# Human Factors In The Automated Highway System: Transferring Control To The Driver

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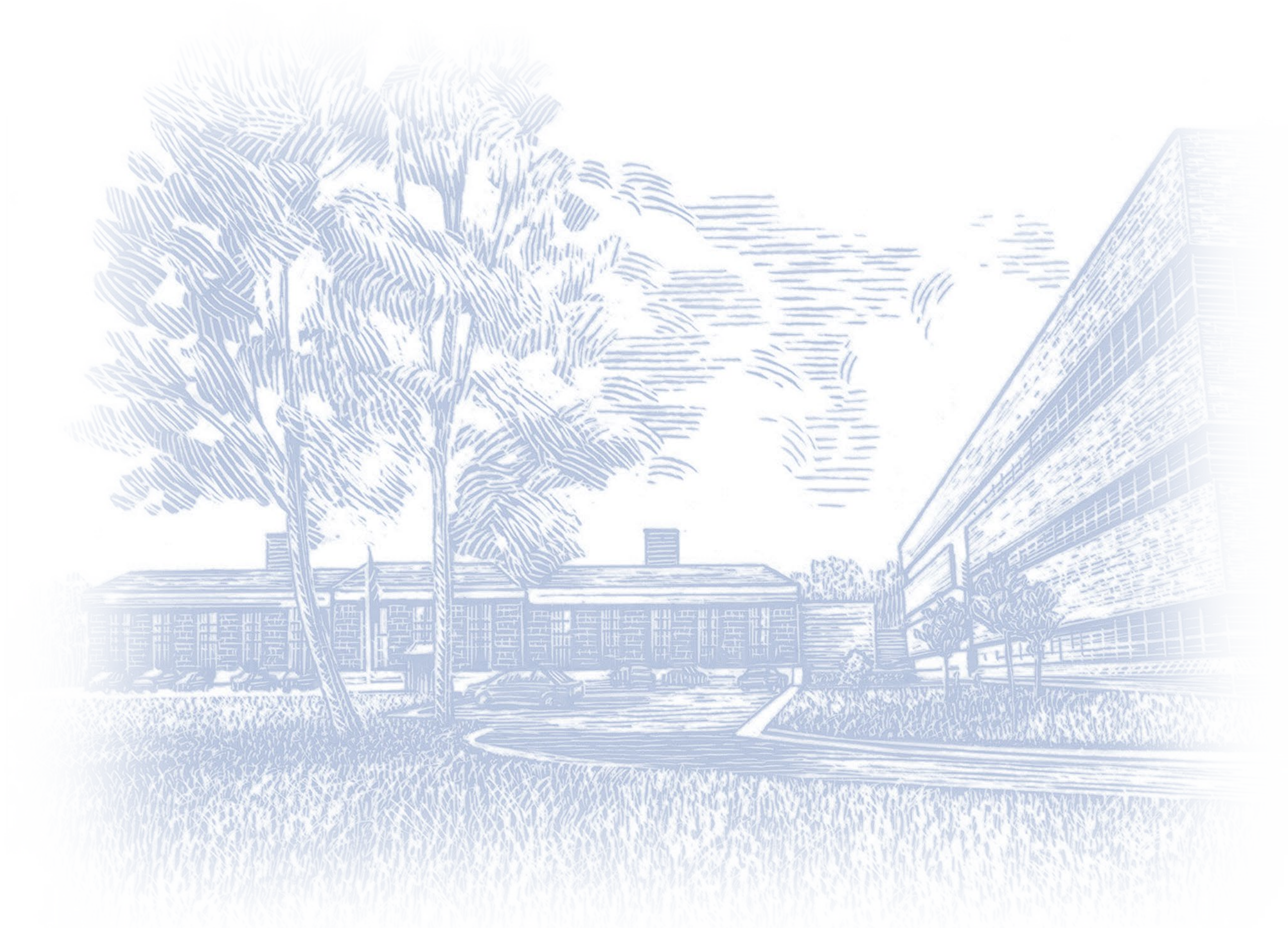

U.S. Department of Transportation
**Federal Highway Administration**

Federal Highway Administration
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, McLean, VA 22101

U.S. Department of Transportation
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## Foreword

Driver capabilities and limitations must be considered to ensure successful implementation of the Automated Highway System (AHS). Human factors investigations of driver performance characteristics provide the basis for determining system design configurations and features. Driver and system attributes are being assessed during the initial design and conceptual phases of the AHS, thereby ensuring the system will be usable and acceptable to the entire driving population. To investigate these issues, a series of experiments has been conducted on the Iowa Driving Simulator (IDS). Results of research focusing on methods of transferring control from the system to the driver are reported here.

## The Automated Highway System

The AHS is a planned roadway–vehicle configuration that will provide "hands–off, feet–off" operations. The AHS will increase highway safety by reducing driver error. The system will provide improvements in throughput, thereby reducing congestion, by carefully controlling the speed and gaps between vehicles. The AHS program is a joint government–industry–academia effort, managed by the National Automated Highway System Consortium.

## The Iowa Driving Simulator

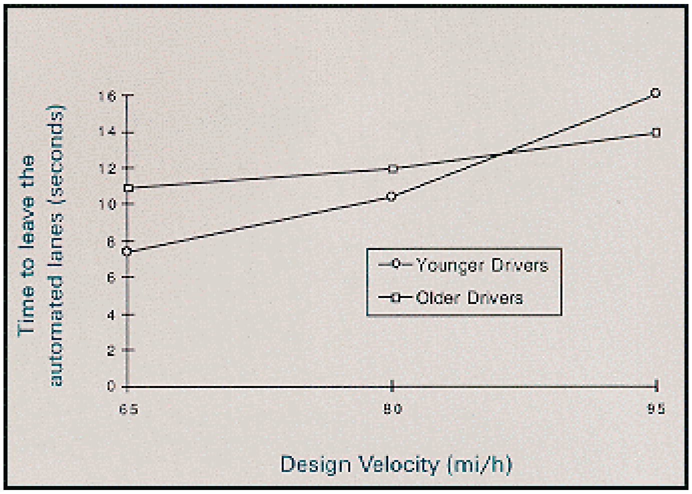
The IDS consists of a projection dome mounted on a hexapod platform. The simulator provides a realistic driving experience through presentation of computer–generated imagery projected to a 192° forward view and a 65° rear view. Sophisticated computer systems draw roadways, signs, buildings, vegetation, and other vehicles. The hexapod platform provides motion cues to the driver operating the vehicle (in this case, a mid–sized Ford sedan that is mounted within the dome). As the driver activates the car's controls (steering wheel, brake, accelerator), the simulator's visual, sound, and motion systems respond appropriately, providing realistic driving cues.

## Method

The "generic" AHS used for these studies was designed as a three–lane highway with the left lane programmed as the automated lane and the center and right lanes unautomated. Drivers began the experiment operating the simulator vehicle in the middle of a string of three automated vehicles. After a period of automated travel, they were given an exit advisory 60 s before their exit and were instructed to leave the automated lane and, ultimately, the highway.

Several conditions were tested. Automated speeds were set at three levels [104.6, 128.8, and 152.9 km/h (65, 80, and 95 mi/h)]. Three different gaps between automated vehicles were tested [0.0625, 0.25, and 1.0 s; resulting in gap lengths ranging from 1.8 to 42.5 m (5.9 to 139.4 ft)]. Two levels of traffic density in the unautomated lanes were assessed [16 and 32 vehicles/lane/kilometer (10 vehicles/lane/mile and 20 vehicles/lane/mile), respectively]. Sixty licensed drivers participated in this study. Twenty–four were age 65 or older, and 36 were between the ages of 25 and 34 years.

## Results




1 mi = 1.61 km

**Figure 1. Time to leave the automated lane as a function of design velocity.**

The time that drivers took to exit the automated lane was related to the AHS design velocities. For all drivers, the higher the design velocity, the longer it took to complete the exit maneuver. Younger drivers' exiting times in the 152.9–km/h (95–mi/h) AHS condition were about twice those for the 104.6–km/h (65–mi/h) AHS velocity condition (see figure 1).

There were no statistically significant differences by age at any of the AHS velocity conditions. The overall trend for older drivers was similar to that for the younger drivers, though their times were more stable across all AHS design velocities. The contrast between the two age groups' exiting times in the 152.9–km/h (95–mi/h) condition might be interpreted as the older driver's desire to complete the AHS exit maneuver quickly and thus be prepared to exit the highway, while younger drivers felt no such urgency.

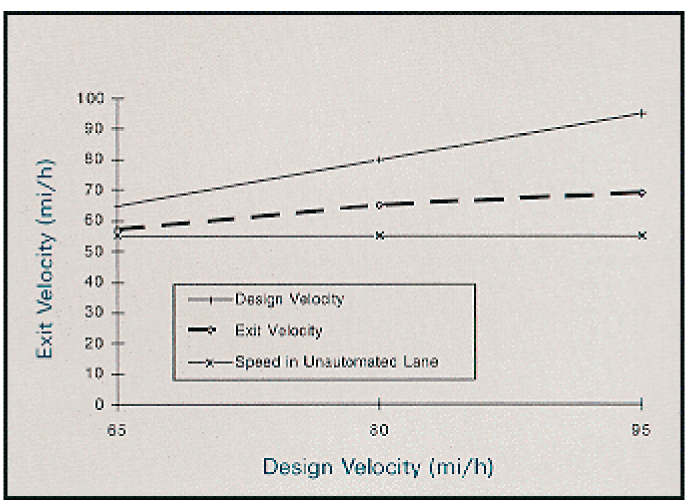



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**Figure 2. Exit velocity as a function of AHS design velocity.**

Figure 2 shows the average exit velocities across all drivers as a function of the AHs design speed, with the average unautomated speed shown for reference. As the AHS design speeds increased, drivers' average exiting speeds increased. In the 152.9–km/h (95–mi/h) AHS configuration, exiting speeds were approximately 112.7 km/h (70 mi/h), almost 24.1 km/h (15 mi/h) higher than the speed limit in the manual lane.

Table 1 summarizes the number and percentage of incursions and collisions experienced by drivers. Incursions were defined as maneuvers in which a driver's front wheel crossed a lane line, but the lane change was not completed. Each trial required only one merging action by the driver. These results, ranging from 1.4 percent (younger driver collisions) to 5.6 percent (older driver incursions), represent a very high rate of unsafe driving performance. These data are especially striking when compared to identical lane–change maneuvers performed by the same drivers in practice trials where they experienced **no** collisions or incursions.

**Table 1. Drivers' rates of collision and incursions while exiting the AHS.**

| | Collisions | | Incursions | |
|---|---|---|---|---|
| | N | Rate | N | Rate |
| Younger Drivers (216 trials) | 3 | 1.4% | 6 | 2.8% |
| Older Drivers (144 trials) | 3 | 2.1% | 8 | 5.6% |

In addition to measuring driving performance, all participants completed a questionnaire assessing their perceptions of the AHS. In general, drivers were positive about their experience driving the simulated AHS. Drivers preferred driving in the automated lane rather than in the unautomated lane, and indicated they thought an AHS would help reduce the stress of driving and that they would use an AHS if it were constructed in their area. Drivers also showed a preference for the larger intervehicle gaps (0.25 and 1.0 s).

## Discussion

Both older and younger drivers positively perceived the benefits of an AHS and reported that they would use it if it were available in their area. Empirical results showed that although both groups of drivers can maneuver from an AHS to an unautomated lane, a very high number of collisions and incursions occurred. A throughput analysis was performed that included the delays experienced in the AHS lanes, based on the time drivers took to exit the lane in these experiments. Findings from this analysis show that for this type of AHS configuration (where no "transition" lane for the driver to slow to unautomated lane speeds is available), differentials greater than 16.1 km/h (10 mi/h) can actually reduce the AHS throughput. In addition, it appears that the "carry–over effect" of velocity may impact driving performance in unautomated lanes, leading to faster driving. Drivers exiting the AHS at speeds that exceeded the posted highway speed limit [88.5 km/h (55 mi/h)] by 16.1 km/h (10 mi/h) to almost 24.1 km/h (15 mi/h) may help explain the high incursion and collision rates.

## For More Information

A full report on this study is available from the FHWA R Report Center, phone no. 703 285–2144.
**Title:** Human Factors Aspects of the Transfer of Control From the Automated Highway System to the Driver.
**Publication No.:** FHWA–RD–W–114.

Further Human Factors investigations of the AHS include how drivers enter the system and possible effects that driving in the AHS may have on regular driving.

This research was conducted by Honeywell, Inc.
For more information, contact:
**Elizabeth Alicandri,** Manager
Human Factors Laboratory, HSR–30,
703 285–2415.