IE Interfaces
Vol 12, No. 2, pp. 294-304, June 1999.

# Development of Human Factors Evaluation System for Car Navigation System†

Doo-Won Cha · Peom Park
Industrial Engineering Department of Ajou University

# 자동차 항법장치의 인간공학 평가시스템 개발

차두원 · 박 범

This paper describes the theoretical background and detailed structure of Navi-HEGS (Navigation system-Human factors Evaluation and Guideline System) which has been developed for the human factors and HMI (Human-Machine Interface) researches for a CNS (Car Navigation System) and a digital map. Navi-HEGS is an integrated system that consists of a digital map UIMS (User Interface Management System), a CNS simulator, various evaluation tools, and a design guideline system. If Navi-HEGS is properly applied and utilized, it is possible to extract the substantial users requirements and preferences of a CNS and a digital map and then, these requirements can be simulated and evaluated with various human factors evaluation techniques. Applications of Navi-HEGS can improve the CNS usability, drivers safety and performance that directly affect the success of ITS (Intelligent Transport Systems). Also, results can be used as the basic data to establish the standards and design guidelines for the driver-centered CNS design.

## 1. Introduction

Because of its various functions and the use of a digital map, CNS is the most competitive ITS-oriented in-vehicle information system among RDS-TMC (Radio Data System-Traffic Message Channel), FM-DARC (DAta Radio Channel), ARS (Automatic Response Service) and so on. It basically provides the map display, positioning, route planning, and route guidance functions as well as its multimedia functions such as TV, video, DVD, and web browsing function. These services are provided to the driver through a CNS display and a digital map via the GPS (Global Positioning System), TIC (Traffic Information Center) and CD-ROM as illustrated in <Figure 1>(*ETRI*, 1994). In this process, the driver driving with CNS acquires the ITS traffic and road information with both internal IP (Instrument Panel) vehicle information and external VMS (Variable Message Signs) and traffic signal. Therefore, it is certain that the CNS is a new additional information source that generates the 'resource competition' situation among above information sources. It takes away some of driver's attention from the road ahead and driving scenes so that the driver's information acquisition and decision-making patterns are changed into the more

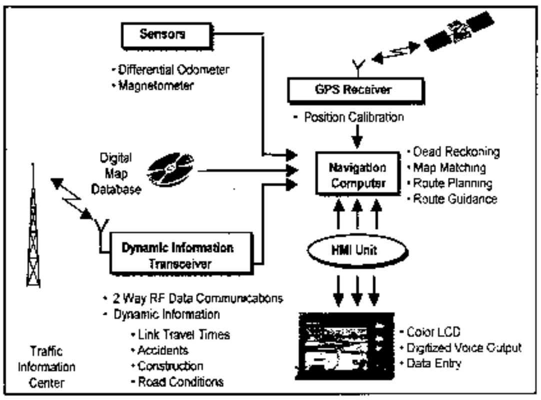


Figure 1. System Structure of CNS.

† This research was supported by G7 Navigation Development System Project (1997.10 ~ 1998.10).

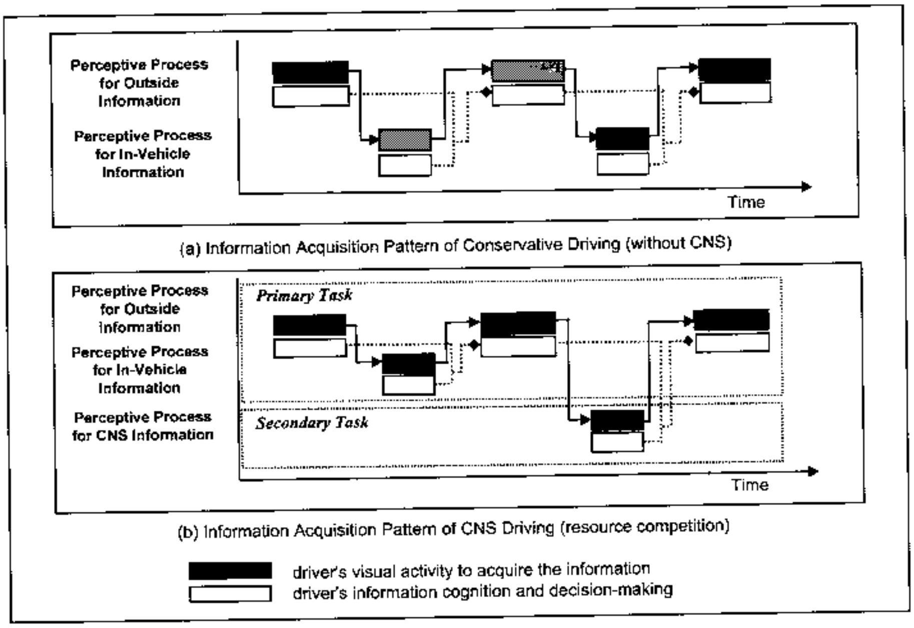


**Figure 2.** Comparison of Information Acquisition and Decision-Making Process between Conservative and CNS-Supported Driving.

complex and disorder ways which described in <Figure 2>. This illustration explains the abundant information, unfamiliar and mismatched characteristics of the CNS display are apt to raise the following effects.

(1) It can take away some of driver's visual and cognitive attention from the road and outside information sources, hence the CNS increase the accidents and near-collision risks.
(2) At the decision points, CNS can slow down the driver's response to the road conditions especially, when the comparative options are presented to the driver.
(3) Impose the mental and cognitive workload when the driver is finding the destination in an unfamiliar area depending on the CNS information.

However, in spite of above disadvantages and the conveniences of the auditory information display, a LCD-based CNS has been widely developed and commercialized because of its various multimedia functions and a current positioning function on the map. Therefore, the digital map is regarded as the most important component for the market success and the user's satisfaction by supplying various digital map formats and scrolling types to improve the driver's information cognition and safety. Hence, the digital map has been considered as the kernel of human factors and HMI research object so that various techniques have been applied to draw out the driver's preference information(Cha and Park, 1997), physical and cognitive limitations such as mental workload (Cha and Park, 1997), visual demand analy-

**Table 1.** Comparisons of Travel and Driving Simulator for ITS Human Factors Research

| | Travel Simulator | Driving Simulator |
|---|---|---|
| Platform | PC-based | Full set of vehicle and driving environments |
| Cost | Inexpensive and short development time | Expensive and rather long development time |
| Dynamics | Static | Dynamic |
| Task | Part task | Full task |
| Objective | Modeling the drivers route choice pattern and ATIS impact Analysis | Data collection for vehicle design, safety, roadway visualization |
| Benefit | Quick response to the research needs | Quick response only after development |
| Developed Simulator | VLADIME, DIDEM, IGOR, Battelle Route Guidance Simulator, FASTCARS, etc. | National Advanced Driving Simulator, Benz driving simulator etc. |

sis (Cha and Park, 1997), human sensitivity ergonomics (Cha and Park, 1998), cognitive evaluation (Cha and Park, 1998), psychophysical evaluation, and so on.

Consequently, these kinds of researches have aimed to extract the human factors design guidelines and standards of CNS HMI. In this process, a properly designed and constructed evaluation system can improve the research effectiveness and utilize the valuable results by diminishing the cost, time, and experiment loads. Navi-HEGS has been developed for this purpose to satisfy the needs of CNS researchers and designers.

## 2. Development and Structure of Navi-HEGS

Generally, human factors simulators for ITS can be categorized into travel and driving simulators as described in <Table 1> (Polydoropoulou and Moshe, 1995). Travel simulators are mostly PC-based applications used to study the subject's travel behavior such as departure time choice and route choice when traffic information is available. On the other hand, the driving simulator is an expensive and elaborate tool that uses a combination of seat, steering wheel, and foot control to provide a realistic driving environment. Navi-HEGS partly adapted the characteristics of travel simulators for the quick response of CNS developer's needs at the beginning stage of CNS human factors research.

It is a low-cost, fixed-based, part-task and PC-based system, however, its functions and objectives are distinguished from previous simulators for human factors research in ITS such as, IGOR (investigate the factors that affect travelers response to route guidance advice, 1991), FASTCARS (study the traveler behavior under ATIS (Advanced Traveler Traveler Information System) and collect data for estimation and calibration of predictive models of travel behavior with various ITS information supply systems) (Adler *et al.*, 1993), Battelle Route Guidance Simulator (impact analysis of navigation system and ATIS) (Kantowitz *et al.*, 1995), VLADIME (collect the data for studying route choice under arious forms of ATIS) (Bonsall, 1996), and DIDEM (model-based human-machine dialogues system to measure the cognitive complexity) (Nirshcl and

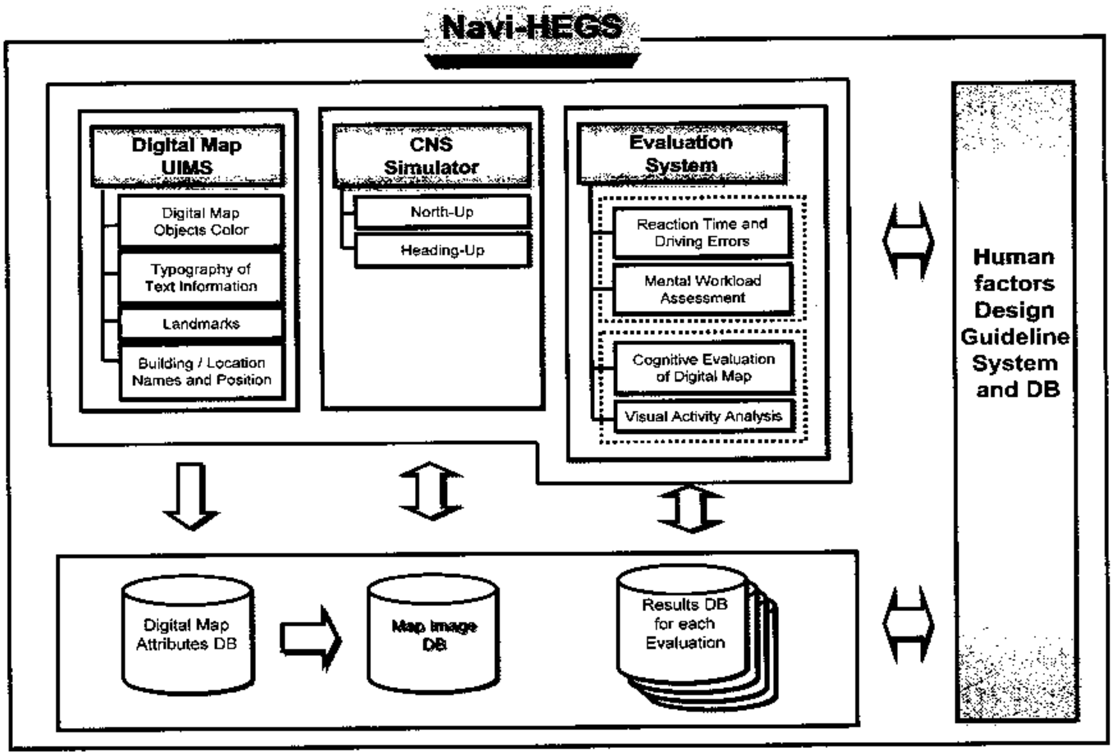


Figure 3. Functions and Structure of Navi-HEGS.

Table 2. HMI Characteristics Differences between Conservative and CNS Digital Map

| | Conservative Map (paper map) | CNS Map (digital map) |
|---|---|---|
| Represent Size | No limitations, its depends on the paper size | Generally, 4 to 6 inch size limited LCD display |
| Using Environment | Static situation (stop or pre-trip situations) | Dynamic situation (driving on the road or highway) |
| Represent Area | Part or entire area by map design goals | Specific local area (restricted in driving area, intersections etc.) |
| Graphics (dimension) | Generally 2D | 2D and 3D with various presentation techniques (birds eye view, niagara view, double windows, jet-view, etc.) |
| Scale | High scale | Low scale (at most 20,000:1) |
| Low scale (at most 20,000:1) | Detail information of target areas including all road networks, roadside information and facilities etc. | Prominent and selected information of districted road network. |
| Information Modality | Verbal and graphical types with various color schemes by map goals | • Verbal type with binary color (EU, America)<br>• Verbal & graphic type with various colors (Korea, Japan)<br>• Voice-guidance is supported for two types |
| Information Density (complexity) | High information density | Low information density with traffic and road information |

Blum, 1996). These simulators are mainly aimed to investigate the driver's route choice patterns and impact of ATIS, whereas, Navi-HEGS contains various human factors functions like below, and <Figure 3> shows the structure and functions of Navi-HEGS.

(1) Collect the human factors and HMI requirements of a CNS and a digital map.
(2) Supply the CNS simulation tool.
(3) Integrate and systemize the various human factors and HMI evaluation techniques.
(4) Database the design guidelines to collect the user's requirements and experiment results.

Visual Basic 5.0 Professional Edition and Access 97 was used as the development tool under Windows 95/98 environment. A portable PC is a recommended platform to regenerate the natural characteristics of CNS LCD display.

## 2.1 Digital Map UIMS

It is a generally accepted fact that the digital map is a critical and important component for the success and the safety of CNS to implement its determined functions. <Table 2> shows the evident differences between the conservative map (paper map) and the CNS digital map. The most distinct characteristics of CNS digital map are the represent size and using environment.

All other differences between two types are due to these two reasons. It means that the CNS must deliver the information efficiently in a restricted size of display, and also, assure the driver's and road safety despite the newly generated interface condition of 'resource competition' among CNS, internal and external information sources in a dynamic situation. Therefore, the CNS digital map should be designed to maximize the driver's information recognition ability and to minimize the dangerous driving situations. Hence, the designers should investigate and reflect the driver's requirements in terms of his or her cognitive ability and preference based on their demographic characteristics and driving ability. As the results, they must offer the properly designed digital map by combining the map interface objects such as landmarks, text information, color and so on. Because the UIMS mediates the interface between the end user of an application and the application code itself, UIMS is regarded as the most useful and convenient tool by directly acquiring the substantial user's requirements of the digital map interface objects to accomplish above activities and aims. This result in a separation of the responsibility between the UIMS and the application, with the application being responsible for carrying out the work' while the UIMS handles all details of communication with the end user (Jenny, 1994). Detailed descriptions and importance of digital map interface objects that can be defined by subjects using UIMS are like below. These objects were selected by the discussion of CNS and human factors engineers with previous researches (Cha and Park, 1997, 1998). <Figure 4> shows the interface feature of Navi-HEGS UIMS for

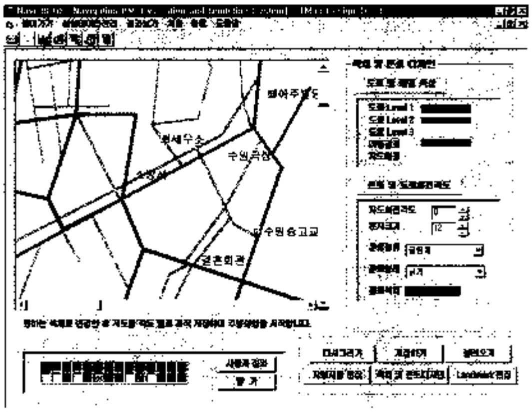

Figure 4. Digital Map UIMS User Interface.

color and font attributes selection and design

(1) Colors

Color is the most important cartographic consideration because even a small amount of color can make an enormous difference in the appearance of a map. Also, color on a map allows greater detail, (1) it adds visual interest, (2) it increases the design possibilities, and (3) it greatly adds to the possibility for hierarchical graphic structure. Because color may be used efficiently to code similarity and dissimilarity between and within a limited number of classes of phenomena, it is a great aid to clarity. Furthermore, color arouses aesthetic reactions and connotes concepts that may be important in creating an effective graphic communication (Roinson and Randoll, 1984). Most of commercialized digital maps adapted above concepts, therefore, their background color is generally the blue, yellow, and green to represent the sky, city color and woods. This UIMS has color design functions of digital map objects such as background, road level 1 to 3 (by its scale), predetermined route, and text information using color palette by Windows system supplied including the user-defined colors.

(2) Text Information

The attributes and quantity of texts and numeral information placed on a map may be one of the considerable items that should be importantly designed. It means that attributes of text should be carefully chosen to clarify the reference locations and the messages that have been symbolized. In addition, variations and size differences can be employed in an orderly way to make all the distinctions that would help the user sort out the different categories of information on the digital map. In this process, the driver should acquire the target information as soon as possible and the information acquisition process does not affect the driver's safety and performance. Therefore, the attributes of font and typography on the digital map play a greatly important role when the driver acquires the information. This UIMS enables the subjects to select the font type, size and its attribute, such as bold, italic, underlined, bold and italic for all Windows system supported fonts about the Korean and English text information.

(3) Landmarks

Landmarks have been defined as the points of reference external to the observer that should exhibit clear form and contrast with the background (Ryncy, 1960). Landmark information has been shown both to be an important aid in wayfinding and to provide a framework from which the environment may be learned (Deakin, 1996). Therefore, properly designed landmarks on the digital map help to efficient wayfinding task in an unfamiliar area by reducing the driving errors, information searching time and driving efforts. When the digital map includes landmarks, usually only features that are likely to be trip destinations are described such as tourist attractions, schools, churches, and government buildings and the like. However, their appearance may not be consistent enough to reinforce what the drivers see in a map and to increase driver's confidence when orienting themselves. Therefore, the standardi- zation of landmarks is a very essential problem through the cognitive and usability evaluation. Using Using this UIMS, subjects can choose the pre- generated landmarks in UIMS and can load any type of landmarks that generally used or user designed.

(4) Buildings or Location Names
(Information Quantity)

A digital map should be designed in the simplest form by properly designing the information quantity that corresponds to the human short-term memory capacity (Cha and Park, 1998). Information quantity of the digital map mainly depends on the numbers of text and numeral, landmarks, color numbers and other object numbers on the digital map. Among them, number of text information directly concerns with the map information quantity, which obligates the complexity of digital map display. It generally represents the reference buildings and locations like landmarks do. Therefore, the text information should be presented in a proper quantity not only for not confusing, but also misunderstanding or misreading by the driver. In addition, text information representation method (for example, full words or abbreviated words, Korean or English etc.) is an important research topic to be dealt with. These research topics can be investigated in Navi-HEGS. This UIMS enables subjects to control the buildings and location names by appending and erasing the text infomation with the definition of its locations on the coordinated digital map. Also, it is possible to gain the proper information quantities and types with its positions in a spatial digital map space.

Table 3. Attribute Database Structure

| Field Name | Definition | Data Type | Size |
|---|---|---|---|
| backcolor | Background color of digital map | long | 4 |
| route | Color of route guidance line | long | 4 |
| line 1 | Color of road level 1 | long | 4 |
| line 2 | Color of road level 2 | long | 4 |
| line 3 | Color of road level 3 | long | 4 |
| widthline 1 | Width of road level 1 | integer | 2 |
| widthline 2 | Width of road level 2 | integer | 2 |
| widthline 3 | Width of road level 3 | integer | 2 |
| widthline 4 | Width of route guidance line | integer | 2 |
| fontcolor | Color of text information | integer | 2 |
| fontname | Font name | text | 30 |
| fonttype | Font attributes of text information | text | 10 |
| landmark | Definition of landmarks uses | boolean | Y/N |

Actually, above 4 main digital map objects are interdependent one from another and their combination generate a set of user-defined or user-designed digital map including the definition of road width. Consequently, this UIMS is the design and experiment data acquisition tool to collect the individual's digital map interface requirements. If once the subject has selected and designed the map objects and attributes by trial and error until he or she satisfy, selected attributes of each object is stored in the attribute database with the definitions of <Table 3>. And then, this data is transferred to the map image DB to reproduce the designed map during evaluation stages.

## 2.2 CNS Simulator & Evaluation System

CNS simulator supports both north-up and heading-up map scroll styles using a user-designed map and other experimenter-defined maps. By clicking the direction-sign marked on the command box under 5-inch digital map, a subject drives the vehicle position mark from origin to predetermined destination (refer the <Figure 5>). A digital map frame is the digitized map of 1:5000 scale of near Suwon areas based on the digital map developed by the Korea Automotive Technology Institute.

Available evaluation modules of Navi-HEGS are described like below.

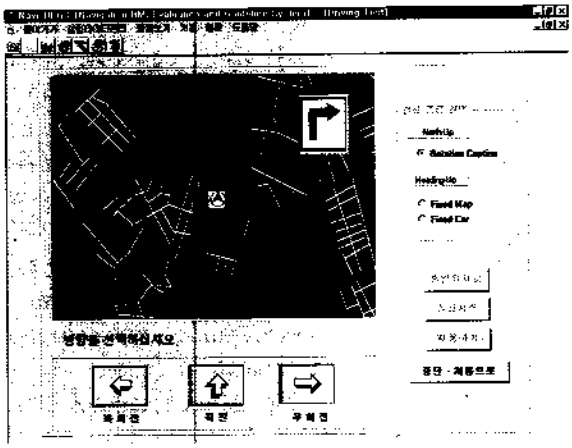

Figure 5. CNS Simulator.

(1) Reaction Time and Driving Errors

From CNS driving tasks, this evaluation module automatically collects the driving errors and driver's response time between information stimuli and reaction (time between direction sign presentation upper right side of digital map and mouse clicking of direction command box) of each intersection and classified interaction types (+-type, Y-type, ├-type, T-type, ┤-type, etc.) for each supported map scrolling type of experimental digital map. By comparing the reaction time, experimenters can suggest the more advantageous digital map format and scrolling method under assumption that the shorter reaction time is more beneficial for a driver's

PIEV (Perception-Identification-Emotion -Volition) process. Also, driving error can be used as the performance criteria of digital map and scrolling method. This type of evaluation results are deeply related to the objective evaluation data, and if properly combined with the subjective evaluation data of mental workload assessment, and then more complete combined and valuable human factors and HMI evaluation results would be acquired (Cha and Park, 1997).

(2) Mental Workload Assessment

Generally, mental workload assessments have been importantly and basically performed when designing and evaluating the CNS to test the system usability and to derive the potential sources of workload that impose to the driver. RNASA-TLX (Revision of National Aerospace and Space Administration-Task Load Index) was developed as the mental workload assessment technique for CNS driver's mental workload evaluation system in Navi-HEGS (Cha and Park, 1997). RNASA-TLX assumes that the CNS driver's mental workload is influenced by six factors such as mental workload, visual demand, auditory demand, temporal demand, difficulty in driving, and difficulty in understanding information. These scales were selected from the real road and simulator-based experiments by the comparison results between NASA-TLX and RNASA-TLX with HMI analysis of CNS. RNASA-TLX has three steps of procedures, (1) assessment of the magnitude of each scale from 0 to 100, (2) perform the pairwise comparisons among six scales, (3) calculate the overall weighted workload score by combining above two procedures like an NASA-TLX. A recent study shows that RNASA-TLX acquires the highest subject acceptance and sensitivity when evaluating the CNS driver's mental workload among prevalently used mental workload assessment techniques, such as SWAT (Subjective Workload Assessment Technique), MCH (Modified Cooper-Harper) Scale, NASA-TLX, and RNASA-TLX (Park and Cha, 1998). Also, the interest of this method has been increased when evaluating the mental workload of various traffic information systems, for example, HUD (Head Up Display), RDS-TMC, VMS (Variable Message Signs), cellular phone and so on. <Figure 6> and <Figure 7> show the interface features of RNASA-TLX evaluation procedures. This systemized RNASA-TLX suggests the compatible and easy user interfaces and evaluation procedures for easy use and application of Navi-HEGS, because of most of CNS researchers and evaluators are the hardware engineers.

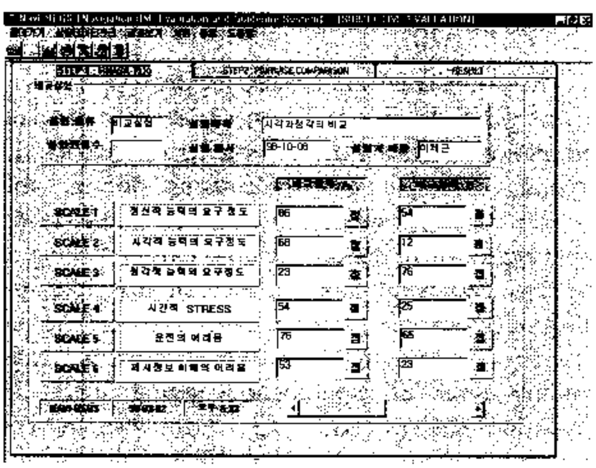

Figure 6. Magnitude Ratings of 6 Scales.

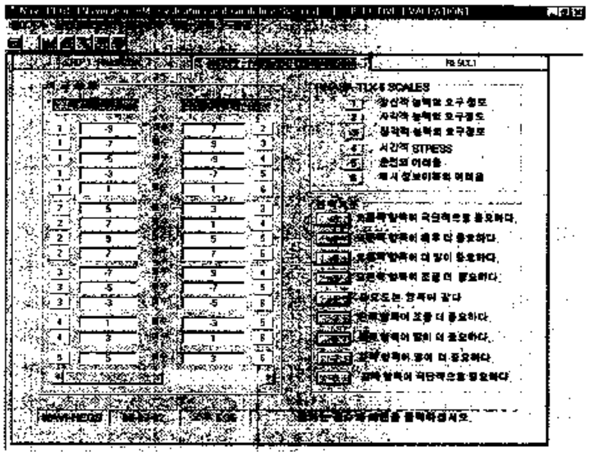

Figure 7. Pairwise Comparisons of 6 Scales.

(3) Cognitive Evaluation System of Digital Map

Spatial orientation treats how human beings recognize the direction of their movement or their location in a given space (Neisser, 1976). It contains the ability to understand a map, frame of reference (environment needed in recognizing their location), the process which mental map changes based on environment and so on. Hereby, when an individual develops a mental representation of the relationships among objects within a given space, a cognitive map has been formed. It is an individual's inherent spatial ability as well as experiences with a given space (or its representation) that determine the content and extent of the cognitive map and how it may be used to solve real navigation problems associated with

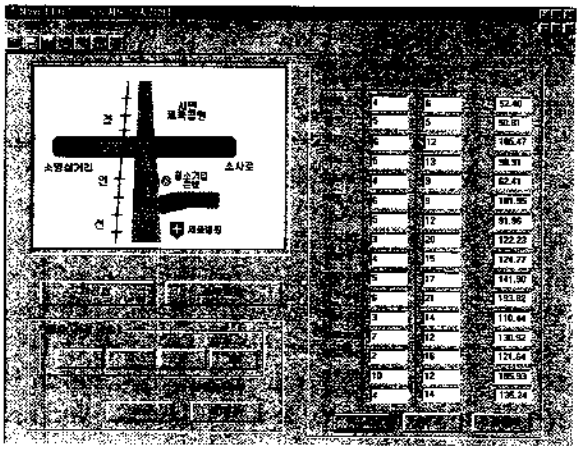

Figure 8. Sample Map of Cognitive Evaluation.

that space(Kerst and Howared, 1978). Based on the cognitive map and mental map theory, this module investigates what type of CNS digital map is the most beneficial for the driver's information acquisition and the capability of short-term memory? <Figure 8> shows the sample map for this evaluation. By suggesting the various map formats during predetermined time interval, subject is asked to reproduce the stored map in his or her short-term memory on the evaluation sheet using drawing method and information theory. A target map can be generated in various formats by the combination of digital map interface objects as the experimenter defined. Through this evaluation, it is possible to evaluate the usability of landmarks, graphic dimension, color schemes, and the like, by comparing the information quantities between the suggested map and subject drawn map. Hereby, the reproduced map which contains the more information quantities or object numbers is regarded as the more beneficial map for driver's map cognition in a spatial space. Also, by investigating the relations between the reproduced information quantity and suggested time, it is possible to derive the driver's information acquisition patterns and short-term memory capacity when using CNS.

(4) Visual Activity Analysis

Perhaps the most negative impact of CNS is the excessive visual distraction of driver attention from the roadway. Therefore, the driver's visual activity analysis is importantly performed with the mental workload assessment when performing the human factors evaluation using a video camera or an eye tracking system. The interpretation of visual activity data has often involved the intuitive assumption that other things being equal, fewer glances and shorter duration away from the road ahead are desirable (David and Mark, 1982). One example of the quantification of the visual demand is the computation of the driver's glance duration toward each visual source used in a driving task, that expressed as a percentage of the total visual time. And the other quantification of the visual activity analysis is the comparison of the number of looks necessary to get a specific infor- mation from an implemented system. This principle has been developed by Zwhalen (1987) and he proposed a tentative design guideline to be used when designing a sophisticated in-vehicle display : one look lasting over 2 seconds or 4 looks lasting more than 1.4 seconds defended the boarder line of an unacceptable area where any higher visual requirements of the display can be considered as being unsafe, leading to potential loss of vehicle control. These parameters can be useful criteria to establish the comparisons between situations, systems or categorized drivers when evaluating the system safety and usability. In this evaluation module, an experimenter could analyze the visual data statistically through the simple data input that acquired by a video camera. By analyzing the driver's visual frequency and duration distracted from 6 major visual sources (rear mirror, instrument panel, road ahead, passenger, road aside, CNS), results can be used as the basic data for developing the human factors standards and system usability test.

## 2.3 Design Guideline System

This subsystem consisted of experimental results or other human factors and HMI information resources of CNS. Also, this system has the store, edit, delete, and query functions of the stored information. Therefore, the experimenter or user of this system can easily compose and upgrade the design guideline database whenever he or she wants. If this system is properly contented and upgraded, this can be efficiently used as the basic human factors and HMI design guidelines when developing the new product and then, could be used as the basic references for the standards development. <Figure 9> shows the interface style and sample content of categorized human factors guideline.

# 3. Fidelity Test of Navi-HEGS

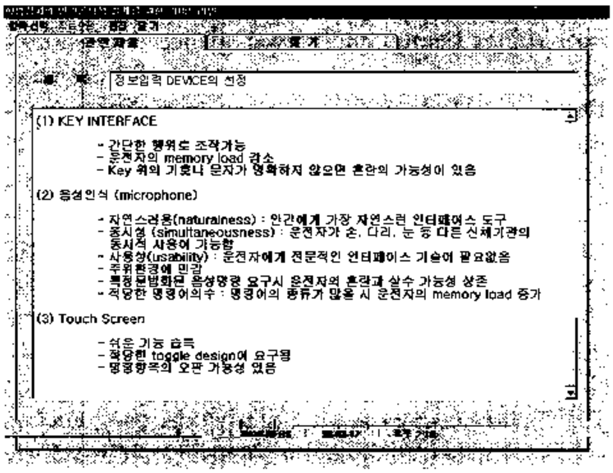


**Figure 9.** Interface of Guideline System.

A fidelity test was performed to investigate how much degree of actual CNS driving environment had been generated by Navi-HEGS and how much workload had been imposed to the subjects. Hays (1980) has identified four dimensions of fidelity : (1) functional fidelity, the degree to which the simulator reproduces stimulus and response choices of the actual equipment, (2) behavioral fidelity, the degree to which the simulator reproduces tasks performed on the actual equipment, (3) psychological fidelity, the degree to which the user perceives the simulator to be a representation of the actual task environment, and (4) physical fidelity, the extent to which the simulator replicates the appearance of the actual equipment. Among them, RNASA-TLX fulfills the content of psychological fidelity by comparing the subjects perceived workloads between CNS and Navi-HEGS task environment. Therefore, RNASA-TLX was used as the fidelity criteria, because it had been initially developed in a real road situation using a CNS simulator and a real CNS considering all workload sources given by the CNS driving task.

A test vehicle (V-100 test vehicle of D company) equipped with a real CNS (commercialized CNS of H company) was used to investigate the fidelity of Navi-HEGS. 10 male participants were recruited, whose age was distributed from 26 to 28 years old (average : 27.6, s.d. : 0.52) with 5.8 years of average driving experiences. Experiments were performed in a daylight to avoid the peak hour for diminish the near-collision situations around Suwon. For each subject, an unknown destination was imposed for about 30 to 60 minutes distance, and then asked to drive the origin to destination by depending on the CNS information. <Table 4> shows the comparison result of RNASA-TLX 6 scales between Navi-HEGS and a real road driving situation.

These regression functions show the statistical relations between suggested two driving situations based on the acquired workloads. This result was directly acquired from the subjects so that it could be the most accurate and realistic result as the fidelity of Navi-HEGS. In <Table 4>, all of regression functions suggest the high $R^2$ values except 'visual demand' scale. It means that Navi-HEGS can impose nearly the same workload to the subject from its functions and interfaces.

Consequently, Navi-HEGS has the high fidelity, however, the reason why the 'visual demand' got the lower $R^2$ value indicates the importance of visual activity analysis. Because Navi-HEGS do not contain the external driving environments so that the visual

**Table 4.** Comparison Result between Real Road and Navi-HEGS Driving

| RNASA-TLX 6 Scales (Navi-HEGS /Real Road) | Regression Functions | $R^2$ |
|---|---|---|
| Mental Demand (Y1/X1) | $Y1 = 0.8193\ X1 + 0.1338$ | 0.9808 |
| Visual Demand (Y2/X2) | $Y2 = 0.2323X2 + 7.2318$ | 0.6406 |
| Auditory Demand (Y3/X3) | $Y3 = 0.7941X3 + 2.1556$ | 0.8385 |
| Temporal Demand (Y4/X4) | $Y4 = 0.7551X4 + 2.2239$ | 0.8864 |
| Difficulty in Driving (Y5/X5) | $Y5 = 0.9928X5 - 0.0248$ | 0.9990 |
| Difficulty in Understanding Information (Y6/X6) | $Y6 = 0.5879X6 - 0.7028$ | 0.8919 |

* X1-X6 = RNASA-TLX 6 Scores of Real Road Situation

** Y1-Y6 = RNASA-TLX 6 Scores of Navi-HEGS Experiments activity analysis strongly recommended as the additional evaluation procedures for the more complete evaluation.

## 4. Conclusion and Applications of Navi-HEGS

Navi-HEGS is an integrated system of digital map UIMS, CNS simulator, human factors evaluation tools and design guideline system. This kind of tool is useful when drawing out the human factors and HMI issues of CNS and establishing the standards and qualitative design guidelines. Also, application and utilization of this system is very useful to corresponds with the ISO TC22 (Road Vehicles) / SC13 (Ergonomics applicable to road vehicles) / WG8 (Traffic Information and Control System on-board MMI) s works to establish the international standards of ITS-oriented information systems.

In practice, available applications of Navi-HEGS can be focused on the usability test and human performance assessment of the CNS and a digital map. In addition, human sensitivity ergonomics is a useful technique to acquire the driver's preferences and requirements of the digital map objects for example, font and typography, color, landmarks and so on. It means that the collected user's requirements from UIMS can be used as the substantial data for human sensitivity ergonomics evaluation, and then the collected from users or experimenter-defined map can be simulated in terms of mental workload, reaction time and driving errors. Hence, if the experiment is performed, it is possible to gain the objective and subjective evaluation results of CNS using Navi-HEGS. Also, if other proper human factors and human sensitivity ergonomics techniques are applied, the more efficient and valuable results can be acquired for the CNS evaluation. Therefore, the proper use of this system can contribute to the improvement of CNS interface quality in terms of safety and usability which directly affect the success of ITS.

For the extension of Navi-HEGS, it has the wide applicability of human factors evaluations for other ITS-oriented information systems such as HUD, RDS-TMC, FM-DRAC, VMS, because of its modularized system structure and prototype characteristics of human factors evaluation methods.

## References


A Basic Research on the ITS / IVHS Communication System, (1994. 12), *ETRI*.

Adler, J. L., Recker, W. W. and Menally, M. G., A conflict model and interactive simulator (FASTCAR) for predicting en-route assessment and adjustment behavior in response to real-time traffic condition information, *Working Paper UCTC,(127)*, The University of California Transportation Center, Berkeley.

Bonsall, P. and Perry, T. (1991), Using an interactive route-choice simulator to investigate drivers' compliance with route guidance advice, *Transportation Research Record 1306*, 59-68.

Bonsall, P. (1996), Simulator experiments and modelling to determine the influence of route guidance on driver's route choice, *Proceedings of 1st World Congress on ITS*, 964 -971.

Cha, D. W. and Park, P. (1996), A study of the design and the implementation for the human-machine interface evaluation system in the in-vehicle navigation system, *Proceeding of 1996 Spring Korea Ergonomics Society*, 13-18.

Cha, D. W. and Park, P. (1997), Simulator-based mental workload assessment of the in-vehicle navigation system driver using revision of RNASA-TLX, *IE-INTERFACES*, 10(1), 145-154.

Cha, D. W. and Park, P. (1997), Development of HMI assessment system and derivation of design variables for vehicle navigation system, *Journal of Korean Society of Transportation*, 15(2), 35-48.

Cha, D. W. and Park, P. (1997), User requirement information and structure of in-vehicle navigation system focused on the urban commuter, *Computers ind. Engng*, 33(3-4), 517-520.

Cha, D. W. and Park, P. (1998), Cognitive evaluation of car navigation digital map prototypes using drawing method, *Journal of Traffic Safety Research*, 17, 125-138.

Cha, D. W. and Park, P. (1998), Human sensibility ergonomics evaluation of the car navigation system digital map, *Journal of the Society of Korea Industrial and System Engineering*, 21(48), 101-111.

David, J. C. and Mark, T. M. (1982), *Thematic maps : Their design and production*, Methuen, New York.

Deakin, A. K. (1996), Landmarks as navigational aids on street map, *Cartography and Geographic Information Systems*, 23(1), 21-36.

Hayes, R. T. (1980), Simulator fidelity, A concept paper, (Technical Report 490), Alexandri, Va.: U.S. Army Research Institute for the Behavioral and Social Sciences.

Jenny, P. (1994), *Human Computer Interaction*, Addision-Wesley Publishing Company.

Kantowitz, S. C., Barry, H. K. and Richard, J. H. (1995), The battle route guidance simulator : A low-cost tool for studying driver response to advanced navigation system, *Proceeding of IEEE Vehicle Navigation & Information Systems Conference*, 104-109.

Kerst, S. M. and Howared, J. H. (1978), Memory psychophysics for visual area and length, *Memory & Cognition*, 327-335.

Lynch, R. A. (1960), *The Image of the City*, The M.I.T. Press and Harvard University Press.

Neisser, U. (1976), Cognitive and Reality, San Francisco, W.H.Freeman.

Nirschl, G. E. and Blum, R. E., DIDEM : An advanced integrated design and evaluation tool for dialogue systems in vehicles , *Proceeding of 1st World Congress on*

*ITS*, 1631-1638.

Pauzi, A., Anne, S. and Ga, L. S., Ergonomic evaluation of a prototype guidance system in an urban area, *Proceeding of IEEE-IEE Vehicle Navigation & Information Systems Conference*, 390-396.

Park, P. and Cha, D. W. (1998), Comparison of subjective mental workload assessment techniques for the evaluation of in-vehicle navigation system usability, *Proceeding of 5th World Congress on ITS (CD-ROM version)*, Seoul, Korea.

Polydoropoulou, A. and Moshe, B. A., Travel simulators for data collection on driver behavior in the response of information, *Transpn. Res-C*, 13, 143-159.

Procterm, R. W. and Trisha, V. (1994), *Human Factors in Simple and Complex Systems*, ALLYN. AND BACON 205-208.

Roinson, A. H., Randoll, D. S. and Joel, L. M. (1984), *Phillip, C. M., Elements of Cartography 5th ed.*, John Wiley & Sons, New York.

Rockwell, T. H., Spare visual capacity in driving-revisited (new empirical results for an old idea), *Proceeding of the Vision in Vehicles II*, Elsevier Science Publishers, B. V. (North-Holland), 317-324.

Zwahlen, H. T., Adams, C. C. and DeBald, D. P. (1987), Safety aspects of CRT touch panel controls on automobiles, *Second International Conference on Vision in Vehicles*, 335-344, Nottingham, U.K.

**차두원**
1996년 아주대학교 산업공학과 학사
1998년 아주대학교 산업공학과 석사
현재: 아주대학교 산업공학과 박사과정
관심 분야: 지능형교통체계 및 교통정보 시스템, Human-Machine Interface, 감성공학, 인지공학 등

**박 범**
1982년 아주대학교 산업공학과 학사
1988년 Ohio University 산업공학 석사
1992년 Iowa State University 산업공학박사
현재: 아주대학교 산업공학과 교수
관심 분야: 전자통신 시스템, 감성공학, Human-Machine Interface, 지능형 교통시스템, 산업안전 등