Vehicle User Characteristics
Research Needs in the New Millennium

THOMAS A. RANNEY, *Liberty Mutual Research Center*
E. DONALD SUSSMAN, *Volpe National Transportation Systems Center*
LOUIS TIJERINA, *Transportation Research Center, East Liberty, Ohio*
LEO TASCA, *Ontario Ministry of Transportation, Canada*
ALISON SMILEY, *Human Factors North, Inc.*
THOMAS H. ROCKWELL, *R&R Research, Inc.*
RODGER KOPPA, *Texas A&M University*

The Committee on Vehicle User Characteristics is concerned with the needs, capabilities, and limitations of vehicle users, which affect the design, operation, and maintenance of personal, commercial, and public transportation systems and embrace highway and rail operations. Our objectives are to maximize performance, safety, comfort, and efficiency in such systems, given the capabilities and limitations of vehicle users.

We present our committee's vision of future trends and the implications for research needs within the committee's scope in the following four sections, which reflect the major interests of our committee: (*a*) special populations of transportation system users, (*b*) user issues common to multiple transportation modes, (*c*) intelligent transportation systems (ITS), and (*d*) design of roadways and traffic control devices.

SPECIAL POPULATIONS OF TRANSPORTATION SYSTEM USERS

Older Drivers

By the year 2020, drivers aged 65 years and older will account for more than 20 percent of the driving population. The fastest-growing group is the old-old category, which includes drivers aged 75 and over. Normal aging is associated with declining visual, attentional, cognitive, and physical abilities. Medical conditions can accelerate deterioration in driving performance among older drivers.

The following research and development studies will be needed:

1. Normative data on the distribution of driving-related vision, attentional, cognitive, and physical impairments;
2. Development and evaluation of short, cost-effective, and legally defensible screening programs and devices to detect older drivers at greater risk of collision involvement;
3. Epidemiological studies on the collision risk associated with age-related medical conditions;
4. Simulation and instrumented-vehicle research to determine how older-driver performance is affected by age-related medical conditions;

5. Simulation and instrumented-vehicle research to determine how older-driver performance is affected by ITS, plus assessments of driver acceptance of and adaptability to these systems; and
6. Development and evaluation of older-driver education programs.

Young Drivers

The proportion of drivers aged 16 to 24 will also increase during the next decade, which will likely lead to an increase in fatal and injury crashes. Crashes are usually attributable to a combination of inexperience and risky driving behaviors. Alcohol and drug use also figures more prominently in fatal crashes involving young drivers above the legal drinking age.

There are six key knowledge gaps pertaining to the young-driver population:

1. *Novice-driver education:* Emerging technologies offer new possibilities for developing innovative approaches to driver education, which may incorporate multimedia curricula. Research will be needed to determine the optimal mix of driving simulation, CD-ROM-based instruction, and in-vehicle practice for training novice drivers. The role of the parents in driver training also needs to be rethought.
2. *Driver testing:* Road testing will need to be redesigned within the context of graduated licensing systems, with emphasis on demonstrating validity and reliability of the tests.
3. *Updates on graduated licensing initiatives worldwide:* Graduated licensing programs are maturing, and results of their effectiveness will soon be available. Newer programs can be modified on the basis of the experience with the current programs.
4. *Young-driver mobility and needs:* Travel behavior research will be needed to better understand young-driver mobility and needs. In particular, why do some teens obtain a license immediately upon attaining the legal age whereas others delay licensure? Finally, a reassessment of the benefits of younger-driver mobility versus the risks will be needed.
5. *Risk-taking behaviors by young drivers:* What constitutes risky driving behavior? What are the risk factors for risky driving? Which risky driving practices are most likely to result in injury?
6. *Age and experience:* Collision analyses are required to assess the contribution of age and experience to crash causation. Which skill-related deficiencies increase collision risk? Does amount of practice driving before full licensure affect future collision risk?

Disabled Drivers

The demand for increased mobility among the disabled will continue to increase as technology improves. Currently, there are approximately 500,000 to 750,000 disabled road users, and this should increase to approximately 1 million drivers by 2020. Although travel demand will continue to increase, the availability of adaptive equipment varies considerably by country.

The field is moving away from cluttered, piecemeal adaptive equipment installation with a "medical appliance" appearance. Second-stage manufacturers are rebuilding vehicles on modern assembly lines. "Bolt-on" equipment that requires minimal change to stock vehicles and plugs into existing wiring is becoming more standard. Despite the greater cost, electronic controls are now routinely used in place of mechanical devices. As vehicle manufacturers move from direct linkage to "fly-by-wire” primary controls, adaptation to special needs will become easier and require less compromise with occupant protection or functionality. As advances in rehabilitation medicine and adaptive technology converge, people who never considered the possibility will be able to drive.

The most pressing need is for better securement systems for occupied wheelchairs in both private and public transportation. Ideal systems will not require special wheelchair hardware or significant effort to fasten. Restraint systems for occupants in wheelchairs are still difficult to use, and some approaches are not effective. Also needed is an optimized "joystick" or lever steering control for persons who have neither the range of movement nor the dexterity to operate a multiple-turn steering wheel with one limb. These approaches are difficult to learn and use effectively and involve significant workload. ITS initiatives may lead to breakthroughs in automatic vehicle control systems and development of innovative primary control adaptation.

USER ISSUES COMMON TO MULTIPLE TRANSPORTATION MODES

Operator Automation Interface

Automation is used to enhance system productivity, efficiency, and safety in all transportation modes. Although the greatest focus has been on the in-cab operator, the automation of dispatch and safety separation functions is becoming equally important. Automated support to dispatch and separation systems includes improved methods of locating vehicles, ships, and railroad rolling stock; conflict probes that identify potential future losses of separation that might result in collisions; and automated optimization systems that either directly communicate with the onboard operators or control the vehicles themselves. With the advent of these systems, the information flow will be increasingly focused on the onboard operator.

Research is needed to address potential problems such as the loss of situational awareness by the dispatcher-controller and the potential lack of coordination, or even contention over right-of-way among operators and dispatcher-controllers. For example, in commercial aviation, it may soon be possible to provide flight crews with position and course information on nearby aircraft for use in maintaining physical separation. However, care must be taken to ensure that pilots do not contend for optimal courses.

In-vehicle-aid technologies continue to evolve. Electronic mapping systems, positioning systems, and collision avoidance systems have been featured in commercial aviation and shipping for some time now. We can expect expanded capabilities and increased reliance on these systems, particularly in noncommercial boating, aviation, rail, commercial, and noncommercial highway operations. Benefits may include enhanced situational awareness and early recognition of potential collisions. Negative effects may include boredom, monotony, and complacency.

Research is needed to assess the effects of complacency and subsequent loss of situational awareness in reducing navigational and other operator demands and the effects of increased cognitive workload resulting from system use.

Impairment Effects

Fatigue remains a major factor in all transportation modes. Companies increasingly have fewer employees working longer hours to increase corporate productivity and personal income. The resulting longer work shifts may provide sufficient sleep time; however, rest periods may not promote uninterrupted sleep if they are not synchronized with the employee's circadian rhythm. This is a particular problem for both operating and maintenance staff in maritime, highway, and rail freight transportation, where work scheduling is keyed to customers' needs, equipment reliability, and weather. Here technology shows great promise. Positive train control may improve schedule regularity. Alertness detection technologies (e.g., PERCLOS, an automated camera-drowsy driver detection device) have the potential to reliably monitor operator alertness. The Global Positioning System provides the potential for enhanced monitoring of adherence to hours-of-service rules.

Research needs include (*a*) development of integrated fatigue management programs, which combine technologies for alertness monitoring with adaptation of hours-of-service regulations to circadian rhythm patterns; (*b*) establishment of the economic advantages of integrated fatigue management; and (*c*) further development of alertness- and vigilance-monitoring technologies.

Alcohol and Drugs

Although the numbers of crashes and incidents attributed to alcohol and drug use are decreasing, they likely will remain a significant causal factor as long as alcohol and drug abuse remain prevalent among the population at large. One successful way of dealing with these problems is through methods that seek to change the industry's culture with regard to such abuse. The railroad industry's Operation REDBLOCK (a labor-developed, company-adopted drug and alcohol prevention and intervention program) is a prime example of a successful effort. One potential problem is the increasing reliance on therapeutic drugs with poorly understood side effects. One current example is the admonition against using the drug Viagra before piloting an aircraft. Research is needed to assess the prevalence of licit performance-altering drug use by commercial and noncommercial operators.

INTELLIGENT TRANSPORTATION SYSTEMS

The ITS initiative attempts to enhance surface transportation efficiency, safety, and comfort through the use of advanced technology. Route guidance and navigation systems, electronic Yellow Pages, weather advisory systems, and traffic status monitoring systems can provide information about traffic, driving conditions, and routing that reduces the driver's exposure to crash hazards. Crash warning and avoidance systems provide drivers with alerts or warnings to avoid crashes or to mitigate their severity. Vehicle stability enhancement and adaptive control systems such as adaptive cruise control may extend the driver's ability to control the vehicle safely. Vision enhancement systems improve visibility at night and under reduced-visibility conditions and allow drivers to see around the vehicle. Cellular telecommunications extend the driver's capabilities to communicate with work, family, friends, and emergency services when needed. Recent voice recognition and output technology promises drivers the ability to compose voice memos, review incoming faxes and e-mails through text-to-speech processing, play voice-interactive games, and possibly even surf the Internet. The "automobile as office" is the most recent manifestation of this trend. ITS may improve the efficiency and throughput of the nation's roadways, shortening travel times and therefore exposure to crash risk. Increased productivity is a pressing national goal as people increasingly spend long periods of time driving. ITS products and services can allow drivers to engage in useful activities during long commutes, thus reducing lost time. Such potential benefits have motivated the government and industry to develop this technology.

Two major questions arise: will the technology live up to its potential and will it be adaptable to the large variability of skills found among drivers? Assuming that the technologies can provide useful information to vehicle operators, the potential disbenefits include increased workload, distraction, loss of situational awareness, and system-induced driver errors. Research must consider both benefits and costs to maximize the fit between the driver and the technology. Research must consider drivers' limitations, including perceptual and psychomotor abilities, working memory capacity, and timesharing abilities as well as their unique capabilities, including pattern recognition skills, look-ahead capabilities, and adaptability. One goal will be to develop a knowledge base that facilitates enhanced coordination of technology with driving. The involved parties include (*a*) manufacturers and developers of technology, who need design guidance; (*b*) standards development groups, who must build on empirical findings; (*c*) regulatory agencies, which would mandate the application or exclusion of certain features or functions while the individual is driving; and (*d*) drivers themselves, who must be informed about the sometimes insidious ways in which their attention may be compromised, their trust in technology abused, and their propensities to take risks aggravated.

Driver Information Systems

The following questions need to be addressed with regard to driver information systems. What are the limits to information acquisition and assimilation and how can these be measured? What are the costs of system-induced errors? How can such errors be minimized? What methods and measures should be used to assess driver workload or distraction? How do individual differences among drivers influence workload effects? Can these individual differences be altered by training or practice? How does the driving situation determine the current demand imposed by the driving task? Can these three areas of knowledge (driving demand, ITS task demand, and driver individual differences) be coordinated by technology in such a way as to maximize safety, efficiency, and comfort?

Would voice input and auditory output make all secondary tasks and activities safe to do while driving? If not, what can be done to make them safer? What is "safe enough"? How do the answers to the above questions change as the driver ages?

Crash Avoidance and Warning Systems

Empirical questions with regard to crash avoidance and warning systems include the following. What is the proper time allowed for collision warning? Do multiple-stage warnings make sense for some types of crash hazards? How do we balance out false positive and false negative detection errors? What information must be gathered to apply such an approach? What are the processes that underlie reactions to false or nuisance alarms? How can this information be used to promote greater safety given that no collision warning or avoidance system is perfect? How much freedom should drivers have in adjusting systems for their own use? What are the indifference thresholds associated with various aspects of collision warning and avoidance technology—that is, the settings of time, range, and range-rate within which safety may be promoted without violation of what the driver considers his or her prerogatives? How should multiple warnings for multiple crash threats be coded, combined, or sequenced? What changes in driver risk taking might be associated with providing greater vehicle control capabilities to drivers?

Numerous fundamental research questions remain concerning system cost-benefit trade-offs. What do people normally do (without the technology)? How does new technology modify the driver's baseline levels of performance and behavior? How frequently are various maneuvers taken and in-vehicle tasks pursued? What are the driving profiles that characterize such maneuvers and in-vehicle tasks? What methods can be developed to relate measures of driver workload or distraction to the probability of a crash or a crash avoided?

DESIGN OF ROADWAYS AND TRAFFIC CONTROL DEVICES

Highway designers and traffic engineers are increasingly aware of the contribution that human factors knowledge can make. At the same time, there is an increasing awareness of the need for design to accommodate the diminishing capabilities of older drivers.

Traffic Control Devices

Traditionally, letter heights and sign specifications in the *Manual on Uniform Traffic Control Devices* (MUTCD) have been based more on roadway design speed than on driver needs. Typically, 50 feet per inch of letter height is used to accommodate drivers with 20/23 vision or better. However, this standard was based on performance of college students during daylight. Legibility is poorer for older people and for everyone at night. Recent studies of guide sign reading suggest that 40 feet per inch is more appropriate.

Fundamentally, any such rule of thumb begs the question of what distance is required by the driver to respond appropriately to the sign information. Computer models, incorporating current human performance parameters, predict minimum required legibility distance for signs. This distance takes into account driver acuity, reading time related to sign message length, as well as the maneuver required before the sign is reached. Most signs are placed in advance of the situation they give information about (e.g., warning signs, advance guide signs). However, other signs must be read at a distance that allows a maneuver to be carried out before the sign is reached. (For example, slowing to a stop must be completed before a stop sign is reached. Slowing and lane changing must be completed before a guide sign is reached when there is no advance sign.) Variations of these models are being developed to predict sign retroreflectivity required for nighttime legibility. Surveys are under way to determine current sign retroreflectivity levels. Research is being directed toward developing a practical minimum standard for sign retroreflectivity based on driver needs. Research is needed to determine if most drivers' legibility requirements are being met for each sign in the MUTCD.

With the increasing number of drivers who do not speak the language of the country in which they are driving, symbol signs are an attractive alternative to word messages. They take up less space (thereby allowing for increased legibility) and elicit faster responses. Much work has been carried out on specific symbol signs. Recently, an extensive evaluation of MUTCD symbol signs has been undertaken. Work is ongoing to modify the design of symbol signs that are poorly understood. A process for testing any new symbol sign involving representative drivers needs to be established.

To address congestion and related driver frustration, real-time information is communicated to drivers via changeable message signs (CMSs). Research is needed to determine legibility distances for various CMS technologies and to determine driver response to various messages.

Traffic signal systems vary in design by jurisdiction, particularly the signals and phasing used for protected left-hand turns. Some drivers are confused by particular signal phasings or by combinations of signals shown simultaneously. Research is required to determine driver comprehension and response to various signal systems.

Credibility of traffic control devices has received little research attention. Research is needed to determine the impact of inappropriate or incorrect use of traffic control devices (such as stop signs or work-zone signs left after work has been completed) on compliance with nearby traffic control devices that are appropriately used.

Delineation Design

Studies of driver visibility requirements for roadway delineation indicate that current designs are inadequate for many older drivers and for all drivers in the rain. Models predicting delineation visibility distances have been developed. Some pavement markings are poorly understood by drivers. Research is needed to continue model development to improve the accuracy of predictions of driver performance.

Geometric Design Standards

Society faces enormous costs as old roads are brought up to current standards. Given the cost of meeting such standards, questions have been raised about the empirical basis of those standards and their impact on safety. The current stopping sight distance standard, requiring sufficient visibility distance to brake for a 6-inch object, is an example. Human factors research has demonstrated that at such stopping sight distances, during the day, drivers cannot detect low-contrast 6-inch objects, like a tire on an asphalt pavement, nor can they recognize even high-contrast objects. At night on low-beam headlights, no unreflectorized object can be seen at sight distances provided for high-speed roads. Furthermore, case studies on sight-restricted curves have shown that only 4 percent of collisions possibly involved inadequate sight distance, and objects hit were large—other vehicles and large animals. Thus the money spent on providing long sight distances may be more effectively spent elsewhere. Empirical studies are needed to establish driver needs related to other design standards, including those for passing zones, lane drops, lane widths, and shoulder widths.

Intersection Design

Approximately two-thirds of personal injury accidents occur at intersections. Little is known about the impact of different intersection layouts, delineation schemes, and signing on driver response. Research is needed to examine driver eye movement behavior, speed, and lane choice in response to various intersection designs.

Work-Zone Design

With the maturing of the highway network, the majority of road building involves reconstruction rather than new construction. Consequently, drivers increasingly encounter work zones. These zones are associated with driver confusion and much higher accident rates than when construction is not present. Lane drops are associated with rear-end and sideswipe crashes. Research is needed to establish standards for lane drop taper length and location and type of advance warning signs that produce optimum merging behavior.

Work zones involve narrowing of available pavement width. Research is needed to determine the best allocation of pavement width to lane and shoulder areas for optimum tracking performance and safety.

Driver Expectancy and Roadway Design

Driver expectation plays a powerful role in determining the speed and accuracy of response. The MUTCD and *Policy on Geometric Design of Streets and Highways* published by the American Association of State Highway and Transportation Officials attempt to ensure consistency in traffic control device implementation and in roadway design. Although there is a strong theoretical basis for supporting consistency in design, there is little empirical information relating driver expectancy and driver performance. Research is needed to determine the impact of design violations of driver expectancy (e.g., left exits on freeways, main roads that curve whereas the off ramp goes straight) on driver performance. Research is also needed to determine how best to warn drivers of such violations. Environmental cues drivers use to determine expectations about the roadway should be determined. For example, drivers do not expect signalized intersections on divided roadways; rear-end crashes are the result. Drivers do not expect frequent movement in and out of driveways in a high-speed highway environment with open ditches and gravel shoulders. The "roadway message" conveyed by roadway design should be consistent with driver expectations.

Driver Adaptation to Road Environment

The widespread disobedience of speed limits is a safety concern. As traffic enforcement has become prohibitively expensive for many jurisdictions, research has demonstrated its limited effectiveness. For these reasons, there is increasing interest in understanding roadway cues that influence driver speed choice. Studies show that road geometry, lane and shoulder widths, delineation, pavement quality, and adjacent land use activity greatly affect speed choice. In addition, drivers coming from a high-speed to a lower-speed facility are adapted to higher speeds and drive faster than they would otherwise. Other studies have shown that simply changing the speed limit, without any other change, has minimal impact on speeding behavior because the environmental cues have not changed. Further research is needed to investigate the role of roadway and environmental cues in reducing driver speed and maintaining safety.