Compendium of Human Factors Projects

Supporting the Intelligent Vehicle Initiative

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By

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Human Factors Projects
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This compendium of human factors research projects is limited to those projects that represent activities that have supported the evolution of the Intelligent Vehicle Initiative (IVI) and have been funded either partially or totally by Federal Highway Administration (FHWA) or the National Highway Traffic Safety Administration (NHTSA). Both internal administration reports and documents and external published publications are included.

For each internal project entry, brief abstracts are provided. External published entries are designated by "open literature" but should not be regarded as inclusive of all published in any category. Contract numbers are identified if available. The intended range for the entries is 1989 through 1999. However, initial for work for each project has varied. Typically the entries begin in 1993 or 1994 but vary by each major category.

The basic categories of classification are listed below:

Advanced Travel Information System (ATIS) - includes in vehicle navigation systems

Automated Highway System (AHS)

Collision Avoidance System (CAS) - includes rear-end, lane change, road departure, and intersection subcategories

Vision Enhancement (VE)

Drowsy Driver (DD) - detection methods and countermeasures for fatigue management

Related Driver Behavior (RDB) - includes crash causation studies, baseline data collection of drive behavior, and impact of vehicle technologies on driver performance. Baseline data collection defines the capabilities and limitations of the drivers, serving as a foundation for functional requirements definition for IVI.

Driver Vehicle Interface (DVI) - other human centered design issues including signs as related to the goals of IVI but not covered by the above categories.

Advanced Travel Information System (ATIS):

FHWA

1993

1993-Open Literature

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[1]Dingus, T.A., and Hulse, M.C. (1993). Human Factors Research Recommendations for the Development of Design Guidelines for Advanced Traveler Information Systems. Proceedings of the Human Factors Society 37th Annual Meeting, 1993, pp. 1067-1071. Seattle, WA: Human Factors Society.

[2]Kantowitz, B.H., Becker, C.A., and Barlow, T. (1993). Assessing Driver Acceptance of IVHS Components. Proceedings of the Human Factors Society 37th Annual Meeting, 1993, pp. 1062-1066. Seattle, WA: Human Factors Society.

[3]Kinghorn, R.A., and Bittner, A.C., Jr. (1993). Truck Driver Anthropometric Data: Estimating the Current Population. Proceedings of the Human Factors Society 37th Annual Meeting, 1993, pp. 580-584. Seattle, WA: Human Factors Society.

[4]McCallum, M. C., and Lee, J. D. (1993). System Objectives and Performance Requirements of ATIS and Commercial Vehicle Components of IVHS. Proceedings of the Human Factors Society 37th Annual Meeting, 1993, pp. 1072-1076. Seattle, WA: Human Factors Society.

[5]Ng, L., and Barfield, W. (1993). User Information Requirements for Intelligent Vehicle Highway Systems as a Function of Driver Category. Proceedings of the Human Factors Society 37th Annual Meeting, 1993, pp. 1077-1081. Seattle, WA: Human Factors Society.

1994

1994-Open Literature

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[6]Dingus, T.A., and Hulse, M.C. (1994). Human Factors Analysis of Information Format Options For Advanced Traveler Information Systems. Proceedings of the International Ergonomics

Association 12th Triennial Congress, 4, pp. 136-139. Toronto, Canada: Human Factors Association of Canada.

[7]Hanowski, R.J., Kantowitz, S.C., and Kantowitz, B.H. (1994). Driver Acceptance of Unreliable Route Guidance Information. Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, 1994, pp. 1062-1066. Santa Monica, CA: Human Factors and Ergonomics Society.

[8]Kantowitz, B.H., Kantowitz, S.C., and Hanowski, R.J. (1994). Driver Reliability Demands for Route Guidance Systems. Proceedings of the International Ergonomics Association 12th Triennial Congress, 4, pp. 133-135. Toronto, Canada: Human Factors Association of Canada.

[9]Kantowitz, B.H., Lee, J.D., and Kantowitz, S.C. (1994). Prioritizing Human Factors Research Issues for IVHS. Proceedings of the First World Congress on Applications of Transport Telematics & Intelligent Vehicle-Highway Systems, 1994, pp. 2200-2207. Paris, France.

[10]Kinghorn, R.A., Bittner, A.C., and Kantowitz, B.H. (1994). Identification of Desired System Features in an Advanced Traveler Information System. Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, 1994, pp. 1067-1071. Santa Monica, CA: Human Factors and Ergonomics Society.

[11]Lee, J.D., Kantowitz, B.H., Hulse, M.C., and Dingus, T.A. (1994). Functional Description of Advanced In-Vehicle Information Systems: Development and Application. Proceedings of the First World Congress on Applications of Transport Telematics & Intelligent Vehicle-Highway Systems, 1994, pp. 2369-2376. Paris, France.

[12]Lee, J.D., Morgan, J., Raby, M., and Wheeler, W.A. (1994). Accommodating Driver Needs and Limits: a Functional Description of ATIS/CVO Systems. Proceedings of the International Ergonomics Association 12th Triennial Congress, 4, pp. 140-142. Toronto, Canada: Human Factors Association of Canada.

[13]Lee, J.D., and Raby, M. (1994). Network Analysis as a Technique to Guide the Task Analysis of ATIS/CVO. Proceedings of the Human Factors Society 38th Annual Meeting, 1994, pp. 1018-1022. Santa Monica, CA: Human Factors and Ergonomics Society.

[14]McCauley, M.E., Clark, D.L., Sharkey, T.J., and Dingus, T.A. (1994). Comparable Systems Analysis of Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) and Comparable Systems. Proceedings of the International Ergonomics Association 12th Triennial Congress, 4, pp. 143-145. Toronto, Canada: Human Factors Association of Canada.

[15]Wheeler, W.A., Lee, J.D., Raby, M., Kinghorn, R.A., Bittner, A.C., Jr., and McCallum, M.C. (1994). Predicting Driver Behavior Using Advanced Traveler Information Systems. Proceedings

of the Human Factors and Ergonomic Society 38th Annual Meeting, 1994, pp. 1057-1061. Santa Monica, CA: Human Factors and Ergonomics Society.

1995

Contract Number: DTFH61-89-C-00044, Prime Contractor: The University of Michigan

[16]Green, P. (1995). Measures and Methods Used to Assess the Safety and Usability of Driver Information Systems. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-088).

> This report concerns in-car systems that may be used to present navigation, hazard warning, vehicle monitoring, traffic, and other information to drivers in cars of the future. It describes in detail measurements researchers have made to determine if those systems are safe and easy to use.
>
> Measures that appear most promising for safety and usability tests of driver information systems include the standard deviation of lane position, speed, speed variance, and the mean and frequency of driver eye fixations to displays and mirrors. In some cases, laboratory measures (errors, etc.) may also be useful. Also, of interest are time-to-collision and time-to-line crossing, although hardware for readily measuring them in real time is not available. Of lesser utility are workload estimates (SWAT, TLX). Secondary task measures and physiological measures are very weak predictors of safety and usability.
>
> To assess usability, application-specific measures (e.g., the number of wrong turns made in using a navigation system) should be collected.

[17]Green, P. (1995). Suggested Procedures and Acceptance Limits for Assessing the Safety and Ease of Use of Driver Information Systems. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-089).

> This report (1) identifies measures of the safety and east of use of driver information systems, (2) describes test protocols for assessing safety and ease of use, and (3) identifies levels of acceptance. Only the driver interface is considered not system safety considerations. Two protocols are described: an initial on-road test to access the basic interface, and follow-on surveys at driver licensing offices after only small changes are made to the interface. The on-road test involves use of an instrumented car. From the data collected, measures of the standard deviation of lane position mean speed, speed variance, the number and duration of eye fixations, and interface-specific performance measures (e.g. the number of turn error) can be obtained. For each measure, three levels of acceptance are specified: best expected, desired/planned, and worst case.

The measures listed above should be viewed as suggestions only. Normative data on driver performance are lacking, and the validity of the test protocols has yet to be established. There are also concerns about these procedures not being cost effective.

[18]Green, P., (edited by D. Boehm-Davis), (1995). Human Factors of In-Vehicle Driver Information Systems: An Executive Summary. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-014).

This report summarizes a multi year program concerning driver interfaces for future cars. The goals were to develop (1) human Factors guidelines, (2) methods for testing safety and ease of use, and (3) a model that predicts human performance with these systems. After reviewing the human factors literature, focus groups were conducted to assess driver attitudes towards new information systems. Next, the extent to which these systems might reduce traffic accidents, improve traffic operations, and satisfy driver needs and wants was examined. Based on that effort and contract requirements, five functions were selected for further evaluation - route guidance, traffic information, road hazard warning, cellular phone, and vehicle monitoring. For each system, experiments were conducted at a licensing office, involving 20 to 75 drivers, to determine preferred display formats. They were followed by a static on-road test of the road hazard warning system, driving simulator experiments for the phone, traffic information, and navigation systems, a response-time experiment examining navigation displays, and a videotape-based experiment concerning navigation and traffic information. Finally, three on-road experiments were conducted using an instrumented car. From this research, tentative standard test protocols and measures were recommended, guidelines were written, and a human performance model was developed.

[19]Green, P., Levison, W., Paelke, G., and Serafin, C. (1995). Preliminary Human Factors Design Guidelines for Driver Information Systems. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-087).

This document is written for the designers of IVHS-related driver information systems. It describes how to make those systems safe and easy to use for ordinary drivers. These guidelines are based on experimental work carried out as part of this project, the literature, and the authors' human factors experience.

This document includes a description of its objectives, general design principles, and guidelines for the design of manual controls, spoken input, visual displays, auditory displays, destination entry, visual displays for navigation, auditory displays for navigation, traffic information, car phones, vehicle monitoring, IVSAWS (a hazard warning system), interface integration, as well as an extensive reference section. For most guidelines, a commentary and examples of how they should be applied are provided. These guidelines should be viewed as preliminary.

[20]Levison, W., and Cramer, N. (1995). Description of the Integrated Driver Model. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-092).

> A simulation model for predicting driver behavior and system performance when the automobile driver performs concurrent steering and auxiliary in-vehicle tasks is described. This model is an integration of two previously existing computerized models referred to as the "procedural model" and the "driver/vehicle model". The procedural component deals primarily with in-vehicle tasks and with the task-selection and attention-allocation procedures, whereas the driver/vehicle component predicts closed-loop continuous control (steering) behavior. Given descriptions of the driving environment and of driver information-processing limitations, the resulting integrated model allows one to predict a variety of performance measures for typical scenarios. These measures include time histories for vehicle state variables such as lane position and steering wheel deflection as well as allocation of visual and cognitive attention. Model calibration and validation are discussed, and use of the model in analyzing complex task situations and in generating human factors guidelines is demonstrated.

Contract Number: DTFH61-91-C-00106, Science Applications International Corporation

[21]Dingus, T., McGehee, D., Hulse, M., Jahns, S., Manakkal, N., Mollenhauer, M., and Fleischman, R. (1995). TravTek Evaluation Task C_3 - Camera Car Study. Washington, DC: US Department of Transportation, Federal Highway Administration (FHWA-RD-94-076).

> The goal of the TravTek Camera Car Study was to furnish a detailed evaluation of driving and navigation performance, system usability, and safety for the TravTek system. To achieve this goal, an instrumented "camera car" was developed to provide comprehensive driving performance and behavior measurement capability. Six navigation test configurations were evaluated in the camera car study. These included: (1) TravTek route-map display, (2) TravTek route-map display with supplementary voice guidance, (3) TravTek symbolic guidance-map display, (4) TravTek symbolic guidance-map display with supplementary guidance, (5) Paper map, and (6) Paper textual direction list.
>
> A primary finding of this research was that turn-by-turn guidance information (whether presented verbally, in a textual list or by a graphic display) enhances the performance, usability, and/or safety when compared with alternatives, which provide holistic route information. For this study, the TravTek turn-by-turn with voice condition and a paper direction list (with a large legible font and similar in layout to a computer generated list found at some rental-car counters) provided the best overall performance. The TravTek turn-by-turn without voice and route-map with voice conditions were comparable in many respects to these conditions, but did not perform as well with respect to driving performance and safety-related driver error. In contrast, the TravTek route-map without

voice had the greatest overall impact on the driving task and was the least safe of all the navigation conditions tested. However, these safety differences are mitigated by user experience, and by driver selection of other available options (as shown in other TravTek studies). The paper may control condition was the lease usable means of navigation in the study and resulted in substantially worse navigation performance than any other condition.

[22]Inman, V., Sanchez, R. , Porter, C, and Bernstein, L. (1995). TRAVTEK Evaluation yoked Driver Study. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-139).

The Yoked Driver Study was 1 of 12 investigations conducted as part of the TravTek operational test of an advanced traveler information and traffic management system (ATIS/ATMS). The TravTek system consisted of the Orlando Traffic Management Center (TMC), the TravTek vehicles, and the TravTek Information and Services Center. The TMC broadcast updated travel times for TravTek traffic links to the TravTek vehicles once each minute. The TravTek vehicles broadcast their completed link travel times back to the TMC for transmission to the other TravTek vehicles. The vehicles were equipped to provide route planning, route guidance, and a data base of local services and attractions.

The primary purpose of the Yoked Driver Study was to evaluate the value of real-time traffic information, route planning, and route guidance to (a) trip efficiency, (b) navigation performance, and (c) driving performance. The study also examined willingness-to-pay, user perceptions of the system, and user recommendations. A controlled experiment was conducted in which sets of three TravTek vehicles traveled between selected origins and destinations during peak afternoon traffic. Each of the three vehicles was configured differently: one provided route planning and route guidance that utilized real-time traffic information. A second provided the same route planning and route guidance except that it did not utilize real-time traffic information. The third required that drivers plan the trip and navigate “as they normally would.” A total of 222 volunteer drivers participated in the experiment.

TravTek benefits to individual drivers included a travel time saving and a reduction in perceived workload. Real-time traffic information produced a network trip efficiency by routing many of TravTek vehicles that received it onto arterials. Although vehicles that received real-time information tended to travel farther, and to travel farther on lower class roadways, they did not have significantly longer travel times. User perception and performance data suggest that the system was easy to learn and easy to use. Participants in this study indicated that they would be willing to pay about $1000 for a system such as the one they drove.

[23]Perez, W., Van Aerde, M., Rakha, H., and Robinson, M. (1995). TravTek Evaluation Safety Study. Washington, DC: US Department of Transportation, Federal Highway Administration (FHWA-RD-95-188).

> One of the major evaluation goals of the TravTek operational test was to assess the safety impact of the TravTek system as implemented in Orlando, FL during the 1-year deployment phase. Also, the results of the TravTek operational test, with respect to safety, were to be used to estimate the potential safety impact of a TravTek-like system under levels of high market penetration.

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[24]Anonymous (1995). Driver Reaction to Unreliable Traffic Information. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-128).

Contract Number: DTFH61-94-C-00003, Prime Contractor: Science Applications International Corporation

[25]Wochinger, K. and Boehm-Davis, D. (1995). Spatial Ability And Advanced Traveler Information System Route Guidance. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-125).

> The objectives of this study were to determine whether an ATIS route guidance system was likely to enhance route-following performance for older drivers and drivers having lower spatial ability; and whether an ATIS route guidance system was a better navigational aid than traditional aids such as paper maps and text directions. The measures of spatial ability predicted the accuracy of navigational decisions, such that drivers with higher spatial ability made more correct decisions than did drivers with lower spatial ability. Also, compared to the younger drivers, older drivers performed worse on the spatial ability measures, made more incorrect navigational decisions, and took longer to decide which way the car should turn. The differences in spatial ability between the older and younger drivers partly explained their differences in navigational accuracy. The ATIS route guidance system led to the best navigational performance for drivers of all ages, of both genders, and of high or low spatial ability. Not only did the drivers perform better when using the ATIS route guidance system, but they preferred to use it.

[26]Wochinger, K. and Boehm-Davis, D. (1995). The Effects of Age, Spatial Ability, and Navigational Information on Navigational Performance. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-166).

The purpose of the study reported here was to examine whether age and spatial ability are factors that influence a driver's ability to navigate and to use navigational displays. These factors were examined because previous research suggests that spatial ability may underlie navigational performance, including route following and map reading, and that these skills may diminish with age. Thus older drivers and drivers with weak navigational skills, may have a heightened need for, and be particularly served by, in-vehicle route guidance displays found in Advanced Traveler Information Systems (ATIS).

A total of 56 drivers were tested on spatial ability. The drivers then performed a navigational task in a part-task driving simulator using different navigational aids, including: (1) text directions, (2) an enlarged, mounted paper may, (3) a standard-scale paper map, and (4) a turn-by-turn route guidance ATIS display. The major findings were that: (1) older drivers showed worse navigational performance than younger drivers, (2) the worse performance found in the older group was attributable to their lower spatial ability, (3) spatial ability predicted navigational performance, and (4) a simulated ATIS turn-by turn display enhanced navigational performance. The implications of the results are that navigational ability declines with age due to decrements in spatial ability and perceptual speed, and ATIS route guidance has the potential to facilitate navigational performance in drivers of varying spatial abilities and age.

1995-Open Literature

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[27]Campbell, J.L. (1995). Development of Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS). Proceedings of the 1995 Pacific Rim TransTech Conference in Association with the Sixth Annual International Conference on Vehicular Navigation and Information Systems (VNIS95), pp. 161-164. Piscataway, NJ: IEEE.

[28]Campbell, J.L., Kantowitz, B.H., and Hanowski, R.J. (1995). Human Factors Design of In-vehicle Traveler Information Systems. Proceedings of the Second World Congress on Intelligent Transport Systems, 1995, pp. 1721-1726. Yokohama, Japan: Intelligent Transportation Systems.

[29]Campbell, J.L., Kinghorn, R.A., and Kantowitz, B.H. (1995). Driver Acceptance of System Features in an Advanced Traveler Information System (ATIS). Proceedings of the ITS 1995 Annual Meeting, 2, pp. 967-973. Washington DC: ITS AMERICA

[30]Kantowitz, B.H., Hanowski, R.J., and Kantowitz, S.C. (1995). Driver Reactions to Unreliable Traffic Information. Proceedings of the ITE 65th Annual Meeting, 1995, pp. 673-676. Washington DC: Institute of Transportation Engineers.

[31]Kantowitz, S.C., Kantowitz, B.H., and Hanowski, R.J. (1995). The Battelle Route Guidance Simulator: a Low-cost Tool for Studying Driver Response to Advanced Navigation Systems. Proceedings of the Sixth Annual International Conference on Vehicular Navigation and Information Systems (VNISÃ95), pp. 104-109. Piscataway, NJ: IEEE.

[32]Kinghorn, R.A. (1995). A Comparison of Two Models to Predict Driver Acceptance of Traveler Information Systems. In A.C. Bittner, Jr., and P.C. Champney (Eds.), Advances in Industrial Ergonomics and Safety VII, pp. 639-646. London: Taylor & Francis.

[33]Kinghorn, R.A., and Bittner, A.C., Jr. (1995). Truck Driver Anthropometric Data: Estimating the Current Population. International Journal of Industrial Ergonomics, 15, pp. 199-204.

1996

Contract Number?

[34]Anonymous (1996). Presenting Hazard Warning Information to Drivers Using an Advanced Traveler Information System. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-183).

> This summary presents some key results of a project to develop a precise and detailed set of preliminary human factors design guidelines for ATIS and Commercial Vehicle Operations devices. A key subsystem of ATIS will be the In-Vehicle Safety Advisory and Warning Systems, which will provide warnings of unsafe roadway conditions and situations affecting the driver. Some recommendations for presenting hazard warning information to drivers by means of an ATIS are presented.

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[35]Clarke, D.L., McCauley, M.E., Sharkey, T.J., Dingus, T.A., and Lee, J.D. (1996). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: Comparable Systems Analysis. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-197).

> A comparable systems analysis was performed on seven systems selected for their relevance to the features and functions of the Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) components of the lntelligent Transportation Systems (ITS) program. The seven systems were selected for their

relevance to ATIS/CVO concepts, user time-sharing characteristics, technology level, dynamics of information flow, level of implementation, and accessibility. Five of the systems were highway transportation or CVO in-vehicle information systems, two were comparable systems featuring advanced navigation and decision aiding in Army aviation. Analyses of the seven systems resulted in human factors lessons learned. The lessons learned were compiled into preliminary human factors design guidelines for ATIS/CVO.

[36]Dingus, T.A., Hulse, M.C., Jahns, S.K., Alves-Foss, J., Confer, S., Rice, A., Roberts, I., Hanowski, R.J., and Sorenson, D. (1996). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: Literature Review. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-153).

This report documents the initial stage (i.e., Task A) of the project whose goal to develop human factors guidelines for the design of ATIS and CVO systems. To achieve this goal, researchers will need to apply existing principles and guidelines to the ATIS/CVO systems and conduct empirical research to fill the gaps in current knowledge. The purpose of Task A was to conduct a literature review of human factors articles associated with ATIS and CVO systems. The articles were reviewed to assess whether existing human factors guidelines were applicable to ATIS systems and to identify research gaps that must be filled to establish comprehensive ATIS guidelines. As with any literature review, Task A served as a foundation for subsequent tasks. To solicit articles, reports, and information, more than 500 letters were mailed to public and private sector organizations and individuals. In addition, numerous computerized databases were searched. Other sources used to procure existing human factors guidelines included existing ATIS/CVO research published in refereed sources, existing ATIS/CVO technical reports, articles describing comparable systems such as aircraft, and existing human factors guideline documents. More than 1,000 articles were collected. The articles were prioritized with respect to the potential value for ATIS/CVO human factors guideline development. Annotated bibliographies were then prepared for approximately 300 of the most relevant articles. These annotations, as well as additional articles, were reviewed in order to prepare this report. In compiling applicable guidelines from these sources, it became apparent that there are literally thousands of guidelines that apply to at least some degree to ATIS/CVO systems. Therefore, an effort was made to prioritize the individual guidelines. Only guidelines that are applicable to ATIS/CVO are included in this report.

The research status of ATIS applied to private vehicles and CVO is mixed. Although private and commercial driver applications are relatively new, both already are involved in large-scale operational test programs. Several projects have advanced to the demonstration project stage; yet, basic aspects of ITS are still being defined. The Intelligent Transportation Society of America, tasked with advising the government on the development of ITS in the U.S., has outlined the development process of ITS over the next 20 years (Intelligent Vehicle Highway Society of America, 1992b). Despite the relative newness of ITS, a number of human factors ATIS-related issues have been resolved. Data from the initial U.S. operational tests and additional European and Japanese projects are expected to fill some of the important gaps in many human factors research issues still need to be addressed before a comprehensive set of guidelines can be developed.

[37]McCallum, M.C., Lee, J., Sanquist, T., and Wheeler, W.A. (1996). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: ATIS and CVO Development Objectives and Performance Requirements. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-109).

This working paper documents Task B of the present project, Identify Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) System Objectives and Performances Requirements. The goal of Task B is to define the transportation community's current conceptualization of ATIS and CVO, providing a baseline of information for subsequent tasks. Information was obtained from a literature review, conducted as the first task of the project, and by interviewing and surveying government and private representatives of the ATIS and CVO development community. The results of this report have supported subsequent project tasks by: (1) Providing basic information regarding the range of operational capabilities to be included in ATIS and CVO systems for use in the more specific definition of system functions and features during the conduct of Task C, Defined Functions. (2) Providing a survey of ATIS and CVO systems currently developed, or under development, in support of Task D, Comparable Systems Analysis. (3) Providing a preliminary set of ATIS and CVO scenarios that can be further elaborated during the conduct of Task E, Task Analysis. (4) Providing a summary of performance requirements currently identified by the transportation community for subsequent incorporation in project research (Tasks H, K, and M)

[38]Wheeler, W.A., Lee, J., Raby, M., Kinghorn, A., Bittner, A.C., and McCallum, M.C. (1996). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: Task Analysis of ATIS/CVO Functions. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-176).

1996-Open Literature

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[39]Campbell, J.L. (1996). The Development of Human Factors Design Guidelines. International Journal of Industrial Ergonomics, 18 (5-6), pp. 363-371.

[40]Hanowski, R.J., Kantowitz, S.C., and Kantowitz, B.H. (1996). Driver Memory for In-Vehicle Advanced Traveler Information System Messages [Abstract]. In Final Program of the Symposium on Night Visibility and Driver Behavior, 1996, presented by the Transportation Research Board and National Research Council, Iowa City, Iowa.

[41]Kantowitz, B.H., Granda, T.M., Moyer, M.J., and Campbell, J.L. (1996). Using Simulators to Study Driver Response to Advanced In-Vehicle Systems[Abstract]. Proceedings of the Third Annual ITS World Congress, 1996, p.48. Orlando, FL: ITS AMERICA.

1997

Contract Number?

[42]Selk, R. and Underwood, S. (1997). Final Focus Group, Traveler Behavior, Fast-Trac Phase III Deliverable. University of Michigan, Ann Arbor. MI. (#16A Final Focus Group Report, EECS ITS LAB FT 97-001).

> It is important to remember that focus group data are not representative of the general population. These results only describe the experiences of those who participated in the focus groups. The results also describe dominant views, with an attempt to include minor views when relevant. When the results of all five focus groups are combined, the issues of accuracy, traffic information, and coverage area were discussed the most. People also had numerous suggestions for making route guidance better, such that they might purchase such a system. First, for travel in a familiar area, it is largely viewed that the system needs to have traffic information integrated into the routing. People know their daily routes and they vary little; few are willing to pay hundreds of dollars for a system they might use once a month when they are content to use a map on those occasions. But, if you let people know what is ahead of them and provide them a route on which they can avoid congestion and construction, people are interested. However, exactly how interested and how much they would be willing to pay is unknown, and cannot be ascertained with this data set. Another study, part of the ADVANCE OPT in Chicago, also used focus groups to determine people's responses to route guidance and had similar findings. As the conclusion summarizes: The results of this test suggest that familiar drivers know their road network and its recurring congestion patterns. Their route planning criteria are likely to differ from those used by publicly-sanctioned route guidance systems. On the other hand, such drivers show a strong interest in real-time traffic congestion information (Schafer et. al, 1996). Second, for travel in an unfamiliar area, the system must have a much broader area than what is currently in place in Oakland County, Michigan. People want to be able to vacation to Florida or visit family in Chicago, and use a system that provides them with directions. Under these conditions, routing based on traffic conditions is not as necessary, although still popular.

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[43]Dingus, T.A., Hulse, M.C., Jahns, S.K., Alves-Foss, J., Confer, S., Rice, A., Roberts, I., Hanowski, R.J., and Sorenson, D. (1997). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: ATIS/CVO Human Factors Literature Review Supplement. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-190).

This report is a supplement to the literature review, FHWA-RD-95-153. The purpose of the review was twofold: first, to conduct a literature review of human factors-applicable articles associated with Advanced Traveler Information Systems (ATIS) and ATIS-related commercial vehicle operations (CVO) systems and to extract existing human factors guidelines for the development of future ATIS devices, and second to identify areas in which further research available in the open literature. Included in the review are relevant technical ATIS reports, literature from automobile and CVO manufacturers, after-market system development companies, ITS university researchers, government agencies and comments from Europe and Japan. The main body of this supplement report contains a brief summary of over 250 articles found for the literature review. The articles appear alphabetically. Applicability to guideline development and usefulness to future project tasks is indicated for each article. There are two appendices. The first contains each citation, the associated keywords and the page number from the main report. The second is a keyword index.

[44]Hulse, M.C., Dingus, T.A., Mollenhauer, M.A., Liu, Y.C., Jahns, S.K., Brown, T., and McKinney, B. (1997). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: Identification of the Strengths and Weaknesses of Alternate Information Display Formats. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-142).

This report is one of the series produced as part of a contract designed to develop precise, detailed, human factors design guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO). The goals of the work covered in this report were to: (1) identify information format alternatives for ATIS devices for both private drivers and CVO applications and (2) identify research issues that must be addressed in order to develop effective information format guidelines. To achieve these goals, and to make the greatest progress possible toward the ultimate project goal of guideline developments, the project developed the strategy of turning the current sate of knowledge into tools applicable to any ATIS design.

Four primary design-decision tools were developed. These tools were intended to help either professional or nonprofessional human factors designers make appropriate tradeoff decisions in the designing effective ATIS displays. The four tools are (1) Sensory

Modality Allocation, (2) Trip Status Allocation, (3) Display Format Allocation, and (4) Display Location.

[45]James, C., Ehret, B., James, W.S., Philips, B., and Alicandri, E. (1997). The Effects of Display Rotation and Location in an Advanced Traveler Information System (ATIS) Intersection Matching Task. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-97-024).

This experiment compared the performance of rotated to conventional Advanced Traveler Information Systems (ATIS) displays. Rotated and conventional ATIS displays were presented in two locations: Heads-up display (HUD) and instrument panel mounted (IPM). Using a part task-driving simulator, subjects evaluated whether an intersection presented on an ATIS display matched the intersection they were approaching. The results indicated that benefits of rotated displays may be location dependent. Although the results do not clearly indicate an optimal display rotation, the HUD location resulted in improved older driver performance.

[46]Kantowitz, B.H., Lee, J.D., Becker, C.A., Bittner, A.C., Kantowitz, S.C. Hanowski, R.J., Kinghorn, R.A., McCauley, M.E., Sharkey, T.J., McCallum, M.C., and Barlow, S.T. (1997). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: Identify and Explore Driver Acceptance of In-Vehicle ITS Information. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-143).

This document is part of an integrated program to develop human factors guidelines for advanced in-vehicle information systems. This document provides both an analytic and empirical determination of the human factors issues specific to user acceptance of Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operation (CVO) systems. Previous research indicates that Automatic Teller Machine technology has not enjoyed widespread acceptance. Two questionnaires based experiments identified features that drivers find desirable for ATIS systems. The use of a model-based approach for determining drivers' preferred features was also used with success. An experiment using a route guidance simulation that presented real-time video of on-the-road driving scenes, and a map used for route selection and the purchase of traffic information showed that drivers accepted the ATIS information even when only 77 percent accurate. An experiment that addressed CVO function acceptance provides tentative recommendations for the introduction of ATIS systems into commercial vehicles.

[47]Kantowitz, B.H., Lee, J.D., and Kantowitz, S.C. (1997). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicles: Definition and Prioritization of ATIS/CVO Research Studies. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-177).

This report produced a prioritized list of candidate studies and issues that would guide data acquisition in this project. This was accomplished in three steps. First, 91 issues were compiled from earlier research in this effort. Second, a set of 14 criteria, 9 substantive and 5 methodological, were defined. Eight experienced human factors experts completed all 2,184 cells in a rating matrix for a total of 17,472 rating entries in the data set. Third, a linear psychometric model was used to prioritize the 91 issues. The model was validated by sending the raters three short prioritized lists, one of which was (unknown to the raters) a stratified random sample of studies and issues. Raters were asked to delete unimportant and impractical research issues from these lists. They deleted significantly more items from the random list. The nine most vital studies/issues from the final prioritized list are: cognitive demands in transitioning across ATIS functions, complex interactions among ATIS functions, how ISIS and IVSAWS information influences behavior, effects of low information reliability, displaying multiple messages, features requiring standardization, single versus multiple display channels, multi modal displays, and effects of display modality and format on CVO driver workload. The key human factors issues listed here must be addressed to assure in-vehicle information systems are a safe and usable components of ITS.

[48]Lee, J. D., Morgan J., Wheeler, W. A., Hulse, M. C., and Dingus, T. (1997). Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations Components of' the Intelligent Transportation Systems: Description of' ATIS/CVO Functions. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-201).

This report analyzes the functional elements of ATIS/CVO systems in the context of the Intelligent Transportation Systems (ITS) goals (reduced congestion, improved environment, enhanced mobility, increased economic productivity, and increased safety) and driver capabilities and requirements. The functional description examines how system functions need to operate to meet the objectives and performance requirement of ATIS/CVO systems. In this context, functions are defined as generic processes or mechanisms required to achieve system objectives and are independent of the description of the physical aspects of the system. Because a many-to-many mapping exists between functions and the physical system, a variety of mechanisms could be used to implement functions. Thus, the functional description provides a link between the specific, physical implementations and the overall system objectives. Since the drivers, dispatcher, regulators, and managers represent system elements integral to ATIS/CVO functions, this description considers how their attitudes; knowledge; and perceptual, motor, and decision-making limits might compromise system functions and objectives. In this way, the functional description provides a common language that links an engineering description of ATIS/CVO systems with a psychological description of the driver's role within ATIS/CVO systems. Future research in this project will build upon this functional description to help identify driver and system characteristics for further investigation, develop a catalog of human limits with similar technology, and help develop a framework for translating these findings into design guidelines.

1997-Open Literature

Contract Number: DTFH61-92-C-00102, Prime Contractor: Battelle Human Factors Transportation Center

[49]Campbell, J.L., Moyer, M.J., Granda, T.M., Kantowitz, B.H., Hooey, B., & Lee, J.D. (1997). Applying Human Factors Tools for ITS Research. Proceedings of the Society of Automotive Engineers Future Transportation Technology Conference, 1997, Warrendale, PA: Society of Automotive Engineers.

[50]Granda, T.M., Moyer, M.J., Hanowski, R.J., and Kantowitz, B.H. (1997). Older Driver ATIS Guidelines. Proceedings of the American Society of Civil Engineers, Traffic Congestion and Traffic Safety in the 21st Century: Challenges, Innovations, and Opportunities, 1997, American Society of Civil Engineers: NewYork.

[51]Kantowitz, B.H., Hanowski, R.J., and Kantowitz, S.C. (1997). Driver Acceptance of Unreliable Traffic Information in Familiar and Unfamiliar Settings. Human Factors, 39, pp. 164-176.

[52]Kantowitz, B.H., Hanowski, R.J., and Kantowitz, S.C. (1997). Driver Reliability Requirements for Traffic Advisory Information. In I. Noy (Ed.), Ergonomics of Intelligent Vehicle Highway Systems, pp. 1-22. Mahwah, NJ: Lawrence Erlbaum Associates.

[53]Lee, J.D. (1997). A Functional Description of ATIS/CVO Systems to Guide and Accommodate Driver Needs and Limits. In I. Noy (Ed.), Ergonomics of Intelligent Vehicle Highway Systems, pp. 63-84. Mahwah, NJ: Lawrence Erlbaum Associates.

[54]Lee, J.D., and Kantowitz, B.H. (1997). Perceptual and Cognitive Aspects of Intelligent Vehicle Highway Systems (IVHS). In W. Barfield & T. Dingus (Eds.), Human Factors in Intelligent Vehicle Highway Systems (IVHS). Hillsdale, NJ: Lawrence Erlbaum Associates.

[55]Wheeler, W.A., Campbell, J.L., and Kinghorn, R.A. (1997). Commercial Vehicle Operations. In W. Barfield & T. Dingus (Eds.), Human Factors in Intelligent Vehicle Highway Systems (IVHS). Hillsdale, NJ: Lawrence Erlbaum Associates.

[56]Wochinger, K. and Boehm-Davis, D. (1997). Navigational Preference and Driver Acceptance of Advanced Traveler Information Systems (ATIS). In Ian Noy (Ed.) Ergonomics and Safety of Intelligent Driver Interfaces. Hillsdale, NJ: Lawrence Erlbaum Associates.

[57]Wochinger, K., Philips, B., and Boehm-Davis, D. (1997). The Effects of Spatial Scanning Ability, Perceptual Speed, Age, and Navigation Aid on Navigation Performance. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, 1997, pp. 1013-1017. Albuquerque, NM: Human Factors & Ergonomics Society.

1998

Contract Number?

[58]Anonymous (1998). Summary Report: Advanced Traveler Information System Capabilities: Human Factors Research Needs. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-186).

> As part of the U.S. Department of Transportation's Intelligent Vehicle Initiative (IVI) program, the Federal Highway Administration investigated the human factors research needs for integrating in-vehicle safety and driver information technologies into usable systems that provide manageable information to the driver. This investigation included a workshop in December 1997 for IVI stakeholders (i.e., universities, automotive manufacturers, vendors, and contractors) and a preliminary assessment of infrastructure and in-vehicle requirements. This flyer summarizes the identified human factors research needs for advanced traveler information system (ATIS) capabilities, one of five configurations of in-vehicle safety and driver information systems. A complete review of the research needs for all five configurations can be found in the final report (FHWA-RD-98-178). These configurations were developed based on: (1) identified safety and driver information systems and functions, (2) a thorough literature review of past research and research gaps related to these in-vehicle systems, and (3) combining logical groups of basic and advanced safety and driver information functions in passenger cars, commercial trucks, and transit vehicles such as buses. Each candidate configuration was meant to provide clear safety benefits to the driver as well as a solid technical foundation for the system configurations for the IVI. The goal of the configuration described below is to provide ATIS capabilities and basic collision warning to the three vehicle types.

Contract Number: DTFH61-92-C-00102, Battelle Human Factors Transportation Center

[59]Campbell, J.L., Carney, C., and Kantowitz, B.H. (1998). Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operation (ATIS/CVO). Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-057).

> Significant advances in electronics and micro computing during the past few decades have led to the feasibility of a functionally powerful, computer-based ATIS as part of the automotive environment. Although these systems range in functionality, they all have the goal of acquiring, analyzing, communicating, and presenting information to assist travelers in moving from a starting location to a desired destination. While systems under development or in production promise to improve travel safety, efficiency, and comfort, they represent a new frontier in ground transportation. This handbook is intended to address a growing information gap between the advanced and diverse status of automotive technologies such as ATIS devices, and the availability of human factors design criteria that can be used during the system design process. Specifically, while ATIS and CVO systems offer great potential benefits, their effectiveness depends on driver acceptance of the new technology, the ability of the systems to integrate the information with other driving tasks, and the extent to which the systems conform to driver physical and cognitive limitations and capabilities. The handbook summarizes human engineering data, guidelines, and principles for use by creative designers, engineers and human factors practitioners during the ATIS design process. These summaries take the form of design guidelines for 75 distinct ATIS design parameters. These design guidelines are intended to: (1) be concise, (2) be unambiguous, (3) be traceable to specific references, where applicable, and (4) highlight implications for driver performance, where appropriate.

1998-Open Literature

<u>NHTSA</u>

N/A

Automated Highway System (AHS):

FHWA

1993

1993-Open Literature

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[1]Bloomfield, J.R., and Buck, J.R. (1993). The Effects of Headway, Velocity, and Traffic Density on the Transfer of Control from System to Driver in the Automated Highway System. Paper presented at the Fifth International Conference on Vision in Vehicles, University of Glasgow, 9-11 September, 1993.

[2]Bloomfield, J.R., Buck, J.R., and Plocher, T. (1993). Human Factors Considerations in the Transfer of Control from System to Driver in the Automated Highway System. Paper presented at the Fifth International Conference on Vision in Vehicles, University of Glasgow, 9-11 September,1993.

[3]Buck, J.R., Stoner, J., Bloomfield, J.R., and Plocher, T. (1993). Driving Research and the Iowa Driving Simulator. In: E. J. Lovesey (Ed.), Contemporary Ergonomics 1993, pp. 392-396, Taylor and Francis, London.

1994

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[4]Tsao, H.S., Hall, R.W., Shladover, S.E., Plocher, T.A., and Levitan, L.J. (1994). Human Factors Design of AHS: First Generation Scenarios. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-123).

> Attention to driver acceptance and performance issues during design will be key to the success of the Automated Highway System (AHS). A first step in the process of defining driver roles and river-system interface requirements for AHS is the definition of system visions and operational scenarios. These scenarios then become the basis for first identifying driver functions and information requirements, and later, designing the driver’s interface to the AHS. In addition, the scenarios provide a framework within which variables that potentially impact the driver can be explored systematically.

Seven AHS operational scenarios, each describing a different AHS vision, were defined by varying three system dimensions with special significance for the driver. These three dimensions are 1) the degree to which automated and manual traffic is separated, 2) the rules for vehicle following and spacing, and 3) the level of automation traffic flow control. The seven scenarios vary in the complexity of the automated and manual driving maneuvers required, the physical space allowed for maneuvers, and the nature of the resulting demands placed on the driver. Each scenario describes the physical configuration of the system, operational events from entry to exit, and high-level driver functions.

1994-Open Literature

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[5]Bloomfield, J.R. (1994). Automated Highway System (AHS) Human Factors Experiments. Paper presented at the Automated Highway System Precursor Analysis Conference, Chantilly, Virginia, 16-18 November 1994.

[6]Bloomfield, J.R. (1994). Investigating Human Factors Aspects of the Automated Highway System with the Iowa Driving Simulator. Paper presented at IMAGE VII Conference, 12-17 June, 1994.

[7]Bloomfield, J.R., Buck, J.R., and Carroll, S.A. (1994). The Feasibility of an Automated Highway System with the Automated and Unautomated Lanes Adjacent to Each Other, with No Intervening Transition Lane or Barriers. Paper presented at the Ergonomics Society Annual Conference, University of Warwick, Coventry, England, 19-22 April 1994.

[8]Buck, J.R., Yenamandra, A., and Bloomfield, J.R. (1994). Ergonomic Issues Related to Vehicle Entry into an Automated Highway System. Paper presented at the International Ergonomic Association Conference in Toronto, Canada, 15-17 August 1994.

1995

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[9]Anonymous (1995). Human Factors Design of Automated Highway Systems: Scenario Definition, Summary Report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-192).

Attention to driver acceptance and performance issues during system design will be key to the success of the Automated Highway System (AHS). A first step in the process of defining driver roles and driver-system interface requirements of AHS is the definition of system visions and operational scenarios. Seven operational AHS scenarios were defined, six of which were differentiated by varying three key dimensions: (1) degree to which automated and manual traffic is separated; (2) degree to which automated lanes are separated from one another; and (3) vehicle-following rules (e.g., groups versus individual vehicles). The first scenario (free agent/self-contained) describes a transitional AHS vision representing an intermediate stage of complexity and technology between current highway practices and full automation scenarios. The scenarios are:

1. Free agent/self-contained.
2. No barriers on the highway with individual vehicles.
3. No barriers on the highway with grouped vehicles.
4. Barriers on the highway with individual vehicles.
5. Barriers on the highway with grouped vehicles.
6. Segregated highway with individual vehicles.
7. Segregated highway with grouped vehicles.

The seven scenarios vary in the complexity of the automated and manual maneuvers required, the physical space allowed for maneuvers, and the nature of the resulting demands on the driver.

[10]Bloomfield, J.R., Buck, J.R., Caroll, S.A., Booth, M.S., Romano, R.A., McGehee, D.V. and North, R.A. (1995). Human Factors Aspects of the Transfer of Control From the Automated Highway System to the Driver. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. (FHWA-RD-94-114).

The first two experiments in a series exploring human factors issues related to the Automated Highway system (AHS) used a generic AHS configuration-the left lane reserved for automated vehicles, the center and right lanes containing unautomated vehicles, no transition lane, and no barriers between the automated and unautomated lanes-that was simulated in the Iowa Driving Simulator (IDS). The IDS has a moving base hexapod platform containing a mid-sized sedan. Imagery was projected onto a 3.35-rad (1808) screen in front of the driver, and onto a 1.13-rad (608) screen to the rear. Thirty-six drivers between the ages of 25 and 34 years participated in the first experiment; 24 drivers who were age 65 or older took part in the second. Both experiments explored the transfer of control from the AHS to the driver when the driver's task was to leave the automated lane. The driver, who was traveling under automated control in a string of vehicles in the automated lane, had to take control, drive from the automated lane into the center lane, and then leave the freeway.

Results: (1) The mean time to respond to an *Exit* advisory decreased from 13.41 s to 10.16 s as the design velocity increased from 104.7 km/h (65 mi/h) to 153.0 km/h (95 mi/h). (2) After the transfer of control, the driver remained in the automated lane, decelerating until the velocity was slow enough to allow a safe transition into the slower traffic in the unautomated lanes. It took longer to decelerate (13.19 s vs. 10.26 s) and the exit velocity dropped {105.30 km/h (65 mi/h) vs. 99.54 km/h (61.83 mi/h)] as the unautomated traffic density decreased from 12.42 v/km/ln (20 v/mi/ln) to 6.21 v/km/ln (10 v/mi/ln). It also took longer to decelerate (15.23 s vs. 8.62 s) and the extent of the deceleration decreased [42.7 km/h (26.49 mi/h) vs. 13.18 km/h (8.16 mi/h)] as the design velocity decreased from 153.0 km/h (95mi/h) to 104.7 km/h (65 mi/h). (3) Once in the unautomated lanes, the younger drivers were in the center lane 70 percent longer that the older drivers. (4) The vehicle immediately behind the driver's vehicle in the automated lane was delayed after control was transferred-the delay increased from 1.36 s to 6.70 s as the design velocity increased from 104.7km/h (65 mi/h) to 153 km/h (95 mi/h). (5) Allowing for the delay times obtained in these experiments, it was determined that the potential capacity of an automated lane should increase from 634.6 v/h to 2087.8 v/h as the design velocity decreased from 153.0 km/h (95 mi/h) to 104.7 km/h (65 mi/h). (6) Collisions and incursions occurred at unacceptable high rates. (7) The responses to the questionnaire that the drivers were receptive to the AHS concept.

[11]Bloomfield, J.R., Buck, J.R., Caroll, S.A., Booth, M.S., Romano, R.A., McGehee, D.V. and North, R.A. (1995). Human Factors in the Automated Highway System: Transferring Control to the Driver. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. (FHWA-RD-95-189).

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, including three levels of automated speeds, three different gaps between automated vehicles, and two levels of traffic density in the unautomated lanes. Empirical results showed that although both young and older 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.

[12]Bloomfield, J.R., Buck, J.R., Carroll, S.A., Booth, M.S., Romano, R.A., McGehee, D.V., and North, R.A. (1995). Human Factors Aspects of the Transfer of Control from AHS to the Driver.

Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-114).

[13]Bloomfield, J.R., Buck, J.R., Christensen, J.M., and Yenamandra, A. (1995). Human Factors Aspects of the Transfer of Control from the Driver to the AHS. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-173).

> The third in a series of experiments exploring human factors issues related to the Automated Highway System (AHS) investigated the transfer of control from the driver of a vehicle entering an automated lane to the AHS. Twenty-four drivers aged between 25 and 34 years drove in the Iowa Driving Simulator-a moving base hexapod platform containing a mid-sized sedan with 3.35-rad (180^0) projection screen to the front and a 1.13-rad (60^0) screen to the rear. The experiment focused on a generic AHS configuration in which the left lane was reserved for automated vehicles, the center and right lanes were reserved for unautomated vehicles, and in which there was no transition lane and no barrier. The driver took the simulator vehicle onto a freeway, moved to the center lane, and the, after receiving an *Enter* command, drove into an automated lane and transferred control to the AHS. The, the AHS moved the vehicle into the lead position of the string of vehicles approaching it from behind.
>
> Results: The entering response time, lane-change time, entering exposure time, and string-joining time, data were used to determine the minimum inter-string gap required to enable the driver's vehicle to enter the automated lane without causing a delay to the string it joins. The required minimum inter-string gap varied with the design velocity and the method of transferring control. With the partially automated transfer method, he required minimum inter-string gap time increased from 1.14s for the 104.7-km/h (65-mi/h) design velocity, through 3.38 s for the 128.8-km/h (80-mi/h) design velocity, to 7.33 s for the 153.0-km/h (95-mi/h) design velocity. The hourly capacity when the design velocity is 104.7 km/h (65mi/h) is likely to be four times greater than when the design velocity is 153.0-km/h (95-mi/h) (the hourly capacity for the latter would be only slightly more than the traffic flow that could be achieved without an AHS). It is not the design velocity of 104.7-km/h (65-mi/h) per se that produces the higher capacity-it is the relatively low velocity differential between the design velocity and the speed limit in the unautomated lanes. If the transfer of control from the driver to the AHS were to occur before the driver moved into the automated lane, the required minimum inter-string gap times should be reduced-a possibility that is being investigated in the next in the experimental series. No collisions occurred, suggesting that the drivers were able to join the automated lane safely-a suggestion reinforced by the responses to a questionnaire indicating that the drivers feels safe and believed they controlled the vehicle well during the entry maneuver.

[14]Bloomfield, J.R., Christensen, J.M., and Carroll, S.A. (1995). The Effect on Normal Driving Behavior after Traveling under Automated Control. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-182).

[15]Levitan, L., Burrus, M., Dewing, W.L., Reinhart, W.F., Vora, P., and Llaneras, R.E. (1995). Preliminary Human Factors Guidelines for Automated Highway System Designers (Volumes I and II). Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-116, FHWA-RD-95-053).

> Human factors are designing to match the capabilities and limitations of the human user. The objectives of this human-centered design process are (1) to maximize the effectiveness and efficiency of system performance, (2) to ensure a high level of safety, and 93) to maximize user acceptance. These objectives are achieved by systematically applying relevant information and principles about human abilities, characteristics, behavior, and limitations to specific design problems. This handbook provides a source document for Automated Highway System (AHS) designers that will facilitate a human-centered design process for the AHS.

1995-Open Literature

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[16]Bloomfield, J.R. (1995). Experimental Investigation of Human Factors and Automated Highway Systems. Paper presented at the Intelligent Transportation Society of America AVCS/Safety and Human Factors Joint Committee Meeting, Iowa City, Iowa, 20 July, 1995.

[17]Bloomfield, J.R. (1995). On the Transfer of Control Between the Driver and the Automated Highway System. Paper presented at the Ergonomics Society Annual Conference, University of Canterbury, Kent, England 4-6 April, 1995.

[18]Bloomfield, J.R., Christensen, J.M., Carroll, S.A., and Watson, G.S. (1995). The Driver's Response to Decreasing Vehicle Separations During Transitions into the Automated Lane. Paper presented at the Sixth International Conference on Vision in Vehicles, University of Derby, Derbyshire, England, 13-16 September, 1995.

[19]Bloomfield, J.R., Christensen, J.M., Peterson, A.D., Kjaer, J.M., and Gault, A. (1995) Transferring Control from the Driver to the Automated Highway System with Varying Degrees of Automation. Paper presented at the Sixth International Conference on Vision in Vehicles, University of Derby, Derbyshire, England, 13-16 September, 1995.

1996

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[20]Bloomfield, J.R., Christensen, J.M., Carrol, S.A., and Watson, G.S. (1996). The Driver's Response to Decreasing Vehicle Separation During Transition into the Automated Lane. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-107).

This experiment is one in a series exploring human factors related to the Automated Highway System (AHS). The comfort level of the driver of the lead vehicle of a string of automated vehicles was determined (a) under normal AHS operating conditions and (b) while a second vehicle was joining the string as the new lead vehicle. The experiment was conducted in the Iowa Driving Simulator. A generic AHS configuration was used-the left lane was reserved for automated vehicles, the center and right lanes contained unautomated vehicles, the center lane was not a dedicated transition lane, there were no barriers between the automated and unautomated lanes. Sixty drivers participated in the experiment-half male, half females; half between the ages of 25 and 34 years, half who were 65 or older. The experiment began with the simulator vehicle leading a string of vehicles in the automated lane-it was controlled by the AHS and traveling at the design velocity. A second vehicle entered the automated lane ahead of the simulator vehicle, traveling at 88.6 km/h (55 mi/h). It began to accelerate and the gap between it and the simulator vehicle decreased. It accelerated until its velocity matched the design velocity-then, it became the new leader of the string of vehicles. While the gap between the entering vehicle and the simulator vehicle was decreasing, the comfort level of the driver was monitored. The experiment determined the effect on the driver's comfort level of varying the design velocity, the inter-string gap, the time at which the second vehicle entered the automated lane, and the age and gender of the driver.

Results: (1) When the simulator vehicle led a string of automated vehicles operating normally, with a fixed inter-string distance between it and the string ahead, positive comfort levels were recorded on 89.9 percent of the trials. (2) Also, when the simulator vehicle led a string of vehicles operating normally, the comfort level varied with the gender of the driver the mean comfort level was higher for male drivers than for female drivers. (3) When a second vehicle entered the automated lane ahead of the simulator vehicle, in 86.2 percent of the trials the comfort level of the drivers decreased. In 71.6 percent of the trials it decreased to a negative comfort level. (4) Also, when a second vehicle entered the automated lane, the comfort level varied with both gender and age-the mean comfort levels were 0.37 for younger males, -0.45 younger females, -0.54 for older males, and -0.71 for older females. (5) There were indications that the sharp decrease in comfort may have been triggered by time to collision estimates, although it does not provide a complete explanation.

[21]Bloomfield, J.R., Christensen, J.M., Peterson, A.D., Kjaer, J.M., and Gault, A. (1996). Human Factors Aspects of Transferring Control from the Driver to the AHS with Varying Degrees of Automation. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-108).

> This experiment is part of a series designed to explore human factors issues related to the Automated Highway System (AHS) that is being conducted using the Iowa Driving Simulator (IDS). The IDS has a moving base hexapod platform containing a mid-sided sedan. Sixty drivers-half between the ages of 25 and 34 years, and half aged 65 or older-drove the simulator vehicle in 6 experimental trials. Imagery was projected onto a 3.35-rad (192^0) screen in front of the driver, and onto a 1.13-rad (65^0) screen to the rear. The experiment focused on a generic AHS configuration in which the left lane was reserved for automated vehicles, the center and right lanes were reserved for unautomated vehicles, and thee was no dedicated transition lane and no barrier between the automated and unautomated lanes. The driver drove onto a freeway and moved to the center lane. Then, in a manual, partially automated, or fully automated manner, the vehicle was moved into the automated lane, control was transferred to the AHS, and the vehicle was positioned at the head of the string of vehicles that were approaching it from behind.
>
> Results: The timing of the entry maneuver is of critical importance-a vehicle that enters the automated lane rapidly will have minimal impact on the efficiency of the AHS. When the fully automated transfer method was used, from the moment that the *Enter* command was issued until the vehicle was completely in the automated lane, the time elapsed was 1.86 s-this was considerably faster than the other two transfer methods which both relied on the driver to move the vehicle into the automated lane. When using the fully automated transfer method, the minimum inter-string gap required for a vehicle to enter the automated lane without delaying the following automated vehicles increased from 0.89s, through 2.81 s, to 6.22s as the design velocity increased from 104.7 km/h (65 mi/h), through 128.8 (80 mi/h), to 153.0 km/h (95 mi/h). Note, it is not the design velocity of 104.7 km/h (65 mi/h) per se that produces the higher traffic flow-rather it is the relatively low velocity differential between the design velocity and the speed limit in the unautomated lanes. There were no collisions in this experiment suggesting that the drivers were able to join the automated lane safely.

[22]Carrol, S.A., Papelis, Y.E., and Bartelme, M.J. (1996). The Driverís Response to an Automated Highway System with Reduced Capability. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-067).

> This experiment, one in a series exploring human factors issues related to the Automated Highway System (AHS), investigated the ability of the driver to deal with reduced capability in an automated highway. Most of the reduced AHS capability segment was on a 735-m (2410-ft) radius curve that veered left. The experiment was conducted the Iowa Driving Simulator. It used a generic AHS configuration in which the left lane was

reserved for automated vehicles, while unautomated vehicles traveled in the center and right lanes. The center lane was not a dedicated transition lane. There were no barriers between the automated and unautomated lanes. Sixty drivers participated in the experiment-half were male, half were female; half were between 25 and 34 years of age, half were age 65 or older. A comparison was made of driving performance when steering was controlled by the AHS (and velocity by the driver), when steering was controlled by the driver (and velocity by the AHS), and when both steering and velocity were controlled by the driver.

Results: (1) Lane-Keeping Performance and Reduced AHS Capability. In the reduced-capability segment, when the driver controlled the steering-whether controlling steering alone or both steering and velocity-the drift across the lane was four time greater, and in a different direction, than when the steering was controlled by the AHS. As the vehicle traveled around the curve, it drifted only 0.16m (0.51ft) to the left when controlled by the AHS. In contrast, it drifted laterally 0.66m (2.17ft) to the right when the driver controlled the steering alone, and 0.77m (2.52 ft) when the driver controlled both the velocity and the steering. When it reached the end of the curve, the vehicle had overshot the center of the lane by 0.56m (1.83ft) and 9.86m (2.81 ft), respectively, under these two conditions. Also, there was more steering instability when the steering was controlled by the driver. (2) Lane-Keeping Performance and Designated AHS Velocity. Whether the AHS or driver was controlling the steering, the vehicle was harder to steer when the designated AHS velocity was 153.0 km/h (95 mi/h) than when it was 128.8 km/h (80 mi/h)-both the steering drift and the steering instability increased substantially with velocity. (3) Velocity Control and Reduced AHS Capability. The time delay was zero when the AHS controlled velocity (and the driver was steering). When the driver controlled the velocity, the vehicle traveled slower: (a) when he/she controlled both velocity and steering rather than velocity alone; (b) with the older driver rather than the yonder driver; (c) when the designated AHS velocity was 128.8 km/h (80 mi/h) rather than 153.0 km/h (95 mi/h); and (d) when the intra-string gap was 0.25 s rather than 0.0625 s.

Recommendations: If the situation explored in this experiment was allowed in an operating AHS, with adequate warning, the driver could take over the steering and/or velocity if there was a reduction in the AHS capability. However, if this was to occur, to avoid the possibility of encroaching into the center lane and threatening the traffic in it, the driver should be encouraged to reduce speed and warned about a possible overshoot. In addition, the lane width should not be reduced from the current standard of 3.66 m (12 ft).

[23]Levitan, L. (1996). Human Factors Design of AHS: Stage I Interim Report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-110).

[24]Levitan, L., and Bloomfield, J. (1996). Drivers' Activities and Information Needs in an AHS.

Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-066).

These experiments investigated what drivers do when traveling under automated control, and what information they would like to have available during that time. Eighteen drivers ages 25-34 and 18 drivers age 65 or older participated in the first two experiments; 6 drivers participated in the third experiment. All experiments were conducted in the Iowa Driving Simulator. The driver drove the simulator vehicle onto a freeway and then moved to the center lane; following a period of manual driving, control was transferred to the AHS, and the driver traveled under automated control for at least 34 min. In the first two experiments, which were run together and consisted of a single trial for each driver, driver activities were videotaped for later analysis. In addition, a laptop computer was mounted near the driver that offered several types of information. Drivers were given a questionnaire after the experiment to allow ratings of and comments on the various information types. In the third experiment, each driver participated in eight trials, once each in the morning and afternoon on 4 days, simulating a commuter experience. Driver activities were again videotape for later analysis, but there was no laptop computer available.

Results: In the two noncommuter experiments, drivers undertook a variety of activities, though despite pre-experiment encouragement to do so, almost no one brought any materials with them. Thus, the activities included such things as reading the strip map that was in the car, talking to the experiment, adjusting the radio, and so on. The most frequent activity was using the laptop computer. A third of the drivers closed their eyes at least once for 5 or more consecutive seconds, with average of 5.7 and 7.1 time for males and females, respectively. Regarding the information available on the laptop computer, drivers found information about the next exit to be least useful. Information about the driver's current location and the traffic ahead were more useful than next exit information. And information about time to the destination was selected significantly more frequently than the other three types of information. Drivers offered several suggestions for additional information they would like to have available during a trip on the AHS. In the commuter experiment, it was noted, however, that only two drivers brought something to do on the next-to last trial, a somewhat surprising result in light of the fact the drivers clearly knew by then that they would have almost half an hour during which they did not have any driving-related responsibilities.

1996-Open Literature

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[25]Bloomfield, J.R. and Carroll, S.A. (1996). New Measures of Driving Performance. In Robertson, S.A. (Ed.) Contemporary Ergonomics 1996, pp. 335-340, Taylor and Francis, London.

1997

1997-Open Literature

Contract Number: DTFH61-89-C-00100, Prime Contractor: Honeywell Inc.

[26]Levitan, L., and Bloomfield, J.R. (1997). Human Factors Design of Automated Highway Systems. In Barfield, W., and Dingus, T. (Eds) Human Factors Considerations In Intelligent Transportation Systems. Lawrence Erlbaum Associates, Hillsdale, N.J.

1998

Contract Number: DTFH61-92-C-00100, Prime Contractor: Honeywell Inc.

[27]Bloomfield, J.R., Levitan, L., Grant, A.R., Brown, T.L., and Hankey, J.M. (1998) Driving Performance After an Extended Period of Travel in an Automated Highway System. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-051).

> The objective of this experiment-part of a series exploring human factors issues related to the Automated Highway System (AHS)-was to determine whether driving performance would be affected by extended travel under automated control at a velocity higher than the speed limit and closer to the vehicles ahead than usual. The experiment, conducted in the Iowa Driving Simulator, used a generic AHS configuration in which the left lane was reserved for automated vehicles. Unautomated vehicles traveled in the center and right lanes, the center lane was not a dedicated transition lane, and there were no barriers between the automated and unautomated lanes. Forty-eight drivers participated in the experiment-half were male, half were female; half were between the ages of 25 and 34 years, half aged 65 or older. Lane-keeping, speed control, following distance, lane-change, and incursion measures were used to compare driving performance before and after the drivers had traveled under automated control. Results: (1) While it is not clear whether the experience of traveling under automated control produced tie reductions in steering instability and velocity instability and the increased number of velocity fluctuations-all of which can be considered as improvements in driving performance that were found for the drivers in the experimental group in the late data-collection-period (since similar improvements were found for the drivers in the control group), it is clear that the experience of traveling under automated control did not have an adverse affect on lane keeping and speed control. (2) The minimum following distance and the minimum size of the rejected incursion gaps may have decreased for the drivers who traveled under automated control for an extended period of time, and they spent more

time in the center lane both before and after they traveled under automated control. (3) The drivers who traveled under automated control expressed a preference for larger intra-string gaps than those that they experienced in this experiment. The drivers who were given control of both steering and speed simultaneously gave a significantly stronger positive response, when asked how they felt about the method of control transfer they used, than the drivers who first had to control speed, and then subsequently steering. (4) The smallest gaps for lane changes and incursions were similar-suggesting the minimum gap acceptable for a lane change is between 1.6s and 2.4s.

[28]Levitan, A.L., Bunus, M., Dewing, W.L., Reinhart, W.F., Vora, P. and Llaneras, R.E. (1998). Preliminary Human Factors Guidelines for Automated Highway System Designers (Second Edition), Volume I: Guidelines for AHS Designers. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-97-125).

Human factors can be defined as "designing to match the capabilities and limitations of the human user." The objectives of this human-centered design process are to maximize the effectiveness and efficiency of system performance, ensure a high level of safety, and maximize user acceptance. These objectives are achieved by systematically applying relevant information and principles about human abilities, characteristics, behavior, and limitations to specific design problems. This handbook provides a source document for automated highway system (AHS) designers that will facilitate a human-centered design process for the AHS. It is the second edition of these guidelines (first edition is report RD-94-116) and includes the addition of key AHS attributes proposed by the National Automated Highway System Consortium, updates to the chapter on general guidelines for electronic visual displays, and the addition of several operational guidelines (chapter 10).

1998-Open Literature

<u>NHTSA</u>

1994

1994-Open Literature

1995

1995-Open Literature

1996

Contract Number?

[29]Stoll, D.A., and Bourne, S. (1996). The National Advanced Driving Simulator: Potential Applications to ITS and AHS Research. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

> The upcoming deployment of various Intelligent Transportation Systems (ITS) and Automated Highway System (AHS) technologies will require major adjustments in the habits of drivers. Implementers of ITS technology must ensure that their systems are safe and lead to real improvements in traffic efficiency. These systems cannot cause excessive driver workload or remove his/her sense of "control" of the vehicle. A highly realistic driving simulator provides a powerful method of evaluating in-vehicle ITS technology in complex situations. Representative traffic scenarios can be examined safely with experimental repeatability, easy reconfigurability and excellent data collection capability. This paper describes the background and potential applications of the National Advanced Driving Simulator (NADS) to be developed by TRW for research supporting the objectives of ITS and AHS systems and product development. Simulator technology has advanced dramatically in the last few years in the areas of vehicle multi-body dynamics simulation. real-time computer performance, ultra-high fidelity visual displays and large motion drive systems. It is now technically and economically feasible to build a driving simulator that can recreate the sense and feel of driving. In a few years, the NADS will be available as a new tool for engineers to develop, evaluate and field advanced ITS and AHS products.

1996-Open Literature

1997

1997-Open Literature

1998

1998-Open Literature

Collision Avoidance System (CAS):

FHWA

1998

Contract Number?

[1]Anonymous (1998). Summary Report: Basic Collision Warning and Driver Information Systems: Human Factors Research Needs. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-184).

> As part of the U.S. Department of Transportation's Intelligent Vehicle Initiative (IVI) program, the Federal Highway Administration investigated the human factors research needs for integrating in-vehicle safety and driver information technologies into usable systems that provide manageable information to the driver. This investigation included a workshop in December 1997 for IVI stakeholders (i.e., universities, automotive manufacturers, vendors, and contractors) and a preliminary assessment of infrastructure and in-vehicle requirements. This flyer summarizes the identified human factors research needs for basic safety and information systems, one of five configurations of in-vehicle safety and driver information systems. A complete review of the research needs for all five configurations can be found in the final report (FHWA-RD-98-178). These configurations were developed based on: (1) identified safety and driver information systems and functions; (2) a thorough literature review of past research and research gaps related to these in-vehicle systems; and (3) combining logical groups of basic and advanced safety and driver information functions in passenger cars, commercial trucks, and transit vehicles such as buses. Each candidate configuration was meant to provide clear safety benefits to The goal of the configuration described below is to provide basic collision warning and driver information capabilities to the three vehicle types.

Contract Number?

[2]Anonymous (1998). Summary Report: Full-Coverage Collision Warning: Human Factors Research Needs. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-185).

> As part of the U.S. Department of Transportation's Intelligent Vehicle Initiative (IVI) program, the Federal Highway Administration (FHWA) investigated the human factors research needs for integrating in-vehicle safety and driver information technologies into usable systems that provide manageable information to the driver. This investigation included a workshop in December 1997 for IVI stakeholders (i.e., universities, automotive manufacturers, vendors, and contractors) and a preliminary assessment of

infrastructure and in-vehicle requirements. This flyer summarizes the identified human factors research needs for a full 360-degree collision warning coverage, one of five configurations of in-vehicle safety and driver information systems. A complete review of the research needs for all five configurations can be found in the final report (FHWA-RD-98-178). These configurations were developed based on (1) identified safety and driver information systems and functions; (2) a thorough literature review of past research and research gaps related to these in-vehicle systems; and (3) combining logical groups of basic and advanced safety and driver information functions in passenger cars, commercial trucks, and transit vehicles such as buses. Each candidate configuration was meant to provide clear safety benefits to the driver as well as a solid technical foundation for the system configurations for the IVI. The goal of the configuration described below is to provide full collision warning coverage for the three vehicle types.

1998-Open Literature

NHTSA

1993

Contract Number: DTRS-57-89-D-00086, Battelle

[3]Knipling, R.R., Mironer, M., Hendricks, D.L., Tijerina, L., Everson, J., Allen, J.C., and Wilson, C. (1993). Assessment of IVHS Countermeasures for Collision Avoidance: Rear-End Collision. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-807-995).

This report describes an analysis of the application of Intelligent Vehicle Highway System (IVHS) technology to the reduction of rear-end crashes. The principal countermeasure concept examined is a headway detection (HD) system that would detect stopped or slower moving vehicles in a vehicle's travel path. The report is organized to correspond to major steps of the project methodology.

1. Quantify baseline target crash problem size and describe target crash characteristics.

2. Describe, analyze, and model target crash scenarios to permit understanding of principal crash causes, time and motion sequences, and potential interventions.

3. Assess countermeasure technology and mechanisms of action to identify candidate solutions.

4. Assess relevant human factors and other (e.g., environmental, vehicle) factors affecting crash scenario and potential countermeasures effectiveness.

5. Model countermeasure action to predict effectiveness and identify critical countermeasures functional requirements.

6. Identify specific priority technological, human factors, and R&D issues to be resolved. Case reconstructions and modeling indicate that most rear-end crashes are due to driver inattention, and that this inattention can in theory be addressed successfully by the HD countermeasure concept and available radar technologies.

[4]Tijerina, L., Hendricks, D., Pierowicz, J., Everson, J., and Kiger, S. (1993). Final Report - Examination Of Backing Crashes And Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-016).

This report examines the potential for Intelligent Vehicle Highway System (IVHS) technology to improve the crash avoidance capability of drivers and vehicles for backing crashes. IVHS has the potential to greatly enhance highway traffic safety. This report attempts to determine the safety implications of IVHS by using analytical methods to model the backing crash type and potential IVHS crash avoidance countermeasures. The causal assessments show that approximately 87.0 percent of the cases occurred because drivers were unaware of (did not see or did not check for the struck vehicle, object, or pedestrian. Of the causal factors which appear to be amenable to IVHS countermeasures in the near term, the main causal factor appeared to be that the backing vehicle's driver was unaware of an obstacle. This suggested that a vehicle-based IVHS countermeasure that warns drivers of obstacles in the backing path might be helpful. The suggested countermeasure was a rear-zone object detection system. It is estimated that the functional rear-zone object detection system would be approximately 70 percent effective in avoiding the parallel path, curved path, and pedestrian/pedalcyclist crash subtypes. In terms of all backing crash subtypes, the system would be approximately 28 percent effective.

Contract Number: DTNH22-91-C-003121, Information Management Consultants, Inc.

[5]Knipling, R.R., Wang, J., and Yin, H. (1993). Rear-End Crashes: Problem Size Assessment and Statistical Description. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-807-994).

This document presents problem size assessments and statistical crash descriptions for rear-end crashes, including two key subtypes: lead-vehicle stationary (LVS) and lead-vehicle moving (LVM). Principal data sources are the 1990 General Estimated System (GES) and Fatal Accident Reporting System (FARS). Rear-end crashes are a potential “target crash” of high technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. In this report, the rear-end crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for three vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans) and combination-unit trucks. LVS and LVM rear-end crashes are described statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and, when data are available, in terms of possible contributing factors.

1993-Open Literature

1994

Contract Number: HS421/S4007, Battelle and Arvin/Calspan

[6]Chovan, J.D., Tijerina, L., Alexander, G., and Hendricks, D.L. (1994). Examination of Lane Changes Crashes and Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 071).

This report provides an analysis of lane change crashes to guide the development of Intelligent Vehicle Highway System (IVHS) crash avoidance system. It introduces the problem of lane change crashes: A lane crash occurs when a driver attempts to change lanes and strikes or is struck by a vehicle in the adjacent lane. Two crash subtypes are identified and causal factors that contribute to lane change crashes are assessed clinically from a sample of lane change crash cases. From these data, functional goals for IVHS lane change crash avoidance systems are described. A simple kinematic model of normal lane change and evasive steering maneuvers introduces key pre-crash variables and outlines the space of time and distance available for crash avoidance from a kinematic perspective, concluding with a discussion of key research needed to extend the analysis presented. (Included with the report is a diskette of the kinematic models developed for this crash type and files for data tables used in generating data plots contained in the report. The file README.TXT is an ASCII file that describes the program and data files on this diskette.)

[7]Chovan, J.D., Tijerina, L., Everson, J.H., Pierowicz, D.L., and Hendricks, D.L. (1994). Examination of Intersection, Left Turn Across Path Crashes and Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 154).

This report provides a preliminary analysis of intersection-related, left turn across path (LTAP) crashes and applicable countermeasure concepts for the Intelligent Vehicle Highway System (IVHS) program. An LTAP crash occurs when the subject vehicle (SV) approaches an intersection, attempts to turn left, and either strikes or is struck by the principal other vehicle (POV) traveling in the opposing traffic lanes. A detailed analysis of 154 such crashes showed that 49 percent are caused by drivers who were unaware of the oncoming vehicle, and that 30 percent were caused by drivers who saw but misjudged the velocity/gap of the oncoming vehicle. Moreover, two LTAP crash subtypes are identified: the SV slows, but does not stop, begins the left turn, and strikes or is struck by the oncoming POV in 71.6 percent of these crashes; and the SV stops, then proceeds with the left turn, and strikes or is struck by the POV in the remaining 28.4 percent of these crashes. The crash avoidance system (CAS) concepts discussed in this report include driver warnings, partially automatic vehicle control systems, and fully automatic vehicle control systems. This report concludes with a number of research needs to better understand LTAP crashes and guide CAS development.

[8]Chovan, J.D., Tijerina, L., Pierowicz, D.L., and Hendricks, D.L. (1994). Examination of Unsignalized Intersection, Straight Crossing Path Crashes and Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 152).

This report provides a preliminary analysis of unsignalized intersection, straight crossing path (UI/SCP) crashes and applicable countermeasure concepts for the Intelligent Vehicle Highway System (IVHS) program. A UI/SCP crash occurs when two vehicles, one with the right-of-way and one without collide at right angles while both are attempting to pass straight through an intersection controlled by stop signs. A detailed analysis of 1000 such crashes showed the drivers ran the stop sign about 42% of these crashes and that the remaining crashes involved drivers who stopped and then proceeded against cross traffic. Moreover, about 75% of UI/SCP crashes were caused by drivers who were unaware of the presence of either the stop sign or crossing traffic. The crash avoidance system (CAS) concepts discussed in this report include driver alerts, driver warnings, partially automatic control systems, fully automatic control systems, and a hybrid system that incorporated these concepts and transitions among them. This report concludes with a number of research needs to better understand UI/SCP crashes and guide CAS development.

[9]Mironer, M., and Hendricks, D.L. (1994). Examination of Single Vehicle Roadway Departure Crashes and Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 144).

This report provides an analysis of single vehicle roadway departure (SVRD) crashes to guide the development of Intelligent Vehicle Highway System (IVHS) crash avoidance systems. It introduces the problem of SVRD crashes: A crash is defined as a SVRD when the first harmful event is the departure from the roadway, thus excluding departures resulting from prior impacts. Two crash subtypes are identified and causal factors that contribute to SVRD crashes are assessed clinically from a sample of SVRD crashes. From these data functional goals for IVHS SVRD crash avoidance systems are described. Three simple models of potential kinematic remedies to pre-crash scenarios are examined: stopping the vehicle, steering to return to the original travel lane, and slowing the vehicle to a safer speed. These models illustrate the distances and times needed to prevent crashes. The report concludes with a discussion of key research needed to extend the analysis presented.

[10]Tijerina, L., Chovan, J.D., Pierowicz, D.L., and Hendricks, D.L. (1994). Examination of Signalized Intersection, Straight Crossing Path Crashes and Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washinton, D.C. (DOT HS 808 143).

This report provides a preliminary analysis of signalized intersection, straight crossing path (SI/SCP) crashes to support development of crash avoidance system (CAS) functional concepts as part of the Intelligent Vehicle Highway System (IVHS). An SI/SCP crash is defined as a crash at a signalized intersection in which two vehicles, one with and one without right-of-way, collide in straight crossing paths. A detailed analysis of 50 such crashes show that 41% of these crashes are caused by drivers who were unaware of the signal presence and its status, and that 16% were caused by drivers who attempted to beat the amber phase. The CAS concepts discussed in this report are driver alerts, driver warnings, partially automatic control systems, fully automatic control systems, and a hybrid system that incorporates the previous four concepts and transitions among them. The report also provides kinematic models to determine the time and distance available for crash avoidance under the various vehicle operating conditions. This report concludes with a number of research needs to better understand SI/SCP crashes and guide CAS development.

Contract Number: DTNH-22-91-C-003121, Information Management Consultants, Inc.

[11]Wang, J., and Knipling, R.R. (1994). Backing Crashes: Problem Size Assessment and Statistical Description. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-074).

This document presents problem size assessments and statistical crash descriptions for backing crashes and several key subtypes of backing crashes. Backing crashes are a potential “target crash” of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. To elucidate potential countermeasure applicability, backing crashes are divided into two types: encroachment and crossing-path backing crashes. The emphasis of this report is on the encroachment backing crashes where the vehicle is under control. This subclass is likely to be most amendable to prevention by an obstacle detection system. Principal data sources are the 1990 General Estimates System (GES) and Fatal Accident Reporting System (FARS). The crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for four vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks and medium/heavy single-unit trucks. Encroachment backing crashes are describe statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and , when data are available, in terms of possible contributing factors.

[12]Wang, J., and Knipling, R.R. (1994). Lane Change/Merge Crashes: Problem Size Assessment and Statistical Description. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-075).

This document presents problem size assessments and statistical crash descriptions for lane change/merge (LCM) crashes and two key subtypes of the LCM crashes. The LCM crashes are a potential “target crash” of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. To elucidate potential countermeasure applicability, the LCM crashes are divided into two types: angle/sideswipe and rear-end LCM crashes. The emphasis of this report is on the angle/sideswipe LCM crashes. This subclass is likely to be most amendable to prevention by an obstacle detection system. Principal data sources are the 1990 General Estimates System (GES) and Fatal Accident Reporting System (FARS). LCM crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for four vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks and medium/heavy single-unit trucks. Angle/sideswipe LCM crashes are described statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and, when data are available, in terms of possible contributing factors.

[13]Wang, J., and Knipling, R.R. (1994). Intersection Crossing Path Crashes: Problem Size Assessment and Statistical Description. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-190)

This document presents problem size assessments and statistical crash descriptions for intersection crossing path (ICP) crashes and three key subtypes of the ICP crashes. The ICP crashes are a potential “target crash” of high-technology Intelligent Vehicle Highway Systems (IVHS) crash avoidance countermeasures. To elucidate potential countermeasure applicability, the ICP crashes are divided into three types: signalized intersection perpendicular crossing path (SI/PCP), unsignalized intersection perpendicular crossing path (UI/PCP), and left turn across path (LTAP) crashes. The principal data source is the 1991 General Estimates System (GES). ICP crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for five vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks, medium/heavy single-unit trucks and motorcycle. Descriptive statistics are provided for all vehicles only. ICP crashes and the three crash subtypes are described statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and, when data are available, in terms of possible contributing factors.

[14]Wang, J., and Knipling, R.R. (1994). Single Vehicle Roadway Departure Crashes: Problem Size Assessment and Statistical Description. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-113).

This document presents problem size assessments and statistical crash descriptions for single vehicle roadway departure (SVRD) crashes. The SVRD crashes, associated with more fatalities than any other accident type, are a potential "target crash" of high-technology Intelligent Vehicle Highway System (IVHS) crash avoidance countermeasures. Principal data sources are the 1991 General Estimates System (GES) and Fatal Accident Reporting System (FARS). The SVRD crash problem size is assessed using such measures as number of crashes, number and severity of injuries, number of fatalities, crash involvement rate, and crash involvement likelihood. Problem size statistics are provided for five vehicle type categories: all vehicles, passenger vehicles (i.e., cars, light trucks, light vans), combination-unit trucks, medium/heavy single-unit trucks and motorcycles. SVRD crashes are described statistically primarily in terms of the conditions under which they occur (e.g., time of day, weather, roadway type, relation to junction) and, when data are available, in terms of possible contributing factors.

Contract Number; DTNH22-93-C-07326, Frontier Engineering Advanced Programs Division

[15]Wilson, T. (1994). IVHS Countermeasures for Rear-End Collisions, Task 1 Volume VI: Human Factors Studies, Interim Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 565).

The program's primary objective is to develop practical performance guidelines or specifications for rear-end collision avoidance systems. The program consists of three Phases: Phase one: "Laying the Foundation" (Tasks 1-4), Phase two: "Understanding the state-of-the-art" (Tasks 5 & 6), and Phase three: "Testing and Reporting" (Tasks 7-9). This work focuses on light (primarily passenger) vehicles and emphasizes autonomous in-vehicle based equipment (as opposed to cooperative infrastructure-based equipment). Phase I of this contract, Laying the Foundation, consisted of 4 Tasks: Task 1: a detailed analysis of the rear-end crash problem, Task 2: development of system-level functional goals, Task 3: hardware testing of existing technologies, and Task 4: development of preliminary performance specifications or guidelines. The goals of Tasks 1, 2 and 3 were to develop the background needed to write the preliminary performance guidelines (Task 4). Task 1, a detailed analysis of the rear-end Crash Problem, consisted of analysis, both clinical and statistical, of available mass accident data bases, some of which include the pre-crash variables, and an initial human factors study. The goal here was to identify, determine the nature of, and quantify the causes of rear-end type crashes. A report volume was written for each of these areas. The Task 1 Interim Report consists of six volumes. This Volume, Volume I, "Summary," presents background information, an overview of the framework used to analyze the rear-end collision problem, an overview of the initial human factors studies, and summarizes the clinical and statistical analysis of the accident data. This report (all volumes) forms the foundation for the work in the later stages of the contract. Descriptions of Volumes II - Vl are as follows: a. Volume II, "Statistical Analysis," presents the statistical analysis of rear-end collision accident data that characterizes the accidents with respect to their frequency, severity, time and place of occurrence, the vehicle, and the involved drivers. Data for this Volume includes NHTSA's Fatal Accident Reporting System (FARS), NHTSA's General Estimates System (GES), and some state accident data files for recent years; b. Volume III "1991 NASS CDS Clinical Case Analysis," presents the results of the detailed analysis of cases from NHTSA's 1991 National Accident Sampling System (NASS) Crash worthiness Data System (CDS) crash data; c. Volume IV, "1992 NASS CDS Clinical Case Analysis," presents the results of the detailed analysis of 200 cases from the 1992 NASS CDS crash data including the new pre-crash variables; d. Volume V, "1985 NASS Analysis," presents the results of the analysis of the 1985 NASS crash data. Data from 1985 was selected for analysis because it provided more insight into roadway variables that are no longer available in the current CDS or GES databases; and e. Volume VI, "Human Factors," presents the results of the initial human factors literature review and study. From this detailed analysis of the accident databases a framework of the dynamic situations of rear-end collisions was developed and used to analyze the rear-end collision problem. From an in-depth analysis of the dynamic situations it was discovered that most rear-end collisions occur with the following vehicle traveling at a constant velocity and the lead vehicle decelerating to a stop, i.e. the close-following or platooning situation. It was determined that the primary causal factors for rear-end collisions were inattention and following too closely. Also determined was a list of preliminary specification information. The results presented during Phase I, including the Preliminary Performance Guidelines or Specifications, are based on work carried out with limited interactions with the academic, research, and industry communities, any conclusions drawn from the results presented must bear this in mind. Phase II goals include a detailed state-of-the-art review of technologies related to rear-end collision avoidance systems and the design of a test bed system. Phase II will complete in June 1996. Phase III goals include the construction and test of the test bed system, the generation of the final performance guidelines or specifications, and the final reporting on all aspects of the project. Phase III will finish in early 1998. Work continues throughout Phase II and III to add to, and to refine, these preliminary performance guidelines or specifications. Numerous items still need to be determined (TBD) throughout the remainder of the research.

1994-Open Literature

Contract Number?

[16]Clarke, R.M., Goodman, M.J., Perel, M., and Knipling, R.R. (1994). Driver Performance and IVHS Collision Avoidance Systems: A Search for Design-Relevant Measurement Protocols. ITS America Annual Meeting, Washington, D.C., 1994.

> Success in developing IVHS collision avoidance systems that are both commercially attractive and effective will depend in large part on how well product designers understand and accommodate human factors considerations in their designs. Help from the human factors community will be sought in this regard and new research will likely be needed to provide designers this information. A review of prior human factors research that may bear on this subject indicates that, in numerous cases, studies were narrowly focused and, as a result, it is sometimes difficult to generalize or extrapolate study findings. This paper suggests that a new set of research tools would be useful to support the identification of design-relevant variables and measures appropriate to the particular issues being studied. Identification of these variables and measures and their validation will help foster the transferability and generalizability of research conducted by different researchers in different research settings. The paper offers a "first-cut" attempt at identifying those variables and measurement approaches, and briefly describes the NHTSA's programs designed to provide tools that can be used to collect design relevant data..

Contract Number: DTRS-57-89-D-00086, Battelle

[17]Najim, W.G., Koziol, Jr., J.S., Tijerina, L., Pierowicz, J.A., and Hendricks, D.L. (1994). Comparative Assessment of Crash Causal Factors and IVHS Countermeasures. IVHS AMERICA Fourth Annual Meeting, Atlanta, Georgia, April 17-20, 1994.

> The National Highway Traffic Safety Administration's Office of Crash Avoidance Research, in conjunction with the Research and Special Programs Administration's Volpe National Transportation Systems Center, has underway a multi-disciplinary program to: identify crash causal factors and applicable Intelligent Vehicle-Highway System countermeasure concepts, model crash scenarios and avoidance maneuvers, provide preliminary estimates of countermeasure effectiveness when appropriate, and identify research and data needs. To date, five crash types have been examined which include rear-end, backing, single vehicle roadway departure, lane change, and intersection/crossing path crashes. This paper describes the methodology employed in analyzing crash scenarios and developing functional countermeasure concepts independent of specific technologies. To illustrate that methodology, several steps in the lane change crash analysis are presented. In addition, the causal factors of four subtypes of intersection/crossing path crash problems are tabulated and functional countermeasure concepts are devised based on a matrix of crash causes and subtypes. Finally, the causal factors of the five crash types mentioned above are synthesized in separate categories dealing with the driving task, driver physiological state, and the driving environment.

1995

Contract Number?, Battelle

[18]Hanowski, R.J., Knipling, R.R., and Byrne, E.A. (1995). Analysis of Older Driver Safety Interventions: A Human Factors Taxonomic Approach. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

> To address issues related to older drivers, a tool has been developed to categorize a spectrum of countermeasures: a taxonomy of safety interventions. This taxonomy provides a framework for examining the problems and research directions associated with nine primary areas of focus: (1) Driver Licensing, (2) Driver Training/Counseling, (3) Crash worthiness/Occupant Protection, (4) Post-Crash Medical Care, (5) Behavioral Medicine, (6) Fitness-For-Duty (FFD), (7) Environmental Issues, (8) Cooperative Systems, and (9) Vehicle Design/Crash Avoidance. The taxonomy is structured such that consideration can be given to each primary area independently and in relation to other primary areas. Consideration of each area independently, and how they interact with other areas, may lead to more countermeasures. The applicability of ITS crash avoidance technology for older drivers can be addressed in this context. Given the reduction of sensory, perceptual, cognitive, and motor capabilities that are associated with aging, designing in-vehicle ITS for older drivers is apt to be challenging. ITS technology has the potential to be a "double-edged sword" for the older driver; systems that are designed to assist in safe driving may also add mental and physical workload and confusion to the driving task. Consideration of older driver issues, and the utilization of a user-centered design approach, may aid in the realization of ITS goals and objectives, making them safe, efficient and usable for both younger and older drivers.

Contract Number?

[19]Mazzae, E.N., and Garrott, W.R. (1995). Human Performance Evaluation of Heavy Truck Side Object Detection Systems. Transportation Research Center. Inc Report No. 951011. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

> Side object detection systems (SODS) are collision warning systems which alert drivers to the presence of traffic alongside their vehicle within defined detection zones. The intent of SODS is to reduce collisions during lane changes and merging maneuvers. This study examined the effect of right SODS on the performance of commercial vehicle drivers as a means of assessing the impact of these systems on safety. In this study, eight professional truck drivers drove a tractor-semitrailer equipped with four different sets of SODS hardware or side view mirror configurations. These subjects had no previous experience with SODS. Subjects were tested with two right SODS (a radar-based system and an ultrasonic-based system), a fender-mounted convex mirror, and, for comparison, standard side view mirrors only. For each case, subjects drove the test vehicle through a

set route for one day. The effect of these systems on driver behavior and the extent to which safety may be improved by implementing SODS in combination-unit trucks were assessed based upon the correctness of responses and verbal response times to the question, "Is the right clear?," which prompted subjects to assess the traffic situation to the right side of the test vehicle. Subject glance behavior during right lane changes and normal driving was also examined. Additionally, a debriefing questionnaire was used to acquire subjects' subjective reactions to these systems. Overall, driver performance with the SODS involved in this study was not significantly improved over that observed with standard side view mirrors. Analysis of the correctness of responses to Right Clear questions showed that subjects' accuracy in assessing the traffic situation along the right side of the vehicle was not improved in the SODS cases, but was improved in the fender-mounted convex mirror case. Verbal response times to Right Clear questions were significantly shorter in the SODS and fender-mounted convex mirror cases than with standard side view mirrors alone. However, this difference may have resulted from a learning effect caused by presenting the standard mirrors first to each subject. Although this data suggests that driver performance was not improved with SODS, it is important to note that no apparent decline in performance was observed either. Subjective responses to debriefing questionnaires indicated that subjects were very positive about the fender-mounted convex mirror. Although, subjects reported using the SODS often while driving in the study, glance data showed that subjects only sometimes visually sampled the SODS displays. In general, subjects seemed receptive to the concept of SODS and welcomed any potential improvement to safety. Although it appears that SODS currently have the potential to provide some benefit, overall results of this study suggest that in order for SODS to make significant improvements to safety in the future, more work is needed to improve their performance and design.

Contract Number?

[20]Mazzae, E.N., Garrott, W.R., and Flick, M.A. (1995). Development of Performance Specifications for Collision Avoidance Systems for Lane Change, Merging, and Backing. Task 3 - Human Factors Assessment of Driver Interfaces of Existing Collision Avoidance Systems. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 433).

This paper describes the assessment of driver interfaces of a type of electronics-based collision avoidance systems that has been recently developed to assist drivers of vehicles in avoiding certain types of collisions. The systems studied were those which detect the presence of objects located on the left and/or right sides of the vehicle. Side Collision Avoidance Systems (SCAS). The strengths and weaknesses of each driver interface were determined. Overall, while none of the SCAS had an “ideal’ interface, most had ergonomically acceptable interfaces. From the evaluations performed, a preliminary set of driver interface specifications that may be of aid to future SCAS driver interface designers has been developed.

Contract Number: F04606-90-D-0001/0052 (TRW-Air Force) under Air Force-NHTSA Inter-agency Agreement DTNH22-93-X-07022 (Air Force-NHTSA), TRW Space and Electronics Group

[21]Eberhard, C.D., Moffa, P.J., Young, S.K., and Allen, R.W, (1995). Interim Report, Development of Performance Specifications for Collision Avoidance Systems for Lane Change, Merging and Backing, Task 4 - Development of Preliminary Performance Specifications. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 430).

> Preliminary performance specifications which accomplish the functional goals outlined in the Task 2 interim report (shown abridged in Appendix A) are developed for lane change, merge and backing crash avoidance systems (CAS). These preliminary performance specifications are based on analyses of Monte Carlo computer simulations, interactive driving simulator results and the evaluations of the CAS driver-vehicle interface (DVI) by human factors experts. The Monte Carlo simulations utilize travel speed distributions derived from the General Estimates System database and accident scenarios constructed from Crash worthiness Data System hard copy files and police accident reports. The structure and methodology of the Monte Carlo simulations and the interactive driving simulator are discussed in detail. In addition, a description of a sensor model, which provides a means of computing detection probabilities and which was included in both the Monte Carlo simulations and the driving simulator, is included. Using the Monte Carlo simulation, various sensor configurations and parameter fields are investigated for both passenger vehicles and large trucks. Using the interactive driving simulator, various configurations and modalities of the DVIs are investigated in lane change/merge and backing scenarios. The results of these analyses are presented herein.

Contract Number: DTNH22-91-C-07004, COMSIS Corporation

[22]Huey, R., Harpster, J., and Lerner, N. (1995). Field Measurement of Naturalistic Backing Behavior. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 532).

> A series of observations and measurements were made as 21 subjects drove their own vehicles in an assortment of naturalistic backing tasks. The tasks were performed on public roads in real world driving conditions. As the Subjects performed the eight tasks, the following data were collected: glance direction, hand position, car speed, and distance to object in back of the vehicle. The results provide a set of normative data usable by automotive system designers for the design of backing warning systems, or other products or environments related to backing. The results were divided into glance direction, backing speed, and time-to-collision. Glance directions were found to vary greatly between tasks, and were distributed widely around the vehicle. Elderly drivers demonstrated a preference for using their mirrors and looked over their shoulder less then the young subjects. Except for the extended backing maneuvers, backing speeds averaged around 3 mph. The maximum backing speed for the young drivers was faster

than the elderly and males backed faster than females. Time-to collision values were approximately the same for males and females as well as young and old. Time-to-collision tended to remain relatively constant as the vehicle backed toward on object. The minimum times-to-collision exceeded 1.0 s, and usually exceeded 2.0 s.

Contract Number: HS521/S5007, Prime Contractor: Volpe National Transportation Systems Center

[23]Najim, W., Mironer, M., Koziol, Jr., J., Wang, J., and Knipling, R.R. (1995). Synthesis Report-Examination of Target Vehicular Crashes and Potential ITS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-263, DOT-VNSC-NHSTA-95-4).

This report synthesizes the results of a preliminary analysis of nine major target crashes (1) rear-end, (2) backing, (3) lane change and merge, (4) single vehicles roadway departure, (5) opposite direction, (6) signalized intersection, straight crossing path, (7) unsignalized intersection, straight crossing path, (8) left turn across path, and (9) reduced visibility. This report provides statistical descriptions of target crash sizes and characteristics, identifies crash subtypes and causal factors, defines Intelligent Transportation System (ITS) Collision Avoidance System (CAS) concepts, and includes a sample of kinematic models representing crash avoidance actions. A case-by-case examination of a sample of 1183 crashes identifies 18 crash subtypes and showed that driver recognition and driver decision errors were the primary causes or 44% and 23% of target crashes, respectively. The CAS concepts discussed in this report provide mechanism of intervention in three basic categories: advisory, warning, and automatic control intervention. Crash avoidance actions are kinematically modeled as applied to target subtypes in terms of braking, steering, and holding course actions. This report concludes by highlighting key results of the analysis.

Contract Number: DTNH22-93-C-07023, Carnegie Mellon University Robotics Institute

[24]Koenig, M., Pape, D., and Pomerleau, D. (1995). Run-Off-Road Collision Avoidance Countermeasures Using IVHS Countermeasures, Task 4 Volume 2: RORSIM Manual, Final Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 504).

The Run-Off-Road Collision Avoidance Using IVHS Countermeasures program is to address the single vehicle crash problem through application of technology to prevent and/or reduce the severity of these crashes. This report documents the RORSIM computer simulation developed in Task 4. RORSIM is a PC program which simulates the combined effects of the dynamical properties of the vehicle, the response of the driver, sensor measurements, environmental conditions and in-vehicle countermeasure systems. RORSIM is an extension of the commercial program VDANL (Vehicle Dynamic Analysis NonLinear) which was developed by Science Technology, Inc. (STI). This report is an operating manual that contains detailed instructions on the operation of

RORSIM. Results obtained using RORSIM are contained in a companion volume, Task 4 Volume I.

[25]Pape, D.,Pomerleau, D., Narendran, V., Hadden, J., Everson, J., and Koenig, M. (1995). Run-Off-Road Collision Avoidance Countermeasures Using IVHS Countermeasures, Task 4 - Volume 1, Final Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 503).

The Run-Off-Road Collision Avoidance Using IVHS Countermeasures program is to address the single vehicle crash problem through application of technology to prevent and/or reduce the severity of these crashes. This report describes the findings of the Task 4 effort. Task 4 focused on the development of preliminary performance specifications for run-off-road countermeasures. A total of 62 performance specifications were developed to ensure that potential run-off-road countermeasures meet the functional goals developed in Task 2. These performance specifications were divided into those that apply generally to run-off-road countermeasures, and those that apply specifically to lateral or longitudinal countermeasures. These performance specifications were generated by developing and running a computer program called RORSIM to simulate the combined effects of the dynamical properties of the vehicle, the response of the driver (included a model of neuromuscular delays during steering response), sensor measurements, environmental conditions and in-vehicle countermeasure systems.

[26]Tijerina, L., Jackson, J.L., Pomerleau, D.A., Romano, R.A., and Peterson, A. (1995). Run-Off-Road Collision Avoidance Countermeasures Using IVHS Countermeasures Task 3 - Volume 2, Final Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 502).

The Run-Off-Road Collision Avoidance Using IVHS Countermeasures program is to address the single vehicle crash problem through application of technology to prevent and/or reduce the severity of these crashes. This report describes the findings of the driving simulator experiments conducted for Task 3. In these experiments, 64 subjects drove a simulated vehicle over a 40-minute course on the Iowa Driving Simulator (IDS), a six degree-of-freedom, moving-base simulator with a wide field-of-view image generation system. For 48 of the subjects, the vehicle was equipped with lateral and longitudinal countermeasures to warn the driver of roadway departure danger. Different subjects experienced a variety of countermeasure algorithms and driver interfaces, including auditory, haptic and combined auditory and haptics displays. There were also 16 subjects who drove the same simulate course, but received no countermeasure support. Results suggest that the roadway departure countermeasures have potential for preventing crashes. Driver interfaces that provide information about the appropriate driver response appear to have some performance benefit. Either auditory or haptic displays appear promising, but a combination auditory and haptic display appeared to produce driver overload.

1995-Open Literature

Contract Number?

[27]Hanowski, R.J., Knipling, R.R.,, Byrne, E.A. and Parasuraman, R. (1995). Analysis of Older Driver Safety Interventions: A Human Factors Taxonomic Approach. Proceedings of the ITS America Conference, Washington, D.C., March 1995.

Contract Number?

[28]Mazzae, E.N., Garrott, W.R., and Flick, M.A. (1995). Human Factors Evaluation of Existing Side Collision Avoidance System Driver Interfaces. International Truck and Bus Meeting & Exposition, Winston-Salem, North Carolina, November 13-15, 1995. SAE Technical Paper Series 952659.

> This paper describes the assessment of driver interfaces of a type of electronics-based collision avoidance systems that has been recently developed to assist drivers of vehicles in avoiding certain types of collisions. The systems studied were those which detect the presence of objects located on the left and/or right sides of the vehicle. Side Collision Avoidance Systems (SCAS). The strengths and weaknesses of each driver interface were determined. Overall, while none of the SCAS had an ideal" interface, most had ergonomically acceptable interfaces. From the evaluations performed, a preliminary set of driver interface specifications that may be of aid to future SCAS driver interface designers has been developed.

[29]Najim, W.G., Mironer, M.S. and Fraser, L. C. (1995). Analysis of Target Crashes and ITS Countermeasure Actions. ITS America 5th Annual Meeting, Washington, D.C., March 15-17, 1995.

> This paper summarizes some of the results of a 3-year project that was undertaken by the Research and Special Programs Administration's Volpe National Transportation Systems Center to identify crash causal factors and applicable Intelligent Transportation System (ITS) countermeasure concepts, model crash scenarios and avoidance maneuvers, provide preliminary estimates of countermeasure effectiveness when appropriate, and identify research and data needs. Eight target crash types were examined: (1) rear-end, (2) backing, (3) lane change and merge, (4) single vehicle roadway departure, (5) opposite direction, (6) signalized intersection, straight crossing path, (7) unsignalized intersection, straight crossing path, and (8) left turn across path crashes. This paper identifies target crash subtypes and causal factors that were determined by a case-by-case examination of a sample of crashes drawn from two National Highway Traffic Safety Administration's accident data bases; defines and categorizes ITS countermeasure system concepts; and includes a sample of kinematic models representing crash avoidance actions

Contract Number?

[30]Tijerina, L. (1995). Key Human Factors Research Needs in IVHS Crash Avoidance. Transportation Research Board 74th Annual Meeting, Washington, D.C., January 1995, Paper No. 950250.

1996

Contract Number?

[31]Griffin, D.C. (1996). Variable Dynamic Testbed Vehicle (VDTV), Functional Requirements. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?, JPL D-I 3459).

> The Variable Dynamic Testbed Vehicle (VDTV) system's objective is to support the National Highway Traffic Safety Administration's (NHTSA's) crash avoidance research. NHTSA's Office of Crash Avoidance Research (OCAR) is the sponsor of this effort. To accomplish this, the vehicle must have two possibly divergent capabilities: (1) dynamic performance which ranges, when compared to performance of production vehicle, from low to high, and (2) characteristics of a production car. To permit research to investigate bounds of dynamic performance, the VDTV's dynamic performance must exceed that of normal production vehicles. To permit investigation of human factors on crash avoidance maneuvers and technology, the VDTV must offer an environment similar to that of production vehicles.

Contract Number: DTNH22-91-C-07004, COMSIS Corporation

[32]Harpster, J.L., Huey, R.W., Lerner, N.D., and Steinberg, G.V. (1996). Backup Warning Signals: Driver Perception and Response. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 536)

> This report describes the findings of three experiments that concern driver reaction to acoustic signals that might be used for backup warning devices. Intelligent warning devices are under development that will use vehicle-based sensors to warn backing drivers of the presence of objects behind the vehicle. The research described here is part of a larger project concerned with the human factors of these warning devices. Specifically, the questions of interest center around what warning information to provide, when to present it, and how to display it. Based on previous work (Lerner, Kotwal, Lyons, and Gardner-Bonneau, 1996; Huey, Harpster, and Lerner, 1996), this research focuses on acoustic signals, which are seen as more suitable for backup warnings than are visual displays. The three experiments were conducted dealing with different aspects of driver perception and response to backup warning signals, with the objective of contributing to the development of a set of recommendations for the human factors aspects of backup warning systems.

[33]Lerner, N.D., Dekker, D.K., Steinberg, G.V., and Huey, R.W. (1996). Inappropriate Alarm Rates and Driver Annoyance. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-533).

> Future in-vehicle crash avoidance warning systems will inevitably deliver inappropriate alarms from time to time, caused for example, by situations where algorithms have correctly identified an object but pose no threat or danger to the driver. The current state of knowledge does not permit an estimate of how many inappropriate alarms users find unacceptable, and how that rate may vary with factors like the type of signal generated by the system (i.e., tone versus voice), or extended experience with the warning system itself. The purpose of this study is a direct comparison of drivers' subjective annoyance towards inappropriate alarms as a function of rate of occurrence and the type of signal generated in naturalistic, on-road driving conditions. Test equipment to generate and present signals, and to collect driver response was installed in fifteen participants' personal vehicles for a nine week period. Signals were presented at random times while the participants engaged in their normal, daily driving routines. In order to simulate future operating conditions where actual alarm warnings will require the driver's attention and reaction, "appropriate" alarms to which the driver had to make a simple motor response, and "inappropriate" alarms to which the driver did not have to make any response, were presented. Inappropriate tonal alarms were presented at four different frequencies of occurrence, including averages of four per hour, one per hour, one per four hours, and one per eight hours of driving time. In addition, a voice warning condition was included, at a rate averaging one per hour. Participants made daily and weekly ratings of the degree of annoyance that resulted from the nuisance alarm schedule. The 4/hour-tone and the 1/hour-voice were significantly more annoying, and less acceptable, than the other conditions. Participants showed a wide range of annoyance sensitivity, but the two most annoying conditions appear to be unacceptable, while the less frequent rates do appear potentially reasonable for functional systems.

[34]Lerner, N.D., Kotwal, B.M., Lyons, R.D., and Gardner-Bonneau, D.J. (1996). Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices, Interim Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 342).

> This document presents a set of preliminary guidelines for the human factors aspects of in-vehicle crash avoidance warnings; that is, how information is displayed to the driver and how the device is operated. The guidelines contain a section addressing generic system requirements, which are intended to be applicable across all crash avoidance warning devices, as well as four sections addressing specific types of crash avoidance warning devices: blind spot warning devices, backup warning devices, driver alertness monitoring devices, and headway warning devices. Major topics addressed include: multiple levels of warning, unique imminent crash warning signals, dual modality for imminent crash warnings, non-specificity to sensor or display technology, warning prioritization, compatibility with driver behaviors, warning message content, device status and controls, and minimization of nuisance warnings. These guidelines are

intended to serve several purposes: 1) to outline the features and functional requirements that any crash avoidance warning device, or collection of devices, should meet in order to perform adequately, regardless of the type of sensing technology employed; 2) to uncover those areas where additional research is required in order to defme optimal criteria; 3) to propose recommendations that will anticipate and avoid many of the problems that can come about if warning products are designed in a piecemeal fashion; 4) to define issues explicitly so that they can be reviewed and debated by specialists within the human factors and IVHS communities.

[35]Tan, A.K. and Lerner, N.D. (1996). Acoustic Localization of In-Vehicle Crash Avoidance Warnings as a Cue To Hazard Direction. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 534).

The purpose of warning sounds is to alert a driver of potential roadway hazards detected by an in-vehicle crash avoidance warning device. This study investigated acoustical localization of the warning sound as a means of indicating hazard location. The research focused on several factors; speed and accuracy of responses, the effects on performance of sound type, speaker location, and using speaker pairs to provide directional cues. Under the conditions of this experiment, subjects were able to localize the direction of a warning signal with reasonable speed and accuracy, indicating directional acoustic cues have the potential to speed driver response to hazards. However, there was meaningful variation among alternative warning sounds and speaker locations. Auditory warnings should not be viewed as generally adequate for localized warnings without consideration of the signal and source. The better-performing sound/speaker combinations of this study led to broadly correct, though imprecise, orientation, with relatively few perceptual reversals. Performance appears promising, though generalizability of the implications is reserved until validation and additional vehicle types and environmental conditions can be confirmed.

Contract Number: DTNH22-92-07001, Human Factors Transportation Center, Battelle Seattle Research Center

[36]Campbell, J.L, Hooey, B.L., Camey, C.C., Hanowski, R.J., Gore, B.F., Kantowitz, B.H., and Mitchell, E. (1996). Final Report - Investigation of Alternative Displays for Side Collision Avoidance Systems. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 579).

Side Collision Avoidance Systems (SCAS) are designed to warn of impending collisions and can detect not only adjacent vehicles but vehicles approaching at such a speed that a collision would occur if a lane change were made. Side object detection systems (SODS) represent a subset of SCAS; they warn of the presence of adjacent vehicles only, whether or not there is a lane change. Despite a measure of success in producing first-generation SODS devices, relatively little is known about Driver Vehicle Interface (DVI) requirements for these complex human-machine systems. The DVI is important because it affects the ability of drivers to detect, understand, and correctly respond to the warning information presented by the system. In the current study, a large range of alternative SODS DVI designs were identified and evaluated to determine potential DVI characteristics that enhance driver acceptance. Key issues, including driver preferences for the format, location, and symbology of SODS alerts, were addressed using static mock-ups and displays in a driving simulator. With respect to the information provided to drivers by a SODS device, three types of information were perceived as valuable: (1) a status indication at vehicle start-up, (2) a caution alert under "no intent to turn" situations, and (3) a hazard alert under "intent to turn" situations. With respect to alert design for an "intent to turn" situation, the Vehicle in Blind Spot, Prescriptive Arrow, and Descriptive Car Crash designs (all in red), accompanied by a tone seem to meet basic requirements of a SODS alert in terms of driver preference, perhaps because they provide directional information about the location of a potential threat vehicle. These alerts should be investigated further under more representative conditions in future research.

1996-Open Literature

Contract Number: DTNH22-91-C-07003, Battelle

[37]Tijerina, L. Jackson, J., Pomerleau, D., Romano, R., and Petersen, A. (1996). Driving Simulator Tests of Lane Departure Collision Avoidance Systems. Proceedings of ITS America Sixth Annual Meeting, Houston, TX, 1996.

1997

Contract Number: DTNH22-91-C-07004, COMSIS Corporation

[38]Huey, R.W., Harpster, J.L., and Lerner, N.D. (1997). In-Vehicle Crash Avoidance Warning Systems: Human Factors Considerations, Summary Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 531).

This project was performed to develop guidelines for the interface design of in-vehicle crash avoidance warnings and to begin the process of filling some of the data gaps exposed during that definition process. It did not have the objective of designing some specific device or system. Rather, it had the more general perspective of identifying the common issues for the range of potential devices, supporting integration and compatibility among multiple types of devices, and promoting compatibility among alternative products for a given warning situation. In support of these objectives, the project conducted critical analyses, developed preliminary guidelines, and conducted new empirical research on selected issues. In addition to the guidelines, a series of experiments was conducted, centering around two issues: (1) the characteristics of effective acoustic alarms for crash avoidance warnings; and (2) features of effective backup warning devices. The present report provides a brief overview of project activities, and references the interim documents that provide full detail. It also presents a set of human factors recommendations for backup warning systems. This set of recommendations is new and has not been presented in any earlier reports, although the supporting research studies were documented in previous reports.

Contract Number: DTN22-93-C-0736, University of Iowa

[39]McGehee, D.V., Brown, T.I., Wilson, T.B., and Burns, M (1997). Examination of Driver's Collision Avoidance Behavior in a Lead Vehicle Stopped Scenario Using Front-To-Rear-End Collision Warning System. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

This study investigated how drivers with and without rear-end collision warning systems reacted when distracted when a stationary vehicle was revealed. The test was conducted on the Iowa Driving Simulator, using two different warning conditions (short: 1.0 s. and long: 1.5 s.). This study showed that the timing of a warning is important in the design of collision warning systems. Furthermore, data suggests the potential to provide a disbenefit to drivers if the warning is done improperly.

1997-Open Literature

Contract Number:?

[40]Lerner, N.D., Harpster, J.L., Huey, R.W., and Steinberg, G.V. (1997). Driver backing behavior Research: Implications for Backup Warning Devices. Proceedings of the Annual Meeting of the Transportation Research Board, Washington, D.C., January 1997.

1998

Contract Number: DTFH61-95-C-00016, Prime Contractor: Volpe National Transportation Systems Center

[41]Anonymous (1998). Customer Acceptance of Automotive Crash Avoidance Devices. Charles River Associates Incorporated (CRA Project No. 852-05).

Report summarizes lessons drawn from a series of eight focus groups conducted to appraise the potential customer acceptance for key ITS products and services directed at individual consumers.

1998-Open Literature

Contract Number?

[42]Hertz, E. (1998). An Analysis of the Crash Experience of Passenger Vehicles Equipped with Antilock Braking Systems - An Update. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?). 98-S2-O-07.

> The purpose of this work was to update the authors' earlier work with the benefit of more recent data and also with a larger database of vehicles with known ABS. The analytic approach, as previously, will proceed as follows: Vehicles in crashes are categorized as (1) rollovers, (2) side impacts with fixed objects, (3) frontal impacts with fixed objects, (4) frontal impacts with another motor vehicle in transit and the control group. The control group consists essentially of vehicles that were struck. These data are used in a logistic regression in which ABS is a covariate. The model also controls for other driver and crash characteristics. The coefficient of ABS is the expected change in the log odds of a positive response due to the presence of ABS with all other factors held constant. This is done separately for good and bad road conditions. In the earlier analyses, some of the results were unexpected. For example, while passenger cars with ABS were less likely to strike another vehicle in transit, they were more likely to experience the loss-of-control type of crashes (2) and (3) and more likely to experience fatal rollovers. Other investigators including Kahane (1994), Kullgren et al (1994) and Evans (1995) around the same time period also reported anomalous changes in the mix of crash types associated with ABS. In recent years, the public has become more used to 'stomping' rather than pumping. Also, ABS is less confined to 'upscale' cars. It is extremely important to examine the effect of ABS with more and newer data. The new analysis will use data from Pennsylvania from 1994-1995, Maryland from 1994-1995 and Florida, 1994. VINPLUS has been applied to identify the ABS status of vehicles. Data for the section of the analysis dealing with fatal crashes will be from the FARS 1 994-5.

1999

Contract Number: DTN22-95-RC-07301, Crash Avoidance Metrics Partnership

[43]Kiefer, R., LeBlanc, D., Palmer, M., and Salinger, J. (1999). Forward Collision Warning Systems, Draft Final Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

> The current human factors efforts demonstrate the critical importance of placing drivers under realistic (rather simulated) crash threat conditions and the merit of gathering baseline data (i.e., without crash alert support) to define drivers’ perceptions of “normal” and “non-normal” driving situations for defining crash alert timing. Gathering this baseline data prior to defining how to present crash alerts is of critical importance from an experimental validity perspective, since the crash alert timing and crash alert modality approaches are intimately related. The current project also demonstrates that this experimental strategy appears very effective for addressing the difficult trade-offs

associated with minimizing "too early" alerts while maximizing the likelihood of the driver successfully avoiding the crash response to the alert. The critical need for obtaining this type of data under closed course, controlled conditions is dictated by the infrequency of near and actual crashes in the real-world (and during large-scale experimental "field" trials), the sparseness of "black box" data available during these situations, the lack of data available to support collision warning benefits modeling, and the inherent difficulties involved in precisely reconstructing an accident.

The objective test procedures use the minimum functional requirements, including those driven by human factors data, to evaluate FCW systems using a set of 26 vehicle-level tests. These tests pass or fail a countermeasure-vehicle pair; no ratings are given. The tests are designed to be repeatable across testing sites and involve scenarios targeted toward two keys to successful deployment: ability to issue timely alerts to drivers in potentially threatening rear-end crash situations and ability to distinguish these situations from non-alarming everyday situations. A set of tests were executed and the results analyzed, validating the concept that such tests are feasible and valid assessment tools for rear-end crash countermeasures. On a larger scale, the results of the test methodology segment of the project suggest that vehicle-level testing procedures, when developed using carefully established requirements, knowledge of the technology challenges and relevant driving behavior data may provide a useful means of facilitating the successful deployment of crash avoidance countermeasures. Further evaluation of these requirements under in-traffic and operational field conditions will undoubtedly provide additional information for refining these requirements.

1999-Open Literature

Vision Enhancement:

FHWA

1995

1995-Open Literature

1996

1996-Open Literature

1997

1997-Open Literature

1998

1998-Open Literature

NHTSA

1995

Contract Number: HS521/S5007, Prime Contractor: Volpe National Transportation Systems Center

[1]Tijerina, L., Browning, N., Mangold, S.J., Madigan, E.F., and Pierowicz, J.A. (1995). Final Report- Examination of Reduced Visibility Crashes and Potential IVHS Countermeasures. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-201, DOT-VNSC-NHSTA-94-6).

> This report provides a preliminary analysis of reduced visibility crashes to support the development of crash avoidance system (CAS) concepts as part of the Intelligent Vehicle Highway System (IVHS). In this report, a reduced visibility crash is defined and background on driver perception is presented in order to identify candidate sources of visibility limitations and enhancements. Some indications as to the size of the reduced

visibility problem are presented. A detailed analysis of a sample of crashes is discussed to provide further insights into the nature of the problem. Candidate functional crash avoidance concepts are presented in terms of in-vehicle warning systems, roadway information systems, direct vision enhancement systems, and imaging vision enhancement systems. The mechanisms of reduced visibility and how it affects stopping sight distance are then presented together with recommended sight distances used in traffic engineering for highway safety. The analysis concludes with a list of research needs that will further an understanding of driver vision and perception requirements and the development of effective reduced visibility crash countermeasures

Contract Number: P50 AGI 1684-01, The Scientex Corporation, Human Factors Division

[2]Gish, K.W., and Staplin, L. (1995). Human Factors Aspects of Using Head Up Displays in Automobiles: A Review of the Literature, Interim Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 320).

This document provides an overview of studies investigating the use of head up displays (HUDs) by aviators and drivers, including a summary of HUD research variables, test procedures and study results. The predicted performance advantages of automotive HUDs include increased eyes-on-the-road time and reduced reaccommodation time, particularly for the older driver. To date, the research does not provide robust evidence for operationally significant performance advantages due to HUDs. However, conclusions are equivocal due to the interaction of independent variables such as workload, display complexity and age. Studies indicate that key operator performance issues with HUDs include contrast interference, where HUD symbology masks safety-critical targets in the forward driving scene, and cognitive capture, or degradation of responses to external targets due to the processing of information from a HUD image. In general, the review supports and extends earlier findings that HUD information cannot be processed separately from external roadway information. Countermeasures reviewed in this paper include the use of conformal symbology, and auditory HUDs. The review identifies a number of implementation issues for automotive HUDs: (1) reliable measures of the effect of HUD use on responses to priority external targets must be obtained, under realistic operating conditions; (2) practical considerations of cost, size, and adaptability to a range of driver eye heights figure prominently if the use of HUDs in the private vehicle fleet in the U.S. is to become routine; and (3) driver age and associated visual/cognitive performance differences which are commonly linked to safe vehicle operation must be taken into account during product design, development, and testing.

1995-Open Literature

1996

Contract Number?

[3]Cohn, T.E. (1996). Idea Project Final Report, Engineered Visibility Warning Signals: Tests of Time to React, Detectability, Identifiability and Salience. IDEA Project Final Report, Contract ITS-16.

> This investigation was completed as part of the ITS-IDEA Program which is one of three IDEA programs managed by the Transportation Research Board (TRB) to foster innovations in surface transportation. It focuses on products and result for the development and deployment of intelligent transportation systems (ITS), in support of the U.S. Department of Transportation's national ITS program plan. The investigators have demonstrated that an innovative means of delivering warning signals by incorporating motion in them, lends quicker reaction time, higher detectability, better salience and better immunity to distraction. These MEWS signals are likely to prove to be more immune to the effects of blur, fog and so on as well. The investigators have developed an icon-centered warning signal display that accommodates as many as eighteen different warning signals placed in logical relation to the vehicle. The vehicle icon serves two indispensable purposes, especially for heads-up viewing: it provides a stimulus for accommodation and it embodies a coordinate system within which to interpret the warnings and to quickly see the appropriate required response. Guidelines for warning signal designers have been developed within the project. The investigators have developed a testing system that can be used by warning signal designers to fashion signals of arbitrary complexity, for use in either head-up or head-down displays, and to test their properties. That system is constructed of readily available components and requires only unsophisticated software. Use of the benchmarks: the main use of the benchmarks presented in data tables cited above is for comparison with those obtained from other warning signals systems developed by designers. If a new design can produce its own benchmark values better than or within the error range of the values presented here, then the designer can be confident that the new design is acceptable as it stands. Benchmark values inferior to those presented here should alert the designer that better results could be achieved with design alteration. Finally, the investigators have been able to answer the fundamental question related to plans for a multiplicity of warning signals: our evidence suggests that there is no visual limitation that would prevent a vehicle operator with normal vision from correctly identifying a warning signal which is one of many (e.g. up to 12) possible; such identification can be virtually error-free at contrast levels achievable in vehicles.

1996-Open Literature

1997

1997-Open Literature

1998

1998-Open Literature

1999

Contract Number: P50 AGI 1684-01, The Scientex Corporation, Human Factors Division

[4]Gish, K.W., Staplin, L. and Perel, M.(1999). Human Factors Issues Related to the Use of Vision Enhancement Systems. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS ?).

> Vision Enhancement Systems (VESs) are currently being developed to improve nighttime driving safety by providing enhanced visual cues to drivers. In order to determine how to evaluate the potential benefits or limitations of such systems, a small-scale investigation of driver performance and behavior using a mockup VES was conducted. To maximize external validity and minimize safety risks, a field experiment was designed and conducted on a closed test track. Four younger (26-36) and four older (56-70) observers drove an instrumented vehicle and verbally reported the detection, and recognition, of targets placed along a predefined route while performing speed monitoring and navigation tasks. Targets near the edges of the lane of travel were detected with/without a mockup VES, and with/without headlight glare. Video recordings of the VES, road scene, driver, and data acquisition screen were obtained. Time code and distance traveled as well as drivers' verbal report, gas pedal, brake pedal, and steering wheel responses were recorded. Results suggest that although the mockup VES provided target contrast at longer preview distances than low beam headlights alone, the VES enhancements were not always detected by drivers due to the visual, scanning, and cognitive demands of the driving tasks. Also, older drivers were less willing to use the mockup VES. Based on verbal reports, the consensus among all observers is that the VES increased curve detection distances relative to low-beam headlights alone. Implications of the study findings for VES use, design, and evaluation are discussed.

1999-Open Literature

Drowsy Driver:

FHWA

1993

1993-Open Literature

1994

Contract Number?

[1]Anonymous (1994). Feasibility of Carrier-Based Fitness-for-Duty Testing of Commercial Drivers. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-95-011).

1994-Open Literature

1995

Contract Number: DTFH61-94-R-00182, Penn + Schoen Associates, Inc.

[2]Anonymous (1995). User Acceptance of Commercial Vehicle Operations (CVO) Services; Task B: Critical Issues Relating to Acceptance of CVO Services by Interstate Truck and Bus Drivers. Final Report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-?).

> This study documents that user resistance is real and must be overcome for successful deployment of driver alertness monitoring in commercial vehicles. In 1,134 in-person interviews with truck drivers (plus an additional 411 interviews with motor coach drivers), respondents were asked questions regarding their potential acceptance of six Intelligent Transportation System (ITS) Commercial Vehicle Operations (CVO) services as listed below:
>
> Commercial Fleet Management
> Electronic Clearance
> Commercial Vehicle Administrative Processes
> Automated Roadside Safety Inspection
> HM Incident Response Service
> On-Board Safety Monitoring [including Alertness Monitoring].

Drivers supported those technologies they perceived as useful, reliable, and effective in making their jobs easier. Of the above six technologies, On-Board Safety Monitoring (OBSM) was the CVO service least accepted by the truck drivers; for every 3 respondents who were "strongly in favor" of OBSM, there were 4 who were "completely opposed." Respondents recognized the potential safety benefits of OBSM, but generally considered it too invasive and too reliant on computers. The following general conclusion from the study is pertinent to OBSM:

A major finding was that actual experience working with CVO technologies generally leads to greater driver acceptance. For example, drivers who had participated in Electronic Clearance and Automated Roadside Safety Inspection operational tests were much more favorable toward these technologies than were other respondents. The report concluded that placing technologies directly in the hands of users themselves, and allowing them to experience and experiment would likely increase driver acceptance. Such programs could be very valuable if they were able to allow drivers to experience the technologies in an unthreatening environment.

1995-Open Literature

[3]Freund, D.M., Knipling, R.R., Landburg, A.C., Simmons, R.R., and Thomas, G.R. (1995). A Holistic Approach to Operator Alertness Research. Transportation Research Board 74th Annual Meeting, Washington, D.C., January 1995.

1996

Contract Number: DTFH61-89-C-096 & DTFH61-909-C-053, Essex Corporation

[4]Wylie, C.D., Shultz, T., Miller, J.C., Mitler, M.M., and Mackie, R.R. (1996). Commercial Motor Vehicle Driver Fatigue and Alertness Study (Final Report). Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-97-002).

This is the full final report of the largest and most comprehensive over-the-road study of commercial motor vehicle driver fatigue ever conducted in North America.

The data collection involved eighty drivers in the U.S. and Canada who were monitored over a period of sixteen weeks. A number of work-related factors thought to influence the development of fatigue, loss of alertness and degraded performance in CMV drivers were studied within an operational setting of real-life, revenue-generating trips. These included: the amount of time spent driving during a work period; the number of consecutive days of driving; the time of day when driving took place; and schedule regularity.

In Chapter 1, the reader is provided with the background to the study as well as the study’s overall objectives and the approach used in their attainment. Chapter2 presents a detailed literature review on driver fatigue and its measurement, as well as the involvement of fatigue in crashes, that was conducted in preparation for the study and considered in the formulation of the study’s own conclusions and recommendations.

For the amount of sleep and the four to five days of driving observed for each driver in this study, it was found that the strongest and most consistent factor influencing driver fatigue and alertness was time-of-day; drowsiness, as observed in video recordings of the driver’s face, was markedly greater during the night driving than during daytime driving. The number of hours of driving (time-on-task) and cumulative number of days were not strong or consistent predictors of observed fatigue. Numerous other findings are provided relating to scientific methodologies and fatigue countermeasure concepts.

[5]Wylie, C.D., Shultz, T., Miller, J.C., Mitler, M.M., and Mackie, R.R. (1996). Commercial Motor Vehicle Driver Fatigue and Alertness Study: Technical Summary. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-97-001).

Derived summary from FHWA-MC-97-002.

1996-Open Literature

1997

Contract Number?

[6]Anonymous (1997). Commercial Motor Vehicle Driver Fatigue, Alertness, and Countermeasures Survey (Final Report). Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-99-067).

1997-Open Literature

[7]Knipling, R.R. (1997). The Technologies, Economics, and Psychology of Commercial Motor Vehicle Driver Fatigue Monitoring. Proceedings of the International Large Truck Safety Symposium. University of Tennessee Transportation Center, Knoxville, pp. 215-224, October 1997.

[8]Knipling, R.R. Supplement on Driver Monitoring: FHWA OMC R&T Programs and Scientific Challenges. Proceedings of the Transportation Research Board Conference on Intelligent Transportation Systems, Highway Safety, and Human Factors. March 1997.

1998

Contract Number: DTFH61-96-00022, Trucking Research Institute

[9]Anonymous (1998). Ocular Dynamics as Predictors of Alertness and Prophylactic Napping as a Fatigue Countermeasure. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-?).

> This study investigated the potential use of eye tracking system for detecting reduced driver alertness, and the impact of prophylactic napping on driver performance and alertness. The study used traditional behavioral and physiological measures of alertness. In addition, an unobtrusive eye tracker attached to the simulator was used to measure eye and behavior. The results showed clear time-of-day (TOD) and time-on-task (TOT) effects for the following eye closure measures: partial closures during fixations, speed of slow eyelid closure (SEC), blink duration, and blink frequency.
>
> Eye closures during fixations exhibited the following alertness monitoring characteristics: 1) the cyclic phases of a driver experiencing brief lapses of alertness and recovery; 2) a continuous decline ultimately leading to an off-road simulator crash; 3) an early warning potential of 10 minutes or more; 4) a dramatic decline in the measure beginning 2-3 minutes before an off-road simulator crash. SEC events and blink duration shoed sustained increases with TOT and TOD. A preliminary algorithm for detecting level of alertness was developed. This algorithm uses the eye closure measure in a way that includes partial eye closure during fixations, blink frequency, blink duration, and speed of eye closure effects.
>
> The 3-hour afternoon nap increased the subjects’ nighttime alertness and improved performance. Beneficial effects of the afternoon nap on nighttime driving performance included significantly fewer crashes, shorter run completion times, and smaller standard deviations of lane position. The results provide evidence that the 3-hour afternoon nap was effective in reducing sleepiness levels during the following night and suggest that prophylactic naps may be more beneficial than recuperative naps during all-night driving situations.

Contract Number?

[10]Anonymous (1998). Local/Short haul Driver Fatigue Crash Data Analysis. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-98-016).

Contract Number: DTFH61-96-C-00105, Center for Transportation Research, Virginia Polytechnic Institute and State University

[11]Hanowski, R.J., Wierwille, W.W., Gellatly, A.W., Early, N., and Dingus, T.A. (1998). Impact of Local/Short Haul Operations on Driver Fatigue. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-98-029).

Eleven focus groups were held in eight cities across five states. The purpose of these sessions was to gain an understanding, from the local/short haul (L/SH) drivers' perspective, of the general safety concerns related to the short-haul industry and, specifically, the degree to which fatigue plays a role. Eighty-two L/SH drivers participated on the focus group sessions. The major portion of each focus group involved a discussion of critical incidents that drivers had either learned about or personally experienced. The purpose of this discussion was to generate a list of causal factors that might highlight safety-critical issues in the L/SH industry. The issues of interest included general safety concerns and those specifically related to fatigue. Drivers were able to generate fifteen general safety issues. The top five critical issues/causal factors, ranked in terms of importance, were: (1) Problems Caused by Drivers of Light Vehicles (i.e., four wheelers, (2) Stress Due to Time Pressure, (3) Inattention, (4) Problems Caused by Roadway/Dock Design, and (5) Fatigue. Regarding fatigue, analyses confirmed that drivers who raised Fatigue as a general safety issue had significantly less self-reported sleep per night (M=6.1 hours) as compared to drivers who did not raise Fatigue as an issue (M=6.7 hours). To further investigate the importance of fatigue, drivers were asked to generate and rank a list of fatigue-related issues. Across all sessions, twenty-two issues were raised. The top five issues, ranked in terms of importance, were: (1) Not Enough Sleep, (2) Hard/Physical Workday, (3) Heat/No Air Conditioning, (4) Waiting to Unload, and (5) Irregular Meal Times. These findings support past research that has suggested that Not Enough Sleep is the single best predictor for fatigue.

Contract Number: DTFH61-96-C-00068, Center for Transportation Research, Virginia Polytechnic Institute and State University

[12]Neale, V.L., Robinson, G.S., Belz, S.M., Christian, E.V., and Dingus, T.A. (1998). Impact of Sleeper Berth Usage on Driver Fatigue, Task 1: Analysis of Trucker Sleep Quality. Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

This report presents the results of a literature review and ten focus groups which were conducted with long-haul drivers in eight cities across seven states. The purpose of these sessions was to gain an understanding, from the long-haul drivers' perspective, of the issues affecting the quality and quantity of sleep drivers receive, as well as other issues that may affect drivers; levels of fatigue. A summary of the issues discussed is presented as the issues fall under the following categories: 1) sleep/rest and duty cycle issues, 2) equipment issues, 3) additional driver responsibilities, 4) facilities issues, 5) regulatory and enforcement issues, 6) driving and traffic issues, 7) terminus issues, 8) company dispatching issues, 9) training issues, 10) miscellaneous issues. The results of drivers' ratings of their sleep quality while at home and on the road are also presented. The gathered from the focus groups is summarized into a list of drivers' recommendations for improving the fatigue level among long-haul drivers. Concerns were highlighted by drivers in most or all of the focus groups included: 1) team driving, 2) equipment, 3) lack of rest area facilities, 4) private education, 5)loading and unloading cargo, and 6) pressure to drive. Based upon the information gathered, independent and dependent variables for evaluation are recommended during an on-road study.

1998-Open Literature

Contract Number?

[13]Knipling, R.R. (1998) The Technologies, Economics, and Psychology of Commercial Motor Vehicle Driver Fatigue Monitoring. Proceedings of ITS America's Eighth Annual Meeting and Exposition. Intelligent Transportation Society of America, Detroit, May 1998.

[14]Knipling, R.R. (1998) Three Fatigue Management Revolutions for the 21st Century. Third International Conference on Fatigue and Transportation, Fremantle, Australia, February 1998.

1999

Contract Number ?

[15]Anonymous (1999). Eye-Activity Measures of Fatigue and Napping as a Fatigue Countermeasure. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-99-028).

Contract Number: DTFH61-98-P-00393, Behavioral Technology, Inc.

[16]Krause, T.R., Robin, J.L., and Knilping, R.R. (1999). The Potential Application of Behavior-Based Safety in the Trucking Industry. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-MC-99-071).

The purpose of this research is to gain an understanding of Behavior-Based Safety (BBS) principles and to determine its applicability to the measurement and management of commercial motor vehicle driver performance and safety. As such, the contractor conducted a series of 3 presentations on BBS in late-August 1998. Two presentations were conducted at the HQ DIT and one was conducted at HQ American Trucking Associations Foundation, Inc. A question and answer session followed each presentation.

As discussed in the presentations, BBS employs "benchmark" behaviors that are identified as safety or productivity-critical. The organization then focuses on these benchmark behaviors for purposes of driver self-management, general management, corrective training and/or rewards. For example, if vehicle highway speed were identified as a safety-critical benchmark behavior, speed would be monitored and both drive and their managers would receive frequent feedback on the driver's degree of speed compliance. Gas compliance is another example of a benchmark behavior.

BBS methods have been implemented with great success in industrial setting and have tremendous potential for improving safety and productivity in the trucking industry. The potential benefits for the trucking community are even more pronounced if BBS principles are used in conjunction with the new or soon to be available, in-vehicle technologies (e.g., actigraphs, alertness monitors and electronic on-board recorders) which potentially provide safety-relevant and/or productivity-relevant behavior/performance benchmark information.

1999-Open Literature

Contract Number ?

[17]Knipling, R.R. and Shelton, T.T. (1999). Problem Size Assessment: Large Truck Crashes Related Primarily to Driver Fatigue. Paper submitted to the: Second International Large Truck Safety Symposium, University of Tennessee Transportation Center, Knoxville, October 6-8, 1999.

NHTSA

1993

1993-Open Literature

Contract Number: DTN22-91-Y-07266, Dept of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University

[18]Knipling, R.R., and Wierwille, W.W. (1993). US IVHS Research: Vehicle-Based Drowsy Driver Detection. Vigilance and Transport Conference, Lyons, France, December 1993 (Sponsored by INRETS).

1994

Contract Number: DTN22-91-Y-07266, Dept of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University

[19]Wierwille, W.W., Wreggit, S.S.,, Kirn, C.L., Ellsworth, L.A., and Fairbanks, R.J. (1994) Research on Vehicle-Based Driver Status/Performance Monitoring: Development, Validation, and Refinement of Algorithms for Detection of Driver Drowsiness. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 247).

1994-Open Literature

Contract Number: DTN22-91-Y-07266, Dept of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University

[20]Knipling, R.R., and Wierwille, W.W. (1994). Vehicle-Based Drowsy Driver Detection: Current Status and Future Prospects. Paper presented at IVHS America Fourth Annual Meeting, Atlanta, GA, April 17-20, 1994.

> Driver drowsiness is a major, though elusive, cause of traffic crashes. As part of its IVHS/human factors program, NHTSA is supporting research to develop in-vehicle systems to continuously monitor driver alertness and performance. Scientific support for the feasibility of this countermeasure concept is provided by research showing that:
>
> > - Drowsy drivers typically do not "drop off" instantaneously. Instead, there is a preceding period of measurable performance decrement with associated psychophysiological signs.
> >
> > - Drowsiness can be detected with reasonable accuracy using driving performance measures such as "drift-and-jerk" steering and fluctuations in vehicle lateral lane position.
> >
> > - The use of direct, unobtrusive driver psychophysiological monitoring (e.g., of eye closure) could potentially enhance drowsiness detection significantly.
> >
> > - The use of secondary/subsidiary auditory tasks (e.g., auditory recognition tasks presented to the driver via recorded voice) could further enhance detection accuracy.
>
> The envisioned vehicle-based driver drowsiness detection system would continuously and unobtrusively monitor driver performance (and "micro-performance" such as minute steering movements) and driver psychophysiological status (in particular eye closure). The system may be programmed to provide an immediate warning signal when drowsiness is detected with high certainty, or, alternatively, to present a verbal secondary task via recorded voice as a second-stage probe of driver status in situations of possible drowsiness. The key requirements and R&D challenges for a successful countermeasure include low countermeasure cost, true unobtrusiveness, an acceptably-low false alarm rate, non-disruption of the primary driving task, compatibility and synergy with other IVHS crash avoidance countermeasures, and a warning strategy that truly sustains driver wakefulness or convinces him/her to stop for rest.

[21]Wierwille, W.W. (1994). Overview of research on Driver Drowsiness Definition and Driver Drowsiness Detection. 14th International technical Conference on the Enhanced Safety of Vehicles, Munich, Germany, May 1994.

[22]Wierwille, W.W., Wreggit, S.S., and Knipling, R.R. (1994). Development of Improved Algorithms for On-Line Detection of Driver Drowsiness. Convergence Ninety-Four Conference, SAE, Detroit, MI, October 1994.

1995

Contract Number: DTN22-91-Y-07266, Dept of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University

[23]Fairbanks, R.J., Fahey, S.E., and Wierwille, W.W. (1995) Research on Vehicle-Based Driver Status/Performance Monitoring; Seventh Semiannual Research Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 299).

1995-Open Literature

Contract Number?

[24]Knipling, R.R., and Wang, J.S. (1995). Revised Estimates of the US Drowsy Driver Crash Problem Size based on General Estimate System Case Reviews. 39th Annual Proceedings of Association for the advancement of Automotive Medicine, Chicago, IL, October 1995.

1996

Contract Number: DTN22-91-Y-07266, Dept of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University

[25]Wierwille, W.W., Lewin, M.G., and Fairbanks III, R.J. (1996). Final Reports: Research on Vehicle-Based Driver Status/Performance monitoring, Part I. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 638).

> A driver drowsiness detection/alarm/countermeasures system was specified, tested and evaluated, resulting in the development of revised algorithms for the detection of driver drowsiness. Previous algorithms were examined in a test and evaluation study, and were found to be ineffective in detecting drowsiness. These previous algorithms had been developed and validated under simulator conditions that did not emphasize the demand for maintaining the vehicle in the lane as would be expected in normal driving. Revised algorithms were then developed under conditions that encourage more natural lane-keeping behavior by drivers in the simulator. In these revised algorithms, correlations between dependent drowsiness measures and independent performance-related measures were lower than expected. However, classification accuracy improved when a criterion of “drowsiness or performance” was used, with performance assessed directly from a lane-related measure.

[26]Wierwille, W.W., Lewin, M.G., and Fairbanks III, R.J. (1996). Final Reports: Research on Vehicle-Based Driver Status/Performance monitoring, Part II. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 639).

> A driver drowsiness detection/alarm/countermeasures system was specified, tested and evaluated, resulting in the development of revised algorithms for the detection of driver drowsiness. Previous algorithms were examined in a test and evaluation study, and were found to be ineffective in detecting drowsiness. These previous algorithms had been developed and validated under simulator conditions that did not emphasize the demand for maintaining the vehicle in the lane as would be expected in normal driving. Revised algorithms were then developed under conditions that encourage more natural lane-keeping behavior by drivers in the simulator. In these revised algorithms, correlations between dependent drowsiness measures and independent performance-related measures were lower than expected. However, classification accuracy improved when a criterion of "drowsiness or performance" was used, with performance assessed directly from a lane-related measure.

Contract Number: DTN22-91-Y-07266, Dept of Industrial and Systems Engineering, Virgina Polytechnic Institute and State University

[27]Wierwille, W.W., Lewin, M.G., and Fairbanks III, R.J. (1996). Final Reports: Research on Vehicle-Based Driver Status/Performance monitoring, Part III. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 640).

> A driver drowsiness detection/alarm/countermeasures system was specified, tested and evaluated, resulting in the development of revised algorithms for the detection of driver drowsiness. Previous algorithms were examined in a test and evaluation study, and were found to be ineffective in detecting drowsiness. These previous algorithms had been developed and validated under simulator conditions that did not emphasize the demand for maintaining the vehicle in the lane as would be expected in normal driving. Revised algorithms were then developed under conditions that encourage more natural lane-keeping behavior by drivers in the simulator. In these revised algorithms, correlations between dependent drowsiness measures and independent performance-related measures were lower than expected. However, classification accuracy improved when a criterion of "drowsiness or performance" was used, with performance assessed directly from a lane-related measure.

1996-Open Literature

Contract Number?

[28]Knipling, R..R., Wang, J.S., and Kanianthra, J.N. (1996). Current NHTSA Drowsy Driver R&D. Fifteenth International Technical Conference on the Enhanced Safety of Vehicles, Melbourne, Australia, May 1966.

Contract Number?

[29]Wang, J., Knipling, R..R., and Goodman, M.J. (1996). The Role of Driver Inattention in Crashes: New Statistics from the 1995 Crash worthiness Data System. In 40th Annual Proceedings of the Association for the Advancement of Automotive Medicine, Vancouver, British Columbia, October 7-9, 1996.

> In 1995, NHTSA began employing the Crash worthiness Data System (CDS) to obtain more in-depth information on driver inattention-related crash causes, including drowsiness and many forms of distraction. CDS is potentially an important source of information on this issue because it is broadly representative of U.S. passenger vehicle towaway crashes and because its investigations are moderately in-depth. This research paper reports the results of the 1995 CDS data collection on this issue. The three major forms of driver inattention and their percent involvement in 1995 CDS crashes are:
>
> - distraction (13.3 %),
> - looked but did not see (9.7%), and
> - sleepy/fell asleep (2.6%).
>
> Findings from this CDS data collection have both similarities to, and differences from, previous research on the role of driver inattention in crashes.

1997

1997-Open Literature

1998

Contract Number: DTN22-93-D-07007, University of Pennsylvania School of Medicine

[30]Dinges, D.D., Mallis, M.M., Maislin, G., and Powell IV, J.W. (1998). Final Report: Evaluation of Techniques for Ocular Measurement as an Index of Fatigue and as the Basis for Alertness Management. National Highway Traffic Safety Administration, Washington, D.C.
(DOT HS 808 762).

> This final report establishes the scientific validity of the ocular measure “Perclose” as a generally useful and reliable index of lapses in visual attention, i.e. the percentage of eyelid closure over the pupil. Perclose was previously specified as a relevant measure of drowsiness in several driving simulator studies (NHTSA final report, DOT HS 808 640). In the present research, further validation of Perclose was established among other

measures, in a controlled sleep deprivation study, using a well-known psychophysical index of lapses in visual attention, i.e. Psychomotor Vigilance Task (PVT). The present study provides the scientific and practical basis to relate real-time lapses in visual attention to over-the road driving performance.

1998-Open Literature

Contract Number?

[31]Rau, P. (1998). A Prototype Drowsy Driver Detection and Warning System for Commercial Vehicle Drivers. 16th International Technical Conference on the Enhanced Safety of Vehicles Abstracts, Windsor, Ontario, Canada (98-S2-P-30).

1999

1999-Open Literature

Contract Number?

[32]Anonymous (1999). The NHTSA & NCSDR Program to Combat Drowsy Driving Report to the House and Senate Appropriations Committees Describing Collaboration Between National Highway Traffic Safety Administration and National Center on Sleep Disorders Research National Heart, Lung and Blood Institute National Institutes of Health.

Drowsy driving is a serious problem that leads to thousands of automobile crashes each year. This report, sponsored by the National Center on Sleep Disorders Research (NCSDR) of the National Heart, Lung, and Blood Institute of the National Institutes of Health, and the National Highway Traffic Safety Administration (NHTSA), is designed to provide direction to an NCSDR/NHTSA educational campaign to combat drowsy driving. The report presents the results of a literature review and opinions of the Expert Panel on Driver Fatigue and Sleepiness regarding key issues involved in the problem.

Related Driver Behavior:

FHWA

1992

Contract Number?

[1]Walker, J., Sedney, C.A., Wochinger, K., Boehm-Davis, D., Perez, W., and Mast, T. (1992). Older Drivers and Useful Field of View in a Part-Task Simulator: A Follow-Up Study. Washington DC: U.S. Department of Transportation, Federal Highway Administration. (FHWA-RD-92-102). (Research document/Staff Study).

> In a follow-up study intended to refine a method of assessing age-related changes in the useful field of new (UFOV), drivers' responses to peripherally presented stimuli under varying central task load were investigated. In the previous study, increased central task load resulted in narrower UFOV among older subjects, but unlike more typical UFOV testing, did not affect younger and middle-aged subjects, but unlike more typical UFOV testing, did not affect younger and middle-aged subjects. It was speculated that one reason for this lack of effect was that the central tracking task used may not have been sufficiently demanding for subjects in these age groups. Modifications to the original procedure included the addition of a cognitive task, both alone and in combination with the original tracking task. Thirty-six subjects from the initial study, ages 20-25, 40-45, and 65-70, participated. Test trials were conducted in a part-task simulator with dynamic roadway images projected on screens to the front and sides. Target stimuli consisted of speed below the motion threshold. In addition to baseline trials, subjects performed the central tasks, both of varying difficulty, while responding to the vehicles on the side screens. As in the original study, only older subjects' performance, as measured by response time, was adversely affected by increased central task load. Analyses of tracking error however suggested that performance decrements occurred in the central tasks, rather than UFOV, among groups as well. It was concluded that the procedures and apparatus are insufficiently sensitive for use in measurement of UFOV. Reasons for this conclusion, and implications of the obtained results, are discussed.

1992-Open Literature

1993

1993-Open Literature

1994

1994-Open Literature

1995

Contract Number?

[2]Anonymous (1995). Traffic Operations Control For Older Drivers And Pedestrians. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. (FHWA-RD-95-169).

Contract Number?

[3]Kloeppel, E., Peters, R., James, C., Fox J., and Alicandri, E. (1995). A Comparison of Older and Younger Drivers' Responses to Emergency Driving Events. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. (FHWA-RD-95-056).

Contract Number?

[4]R.L. Knoblauch, M. Nitzburg, and R.F. Seifert (1995). Investigation of Older Driver Freeway Needs and Capabilities, Final Report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-194).

1995-Open Literature

1996

[5]Anonymous (1995). Driver Acceptance of Commercial Vehicle Operations (CVO) Technology in the Motor Carrier Environment. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

> This study of CVO Services shows that on the whole, Commercial Vehicle drivers are receptive to and supportive of the use of CVO services on the road and in their vehicles. Technologies which received the most support were those that would "make my work easier," are "useful for me" and "will work [in my vehicle]", and "I would rely on it." However, there was some concern that certain of the technologies would be an invasion

of driver privacy by either the government or the driver's company, and also a concern that the systems would rely too much on computers and diminish the role of human judgment. Drivers were wary of services that promised too much and would leave them dependent on unproven, inexperienced technology. They wanted systems that would be reliable, workable, and useful on a consistent basis, and would not pose a threat to themselves, their vehicles, their privacy, or their livelihood. On the whole, drivers tended to evaluate the CVO services from the perspective of their personal experience, rather than focusing on the bigger picture of the industry as whole. For example, independent owner operators, who have historically been more skeptical of technology and wary of intrusion by the government or companies, reacted more negatively toward the technologies than did other drivers. Therefore, when reviewing the results of this study it is important to pay particular attention to the analysis of subgroups, because their personal experience as a driver shaped their view of the technologies. In particular, there was significant difference between the following groups: Union vs. Non-union drivers, Company drivers vs. Independent owner operators, Younger vs. Older drivers, Newer drivers vs. Drivers who have been driving for many years, and Truck drivers vs. Bus drivers. Driver acceptance of the installation of the technology in their vehicles is most closely linked with feelings that the technology is useful, reliable, and effective in making their jobs easier. Therefore, a primary focus of this study is to identify those drivers who stand to benefit the most from the technology, determine their initial reactions, and provide the government with actionable recommendations that they can use to make the drivers more favorable to CVO services.

Contract Number?

[6]Anonymous (1996). Analysis of Older Drivers on Freeways. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration. (FHWA-RD-96-035).

Identifying the unique problems of elderly drivers on freeways was the principal purpose of the analysis undertaken in this effort. The accident data bases used in achieving the study objective included files from five of the State data bases presently maintained in the Highway Safety Information System (HIS). The years of data included in the analysis were as follows: Illinois (1988 - 1991), Michigan (1988 - 1991), Minnesota (1988 - 1991), North Carolina (1988 - 1992), and Utah (1990 - 1992). The results from this analysis were combined with the results of a literature review, focus group discussions, and other tasks conducted in the FHWA study "Investigation of Older Driver Freeway Needs and Capabilities" to develop a series of recommended research ideas to address the identified problems of older drivers on freeways. The problems identified in this accident analysis were related to lane-change and merge maneuvers of older drivers and their likelihood of being the driver at fault by failing to yield. Recommended research that has been identified as the result of this accident analysis includes: identification of the ramp and mainline geometrics and characteristics that contribute to freeway merge problem, identification of geometric features and traffic control devices that can be used to minimize problems in transition areas, and analysis of the behavior exhibited during lane-change and passing/overtaking maneuvers.

1996-Open Literature

1997

1997-Open Literature

Contract Number?

[7]James, C.L., Wochinger, K., James, W.S., and Boehm-Davis, D. (1997). Visual, Perceptual, and Cognitive Measures as Predictors of Collision Detection in Older Drivers. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, 1997, pp. 1018-1022. Albuquerque, NM: Human Factors and Ergonomics Society.

This experiment examined whether visual, perceptual, or cognitive measures predicted the ability to detect vehicle collisions in intersections. Sixty subjects, comprised of three age groups balanced by gender, were presented dynamic intersection approaches in a part-task simulator. The subjects were asked to project the forward progress of crossing traffic and to indicate whether any of the crossing vehicles would conflict with their traffic. Independent variables included visual, perceptual, and cognitive test batteries. Dependent variables included accuracy in collision detection and error type. Results showed that all three batteries predicted accuracy, but that the perceptual battery was the most predictive for each age group.

1996-Open Literature

1998

1998-Open Literature

NHTSA

1989

Contract Number?

[8]Anonymous (1989). Older Drivers: The Age Factor in Traffic Safety. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 807 402).

This study analyzed crash involvement rates based upon estimates of miles driven. The study indicated that motor vehicle crashes are not a major cause of death for older persons (0.5% for those over 60). Motor vehicle crash involvement per unit population is highest for 18 year olds (5 times those over 80) and declines steadily with increasing age until 70, at which point the rate increases somewhat. The study went on to show that older drivers have more crashes in urban areas, at intersections and driveways, during the day, and with one other vehicle. Also, older drivers in crashes were more likely to be cited for right-of-way and sign violations.

Contract Number?

[9]Anonymous (1989). Driving Practices of Older Drivers in Rural and Urban Areas. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

Under interagency agreements with the National Institute on Aging, NHTSA sponsored projects by Yale University and the University of Iowa to study how functional capability influences the driving practices of older drivers. The Yale study focused on an urban driving environment, the Iowa study on a rural environment. Research indicated that older drivers tend to self-adjust their driving to accommodate any reduction in functional capacity. The results also showed that older driver safety problems are concentrated among drivers who are either unaware of their difficulties or unable to make compensating adjustments to their driving. A series of journal articles on functional impairments and driving patterns among older drivers in a rural and urban communities have been published.

1989-Open Literature

1990

1990-Open Literature

1991

1991-Open Literature

1992

1992-Open Literature

1993

Contract Number: DTRS-57-89-D-00086, Battelle

[10]Kiger, S., Rockwell, T., Niswonger, S., Tijerina, L., Myers, L., and Nygren, T. (1993). Heavy Vehicle Driver Workload Assessment-Task 3: Task Analysis Data Collection. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 467(3) Final Report Supplement).

[11]Tijerina, L.,, Kiger, S., Wierwille, W., Rockwell, T., Kantowitz, B., Bittner, A., Nygren, T., Myers, L., Tolbert, C.,and McCallum, M. (1993). Heavy Vehicle Driver Workload Assessment-Task 3: Task Analysis Data Collection. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 467(3) Final Report Supplement).

[12]Wierwille, W., Tijerina, L., Kiger, T., Rockwell, Lauber, E., and Bittner, A. (1993). Heavy Vehicle Driver Workload Assessment-Task 4: Review of Workload and Related Research. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 467(4) Final Report Supplement).

1993-Open Literature

1994

1994-Open Literature

Contract Number: DTRS-57-89-D-00086, Battelle

[13]Tijerina, L.,, Kantowitz, B., Kiger, S., and Rockwell, T. (1994). Driver Workload Assessment of In-Cab Technology Devices. The Fourteenth International Technical Conference on the Enhanced Safety of Vehicles Abstracts.

1995

Contract Number?

[14]Anonymous (1995). Understanding Youthful Risk Takers. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 318).

> To make major inroads in the youth crash problem, countermeasures are needed that can deal effectively with youthful risk taking. Developing these countermeasures requires an understanding of the mechanisms underlying risk taking. This project is part of a broader effort by NHTSA to develop that understanding, and those countermeasures. The project

looks at risk taking in a broader context than highway safety, and includes extensive literature review as well as a workshop with experts.

Contract Number?

[15]Anonymous (1995). Understanding Youthful Risk Taking and Driving: Database Report. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 346).

This report catalogs national databases that contain information about adolescents and risk taking behaviors. It contains descriptions of the major areas, unique characteristics, and risk-related aspects of each database. The report also contains information on databases that states collected on various domains of risk taking behaviors.

1995-Open Literature

1996

Contract Number: DTNH22-91-C-07003, Battelle Memorial Institute

[16]Tijernia, L. (1996). Heavy Vehicle Driver Workload Assessment. National Highway Traffic Safety Administration, Washington, D.C. (DOT-HS-808-466).

This report summarizes a program of research to develop methods, data, and guidelines to conduct heavy vehicle driver-oriented workload assessments of new, high-technology, in-cab devices. Many such devices are being developed and implemented in heavy trucks and cars. Examples include navigation systems, text message display systems, and voice communications systems, to name a few. The objective of this research was the development of methods to assess the degree to which in-cab device use competes with the primary task of safely controlling the vehicle at all times. The following seven tasks, conducted throughout this program, are summarized: reviewing task analysis data and protocols literature; defining standard heavy vehicle configuration and tasks; collecting original task analysis data; reviewing workload measures and related research; developing a workload measurement protocol document; collecting baseline data of workload measures; and evaluating two high-technology systems using the develop protocols. Presented for each task is a summary of the objectives, approach, and key results highlights. From this research, tentative heavy vehicle workload assessment measures and methods were recommended and a protocol document was prepared. The program of research was comprised of the following tasks:

- Task 1: Task analysis data and protocol review
- Task 2: Define standard heavy vehicle configuration and tasks
- Task 3: Task analysis data collection
- Task 4: Review of workload measurement and related research
- Task 5: Develop workload measurement protocols

- Task 6: Collect baseline workload data
- Task 7: Evaluate 2 high-technology systems (in-cab text message system and cellular phone).

Each task also resulted in Task reports. A total of 9 volumes (including this executive summary) were complied under the contract.

1996-Open Literature

Contract Number: DTNH22-91-C-07003, Battelle

[17]Kantowitz, B.H., Hanowski, R.J., and Tijerina, L. (1996). Simulator Evaluation of Heavy Vehicle Driver Workload II: Complex Tasks. Proceedings of the Human Factors and Ergonomics 40th Annual Meeting, Philadelphia, PA, September 1996.

[18]Tijerina, L. and Goodman, M.J. (1996). Use of Workload Assessment Measures and Methods to Assess Safety-Relevant Impacts of In-Vehicle Devices Use Among Heavy Vehicle Drivers. 15th International Technical Conference on Enhanced Safety of Vehicles, Melbourne, Australia, May 1996. Paper No. 96-11-W-25.

1997

1997-Open Literature

1998

1998-Open Literature

Driver Vehicle Interface (DVI):

FHWA

1993

1993-Open Literature

1994

Contract Number?

[1]Anonymous (1994). Symbol Signing for Older Drivers. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-069).

1994-Open Literature

Contract Number: DTFH61-92-C-00102, Battelle Human Factors Transportation Center

[2]Mollenhauer, M.A., Lee, J., Cho, K., Hulse, M.C., and Dingus, T.A. (1994). The Effects of Sensory Modality and Information Priority on In-Vehicle Signing and Information Systems. Proceedings of the Human Factors Society 38th Annual Meeting, 1994, pp. 1072-1076. Santa Monica, CA: Human Factors and Ergonomics Society.

1995

Contract Number?

[3]Anonymous (1995). Improvements in Symbol Sign Design to Aid Older Drivers. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-95-128).

> The study was conducted in two phases of laboratory investigations. The first phase assessed daytime visibility and comprehension of all 85 of the symbols in the Manual on Uniform Traffic Control Devices (MUTCD). Based on these results, a sample of 18 symbols (6 "best," 6 "intermediate," and 6 "worst") were selected for further testing of glance legibility, reaction time, and conspicuity. Phase I results found: (1) older drivers' comprehension of symbol signs was poorer than both younger and middle-aged drivers; and (2) older drivers' legibility distances were shorter. These findings were especially true of recreational and cultural signs, where the symbols are ambiguous and background color tends to provide poor conspicuity. Phase II results from the modified and novel sign studies found that sign modification did little to improve comprehension, which was

from 67 to 100 percent across all signs. Overall, the degree of improvement for the redesigned signs was greater than for the modified signs, and the redesign was especially helpful for the least legible signs.

1995-Open Literature

1996

Contract Number: DTFH61-90-C-00030, Hughes Aircraft Company

[4]Shirkey, K., Mayhew, G., and Casella, B. (1996). In-Vehicle Safety Advisory and Warning System (IVSAWS), Volume I: Executive Summary. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-061).

> The In-Vehicle Safety Advisory and Warning System (IVSAWS) is a Federal Highway Administration effort to develop a nationwide vehicular information system that provides drivers with advance, supplemental notification of dangerous road conditions using electronic warning zones with precise areas of coverage. The research study investigated techniques to provide drivers with advance notice of safety advisories and hazard warnings so drivers can take appropriate actions. The technical portion of the study identified applicable hazard scenarios, investigated possible system benefits, derived functional requirements, defined a communication architecture, and made recommendations to implement the system. This volume is the first in a series. The other volumes in the series are:
> FHWA-RD-94-190 Volume II: Final Report
> FHWA-RD-94-191 Volume III: Appendixes A Through H (Reference Materials)
> FHWA-RD-94-192 Volume IV: Appendixes I Through K (Reference Materials)
> FHWA-RD-94-193 Volume V: Appendixes L Through V (Reference Materials)

[5]Shirkey, K., Mayhew, G., and Casella, B. (1996). In-Vehicle Safety Advisory and Warning System (IVSAWS), Volume II: Final Report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-190).

> The In-Vehicle Safety Advisory and Warning System (IVSAWS) is a Federal Highway Administration effort to develop a nationwide vehicular information system that provides drivers with advance, supplemental notification of dangerous road conditions using electronic warning zones with precise areas of coverage. The research study investigated techniques to provide drivers with advance notice of safety advisories and hazard warnings so drivers can take appropriate actions. The technical portion of the study identified applicable hazard scenarios, investigated possible system benefits, derived functional requirements, defined a communication architecture, and made recommendations to implement the system. This volume is the second in a series. The other volumes in the series are:

FHWA-RD-94-061 Volume I: Executive Summary
FHWA-RD-94-191 Volume III: Appendixes A Through H (Reference Materials)
FHWA-RD-94-192 Volume IV: Appendixes I Through K (Reference Materials)
FHWA-RD-94-193 Volume V: Appendixes L Through V (Reference Materials)

[6]Shirkey, K., Mayhew, G., and Casella, B. (1996). In-Vehicle Safety Advisory and Warning System (IVSAWS), Volume III: Appendixes A Through H. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-94-191).

> The research study investigated techniques to provide drivers with advance notice of safety advisories and hazard warnings so drivers can take appropriate actions. The technical portion of the study identified applicable hazard scenarios, investigated possible system benefits, derived functional requirements, defined a communication architecture, and made recommendations to implement the system. This volume is the third in a series and describes details of the human factors tasks. The other volumes in the series are:
> FHWA-RD-94-061 Volume I: Executive Summary
> FHWA-RD-94-190 Volume II: Final Report
> FHWA-RD-94-192 Volume IV: Appendixes I Through K (Reference Materials)
> FHWA-RD-94-193 Volume V: Appendixes L Through V (Reference Materials)

Contract Number: DTFH61-91-C-00042, Prime Contractor: The Last Resource Inc.

[7]Garvey, P., and Mace, D. J. (1996). Changeable Message Sign Visibility. Washington, DC: US Department of Transportation, Federal Highway Administration (FHWA-RD-94-077).

> The object of this contract was to identify problems with the visibility of CMS's, particularly for older drivers, and to develop design guidelines and operational recommendations to ensure adequate conspicuity and legibility of in-service CMS's. This project was divided into three main sections; a field survey of in-use CMS's, a series of laboratory experiments and static field studies, and a partially controlled dynamic field study. The research was designed to optimize CMS components, including the character variables (font, width-to-height ratio, color, and contrast orientation) and the message variables (inter-letter, inter-word, and inter-line spacing).

1996-Open Literature

1997

Contract Number?

[8]Anonymous (David Evans and Assoc.) (1997). User Group Deployment: Puget Sound Help Me (PuSHMe) Operational Test Task 3: Technical Memorandum. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-?).

Safety is a major goal of the National Intelligent Transportation System (ITS) Program. To promote safety, the Federal Highway Administration (FHWA) funded several field operational tests to evaluate technologies designed to decrease transportation related risk. Mayday services were among these technologies. Mayday services allow motorists to report incidents to service centers which, in turn, alert a service provider who dispatches aid to the scene. Mayday services meet the national ITS goal of improving safety by "improving [emergency medical] and roadway service response, reducing the number of fatalities and the severity of injuries resulting from a collision, and reducing the number of pedestrian and vehicle collisions secondary to an incident." These technologies will be introduced into a well established E-911 / Emergency Service arena. This arena has its own protocols, technologies, regulations, liability, and risks. New technologies that enter into this arena must adhere to or complement the existing structure in order to be effective. The User Deployment phase of the Puget Sound Help Me (PuSHMe) project conducted a series of tests to determine if two prototype Mayday technologies would provide such information and be able to integrate into the existing E-911 system. This report documents the User Deployment Phase of the Puget Sound Help Me (PuSHMe) Field Operational Test in Seattle, Washington. This phase of the PuSHMe evaluation directly tested the functioning and reliability of the PuSHMe technologies.

Contract Number: DTFH61-01-C-00018, Prime Contractor: Swanson Transportation Consultants, Ltd.

[9]Marshall, R. and Mahach, K. (1997). The Effects of IVIS on Driver Response to Stop Signs and Traffic Signals on a Simulated Rural Highway. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-96-213).

An important goal in the ongoing evolution of the In-Vehicle Information System (IVIS) is to provide dynamic and accurate regulatory, warning and guidance information to drivers in an effective and safe manner. This is necessary due to the limitations of conventional traffic control devices in providing consistent delectability and legibility in clear and adverse visibility conditions. In addition, as the driving population continues to age, the calculations on which sign visibility distances are based will decreasingly reflect the visual capabilities of road users. In contrast, an in-vehicle information system would be consistently detectable and legible, and may be user-configurable for optimal presentation.

While there is currently much interest in this technology, few reports have been published that evaluate how drivers feel about the design and implementation of the IVIS. In this study, 48 young (ages 18-21), middle (ages 30-45), and older (ages 65+) licensed drivers were recruited to navigate through a simulated highway environment under clear or adverse visibility conditions. Regulatory and warning traffic control devices were presented throughout the scene, either with current standard devices or via a dash-mounted IVIS display, located to the immediate right of the steering wheel. At the completion of the driving scenario, drivers rated the usability of the IVIS.

Results indicated that the IVIS led to quicker response times to traffic control devices in adverse visibility conditions and was particularly helpful for older drivers. Most participants found the IVIS easy to detect and read. However, many voiced concern that in-vehicle information may divert attention away from the road. The cost of implementing such a system was also a common concern. These results will be used as a basis for future IVIS research, particularly in the areas of display placement, the need for proper temporal and visual cues, and user options.

1997-Open Literature

1998

Contract Number?

[10]Anonymous (1998). Summary Report: Human Factors Research Needs For The Intelligent Vehicle Initiative (IVI) Program. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA FHWA-RD-98-147).

This flyer summarizes the activities and results of a preliminary human factors review for the Intelligent Vehicle Initiative (IVI) Program. As part of the IVI program, the Federal Highway Administration funded a project to investigate the human factors issues for an IVI and identify human factors "research needs" that currently exist. The objective of the project was to help the United States Department of Transportation (U.S. DOT) identify human factors work that needs to be done early in the life-cycle of the IVI program to ensure safe and well-engineered vehicles. The IVI has the potential to provide drivers with useful information for many driving conditions and situations, to improve driving performance, and, ultimately, to increase the mobility and safety of the entire driving public. The IVI clearly represents an increase in the number of displays and controls for the in-vehicle environment, with a concurrent increase in the amount and complexity of information presented to the driver. If human factors integration and design issues are not addressed throughout the development process for the Generation I IVI, there is a risk that this increase in information will lead to information overload, driver confusion, and actual decreases in driver performance and safety. This project was comprised of two major activities. First, a "Preliminary IVI Human Factors Technology Workshop" to draw together the stakeholders in the IVI program to begin to define the technologies and the human factors issues that need to be considered in developing an IVI. Second, the project team investigated the preliminary infrastructure and human factors in-vehicle requirements for alternative configurations of an IVI. The data collected during the Human Factors IVI Workshop served as a basis for human factors research needs that were identified.

Contract Number?

[11]Anonymous (1998). Summary Report: Integrated Capabilities in Heavy Vehicles: Human Factors Research Needs. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-187).

> As part of the U.S. Department of Transportation's Intelligent Vehicle Initiative (IVI) program, the Federal Highway Administration (FHWA) investigated the human factors research needs for integrating in-vehicle safety and driver information technologies into usable systems that provide manageable information to the driver. This investigation included a workshop in December 1997 for IVI stakeholders (i.e., universities, automotive manufacturers, vendors, and contractors) and a preliminary assessment of infrastructure and in-vehicle requirements. This flyer summarizes the identified human factors research needs for integrated in-vehicle systems for Commercial Vehicle Operations (CVO), one of five configurations of in-vehicle safety and driver information systems. A complete review of the research needs for all five configurations can be found in the final report (FHWA-RD-98-178). These configurations were developed based on: (1) identified safety and driver information systems and functions; (2) a thorough literature review of past research and research gaps related to these in-vehicle systems; and (3) combining logical groups of basic and advanced safety and driver information functions in passenger cars, commercial trucks, and transit vehicles such as buses. Each candidate configuration was meant to provide clear safety benefits to the driver as well as a solid technical foundation for the system configurations for the IVI. The goal of the configuration described below is to provide an integrated set of Intelligent Transportation System (ITS) technologies for drivers of commercial or heavy vehicles.

Contract Number: DTSO-96-D-00429, Battelle Seattle Research Center

[12]Campbell, J.L., Everson, J.H., Garness, S.A., Pittenger, J.L., Kennedy, J., and Llaneras, E. (1998). Preliminary Human Factors Review for the Intelligent Vehicle Initiative (IVI) Program: Identification of Human Factors Research Needs--Final Report. Washington, DC: U.S. Department of Transportation, Federal Highway Administration (FHWA-RD-98-178)

> This report summarizes the activities and results of a preliminary human factors review for the Intelligent Vehicle Initiative (IVI) program. The objective of the project was to help the U.S. Department of Transportation identify human factors work that needs to be done early in the life cycle of the IVI program to ensure safe and well-engineered vehicles. This project was comprised of two major subtasks: Subtask 1 provided for a Preliminary IVI Human Factors Technology Workshop to draw together the stakeholders in the IVI program to begin to define the technologies and the human factors issues that need to be considered in developing an IVI. Subtask 2 investigated the preliminary infrastructure and human factors in-vehicle requirements for alternative configurations of an IVI. The data collected in the Human Factors Technology Workshop in subtask 1

served as a basis and starting point for the research performed to identify human factors research needs that exist. The following conclusions were developed during the conduct of this project: (1) human factors research needs for the Generation I IVI focus on the need to integrate and manage the information presented to the driver; (2) no publicly available human factors research has examined the effects of integrating multiple Intelligent Transportation Systems (ITS) devices into a vehicle as envisioned by the IVI; (3) considerable human factors research has been conducted to support the development of individual User Services within the IVI; (4) a broad range of ITS technologies are available to support the development of a Generation I IVI prototype; and (5) for the Generation II and III IVI especially, extensive algorithm/software, infrastructure, and specific technologies are needed.

1998-Open Literature

NHTSA

1994

1994-Open Literature

1995

Contract Number: DTNH22-91-C-07003, Battelle

[13]Hanowski, R.J., Kantowitz, B., and Tijerina, L. (1995). Heavy Vehicle Driver Workload Assessment-Task 7B: In-Cab Text Message System and Cellular Phone Use by Heavy Vehicle Drivers in Part-Task Driving Simulator. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 467(7B) Final Report Supplement).

Previous research has shown that heavy-vehicle driver workload can be measured in a simulator with simple secondary tasks such as choice reaction time and immediate recall (Kantowitz, 1995). The present experiment replicates and extends these findings to complex tasks requiring drivers to use cellular phones and to interpret text message displays. Fourteen commercial drivers each drove eight simulator modules, each 100,000 feet in length. In-cab tasks were divided into cellular phone dialing, phone dialogue, text message reading, tachometer reading, clock reading, and manual dial tuning. These were evaluated in light and heavy traffic with and without pedestrian detection tasks. Complex tasks requiring message reading had the greatest impact on driver performance. Results illustrate both advantages and limitations of driving simulators.

1995-Open Literature

Contract Number: DTNH22-91-C-07003, Battelle

[14]Kantowitz, B.H. (1995). Simulator Evaluation of Heavy-Vehicle Driver Workload. Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, 1995, pp. 1107-1011. Santa Monica, CA: Human Factors and Ergonomics Society.

> Six primary-task and four secondary-task workload measures were investigated in a fixed-base-truck simulator. Twelve commercial drivers each drove twelve simulator modules, each 55,000 feet in length. Independent variables were road geometry, traffic density, and secondary task. Two secondary tasks, reaction time to reading the vehicle tachometer and immediate recall of a 7-digit auditory number provided effective measures of driver workload.

1996

Contract Number: DTNH22-27016, Ford Motor Company Advanced Vehicle Technology

[15]Allen, W., Eckert, S., Magdaleno, R., Sieja, T., Serafin, C., and Zoebel, G. (1996). Manual Headway Control Experiments Conducted Under Test Track and Open Road Driving Conditions. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS?).

> This report documents a series of experiments (Human Factors Studies for the Evaluation Analysis, and Operational Assessment of the Intelligent Cruise Control System) designed to identify the dynamic behavior of drivers controlling headway behind a lead vehicle. The experiments were performed on both a test track and the open highway. Time series were recorded during relatively periods of vehicle following. The main recorded variables included headway distance to the lead vehicle, following vehicle velocity, and driver throttle activity. FFT (Fast Fourier Transform) analysis procedures were used to identify transfer functions of driver/vehicle response to changes in headway distance with respect to the lead vehicle. Transfer function analysis allowed the identification of driver gain and time delay in manual headway control. The results showed that manual headway control is a low bandwidth process carried out with average, continuous control time delays on the order of seconds. Phase margins showed the headway control process tends to be under damped (i.e. somewhat oscillatory) with bandwidths on the order one-third of a radian per second (0.05 Hz). This identification of the coupling dynamics of manual headway control will be useful in setting desirable automatic headway control (Intelligent Cruise Control) system characteristics.

[16]Serafin, C. (1996). Human Factors Studies for the Evaluation, Analysis, and Operational Assessment of an Intelligent Cruise Control System; Driver Preferences and Usability of Adjustable Distance Controls for an Adaptive Cruise Control (ACC) System. National Highway

Traffic Safety Administration, Washington, D.C. (DOT HS?).

> This report describes an investigation of driver preferences and usability of adjustable distance controls for an adaptive cruise control (ACC) system. ACC is conceived as an enhancement to conventional cruise control that would accommodate a slower moving vehicle in the lane of travel by providing some moderate level of deceleration and distance maintenance behind the slower vehicle. While the ACC system is maintaining a distance behind a slower vehicle, there is the possibility for the driver to adjust the following distance according to his/her preferences. In this study, thirty-six participants (equal numbers of men and women grouped according to ages 25-39, 40-54, and 55 and over) were introduced to the concept of ACC by using a computer prototype of an ACC system. Participants were asked to provide their preferences for labels for two types of adjustable distance controls: one type that adjusts both speed and distance (shared controls) and another that adjusts only distance (separate control). They also used the controls to get closer and farther away from a slower vehicle in front of them and provided their preferences for shared or separate controls for distance adjustment. Participants preferred shared controls to a separate control for distance adjustment. They preferred the labels ACC/DEC for shared controls over "+/-" and ACC/COAST. The labels preferred for the separate control were NEAR/FAR as opposed to symbols (arrows or chevrons). Because these preferences were obtained through the use of a computer prototype of ACC, usability tests should be conducted on the road to validate the data.

Contract Number: Mn/DOT Agreement Nos. 71789 and 72984, University of Minnesota

[17]Stackhouse, S.P., and Burrus, M. (1996). Genesis Pilot Human Factors Test, Human Factors Evaluation of Driver Multitasking And Message Formats. Final Report. University of Minnesota, Minneapolis, MN.

> The work reported here was on two separate topics. The first of these was the multitasking effects on driving performance of using pagers or PDAs while driving. The literature showed that such effects can occur but that they are task specific. Findings cannot be generalized from one task situation or device to another. The second topic was the format for message presentation on the pager or PDA. The message formats could be improved. Improvement would result in improved legibility and comprehension and decrease the time a driver would attend to the display.

1996-Open Literature

Contract Number?

[18]Carter, R., Barickman, F.S., and Goodman, M. (1996). A Driver Performance Data Acquisition System for Human Factors Research. International Conference on Traffic and Transportation Psychology, Valencia , Spain, May 1996.

1997

Contract Number?

[19]Haskelkorn, M., Spyridakis, J., Gaitchi, D., Semple, K., and O'Connor, C. (1997). Evaluation of the Pushme Regional Mayday System Operational Test. National Highway Traffic Safety Administration, Washington, D.C. and Washington State Transportation Center (WA-RD 443.1).

> PuSHMe tested two systems, one voice and the other text-based, that allowed drivers to signal a need for in-vehicle emergency assistance to a monitored response center. Evaluation occurred in four areas: (1) performance, (2) usability, (3) market analysis and (4) institutional issues. It was concluded that these systems could approach 100% successful operation in a true market deployment though in a simulated deployment there was a 70.5% success rate of all trials. Users response was generally favorable. Market analysis suggested numerous strategies, including that pricing should favor usage fees over purchase cost. Institutional analysis found serious obstacles to collaboration between private and public response centers, but also alternatives to the collaborative model such as focus on non-emergency services or private response groups "becoming" the public emergency service provider through outsourcing.

Contract Number: DTNH22-95-P-07219, ?

[20]Hulse, M.C., Jahns, S.K., and Mollenhauer, M.A. (1997). An Analysis of "Near-Miss" Data from the TravTek Operational Test. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 621).

1997-Open Literature

1998

Contract Number: DTNH22-95-H-07428, University of Michigan Transportation Research Institute

[21]Fancher, P., Ervin, R., Sayer, J., Hagan, M., Bogard, S., Bareket, Z., Mefford, M., and Haugen, J. (1998). Intelligent Cruise Control Field Operational Test Final Report -- Volume I, II and III. National Highway Traffic Safety Administration, Washington, D.C. (DOT HS 808 849).

> This document reports on a cooperative agreement between NHTSA and UMTRI entitled Intelligent Cruise Control (ICC) Field Operational Test (FOT). The main goal of the work is to characterize safety and comfort issues that are fundamental to human interactions with an automatic, but river-supervised, headway-keeping system.

Volumes I and II of this report describe the work done to prepare and instrument a fleet of 10 passenger cars with infrared ranging sensors, headway-control algorithms, and driver interface units as needed to provide an adaptive-cruise-control (ACC) functionality, and these volumes present results and findings deriving from operational testing lasting from July 1996 to September 1997. The vehicles were given to 108 volunteer drivers to use for two or five weeks as their personal cars. An extensive data base covering objective and subjective results has been assembled and analyzed. The central finding presented here is that ACC is remarkably attractive to most drivers. The research indicates that, because ACC is so pleasing, people tend to utilize it over a broad range of conditions and to adopt tactics that prolong the time span of each continuous engagement. Notwithstanding having some concerns, field test participants were completely successful at operating ACC over some 35,000 miles of system engagement. In examining the results, the researchers observe that the role played by the driver as the supervisor of ACC entails subtle issues whose long-term safety and traffic impacts are unknown. These issues pertain to the shared-control nature of ACC driving requiring a fine match to the perceptual and cognitive behavior of drivers in a safety-central task that affects others driving nearby. Thus, while offering great promise for improving the quality of the driving experience, ACC implies an inherent necessity for human-centered design.

Volume III addresses the operation of a serial string or dense cluster of passenger cars equipped with a new automotive technology called adaptive cruise control (ACC). The string or cluster conditions are expected to arise commonly on public roadways in the future if ACC reaches high levels of penetration in the vehicle population. This report presents results derived from a very limited experimental study of string and cluster operations, as enabled by the availability of vehicles equipped with ACC systems after their use in an extensive field operational test (see volumes I and II of this report). The experiments involved a naturalistic traffic setting but a contrived procedure for inserting a dense grouping of ACC-equipped vehicles within the traffic stream. This work also served as a probing attempt to evaluate the impact of multiple ACC-equipped vehicles on such general issues as safety, traffic flow, and interference with unequipped vehicles. Conclusions from this activity pertain both to the issue of test methodology and to the long-term impacts of ACC on traffic operations.

1998-Open Literature

Contract Number: DTNH22-95-H-07428, University of Michigan Transportation Research Institute

[22]Fancher, P., Ervin, R., and Bogard, S. (1998). A Field Test of Adaptive Cruise Control : System Operability in Naturalistic Use. 1998 SAE International Conference and Exposition, Detroit, MI, May 1998 (SAE paper No. 980852).

Contract Number: DTNH22-95-H-07428, University of Michigan Transportation Research

Institute

[23]Sayer, J.M., Mefford, P., Fancher, P., and Sekharan (1998). Focus Group Results form an Intelligent Cruise Control Field Operational Test. 16th International Technical Conference on the Enhanced Safety of Vehicles Abstracts, Windsor, Ontario, Canada (98-S2-P-28).