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SIMULATOR-BASED HUMAN FACTORS EVALUATION OF AUTOMATED HIGHWAY SYSTEM

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ABSTRACT–From a viewpoint of human factors, automated highway systems (AHS) can be defined as one of the newly developing human-machine systems that consist of humans (drivers and operators), machines (vehicles and facilities), and environments (roads and roadside environments). AHS will require a changed vehicle control process and driver-vehicle interface (DVI) comparing with conventional driving. This study introduces a fixed-based AHS simulator and provides questionnaire-based human factors evaluation results after three kinds of automated driving speed experiences in terms of road configuration, operation policies, information devices, and overall AHS use. In the simulator, the "shared space-at-grade" concept-based road configuration was virtually implemented on a portion of the Kyungbu highway in Korea, and heads-up display (HUD), AHS information display, and variable message signs (VMS) were installed for appropriate AHS DVI implementation. As the results, the subjects expressed positive opinions on the implemented road configuration, operation policies, and the overall use of AHS. The results of this study would be helpful in developing the road configuration and DVI design guideline as the basic human factors research for the future implementation of AHS.

KEY WORDS : Human factors, Automated highway system, Driver-vehicle interface, Fixed-based AHS simulator, User preference evaluation, Shared space-at-grade concept

1. INTRODUCTION

AHS would be useful not only to regulate traffic flow, but also to control vehicle operations such that the traffic flow would be optimized in terms of capacity and energy use. Further, AHS could reduce driver's fatigue and improve comfort of travel, and ultimately, improve the quality of life by reducing the time spent in congestion and by decreasing the number of severe traffic accidents through the supply of various vehicle information and functions (Kikuchi and Tanaka, 1997). However, even though AHS will service "hands-off" and "feet-off" driving by supporting the automation and replacement of human functions, such as hand functions (steering control), foot functions (throttle and brake control), and eye functions (information collection), carry-over effects (Osgoods, 1949) and the possibility of catastrophic disaster are expected when considering the importance of human error and driver-vehicle interface problems (Funke *et al.*, 1997). Although the tasks that human drivers will be expected to execute have not yet been fully defined for AHS operation (Ran *et al.*, 1997), human factors considerations are crucial issues for AHS design to integrate human drivers and AHS control process regarding the driver's characteristics of variance and unpredictability (Cha and Park, 2002).

The integration of drivers and AHS is important for the following three reasons. First, drivers may be involved in automated driving by setting up parameters such as the driving route and destination, speed and desired inter-vehicle gap, or taking control in some emergency situations (Ran *et al.*, 1997). Second, AHS is not, at this time, being developed to control all vehicles at all times, so that drivers will perform the conventional manual driving before entering and after leaving the automated lane to reach their destination. Therefore, the vehicle control process would be changed in comparison to that of conventional ones (Taso, 1996). Third, newly developed in-vehicle information systems, such as an AHS information display and an HUD will be essentially equipped to deliver the AHS related information combined with the conventional navigation, telematics, or entertainment systems. Therefore, the driver's information acquisition and reaction process will be changed compared to that of conventional vehicle driving (Cha and Park, 2002).

Ran *et al.* (1997) explained the driver and AHS integration model based on Michaels' conventional driving process (Michaels, 1961) as the parallel and separate

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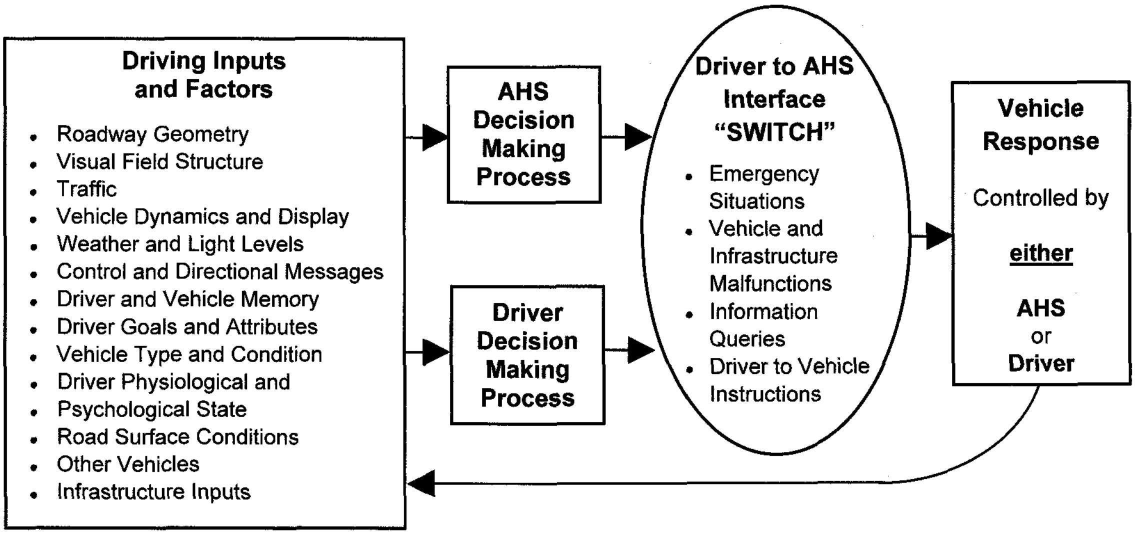

Figure 1. Parallel and separate human and vehicle control process of AHS.

human and vehicle control process model similar to that shown in Figure 1. In Figure 1, in automated driving, a range of inputs will feed into two (dual) parallel control processes. One is the human control process and the other is the AHS automated control process. The outputs from these two processes will be fed into a driver-to-vehicle interface switch, which determines whether the human or the machine has control of the vehicle and allows for human intervention in the control process. Therefore, when deploying AHS in the real world, the driving functions that will be automated and the limitations of such automation must be clearly identified, and the degree of safety must be rigorously assessed. If the replacement of any normal operation function in an AHS is not technologically and economically feasible, the human driver's role must be considered as an integral part of the normal operation (Taso, 1996). Then, AHS drivers must perform the AHS-related functions of communication, maneuver coordination, and system functions from the vehicle check-in to begin automated driving to the check-out to conclude automated driving (Funke *et al.*, 1997).

Considering the change of vehicle control process in which the driver should perform both manual and automatic driving operations and DVI for AHS use, there are questions on whether there will be human factors problems related to AHS human factors-related attributes.

The objective of this study is to introduce the developed AHS simulator for human factors and human-machine interface (HMI) researches, and to predict the user preferences of AHS human factors-related attributes for three automated driving speeds as the basic research for AHS human factors. Preference questionnaires were investigated in terms of implemented "shared space-at-grade" concept-based road configuration and operation policies, the usefulness of information presented from in-vehicle information devices, and overall AHS use.

2. AHS SIMULAOTR DESCRIPTION

2.1. Simulator Specifications

A simulator was constructed on an actual vehicle cockpit module with a sixteen degree-of-freedom vehicle dynamics model. The operation system of the main computer used Microsoft™ Windows, and virtual driving environments were implemented using Microsoft™ Visual Studio and Kyungwoo IT™ Spectrum version 1.5 (SGI™ Open GL-based program). The software module consisted of interface processing, calibration, vehicle dynamics calculation, check and inspection, display, vehicle generation, camera calculation, communication, and menu module.

The field of view was 45°–55°, and a virtual driving environment was injected from a beam projector on a 110-inch screen. The distance from the projector and the screen was 3.6 m to represent the actual-sized objects and road environments with a 40–60 Hz refresh rate. The resolution of the simulator was 800×600, and the injected objects were designed with 32-bit true color bitmap images. A three dimensional real vehicle sound was generated through four speakers around the seating buck.

Figure 2 indicates the functional block diagram of the constructed simulator. Four function keys for the calibration of vehicle control parameters (function key 1–4) and the cruise control button (CCB) for the start of automated driving were arranged on the center facia area as shown in Figure 3. By the experimenter's settings, the inter-vehicle gap can be controlled from 1 m to 30 m, and

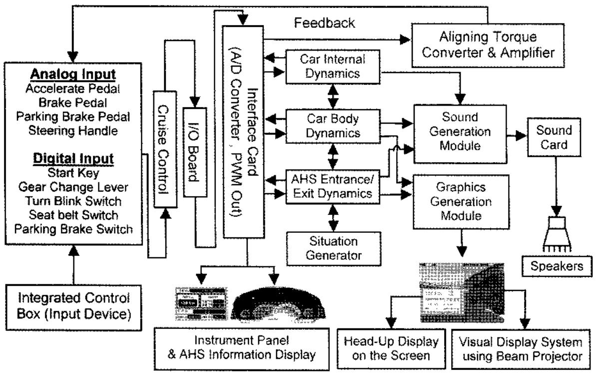

Figure 2. Functional block diagram of AHS simulator.

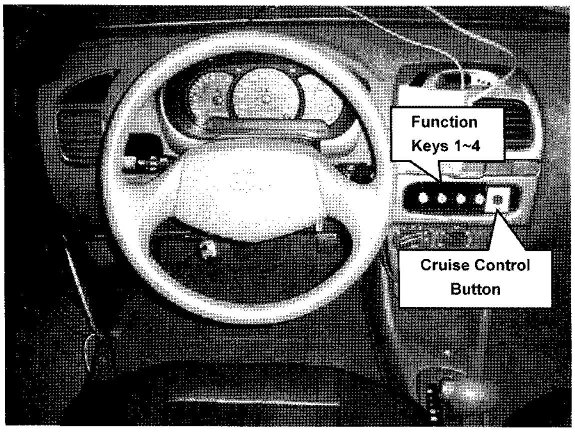

Figure 3. Picture of the center facia area.

the platoon speed can also be controlled from 100 kph to 200 kph, so that these functions enable the convenience of experiments for the investigation of a user-centered AHS speed and inter-vehicle gap design.

2.2. Road Configuration Design

Fully automated driving would, in theory, allow closer vehicle spacing and higher speeds than conservative driving, which could enhance traffic capacity in places where additional road building is physically impossible, politically unacceptable, or prohibitively expensive (Transportation Research Board National Research Council, 1998). Although numbers of AHS deployment concepts have been presented in the literature, few studies have attempted to evaluate the issues and the risks associated with alternative deployment concepts (Hall and Taso, 1997; Variya, 1991). Partnerships for Advanced Transit and Highways (PATH) analyzed the integration of AHS facilities and road configurations and then investigated the two basic configurations of "shared space" and "dedicated space" (Yim *et al.*, 1997).

Under the "shared space" concept, a minimum of two manual lanes would be required to adequately accommodate weaving movements between the manual and transition lane, and merging and diverging movements near on- and off-ramps.

Under the "dedicated space" concept, the automated and manual portion of the road would be physically separated from one another by a continuous lane barrier. Under this concept, the automated facility could be constructed at, above, or below grade with respect to the adjacent manual facility or, when located within an exclusive right-of-way, with respect to the surrounding terrain. A minimum of two manual lanes would be needed under both the "shared space" and "dedicated space" concepts to enable passing maneuvers among faster and slower manually operated vehicles.

Among the four types of available AHS road configurations including "shared space-at-grade," "dedicated space-at-grade," "dedicated above-grade "and" dedicated below-grade" concepts for real world implementation as suggested by PATH, the "shared space-at-grade" concept-based road configuration was designed and implemented in a simulator. This concept would require a minimum cost for a change in current road configuration for AHS implementation considering Korean road environments by expert review (Cha and Park, 2002), and it satisfies the following principles governing the configuration of AHS and the maneuvers of vehicles (Hitchcock, 1995).

(1) Vehicles are organized into closely spaced platoons, which have inherently low casualty rates.
(2) There is a barrier between the automated lanes (AL) and the manual lanes (ML) on the rest of the right-of-way; vehicles must enter and exit through the gates in the dividers.
(3) Platoons do not merge at speed, either on the ALs or on the transition lane (TL).

As shown in Figure 4, implemented configuration basically consists of two lanes of ML and a lane of TL and AL. ML and AL are the road sections in which the vehicle control authority belongs to the driver and the vehicle, respectively. TL is the area in which the vehicle control authority changed from the driver to the vehicle on the AHS entrance area, or in reverse order on the AHS exit area. On the AHS entrance area, TL is the road section for the preparation for automated driving before entering AL. In this area, TL consists of the entrance maneuvering length (EML), where the driver should push the CCB to initiate automated driving after successful vehicle status check, and control change length (CCL), where the area of the driving authority is transferred from the driver to the AHS after successful vehicle status check and CCB push. Through the failure maneuvering length (FML) gate, the driver should move the vehicle to ML in case there is a problem with the automated driving

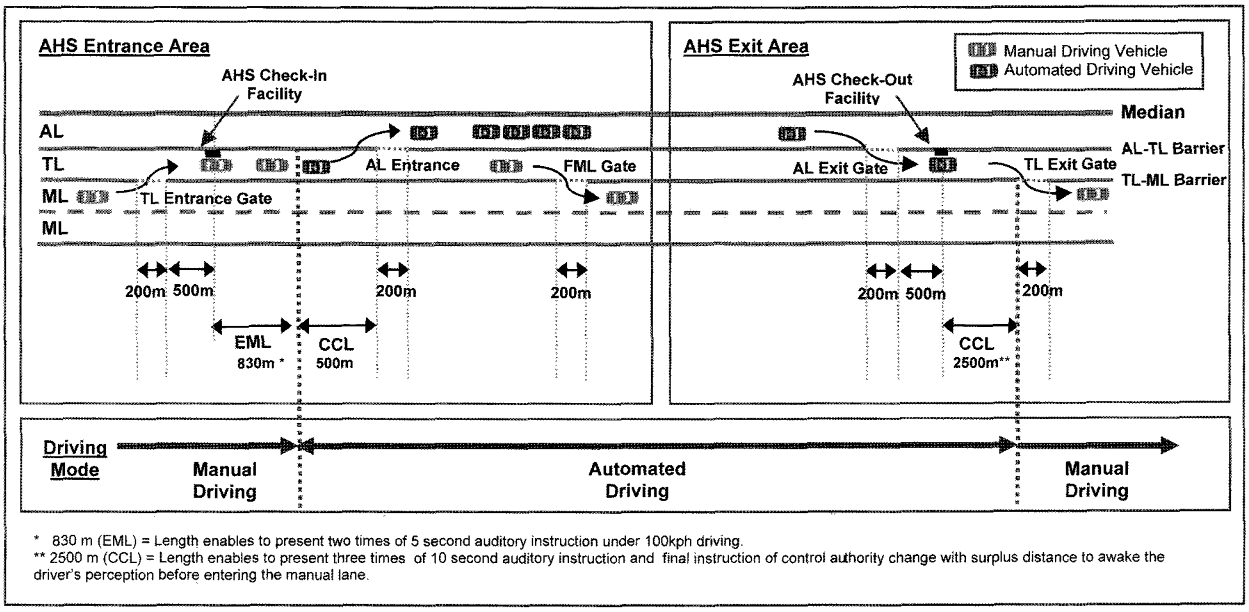

Figure 4. "Shared Space-at-Grade" concept-based road configuration implemented in the simulator.

before entering to AL.

On the AHS exit area, TL is the road section for the preparation for manual driving before exiting automated driving, and CCL is the area in which the driving authority is changed from AHS to the driver. The length of the CCL on the AHS exit area is longer than that of the AHS entrance area because there is a possibility that the driver may fall asleep during automated driving, or encounter unpredicted situations during manual driving mode changes.

Based on the described concept, virtual road environments were developed similar to the part of the Kyungbu highway from Osan to Cheonan after analyzing the recorded road environment data and geometric information system. The total length of the road was about 40 km. Among this route, the pre- and post-AHS manual road sections were 6.5 km each, and the lengths of the TL on the AHS entrance and exit area were 1.83 km and 3 km, respectively. Then, the AL length was 21.37 km excluding the entrance and exit gate. And, the length of all gates is 200 m to supply sufficient space for the safe inter-lane movements.

The road width of all lanes was 3.5 m, which is the minimum highway road width requirement for design specified in "Korean regulations on road structure and facility" (Korean Ministry of Construction and Transportation, 1999). Because several studies have indicated that lane barriers are necessary to separate the automated and manual portions of the road for reasons of safety and operation efficiency (Yim *et al.*, 1999), the median barrier and AL-TL barrier were installed and designed based on "Guideline for road safety facility install and management" (Korean Ministry of Construction and Transportation, 2001).

3. DVI DESIGN AND DRIVING SCENARIO

3.1. DVI Design

An HUD was transparently projected onto the screen, and a seven-inch sized AHS information display was developed on the laptop computer mounted on an instrument panel using Internetwork Packet eXchange (IPX) protocol for the synchronization between the vehicle parameters and the information on both displays. Figures 5 and 6 indicate the wire-frame user interfaces of implemented HUD and AHS information display, respectively. In Figure 5, an HUD presented vehicle speed (①), rest time to destination (②), current lane position (③), inter-vehicle gap (④), rest distance to destination (⑤), and vehicle operation mode (⑦) (automated, manual driving, or automated steering) as an ordinary information set. The instant messages for current maneuvering information (⑥) (e.g., entering the AL, entrance completion of AL, changing to automated driving, exiting the AL, exit completion from AL, and changing to manual driving) were displayed whenever related vehicle maneuvers occurred.

In Figure 6, the AHS information display presented the information regarding the vehicle operation mode (①) (automated, manual driving or automated steering), vehicle speed (②), destination name (③), rest time and the distance to destination (④ and ⑤), and inter-vehicle gap (⑥). Eight VMSs were installed to help the driver's rapid information acquisition about the vehicle operation

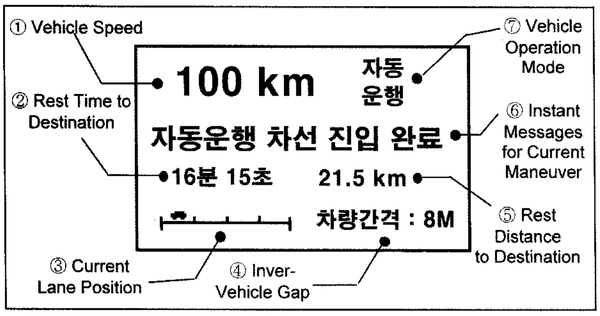

Figure 5. Wire-frame of HUD user-interface.

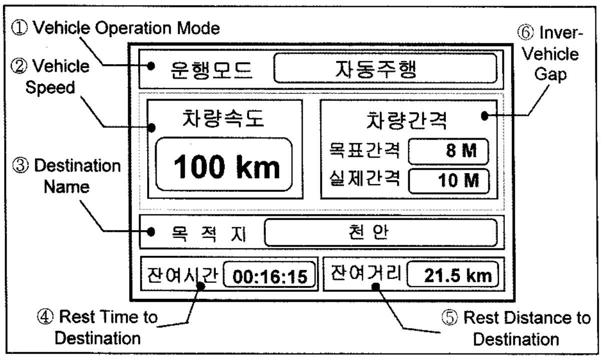

Figure 6. Wire-frame of AHS information display user-interface.

in front of 500 m at each gate with female voice instructions.

3.2. Driving Scenario

Figure 7 shows the vehicle maneuvering and the driver's operation procedure with voice instruction entered from the TL to the end of automated driving, and the following lists are the female voice instructions presented in front of each gate.

[Instruction 1] If you want to use the AHS, please move to the TL.

[Instruction 2] Maintain the TL, and approach the check-in facility.

[Instruction 3] You have entered the TL, but you are not authorized to be in the AHS. Return to the ML through the next FML.

[Instruction 4] You have succeeded to be in the AHS. To engage the automated lane, push the CCB.

[Instruction 5] You did not push the CCB. If you want to engage the automated system, please push the CCB again. If not, return to the ML through the next FML.

[Instruction 6] From now on, your vehicle is controlled by AHS, and you will enter the AL through the AL entrance gate 500 m ahead.

[Instruction 7] Your vehicle joined with the platoon.

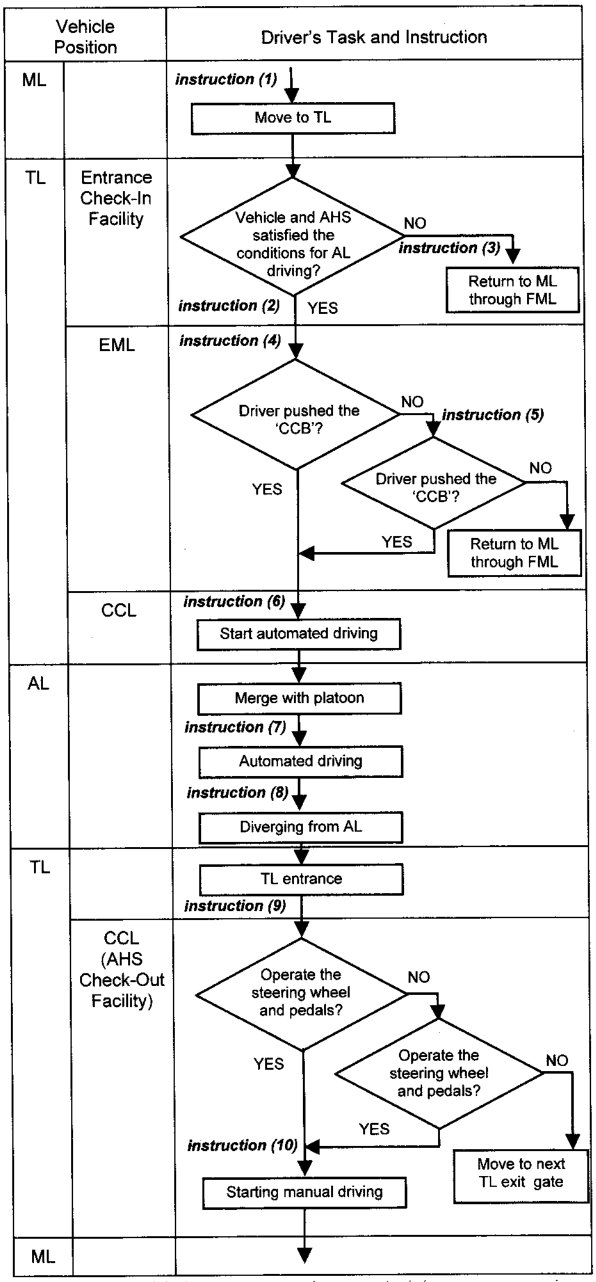

Figure 7. Vehicle maneuvering and driver's operation procedure.

Enjoy AHS driving!

[Instruction 8] You will exit the AL in 500 m. When you arrive there, await subsequent instruction.

[Instruction 9] Your vehicle will enter the ML in 500 m. To regain manual control authority of the vehicle, put your hands on the steering wheel and control the accelerator or brake pedal.

[Instruction 10] Your vehicle's driving authority has changed from automated to manual driving. From now on, control your vehicle safely, and enjoy your driving.

Even if the drivers could arrive at their destination by manual driving, the subjects were requested to drive the vehicle by the following order of road sections: ML → TL → AL → TL → ML. On the MLs, drivers maintained manual driving mode, and even if the CCB was pressed, there was no driving authority change into automated mode. They could change the automated mode only on the TL in an entrance area, and there was no permission to change the automated driving into manual during automated driving.

After the success of the vehicle check-in process on the TL in the AHS entrance area, the vehicle automatically enters the AL through the AL entrance gate controlling the vehicle speed until the predetermined AHS speed allows the merge at the end of the incoming platoon. In cases when the subject fails to push the CCB or when there is no intention to use AHS, the vehicle or AHS malfunctions, or there is an unauthorized vehicle check-in, the driver should escape from the TL into the ML through the FML, and continue the manual driving on the ML. When the vehicle arrives at the nearest AL exit gate from the destination, it automatically escapes from the AL and vehicle control authority is transferred from AHS to the driver. Then, the driver should escape from the TL through the TL exit gate and drive the vehicle manually to the destination.

4. EXPERIMENTAL DESIGN

Prior to performing the experiment, a pilot experiment with three subjects was carried out to examine the suitability of the questionnaire description format and to predict the required experiment time and expected problems for more exact results derivation. Then, twenty-five male subjects (aged 23 to 33 years old, mean: 26.8, s.d.: 2.87 years) were used for analysis who had had their driver's license for an average of 4.68 years (s.d. : 1.5) under normal physical and psychiatric conditions.

Since the AHS is not yet implemented in the real world, the experimenter should explain the detailed concepts of AHS, simulator structure and operation procedure, road configuration, and development trends in other countries to provide a better understanding of the experiment objectives and to fulfill their curiosities.

Exercise opportunities on simulator operation and driving were supplied until the subject satisfactorily operated the simulator. Then, three sessions of driving at 120 kph, 140 kph, and 160 kph automated driving speeds were performed on the implemented road section. Driving time on the AL was about 10.8, 9.2, and 8 minutes for each automated speed, and a 0.0625-second inter-vehicle gap was applied for three automated driving speeds. This time-based gap was derived by Bloomfield *et al.*'s (1995) experiment results based on the driver's preferences, and "Human Factor Design Guidelines of AHS" recommended this gap when the automated driving vehicle speed is over 104.7 kph (Lavitan *et al.*, 1998). Then, the real distance between vehicles in a platoon was 2.08 m, 2.43 m, and 2.78 m for 120 kph, 140 kph, and 160 kph automated speeds, respectively.

Traffic density was five vehicles/km/lane and the platoon was composed of only passenger vehicles, because a mixed flow with trucks or buses could arouse another human factor problem in the driver's field of view and operation. All subjects were required to wear seat belts, and there was no person riding in the passenger seat. During manual control driving, subjects were required to try to maintain the 100 kph, which is the regular upper speed limit regulation on highways in Korea.

Before starting the experiment, the camera module of the simulator was calibrated for each subject to accord between eye position and road scene. Figures 8 to 10 show the ML, TL, and AL driving road screens, respectively, and Figure 11 shows the experimental driving scene.

5. PREFERENCE EVALUATION RESULTS

Three categories of questionnaire-based evaluations about AHS human factors attributes were performed after automated driving speeds using frequently applied 5-point scales (Dyer *et al.*, 1976) and the rank order scale to establish the hierarchical orders of preferences.

Each 5-point scale means the following:

(1) 1 : very unacceptable (unsatisfactory, ineffective)
(2) 2 : unacceptable (unsatisfactory, ineffective)
(3) 3 : borderline
(4) 4 : acceptable (satisfactory, effective)
(5) 5 : very acceptable (very satisfactory, very effective)

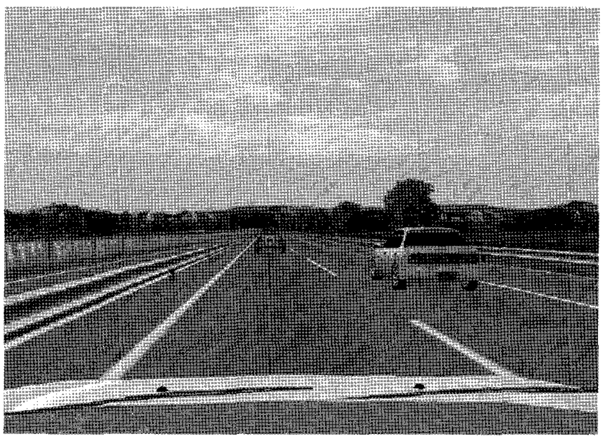

Figure 8. Simulated road scene of the ML.

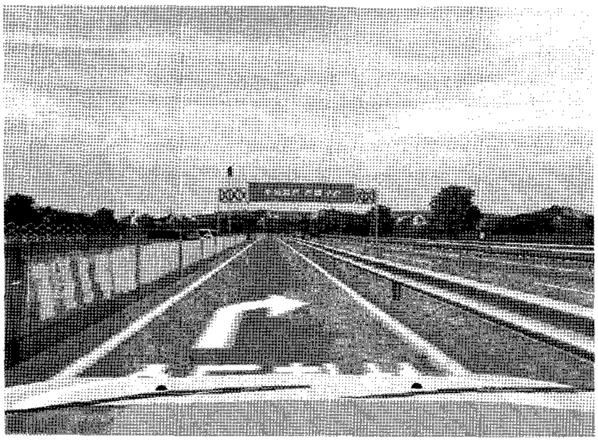

Figure 9. Simulated road scene of the TL.

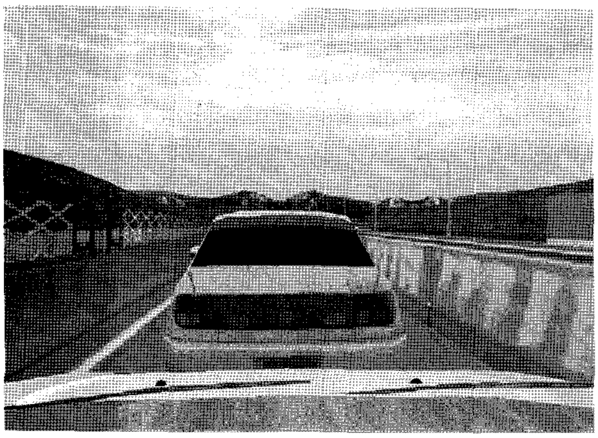

Figure 10. Simulated road scene of the AL.

5.1. Road Configuration and Operation Policies

Table 1 describes preference evaluation results on the implemented road configuration and operation policies. This category is deeply related to the basic road configuration parameters and system operation design, which are the important human factors considerations that affect the driver's acceptability, comfort, safety, and system usability. Subjects were satisfied with the driving scenario and the use of TL and barriers between lanes. They expressed the highest preference for 140 kph among three automated speeds. However, regarding the inter-vehicle gap, subjects evaluated the 0.0625 second inter-vehicle gap around the borderline point for three automated speeds. The 0.0625 second inter-vehicle gap was an insufficient distance between vehicles. This parameter is deeply related with driving comfort, safety, and traffic efficiency. Therefore, further investigation would be required to determine the proper inter-vehicle gap and not compromising user requirement and traffic efficiency.

Considering simultaneous steering and speed control

Figure 11. Experimental driving scene.

authority transfer when transferring the driving authority from AHS to the driver, subjects graded between borderline and acceptable. Even if 86% of subjects graded the average point, driving authority change policy from the vehicle to the driver is a significant issue that should be dealt with in detail, because it is related with the driving safety and system usability.

5.2. Usefulness of In-Vehicle Information Devices

Table 2 describes the usefulness evaluation results on the information presented from in-vehicle information devices. This category includes the questions related to the importance and usefulness evaluation results of the presented information from both HUD and AHS information display. HUD has the characteristics in which the driver can see the information on the windshield with minimum visual distraction by overlapping with the front view, and the AHS information display will be mounted on the center facia area or on the instrument panel combined with conventional in-vehicle information systems, such as telematics, navigation, and AV systems.

Considering the HUD, the current vehicle operation mode was regarded as the most imperative information, which is the important message governing the driver's vehicle control behavior. The vehicle speed that the driver should watch while driving, as well as the rest time and the distance to destination, the current lane position, the inter-vehicle gap, and the instant message about the current maneuver were followed. Among information on the AHS display, the vehicle speed acquired the highest level of importance, and the vehicle operation mode, inter-vehicle gap, rest distance, time to destination, and destination name followed.

Both devices, the vehicle speed and the vehicle operation mode information, which the driver should keep monitoring for their effect on vehicle control, acquired the highest level of significance, but the others that they

Table 1. Preference evaluation results on road configuration and operation policies.

No.	Questionnaire	Average Point	Above Average (%)
1	How satisfied were you after experiencing the driving scenario experienced with a simulator (ML → TL → AL → TL → ML)?	4.1	100%
2	There existed the TL to enter and exit the AL. How necessary did you think it was?	4.6	96%
3	There existed barriers (between AL and TL, TL and ML) for driving safety. How much did you feel the necessity of them?	4.6	96%
4	What is the most suitable AHS speed after you experienced the simulator?		
	① 120 kph	2.3	Rank Order Scale
	② 140 kph	1.3	
	③ 160 kph	2.2	
5	How did you feel about the inter-vehicle gap in a platoon? Satisfied or not? Check the satisfaction level by each speed.		
	① 120 kph (2.08 m inter-vehicle gap)	2.9	61%
	② 140 kph (2.40 m inter-vehicle gap)	2.9	72%
	③ 160 kph (2.73 m inter-vehicle gap)	3.1	68%
6	When transferring control from AHS to the driver, this simulator transferred the control authority of the steering and the speed simultaneously. How did you feel about this simultaneous transfer?	3.6	86%

already recognized, such as current lane position, inter-vehicle gap, and destination name acquired lower importance. This result will be helpful in deciding the priority of information for an in-vehicle information device HMI design for efficient information delivery and reduced visual distractions.

Comparing the usefulness of in-vehicle information devices including the cluster, subjects most preferred the HUD, and they expressed the necessity of the conventional cluster information between borderline and acceptable, because even if using the AHS the driver should control the vehicle manually, and then need the conventional cluster information on the ordinary lane. In addition, the voice instruction received high preferences as the multimodality interface media with visual display, and its voice presentation point in front of 500 m at each gate received a satisfactory evaluation for the driver maneuver supports.

5.3. Overall AHS Use

Table 3 shows the general questions about AHS use after simulator driving. Subjects highly expressed the implementation needs and the intention of use. They experienced drowsiness because of the dull and monotonous automated driving environment, so that they strongly required the drowsiness warning system. Also, they did not want to platoon composition with trucks or buses.

6. CONCLUSION AND FUTURE STUDY

The Korean Ministry of Construction and Transportation announced that nationwide intelligent transport systems will be installed until 2010 and AHS will be used until 2020 (Korean Ministry of Construction and Transportation, 2001).

This study, as the initial AHS human factors research, introduced the fixed-based AHS simulator for human factors research and performed the human factors evaluation of automated highway system operation-related attributes after three kinds of automated driving speeds.

Subjects satisfied the simulated driving scenario, the use of TL and barriers which are related with the road configuration. And, 140 kph automated driving speed acquired the highest preference, but did not satisfied the 0.0625 second inter-vehicle gap and the simultaneous steering and speed control authority transfer when starting the manual driving after the end of automated driving.

Among available information devices in the simulator, the subjects evaluated HUD was the most preferred device, and the vehicle speed\and the vehicle operation mode were the most importantly regarded information both HUD and AHS information display. And, they

Table 2. Usefulness Evaluation of In-Vehicle Information Devices.

No.	Questionnaire	Average Point	Above Average (%)
1	You received the following seven kinds of information from HUD. Fill in the blanks according to importance order that you used during experimental driving (Ex. 1, 2, 3, 4, 5, 6, 7).		
	① Vehicle speed	2.6	Rank order scale
	② Rest time to destination	3.3	
	③ Current lane position	4.8.	
	④ Inter-vehicle gap	5.5	
	⑤ Rest distance to destination	3.9	
	⑥ Instant messages about current maneuver	6.1	
	⑦ Vehicle operation mode	1.8	
2	You received the following six kinds of information from the AHS flat panel display on the instrument panel. Fill in the blanks according to importance order that you used during experimental driving (Ex. 1, 2, 3, 4, 5, 6, 7).		
	① Vehicle operation mode	2.8	Rank order scale
	② Vehicle speed	1.9	
	③ Destination name	3.0	
	④ Rest time to destination	5.7	
	⑤ Rest distance to destination	3.9	
	⑥ Inter-vehicle gap	3.7	
3	In addition to the HUD and the AHS information displays, you received vehicle information from the cluster. If your vehicle equipped above has two information displays, how did you view the usefulness of the cluster information?	3.7	85%
4	Fill in the blanks according to order of preference concerning the above three kinds of information sources presented during experimental driving (ex. 1, 2, 3, 4, 5, 6, 7) (Average value of preference order).		
	① Heads-up display	1.1	Rank order scale
	② AHS information display	2.9	
	③ Cluster information	2.3	
5	You received voice instructions about lane changes and vehicle operations through experimental driving. How did you view the usability of those instructions?	4.6	100%
6	Voice instructions were presented 500 m before your operational actions. Was the distance suitable for your action?	3.9	89%

satisfied the use of voice instruction as the multimodal interface media with display information, and its presentation point before 500 m at each gate.

Finally, the subjects expressed the positive opinions about the use of AHS, and they required the drowsiness warning system when use the AHS.

For the future study, there exist remaining human factors issues for more usable and safe system development. First, considering the increasing number and portion of older drivers, they show the greatest individual variability of any age cohort. Identified difficulties of the older drivers are visual functions (seeing while driving at night, reading traffic signs, and reading instrument panels), neck and torso mobility (turning head while backing, merging and exiting in high-speed traffic, changing lanes), and paying attention (Yasnder and Herner, 1976; Yee, 1985). For example, in a navigation system evaluation, Dingus *et al.* (1986) found that driving and navigation

Table 3. Preference of overall AHS use.

No.	Questionnaire	Average Point	Above Average (%)
1	How great did you feel the necessity of the AHS after experimental driving?	4.1	93%
2	How great did you feel for the necessity of road and vehicle environmental monitoring when you drove on the AL?	4.0	93%
3	In Korea, the Ministry of Construction and Transportation announced that they would implement the AHS until the year 2020. Do you have intention to use the AHS after its implementation?	YES: 89%	
4	If you have intention to use the AHS, do you have intention to pay for its use?	YES: 61%	
5	Did you feel drowsy during simulator driving?	4.0	93%
6	If you felt drowsy, how necessary do you think is the need for a drowsiness warning system?	4.0	100%

performance for drivers over age 50 degraded more than that of drivers aged 18 through and 35 through 45. Additionally, both younger and older drivers have higher crash rates in general than do middle-aged drivers (National Safety Council, 1990). Therefore, investigation of the older driver's preferences of AHS human factors attributes should be investigated and compared with the preferences of younger driver's. Second, in-vehicle information displays becomes one of the essential multimodal interface devices in a vehicle, so that when implementing the AHS, the AHS information system would be integrated with currently available systems such as telematics, navigation, entertainment, HUD, and so on. Therefore, HMI components design of these devices and proper LCD position should be carefully investigated based on the driver's cognitive and information-processing characteristics in an automated environment for more efficient information delivery and safety system usage with less visual distraction.

For these kinds of future study, a network-based and multi-user driving simulator would be strongly needed, making it possible to design the optimal DVI and use-cases to predict the drivers interactions among various demographic groups, and could estimate the AHS effects on the traffic flow and capacity in simulated environments among various inter-vehicle gap and platoon speeds, which are one of the key human factors issues for AHS implementation.

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