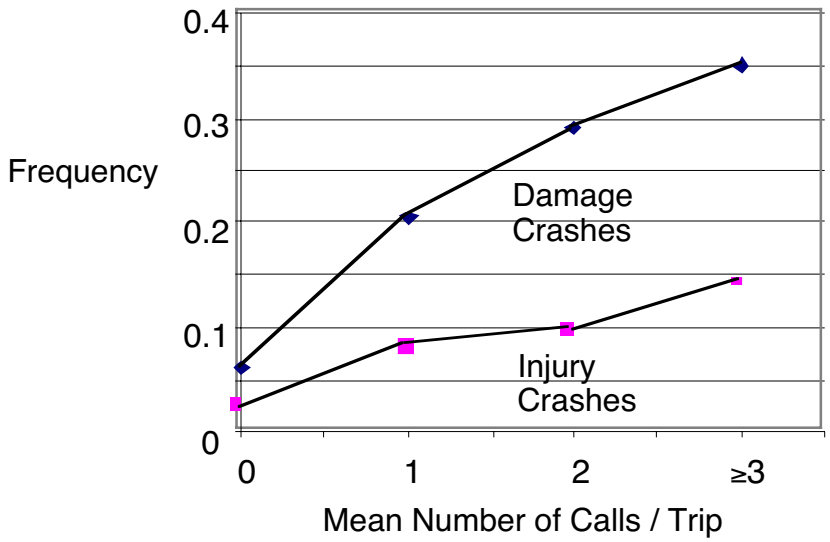

Figure 1. Mean Number of Calls / Trip Versus Crash Frequency

Furthermore, the respondents to the survey reported 13 deaths that were mobile phone related, representing 0.8 percent of all crash-related deaths in Kuwait. Details of those deaths are not provided. Based on this evidence Koushki, Ali, and Al-Saleh "strongly recommend the banning of driver mobile-phone use while the driver's vehicle is in motion" (Koushki, Ali, and Al-Saleh, 1999, p. 32).

Thus, crash data indicate a significant increase in crash risk associated with using mobile phones in moving vehicles, with the increase in risk being on the order of 3 or so, and with the risk increasing with greater phone use. Evidence of crashes induced by navigation systems also exists, but based on fewer studies.

QUESTION 2: WHICH TASKS LEAD TO CRASHES?

By identifying the types of tasks and task characteristics that currently result in overload, future systems can be designed to minimize opportunities for overload. There are 2 phenomena to be considered: (1) eyes-off-of-the-road and (2) mind-off-of-the-road. Clearly, drivers need to see the road in order to drive safely. Hence in-vehicle tasks that are visually demanding, such as reading detailed maps or long strings of text, are likely to lead to crashes. Also visually demanding are manual tasks that require visual guidance, such as entering a long string of text on an unfamiliar keyboard.

Mind-off-of-the-road refers to situations where the driver is thinking about something other than the road situation. This can occur when the driver is daydreaming, but can also occur when the driver is listening to a long or complex auditory message, such as from a phone or electronic device.

Examples of tasks in these categories are shown in Table 2 from the National Police Agency of Japan data described earlier. The task most often associated with mobile phone-related crashes (45 percent) was receiving a call. This makes sense for two reasons. First, although mobile phones are sometimes located in readily reached locations, such as a mobile phone mount, they could also be in a coat pocket, in a jacket pocket on the passenger seat, or in a brief case in the back seat. People tend to abandon whatever they are doing when the phone rings (especially in an office setting) and this happens while driving as well, to the detriment of safe driving, although this tendency may decrease as voice mail becomes more common.

Table 2. Driver Tasks and Crashes (January – November, 1999)

Cell Phone		Navigation System	
Task	Crashes	Task	Crashes
Receiving Call	1077		
Dialing	504	Looking	151
Talking	350	Operating	46
Other	487	Other	8
Total	2418		205

Notice that a significant fraction of the calls (350 cases in 11 months) were associated with talking. While some have suggested that hands-free (voice dialing) will eliminate the risk of using a cell phone while driving, these data suggested the risk will be reduced, but not eliminated. It is important to distinguish uttering a brief command, say to operate a voice-controlled radio, from speaking on the phone. Radio operation is likely to require minimal thought followed by a short command (e.g., "change to WUOM"). Phone use requires more thought and the output is likely to be longer than a single word or phrase. Hence, the phone call is likely to lead to a much greater workload.

In considering the visual and cognitive demands of voice interaction, it is important to distinguish between speaking to a passenger and speaking over the phone. A passenger, if anything, provides another pair of eyes, searching the driving environment for hazards and assisting in navigation. Further, to some degree, passengers limit the difficulty of what they say to match the driver's ability to process that information at the moment. So, for example, conversations about complex financial matters demanding concentration are not common. Many passengers regulate when they speak based on the traffic situation they observe and the driver's mannerisms. For example, when making a turn at a busy intersection, passengers are often silent when not providing navigation assistance. A person on the phone has no knowledge of the driving situation and continues to speak.

The necessity for various tasks can depend on the driving context. In the Japanese crash data, the navigation task most commonly linked to crashes was looking, which in Japan, would probably be looking at a map. Because of the nongrid-like nature of the Japanese road network, the lack of street names, and the identification of street addresses in chronological rather than spatial order, maps are essential to navigation in Japan. In the United States, simpler (and less visually demanding) turn-by-turn displays are preferred (Brooks, Nowakowski, and Green, 1998) and, in fact, auditory guidance alone can be sufficient for navigation.

Also noteworthy is that about one third of the navigation-related crashes in Table 2 are associated with device operation. The primary operational problem is likely to be destination entry, even though destination entry in a moving vehicle is not allowed by a Japan Automobile Manufacturers Association (JAMA) 1996 regulation. As was noted earlier, these crashes are presumed to be associated with aftermarket products that do not comply with the JAMA regulation, about half of the systems produced.

Other evidence comes from Violanti (1997) who examined crashes in Oklahoma in which a mobile phone was present (though not necessarily used). Crashes of phone users were more likely to be caused by inattention, unsafe speed, or being on the wrong side of the road, and were much more likely in the city, a location assumed to be more attention demanding. Ran-off-the-road crashes were also much more likely. This evidence reinforces the notion that using a phone demands attention that detracts from people's ability to drive safely.

In addition to crash data, several human performance studies have shown the deleterious effects of using these devices while driving. Pachiaudi, Morgillo, Pauzie, Deleurence, and Guilhon (1996) examined phone use while driving in a simulator. When compared with a baseline of driving but not using the phone, reaction time while using the phone increased 45 percent for nonphone users and 60 percent for phone users. Glance data also suggested decreases in attention to the road due to using the phone while driving.

Tijerina, Parmer, and Goodman (1998) had drivers operate 4 commercial navigation systems while driving on an oval test track with traffic. They did not conduct the experiment on a real road because of the risk involved. In this experiment, there were 16 drivers (8 age 35 or less, 8 over 55), all of whom were given practice using each device prior to the experiment. Table 3 shows their summary performance data for several navigation systems and for a mobile phone used for comparison.

Table 3. Results from Tijerina, Parmer, and Goodman (1998)

	Group	Alpine Nav.	Delco Nav.	Clarion Nav.	Zexel Nav.	cell phone
Driver interface type -> Performance Measure		Hand-held controller	manual entry	voice operate	scrolling list	manual dial
Trial time (s),	young	78	56	74	70	22
Point of Interest (POI)	old	158	98	76	140	30
Mean eyes-off-road	young	60	44	24	35	18
Time (s), POI task	old	121	78	26	108	16
Mean glance to device (s)	all	2.6	2.7	1.1	2.7	3.2
Mean lane excursions / trial	all	0.88	0.24	0	0.99	0.07

Four key points emerge from these results. First, the time to select a point of interest, a relatively easy destination entry task, was over a minute. The point of interest-task time was 3 times longer than dialing a cell phone number (11 digits), and the crash data suggest that the distraction associated with dialing can lead to deaths. Risk should be proportional to task time (and eyes-off-the-road time), so the risk of manually entering a destination could be at least triple that of dialing a phone. Tasks that are generally considered to be acceptable, such as turning on the wipers, adjusting the fan speed, and so forth, have task times more than an order of magnitude less than those for navigation data entry (Green, 1999).

Second, a key aspect of the risk is that when operating these devices, drivers are often not looking at the road. In this experiment, eyes-off-the-road time was about two-thirds to three-fourths of the total task time when the entry was manual. Drivers using full-featured navigation systems with manual entry (Alpine, Zexel) averaged almost 1 lane excursion per entry sequence, a level of driving performance that is unlikely to be publicly acceptable.

Third, even with voice entry, people tend to look towards the speaker or microphone. For the Clarion navigation system, about 1/3 of the total task time was spent looking in the vehicle (away from the road).

It would be a mistake, however, to assume that phones are the only auditory instance of attentional conflict. In Fleming, Green, and Katz (1998), 32 drivers drove an instrumented car on an expressway while listening to a series of traffic messages of varying length (e.g., “I-94 eastbound at Southfield freeway, continuing construction, right lane blocked, 3 mile backup”). Interestingly, there was a slight increase in speed variance over baseline driving due to listening to the message and a small increase in speed variance when reporting the message to the experimenter. This suggests some consequences of just listening to audio.

In addition to the specific studies listed here, readers should see Goodman, Bents, Tijerina, Wierwille, Lerner, and Benel (1997) for a complete discussion of the research on mobile phones and Green (1999c) for an extensive review of the visual and manual demands of in-vehicle devices.

Future driver information systems may require drivers to look away from the road, to operate controls, to speak to, or even just listen to them. Performance of these tasks can distract drivers from the primary task of driving and lead to crashes. Hence, design-induced problems can make driver information systems hazardous to use. Responsible product designers must seek approaches to minimize the risks to drivers and maximize product usability and customer satisfaction. Some of those approaches are described in the next section.

QUESTION 3: HOW CAN DRIVER INTERFACES BE DESIGNED TO MINIMIZE CRASH RISK?

Given the research results described, one might believe the author favored complete elimination of all high-technology in-vehicle devices. That is not true. These devices have enormous benefits to driving safety and convenience. Navigation systems allow drivers to travel to unknown destinations in safety, avoiding the need to refer to paper maps and other materials. Mobile phones provide rapid access to police and emergency services, allowing them to reach crash scenes quickly and save lives. Email, web access, traffic information, and other systems will provide useful information to drivers in a timely manner, and make drivers more productive. The point is not that these devices in themselves are bad, but that when used at particular times and for certain tasks, they present and unacceptable risk to the motoring public by overloading drivers. A 3-pronged approach is proposed to reduce risk to a minimal level.

1. Apply and extend driver interface regulations and design guidelines.
2. Utilize human factors experts, data, and methods to develop driver interfaces.
3. Conduct research on and development of a workload manager.

1. Apply and Extend Driver Interface Regulations and Design Guidelines

Several rules and guidelines affect the design of driver interfaces. Constraints on mobile-phone use are fairly well known. It is illegal to drive and use a cellular phone in a moving vehicle in Japan, and the law is enforced. Use of hand-held phones is illegal in Australia, England, Israel, Italy, Switzerland, and Spain, and legislation is pending in several states in the United States. Hand-held phone use is illegal in several cities (Goodman, Bents, Tijerina, Wierwille, Lerner, and Benel, 1997). Many other locations are considering banning phone use in a moving vehicle, though 911 emergency calls and N11 traffic calls should be exempted. One possible scenario for the future will be bans on all calls that require real-time human interaction (dialing, speaking, or listening), with the exception of 911 and N11 calls.

With regard to navigation-system interfaces, no laws affect their use that the author knows of, but there are many guidelines of varying authority. The navigation rules are important because they serve as a benchmark for what drivers can and cannot do in a moving vehicle. So, if some combination of reading visual displays and operating manual controls presents similar excessive visual and/or cognitive demands to a driver, and that combination is not allowed by the navigation system rules, then that combination should also not be allowed for other purposes, say, email.

All of the Original Equipment Manufacturers (OEMs) in Japan comply with the JAMA guideline for navigation-system interface design (Japan Automobile Manufacturers' Association, 1996; Ito and Miki, 1997; Takaishi, 1997). Technically, the guideline is voluntary, but because of cultural pressures, all OEMs comply with it. It is the most restrictive of the driver interface guidelines. That regulation prohibits images of television broadcasts or video playback, phone numbers and addresses as guiding information, introductions to restaurants and hotels by showing pictures of their interiors, scrolling characters, messages longer than 31 characters, and complex switch operations. The Japanese OEMs would like to see this regulation adopted more widely. If that is to occur, Japanese Society of Automotive Engineers (JSAE) will need to produce documentation in English describing the rationale for each article of the rule and publicly replicable descriptions of the supporting research. Information produced to date has sometimes not contained the desired details on the driver tasks (with pictures of the interfaces), the vehicles and roads driven, the instructions to subjects, the test measures, and the statistical analysis. Subject samples have been small.

The major guidance document in the U.S. is SAE Recommended Practice J2364, commonly known as the "15-Second Rule" (Society of Automotive Engineers, 2000; Green, 1999b). SAE J2364 has been approved by SAE at the subcommittee level. This document should eventually be approved at the division level and become an official SAE practice. At this point, compliance with J2364 is policy at several manufacturers.

The 15-Second Total Task Time Rule specifies tasks that are not allowed in moving vehicles. Specifically, no navigation system task involving visual displays and manual controls can take more than 15 seconds to complete when timed staticly, that is, in a parked vehicle or in a simulator. The rule does not apply to dialing a cell phone or using a voice interface. The J2364 Practice provides details about how many subjects should be tested, their ages, and the amount of practice allowed. The rationale behind the rule is that it is important to be able to conduct testing early in design while modifications are feasible. To encourage testing, tests should be inexpensive. The research literature has shown that crash frequency is well correlated with total eyes-off-the-road time (Wierwille, 1995) and that eyes-off-the-road time is well correlated with total task time. Total task time measures can be determined with computer mockups of the driver interface, something that most system developers produce early in design. The 15-second limit is consistent with design recommendations in the literature and in design guidelines. Fifteen seconds is a time well in excess of accepted design practice for most driver interfaces, and is a time that for reasonable task frequencies and product market penetrations will lead to an acceptable number of crash related deaths (Green, 1999c).

A next step in the evolution of J2364 is the development of an equivalent requirement for speech interfaces. U.S. Department of Transportation financial support, a key factor in moving the initial draft forward, has ended. Further, given there is much less literature on automotive applications of speech interfaces than visual/manual interfaces (on which J2364 is based), developing a practice will be a challenge. However, given that so many manufacturers and suppliers are marketing or about to market speech interfaces, some guidance is needed.

In addition to SAE J2364, 2 sets of comprehensive guidelines were produced for the U.S. Department of Transportation under contract, one by UMTRI (Green, Levison, Paelke, and Serafin, 1995) and one by Battelle (Campbell, Carney, and Kantowitz, 1997). Both are very comprehensive and linked to research. These

guidelines are voluntary and compliance with them is unknown. Many organizations producing driver interfaces are probably unaware of the existence of these guidelines, though they are reasonably well known by human factors professionals involved in automotive research. Coverage of speech interfaces in both guidelines is very general.

In Europe, the HARDIE Guidelines (Ross, Mitland, Fuchs, Pauzie, Engert, Duncan, Vaughan, Vernet, Peters, Burnett, and May, 1996) provide comprehensive guidance for navigation-system design. The most recent version of the guidelines provides both general advice on interface design and detailed design recommendations for specific interface elements, such as turn-by-turn displays. However, many of those recommendations are based on general principles, not specific studies of each element. Compliance with the HARDIE guidelines is voluntary, and their impact on product design in Europe is unknown. Practice in the United Kingdom is influenced by the BSI (British Standards Institution) Guidelines (DD234:1996), but BSI guidelines are even more general, and also voluntary. Their impact is believed to be minor.

At the international level, there have been discussions within International Standards Organization Technical Committee 22 (Road Vehicles), Subcommittee 13 (Ergonomics), Working Group 8 (Transport Information and Control Systems-TICS) of developing an ISO standard for advanced driver interface design. Since a preliminary work item for that purpose has not been established, an ISO standard is at least several years in the future. A major part of developing that standard will be the assembly and integration of research performed since the Battelle, HARDIE, and UMTRI guidelines were completed.

Thus, current practice is to comply with the JAMA guideline in Japan and J2364 in the U.S., with informed designers using the Battelle, HARDIE, and UMTRI guidelines to improve interface design. Research-based guidelines for automotive speech interfaces are urgently needed, but research that might serve as a basis for them is lacking.

2. Utilize Human Factors Experts, Data, and Methods to Develop Driver Interfaces

The extent to which human factors knowledge and methods are incorporated into the design of advanced driver interfaces varies with the development firm. Most of the major automotive manufacturers have talented human factors professionals working on interface design. At the suppliers, the situation is highly variable, with some organizations having no trained professionals or those with minimal training (e.g., attendance at the University of Michigan's Human Factors Engineering Short Course; Pew and Green, 2000; www.umich.edu/~driving/shortcourse). Just as one cannot learn electrical engineering in 2 weeks, one cannot become a human factors expert in 2 weeks at the University of Michigan course, though 2 weeks is better than nothing. The author has observed situations where interface designers have not read the human factors literature nor have they done any formal user testing. All too often, the test subjects are other engineers, individuals who are quite different in knowledge and abilities from the majority of the driving population.

In addition to greater reliance on human factors experts, expanded use of human factors analytic methods is needed (Kantowitz, 2000). This includes task analyses to assure compliance with SAE J2364, in particular following the procedures of SAE Recommended Practice J2365 now under development (Green, 1999a). In addition, a closer look at the UMTRI and Battelle guidelines, along with recent UMTRI research on reading electronic maps (Brooks and Green, 1998; Brooks, Nowakowski, and Green, 1998; Nowakowski and Green, 1998; Brooks, Lenneman, George-Maletta, Hunter, and Green, 1999) is desired. Further, the U.S. Department of Transportation is in the process of releasing software to estimate task times and visual demands, software that may be useful in assessing design alternatives.

However, the most likely and important step is driver testing, in static mockups, in driving simulators, and on the road. There are no commonly cited on-the-road studies of driver entry of destinations.

3. Conduct Research on and Development of a Workload Manager

What drivers are able to do in a moving vehicle depends upon the workload of the driving situation and their capabilities, capabilities that depend on their age and expertise (Tsimhoni and Green, 1998). For example, on Sunday morning, sections of M-14 (an expressway) just east of Ann Arbor, Michigan are virtually devoid of traffic. Since the lanes are wide and straight, and the road surface is in good repair, driving demands very little of the driver. On the other hand, I-696, another expressway just a few miles to the east, has some badly potholed sections, has numerous curves and merging traffic, and is almost always congested. On that road, attention to anything other than driving is a challenge.

Given that what drivers can do is situation dependent, one could identify a reasonable worst case and using the workload of that situation, design interfaces. Although this approach is simple and prosafety, it effectively eliminates many ITS functions from use in a moving vehicle. An alternative and recommended approach is to regulate information flow to the driver based on the

momentary driving demand, the availability of remaining visual and mental resources to process in-vehicle information, and the priority of each task. So, for the I-696 situation described above, 30,000 mile-checkup reminders would be delayed until the driver was on a less demanding road and mobile-phone calls would be blocked. However, for most drivers, information flow to and from the driver would be unrestricted in the M-14 example.

All of the information needed by a workload manager is likely to be present in a near-term vehicle that could most effectively utilize one. Workload depends on the road geometry, traffic, speed, signs, weather, time of day, and in-vehicle system tasks. The navigation system (from the road database and GPS signals) would know where the vehicle is located, the lane width, and the curvature of the current and upcoming segments). The adaptive cruise control system will be able to detect nearby vehicles, providing the necessary traffic data, and potentially detect signs to be read. Weather information and time of day (along with ambient illumination) should be available from various broadcast sources and onboard sensors. A personality module in the ignition key should know about the driver. Management of phone communications is possible for Bluetooth-capable phones (www.bluetooth.com).

Unfortunately, how to compute workload from these data is unknown. The development of the expressions to calculate workload is a research project needing urgent attention. The data needed for this purpose do not exist and will require the simultaneous efforts of several teams of investigators over many years. At the present time, funding for this type of project is minimal. This situation does not bode well for many vendors who are about to market next-generation driver interfaces. The Driver Interface Team at UMTRI is attempting to make progress on this topic (e.g., Tsimhoni, Yoo, and Green, 1999; Wooldridge, Bauer, Green, and Fitzpatrick, 2000), building upon the GIDS (Generic Intelligent Driver Support, Michon, 1993) and CemVocAS (http://www.inrets.fr/ur/lescot/CeMVocAS/Pagedepa.htm) efforts.

CLOSING THOUGHTS

Manufacturers are rushing to market ITS/telematics applications that will provide enormous increases in the functionality available to drivers. There is great excitement about the possibility of how these systems might enhance the driving experience. However, relatively little emphasis has been given to the potential risks associated with overload these systems might pose to drivers, and much greater emphasis is needed (Anonymous, 2000). Driver interface-induced crashes have been shown to occur in quantity, for mobile phones and navigation systems, where someone has bothered to collect the data. Other ITS applications now being developed could also lead to crashes because the driving environment, drivers, and the tasks performed with new devices are similar to those for phones and navigation systems.

For now, restrictions on the use of these devices while driving are warranted, but not a blanket ban. In the long term, the most effective means of minimizing risk to drivers will be through improved product design. There is a need to (1) engage human factors professionals in the development of these interfaces, (2) make greater use of usability testing, especially on the road, (3) comply with existing guidelines such as the JAMA regulation and SAE J2364, (4) expand these guidelines to cover speech, and (5) fund the development and application of workload managers to avoid driver overload. At this point, safety and human factors efforts lag far behind electronics development. If action is not taken, a significant number of information system-related deaths and injuries will result. Potential reactions could be a tarnished public image of these products and result in a loss of a potential market, product liability suits that could put suppliers out of business, and federal regulations banning the use of many products in moving vehicles. The choice is who the manufacturers and suppliers want to support: human factors experts to help them develop better products, or lawyers to defend them.

REFERENCES

Anonymous (2000). Fancy Doodads Are Great, but Safety First, *Automotive News*, February, 7, 2000, 12.

British Standards Institution (1996). *Guide to In-Vehicle Information Systems* (Draft Document DD235:1996), London, U.K.: British Standards Institution.

Brooks, A. and Green, P (1998). *Map Design: A Simulator Evaluation of the Time to Read Electronic Navigation Displays* (Technical Report UMTRI-98-7, ITS RCE Report #939420), Ann Arbor, MI: University of Michigan Transportation Research Institute.

Brooks, A., Lenneman, J., George-Maletta, K., Hunter, D.R., and Green, P. (1999). *Preliminary Examinations of the Time to Read Electronic Maps: The Effects of Text and Graphic Characteristics* (Technical Report UMTRI-98-36, ITS RCE Report #939418), Ann Arbor, MI: University of Michigan Transportation Research Institute.

Brooks, A., Nowakowski, C., and Green, P. (1998). *Turn-by-Turn Displays Versus Electronic Maps: An On-the-Road Comparison of Driver Glance Behavior* (Technical Report UMTRI-98-37, ITS RCE Report #939419), Ann Arbor, MI: University of Michigan Transportation Research Institute.

Campbell, J.L., Carney, C., and Kantowitz, B.H. (1997). *Draft Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO)*, Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration.

Goodman, M., Bents, F.D., Tijerina, L., Wierwille, W., Lerner, N., and Benel, D. (1997). *An Investigation of the Safety Implications of Wireless Communication in Vehicles* (Technical Report DOT HS 808 635), Washington, D.C.: U.S. Department of Transportation.

Green, P. (1999a). Estimating Compliance with the 15-Second Rule for Driver-Interface Usabilty and Safety, *Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting*, Santa Monica, CA: Human Factors and Ergonomics Society (CD-ROM).

Green, P. (1999b). The 15-Second Rule for Driver Information Systems, *ITS America Ninth Annual Meeting Conference Proceedings*, Washington, D.C.: Intelligent Transportation Society of America, CD-ROM.

Green, P. (1999c). *Visual and Task Demands of Driver Information Systems* (Technical Report UMTRI-98-16), Ann Arbor, MI: University of Michigan Transportation Research Institute.

Green, P., Levison, W., Paelke, G., and Serafin, C. (1995). *Preliminary Human Factors Guidelines for Driver Information Systems* (Technical Report FHWA-RD-94-087), McLean, VA: U.S. Department of Transportation, Federal Highway Administration.

Ito, T. and Miki, Y. (1997). Japan's Safety Guideline on In-Vehicle Display Systems, *Proceedings of the Fourth ITS World Congress*, Brussels, Belgium: VERTIS, CD-ROM.

Japan Automobile Manufacturers' Association (1996, September 13). *JAMA's Guideline for Picture Display Equipment (English translation of revised version),* Tokyo, Japan (distributed as ISO document ISO/TC22/.SC13/WG9/N62).

Kantowitz, B.H. (2000). *Effective Utilization of In-Vehicle Information: Integrating Attractions and Distractions* (SAE paper 2000-01-CO11) Warrendale, PA: Society of Automotive Engineers.

Michon, J.A. (1993). *Generic Intelligent Driver Support*, London, U.K.: Taylor and Francis.

National Safety Council (1999). *International Accident Facts,* Chicago, IL: National Safety Council.

Nissan (1999). Status of Traffic Accidents Involving Personal Injury as of One Month after the New Law Forbidding the Use of Cell Phones while the Vehicle Is in Motion (translation of National Police Agency of Japan document), Farmington Hills, MI, December, 1999.

Nowakowski, C. and Green, P. (1998). *Map Design: An On-the-Road Evaluation of the Time to Read Electronic Navigation Displays* (Technical Report UMTRI-98-4, ITS RCE Report #939421), Ann Arbor, MI: University of Michigan Transportation Research Institute.

Pachiaudi, G., Morgillo, F., Pauzie, A., Deleurence, P., and Guilhon, V. (1996). Impact of the Use of Car Phones on Road Safety, paper presented at International Conference on Traffic and Transport Psychology, Valencia, Spain, May, 22-25, 1996.

Pew, R.W. and Green, P. (eds.) (2000). *Human Factors Engineering Short Course Notes (41st ed.)* , Ann Arbor, MI: University of Michigan, Center for Professional Development.

Redelmeier, D.A. and Tibshirani, R.J. (1997). Association between Cellular-Telephone Calls and Motor Vehicle Collisions, *New England Journal of Medicine*, *336*(7), 453-458.

Ross, T., Mitland, K., Fuchs, M., Pauzie, A., Engert, A., Duncan, B., Vaughan, G., Vernet, M., Peters, H., Burnett, G., and May, A. (1996). *HARDIE Design Guidelines Handbook: Human Factors Design Guidelines for Information Presentation by ATT* (Deliverable 20, Workpackage L5), Luxembourg: European Commission Host Organization.

Society of Automotive Engineers (2000). *Navigation and Route Guidance Function Accessibility While Driving* (SAE Recommended Practice J2364), version of January 20, 2000, Warrendale, PA: Society of Automotive Engineers

Takaishi, Y. (1997, March 5). Regulation of Video Monitors in Automobiles in Japan (letter to Mr. Harry Massey, Consumer Electronics Manufacturers Association).

Tijerina, L., Parmer, E., and Goodman, M.J. (1998). Driver Workload Assessment of Route Guidance System Destination Entry While Driving: A Test Track Study, *Proceedings of the 5th ITS World Congress (CD-ROM),* Seoul, Korea.

Tsimhoni, O. and Green, P. (1999). Visual Demand Driving Curves Determined by Visual Occlusion, pap presented at the Vision in Vehicles 8 Conference.

Tsimhoni, O., Yoo, H., and Green, P. (1999). *Effects of Workload and Task Complexity on Driving and Task Performance for In-Vehicle Displays As Assessed by Visual Occlusion* (Technical Report UMTRI-99-37), Ann Arbor, MI, The University of Michigan Transportation Research Institute.

U.S. Department of Transportation (1999). *Traffic Safety Facts 1997*, http://www.nhtsa.dot.gov/people/ncsa/ovrfacts.html.

Violanti, J.M. (1997). Cellular Phones and Traffic Accidents, *Public Health*, *111*, 423-428.

Violanti, J.M. and Marshall, J.R. (1996). Cellular Phones and Traffic Accidents: An Epidemiologoical Approach, *Accident Analysis and Prevention*, *28*(2), 265-270.

Wierwille, W.W. (1995). Development of an Initial Model Relating Driver In-Vehicle Visual Demands to Accident Rate, *Proceedings of the 3rd Annual Mid-Atlantic Human Factors Conference*, Blacksburg, VA: Virginia Polytechnic Institute and State University, 1-7.

Wooldridge, M., Bauer, K., Green, P., and Fitzpatrick, K. (2000). Comparison of Workload Values Obtained from Test Track, Simulator, and On-Road Experiments, paper presented at the Transportation Research Board Annual Meeting, Washington, D.C.

CONTACT

Paul Green is a senior research scientist in the Human Factors Division of the University of Michigan Transportation Research Institute and an adjunct associate professor of Industrial & Operations Engineering and Mechanical Engineering & Applied Mechanics at the University of Michigan.

Postal address:

University of Michigan Transportation Research Institute
2901 Baxter Road
Ann Arbor, Michigan 48109-2150 USA

Email: pagreen@umich.edu

URL: www.umich.edu/~driving