Contribution of Human Factors to Highway Safety

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In developing the U.S. road network, highway designers and traffic engineers relied on a common-sense understanding of drivers. For example, designers attempted to build safety into the roadways by ensuring that drivers could see far enough over hill crests and around curves to stop in time to avoid a hazard ahead. Designers made estimates of such factors as driver reaction times and ability to brake, based on small samples and the limited research that was available. These values were used to calculate stopping sight distances, which were then used to determine the road design.

This common-sense approach served well for many years. With the passage of time, however, roads have become more crowded, and the roadway network has grown more complex. The road rage associated with these developments is a focus of much media attention. Moreover, the driver population is aging, and there is growing awareness that the roadways can be especially challenging for older drivers. These trends, along with the continuing toll of accidents and injuries on the nation's highways, have made it clear that a more sophisticated understanding of drivers is required. This understanding is offered by human factors research.

As an example, human factors specialists have enhanced understanding of the design of traffic signs. Most traffic signs in the *U.S. Manual of Uniform Traffic Control Devices for Streets and Highways* were developed without explicit consideration of driver needs (*1*). For many years, traffic engineers used a rule of thumb of "50 feet per inch"; that is, a sign with letters 1 inch high would be legible at 50 feet, one with letters 2 inches high at 100 feet, and so on.

There were two problems with this rule of thumb. First, it was based on the performance of college students during daylight; legibility is poorer for older people and for everyone at night. Studies of guide sign reading suggest that a better rule of thumb would be 40 feet per inch (*2*). A second problem is that any such rule of thumb begs the question of what distance is required by the driver (*3*). Most drivers have experienced the frustration of trying to read street signs in an unfamiliar area in time to make turns. Clearly, driver needs were not adequately considered by the designers in these cases.

Currently the author is assisting highway designers in determining legibility distance requirements for drivers entering a complex airport at freeway speeds. These drivers must make four critical decisions in a very short period of time. Letters on signs must be high enough and decision points spaced far enough apart so that the majority of drivers have time to read the message, make a decision (e.g., arrivals or departures), select the appropriate lane, search for a gap in the traffic, and complete a lane change, all before they reach the turnoff. The designers are following a novel approach in determining whether the design meets driver needs before the highway is built. Estimates of time required by drivers are based on human factors research into drivers' detection, reading, decision-making, and maneuver times. The design is being adjusted to ensure that the distance allowed for these activities will be adequate. By basing the design on explicit driver requirements, these designers are building in safety.

Funds for highway safety are limited, so it is important that they be used as cost-effectively as possible. A great deal of money has been spent on providing adequate stopping sight distances for drivers on hill crests, on the common-sense premise that drivers must be able to see objects in time to stop if necessary, even on poor pavement and with bald tires. It has been assumed that drivers should be able to see objects with a height of 6 inches in time to stop, and that at 55 mph, the sight distance necessary for this purpose is 425 ft.

Recent human factors research has shown, however, that during the day, drivers cannot detect low-contrast 6-inch objects, such as a tire on asphalt pavement, at the 425-ft distance, nor can they recognize even high-contrast objects (*4*). At night with

BACKGROUND PHOTO BY KENNETH S. OPIELA

low-beam headlights, no unreflectorized object can be seen at this sight distance. This finding calls into question the need for providing long sight distances to small objects. Furthermore, case studies on sight-restricted curves have shown that only 4 percent of collisions associated with these curves may have involved inadequate sight distance. In any case, the objects that were hit—vehicles and large animals—were considerably bigger than the 6-inch target object assumed. Thus the money spent on providing long sight distances on hill crests might be spent more effectively on other safety features. A recent National Cooperative Highway Research Program report therefore contains a recommendation to the American Association of State Highway and Transportation Officials that the current sight distance standard be changed (4).

Considerable funds have also been spent on providing adequate sight distances at intersections. The longer the sight distance, the more easily the driver is able to select a safe gap for making a right or left turn onto the crossing road. The current standard assumes that drivers need about double the time for this purpose at higher-speed as compared with lower-speed intersections. Measurements of driver behavior at intersections that have been operating safely do not support this assumption, however (5). Drivers appear to select gaps of the same size—about 9 seconds on average—regardless of the speed limit. Consequently, researchers have recommended sight distances at high-speed intersections that would better reflect driver requirements and save construction costs at the same time.

Human factors research also has contributions to make in the area of speed control. The widespread disobedience of speed limits is a safety concern. Enforcement of traffic laws has become prohibitively expensive for many jurisdictions. At the same time, the limitations of enforcement are being recognized. A marked stationary police car will affect traffic speed for only 1 to 15 miles after being passed. And a single spot check will affect speeds at that location for only 5 to 10 days afterward. The longest effect of intense enforcement yet measured was 12 weeks after the enforcement ended. Thus there are only two means of controlling speed: enforcement through widespread use of photo radar (see article by Retting in this issue) or roadway design that elicits the desired behavior from drivers.

Human factors research has shown the importance of environmental cues and adaptation effects in drivers' estimation of their own speeds. For a given speed, drivers on a highway lined with trees perceive they are going faster than do drivers passing open fields. Drivers having completed a long period of driving on a freeway have adapted, and tend to underestimate how fast they are going when they transition to local driving. Studies of driver speeds have also shown that lane and shoulder widths, pavement quality, and adjacent land use activity greatly affect speed, and that simply revising the speed limit has a minimal impact on speeding behavior because the environmental cues have not changed.

Driver error contributes to majority of highway crashes. Roads will be safer if designed with knowledge of why and where drivers make errors.

Human factors research in the Netherlands has resulted in a creative approach to controlling speed (6). The goal was to induce drivers to slow down on 50 mph roads near village entry points. Narrower lanes make drivers slow down; however, they are also less safe. Consequently, researchers used a roughened lane edge treatment that narrowed the comfortable lane width, but did not actually lessen the width of the lane. The driving task was made more difficult so that drivers had to slow down, but safety was not compromised. Researchers then thought about how drivers were likely to respond to this design change. They were concerned that drivers attempting to stay on the smooth path would move closer to the center-line, again decreasing safety. Thus the researchers widened the center-line markings and underemphasized the lane-edge markings, and as a result drivers maintained the same lane position as before. This design, based on careful consideration and measurement of driver response, was successful in reducing speeds and decreasing the number of crashes.

Roads are designed for people, and people have limitations. Drivers are more likely to make errors on some road designs than on others. Increasingly this fact is being acknowledged by the inclusion of human factors professionals on roadway design and reconstruction safety audit teams. After all, it is driver error that leads to the majority of crashes. Roads designed with the knowledge of why drivers make errors and where they are most likely to make them will be safer.

References

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Driver Information Overload

NCHRP Project 3-50

Research being conducted under the National Cooperative Highway Research Program is focused on the human factors associated with the provision of route guidance information on freeways. In this research, a model of driver information processing is hypothesized. This model reflects the impact of the driving task, and assumes that each sign adds to the information processing load imposed on a driver. Each type of sign has a different impact on the information loading and the point at which the information is perceived and dismissed. Where there are complex signs or many signs, drivers must process increasing amounts of information. It is hypothesized that there is a limit on the amount of information each category of driver can reasonably absorb. Information provided beyond this overload threshold may not reach the driver.

Under NCHRP Project 3-50, Driver Information Overload, a series of laboratory and field experiments has been conducted to estimate the relative importance of various types and intensities of guide signs and to measure information loading on drivers in on-the-road situations. These experiments yielded numerical values for use in the driver information processing model and provided partial validation for the model's information loading assumptions. Further experiments are planned to validate the model and establish information overload thresholds.

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