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Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations: Definition and Prioritization of Research Studies

Research and Development
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FOREWORD

This report is one of a 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 contractual effort consists of three phases: analytic, empirical, and integration. This report is a product of the analytic phase. Among the other analytic topics discussed in the series are ATIS and CVO system objectives and performance requirements, functional description of ATIS/CVO, comparable systems analysis, task analysis of ATIS/CVO functions, alternate systems analysis, and identification and exploration of driver acceptance.

This report documents the systematic definition and prioritization of human factors research issues related to the implementation of in-vehicle ATIS and CVO systems.

Copies of this report can be obtained through the Research and Technology Report Center, 9701 Philadelphia Court, Unit Q, Lanham, Maryland 20706, telephone: (301) 577-0818, fax: (301) 577-1421, or the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22 16 1, telephone: (703) 487-4650, fax: (703) 32 l-8547.

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Office of Safety and Traffic
Operations Research and Development

NOTICE

Technical Report Documentation Page

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16. Abstract

The goal of the activities documented in this report was to produce a prioritized list of candidate studies and issues that would guide data acquisition in this project. This goal 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, multimodal displays, and effects of display modality and format on CVO driver workload. The key human factors issues listed here must be address to assure in-vehicle information systems are a safe and usable components of ITS.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd ❑ 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (Lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp ❑ 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F ❑ y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) ❑ 0.03 fluid ounce (fl oz)
1 liter (1) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C ❑ x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5	6	7	8	9	10

CENTIMETERS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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LIST OF ABBREVIATIONS

ATIS . . . . Advanced Traveler Information Systems
CVO . . . . Commercial Vehicle Operations
FHWA . . . . Federal Highway Administration
GPS . . . . global positioning system
h . . . . hour
HUD . . . . head-up display
ISIS . . . . In-Vehicle Signing Information Systems
ITS . . . . Intelligent Transportation Systems
IVSAWS. . . . . In-Vehicle Safety Advisory and Warning Systems

EXECUTIVESUMMARY

The goal of the activities documented in this report was to produce a prioritized list of candidate studies and issues that would guide data acquisition in this project. This goal was accomplished in three steps. First, 91 issues were compiled from earlier research in this effort. The 91 issues were organized into the following 11 categories:

- Coordination of multiple Advanced Traveler Information Systems (ATIS) functions.
- Driver function and information requirements.
- Reliability, timing, and priority of information.
- Interface form and modality.
- Timesharing, attention, and workload.
- Effect of ATIS on driving performance.
- Driver Acceptance.
- Navigation and route selection strategies.
- Training and education.
- Design and presentation of human factors design guidelines.
- Research strategies and methods.

Second, a set of 14 criteria, 9 substantive and 5 methodological, were defined. Rating criteria included five recommended by ITS America (congestion, safety, mobility, environment and economic) relevance to existing data, guidelines, older drivers and younger drivers. In addition, three potential methodologies (laboratory, field, and survey) were rated on dimensions of cost, time, practicality, generality, and overall suitability. 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: List A contained the highest rated 16 issues for the entire data set; List B contained the highest rated 16 issues based only on the data for the individual rater, and List C contained a stratified random sample of 16 candidate issues. issues. Raters were asked to delete unimportant and impractical research issues from these lists. They deleted significantly more items from the random list, demonstrating that the prioritized list was valid.

The final prioritized list contained the 9 most vital studies/issues followed by the 12 most important remaining studies/issues. The nine vital issues are:

- Cognitive demands in transitioning across ATIS functions.
- Complex interactions among ATIS functions.
- How In-Vehicle Signing Information Systems (ISIS) and In-Vehicle Safety Advisory and Warning Systems (IVSAWS) information influences behavior.
- Effects of low information reliability.
- Displaying multiple messages.
- Features requiring standardization.

- Single versus multiple display channels.
- Multimodal displays.
- Effects of display modality and format on Commercial Vehicle Operations (CVO) driver workload.

The 12 most important remaining studies/issues:

- How specific information needs vary as a function of driver characteristics.
- Information drivers need and want from ISIS and IVSAWS.
- CVO needs for situations as local vs long distance, urban vs rural, and emergency response vs commercial.
- Timing of ISIS and IVSAWS information influence driver reaction.
- Assess fatigue and driver performance.
- Information display and emergency response dispatches.
- Display design and the dynamic allocation of driver visual and cognitive resources.
- Type of information using a head-up display (HUD) and cognitive attention to the roadway.
- The effect of in-vehicle information and compensatory driving actions.
- The effect of information reliability and inaccuracies on driver acceptance and use.
- The structure of design guidelines most helpful to designers in addressing human factors issues.

This report documents the evaluation of human factors issues uncovered in the analytic segment of this effort. Filtering all the results to obtain a prioritized list of key research topics was not a simple task. Producing the final list required a psychometric analysis of 17,472 data points generated by 8 human factors experts. Analyzing a set of issues that has already been selected from a very large set of reports is technically difficult, because the selected issues form a narrow range of items: inappropriate items have already been weeded out by the selection process itself. Nevertheless, the validation study showed that this psychometric analysis was successful. Thus, we can have great confidence that the final prioritized list is well-suited to guide future research. The key issues listed here must be addressed if human factors as a discipline is to make a substantial technical contribution to the development of ATIS and CVO components of ITS.

1. INTRODUCTION

GOALS

The activities documented in this report were conducted in Task I of this effort. The major goal of this Task was to produce a prioritized list of candidate studies and issues. Figure 1 shows the three steps taken to reach this goal. First, issues were compiled from earlier research based upon working papers for Tasks A through H. Table 1 lists the reports prepared for the Federal Highway Administration (FHWA). Second, a set of criteria are defined for evaluating the list of issues. Third, a linear psychometric model is used to prioritize this list and a brief validation study is conducted to ensure that the method used to generate the prioritized list was effective.

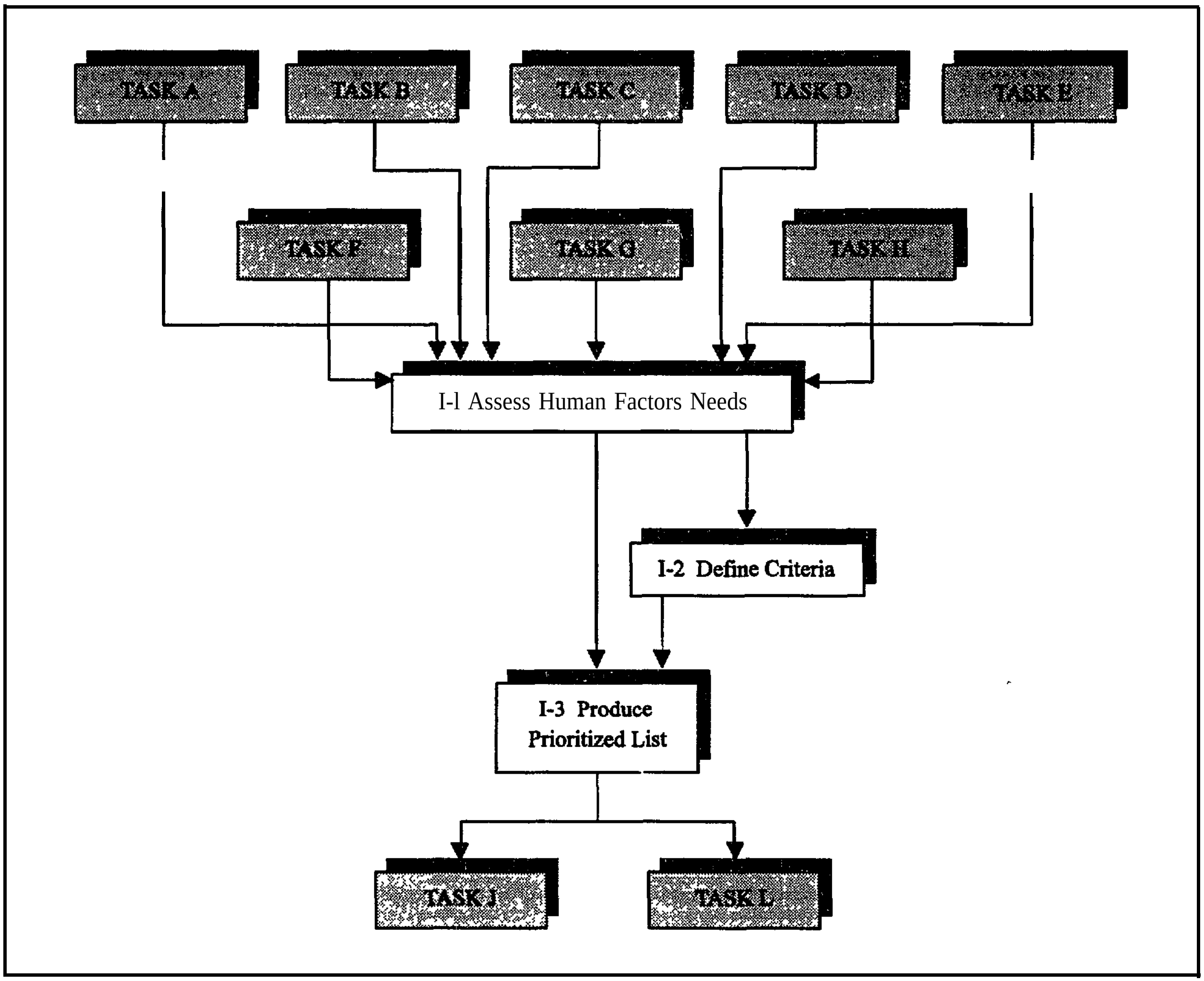


Figure 1. Flowchart of Task I subtasks.

Table 1. Summary of working papers.

TASK	TITLE	AUTHORS	
A	CONDUCT AN ATIS/CVO RELATED LITERATURE REVIEW WORKING PAPER	Thomas Dingus Melissa Hulse Janice Alves-Foss Scott Conger Steven Jahns	Andrew Rice Ian Roberts Richard Hanowsk Douglas Sorensor
B	IDENTIFY ADVANCED TRAVELER INFORMATION SYSTEM (ATIS) AND COMMERCIAL VEHICLE OPERATIONS (CVO) SYSTEM OBJECTIVES AND PERFORMANCE REQUIREMENTS WORKING PAPER	Marvin McCallum John Lee	Thomas Sanquist William Wheeler
C	DEFINE ATIS/CVO FUNCTIONS WORKING PAPER	John Lee Jennifer Morgan Melissa Hulse	William Wheeler Tom Dingus
D	PERFORM A COMPARABLE SYSTEMS ANALYSIS DRAFT WORKING PAPER	David Clarke Michael McCauley Thomas Dingus	Thomas Sharkey John Lee
E	PERFORM TASK ANALYSIS SUMMARY WORKING PAPER	William Wheeler John Lee Mireille Raby	Rhonda Kinghom Alvah Bittner Marvin McCallum
F	IDENTIFY ATIS/CVO USERS AND THEIR INFORMATION REQUIREMENTS WORKING PAPER	Woodrow Barfield Alvah Bittner Neil Charness Martha Hanley Rhonda Kinghom	Francine Landau John Lee Fred Mannering Linda Ng William Wheeler
G	IDENTIFY STRENGTHS/WEAKNESSES OF ALTERNATE INFORMATION DISPLAY FORMATS WORKING PAPER	Melissa Hulse Thomas Dingus Michael Mollenhauer Brian McKinney	Yung-Ching Liu Steven Jahns Timothy Brown
I-I	IDENTIFY AND EXPLORE DRIVER ACCEPTANCE OF I N VEHICLE ITS (INTELLIGENT TRANSPORTATION SYSTEMS) SUMMARY WORKING PAPER	Barry Kantowitz John Lee Curtis Becker Alvah Bitmer Susan Kantowitz Richard Hanowski	Rhonda Kinghom Michael McCauley Thomas Sharkey Marvin McCallum S. Todd Barlow

STUDIES/ISSUES

Table 2 lists candidate studies and issues in 11 categories labeled A through K:

(A) Coordination of multiple ATIS functions.

(B) Driver function and information requirements.

(C) Reliability, timing, and priority of information.

(D) Interface form and modality.

(E) Timesharing, attention, and workload.

(F) Effect of ATIS on driving performance.

(G) Driver acceptance.

(H) Navigation and route selection strategies.

(I) Training and education.

(J) Design and presentation of human factors design guidelines.

(K) Research strategies and methods.

These issues have all been drawn from working papers for Tasks A through H.

Table 2. Rated studies/issues.

LABEL	STUDY/ISSUE
	COORDINATION OF MULTIPLE ATIS FUNCTIONS
A l	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another.
A2	Examine the physical demands placed on the driver by the need to transition from one ATIS function tc another.
A3	Observe actual driving behavior to reveal the need to integrate functions in ways that were not identified in the analytic approach. These observations should not be bound by current ATIS technology.
A4	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system.
A5	Examine the workload implications of requiring drivers to transform and enter information into the system.
A6	Examine the driver acceptance implications of requiring drivers to transform and enter information into the svstem.

Table 2. Rated studies/issues (continued).

LABEL	STUDY/ISSUE
A7	Examine the effect on driver performance of integrating non-ATIS/CVO equipment (radar/laser detectors, laptop computers, cellular phones) with ATIS equipment.
AS	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatches to ensure effective decision making.
	DRIVER FUNCTION AND INFORMATION REQUIREMENTS
B1	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.).
B2	Identify information drivers need and want from In-vehicle Signing Information Systems (ISIS) and In-vehicle Safety Advisory and Warning Systems (IVSAWS).
B3	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior.
B4	Identify what types of ATIS information should be displayed to drivers automatically.
B5	Identify what types of ATIS information should be available upon request.
B6	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban views. rural, and emergency response versus commercial.
	RELIABILITY, TIMING, AND PRIORITY OF INFORMATION
C1	Identify how priorities specific to CVO information compare to other ATIS information.
c 2	Investigate how best to support driver performance when the ATIS fails due to unreliable global positioning svstem (GPS) signals or other anomalous circumstances.
c 3	Identify how ATIS information prioritization can enhance driving performance and response to ATIS information.
c 4	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhance the potential for an improper response to ISIS/IVSAWS.
C5	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.
C6	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information.
c 7	Identify how and when information related to weather conditions and availability of specialized fuel and services should be provided to CVO drivers.
C8	Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers.
c9	(Examine how the reliability and priority of regulatory information affect CVO driver workload.
	INTERFACE FORM AND MODALITY
Dl	Identify the performance implications of inconsistent display formats across ATIS subsystems.
D2	Identify features that will benefit/require standardization across many types of ATIS systems and functions.
D3	Identify how display characteristics, such as modality, influence driver comprehension of advisory system information.
D4	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels.
D5	Evaluate how input device characteristics might need to vary across subsystems.
D6	Evaluate driver perception and control characteristics such as hand-finger coordination and touch accuracy that might influence ATIS design.
D7	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection.

Table 2. Rated studies/issues (continued).

LABEL	STUDY/ISSUE
D8	Examine how the interface form (e.g., text versus graphic, touch screen versus steering wheel controls) should change from pre-drive to drive and park modes.
D9	Evaluate the types of information suitable for a HUD display.
D10	Determine how interface form and modality influences driver interpretation of ISIS and IVSAWS features.
D11	Generate rules to pair types of information with display modality, for individual displays and for combinations of displays.
D12	Evaluate the effectiveness of multimodality displays, such as voice in combination with text.
D13	Identify the relationship between icon characteristics and information types that maximize icon effectiveness and salience.
D14	Identify how message length and wording for voice-based interfaces affect driving performance and message comprehension.
D15	Determine what factors influence synthesized voice message intelligibility.
D16	Assess how the fatigue that plagues CVO drivers (e.g., 8 to 12 h shift) might interact with complex in-vehicle systems to degrade driver performance.
D17	Identify specific concerns regarding how display formats and modality impact CVO driver workload.
D18	Identify the display design characteristics required to support ATIS/CVO systems in large, noisy, and vibration prone commercial vehicles.
D19	Examine how to display information such as "weight-in-motion" to promote regulatory compliance, especially if the information is different than expected.
D20	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews.
D21	Examine how display design might aid the dynamic allocation of driver visual and cognitive resources.
	TIME SHARING, ATTENTION, AND WORKLOAD
E1	Identify a subset of environmental factors that interacts with ATIS to influence driver workload levels.
E2	Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway.
E3	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving.
E4	Identify which functions to "lock out" during in-transit and provide only during zero-speed and pre-drive conditions.
E5	Identify ATIS functions a driver might need or want to use during the various driving activities, such as driving, parking, and stopping.
E6	Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience.
E7	Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment.
E8	Identify how ATIS information flow might be managed to capitalize on the dynamic nature of driver workload.
E9	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS.
E10	Identify the compensatory actions drivers take to moderate their workload, and how ATIS/CVO systems might affect those actions.
E11	Identify how the dynamic characteristics of driver workload interact with the form of the ATIS interface.
E12	Examine the requirements to support the complex onboard data management requirements that commercial vehicle drivers experience.

Table 2. Rated studies/issues (continued).

LABEL	STUDY/ISSUE
El3	Identify potential for overload of specialized CVO drivers such as emergency vehicle operators.
El4	Examine how in-vehicle road sign information (e.g., ISIS) affects workload especially under nighttime, poor weather, and other reduced visibility conditions.
	EFFECT OF ATIS ON DRIVING PERFORMANCE
Fl	Examine how attention to different types of ATIS information influences the primary task of driving.
F2	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events.
F3	Determine whether drivers' reliance upon navigational cues outside the vehicle influence their observation of external hazards, compared to when they rely on navigational cues presented by an ATIS.
F4	Identify factors that may influence drivers to defer to the "Expert System" and fail to recognize a hazard when one is present.
F5	Examine how to display CVO-specific highway safety information (e.g., bridge clearance, width, and restrictions) with minimum interference in attention to the roadway.
	DRIVER ACCEPTANCE
Gl	Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems.
G2	Evaluate driver acceptance of "lock-out" designs that only allow driver to access functions under certain circumstances.
G3	Evaluate how driver acceptance may decline when the driver is forced to interact with multiple subsystems, particularly when this interaction is exacerbated by demanding road conditions.
G4	Investigate factors that influence acceptance of non-verbal and verbal alerts and messages, such as repeat cycle frequency
G5	Evaluate acceptability of different types of In-Vehicle Routing and Navigation Systems maps, symbols, and icons.
G6	Investigate the effect of dynamic route scheduling on the perceived quality of worklife and corresponding driver acceptance.
G7	Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment.
G8	Determine whether CVO drivers will accept a "lock-out" design which limits access to all or selected functions while moving.
G9	Determine how learning about ITS systems and increased experience with them over time affects acceptance of ATIS/CVO.
G10	Examine how the accuracy of information pertaining to availability and current deployment of resources affects dispatcher acceptance and interaction with the system.
	NAVIGATION AND ROUTE SELECTION STRATEGIES
Hl	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability.
H2	Investigate factors that influence driver's perception of the effectiveness of automatic routing.
H3	Investigate information requirements associated with driver "way-finding" and destination selection strategies.
H4	Evaluate the effect of destination-focusing navigational strategies on driver stress and driver acceptance
H5	Determine the information content of maps to support different ATIS/CVO functions.
	TRAINING AND EDUCATION
I1	Determine system characteristics that eliminate or minimize training needs.

Table 2. Rated studies/issues (continued).

LABEL	STUDY/ISSUE
I2	Examine how training might enhance driver acceptance of routing suggestions.
I3	Identify what training techniques could be incorporated into the operation of the different subsystems.
I4	Examine how best to develop videotape-based training to illustrate ATIS functions.
I5	Examine the cost/benefit trade-off associated with training CVO drivers to accommodate more ATIS information.
	DESIGN AND PRESENTATION OF HUMAN FACTORS DESIGN GUIDELINES
J1	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver.
J2	Investigate alternate guideline presentation formats (e.g., expert systems, electronic data base, standard data base) so as to be compatible with designer needs.
J3	Investigate the design process to identify designer needs for guideline content and format.
	RESEARCH STRATEGIES AND METHODS
K1	Generate multivariate constructs to measure driver capacity and workload.
K2	Identify measures comprehensive enough to allow metacomparisons with existing research.
K3	With mass market penetration, identify methods to evaluate and predict consequences of ATIS/CVO system use.
K4	Develop methods to link driver performance to more global measures of system performance, such as specified by the ITS goals.
K5	Develop a set of consistent subjective measures across experiments so that rating scales are common across experiments.

RATING CRITERIA

Table 3 lists rating criteria drawn from three broad categories. The first set of criteria are the five categories used in the ITS America Strategic Plan; these were discussed in detail in the Task B working paper. From a human factors perspective, it seems that Safety would be the most important of these 5; indeed, ITS America places human factors in a Safety and Human Factors committee. This hypothesis will be evaluated in the following Results section of this report. Four other important criteria follow in table 3. Existing Data refers to the presence in the human factors literature of empirical results that apply directly to ITS design guidelines. There is no need to duplicate existing efforts; project resources are best saved for areas where there are no existing data. Guidelines refers to the applicability of issues to the major end product of this entire research project. While the Task F working paper found many guidelines, they were not suitable for direct application to ATIS/CVO Older Drivers refers to the specific applicability of issues to the population of aging drivers. A special concern for this population has been mandated by FHWA. Younger Drivers refers to the opposite end of the driving continuum. While this population, although most at risk, is not specifically mandated as an object of study, it might be worthwhile to include it as a criterion to be contrasted against the Older Driver criterion. For example, an issue that scored high on the Older Driver criterion might be viewed differently depending upon its score for the Younger Driver. Issues scoring high on the Older Driver criterion but low on the Younger Driver criterion would be more salient than issues scoring high on both Older and Younger Driver criteria.

Table 3. Rating criteria.

ITS AMERICA CRITERIA RATINGS	FIELD METHODOLOGY
• Congestion • Safety • Mobility • Environment • Economic	• Cost • Time • Practicality • Generality • Suitability
OTHER CRITERIA RATINGS	**SURVEY METHODOLOGY**
• Existing Data • Guidelines • Older Drivers • Younger Drivers	• Cost • Time • Practicality • Generality • Suitability
LABORATORY METHODOLOGY	
• Cost • Time • Practicality • Generality • Suitability	

The last five criteria are related to methodology. Three general methodologies are considered: laboratory (including simulators), field studies (on the road), and surveys. For each methodology all five criteria were rated.

Table 4 contains the precise definition of each criterion given to the raters. These definitions were provided in writing to all raters.

Table 4. Criterion definition.

CRITERIA	DEFINITION
Congestion	Decreased traffic congestion has been identified as the primary goal of ITS. Major benefits include better use of roadway capacity by shifting traffic from congested roadways to routes with excess capacity. Benefits to both private and commercial vehicle operators are seen as directly related to reduced travel time. Decreased traffic congestion may result from a variety of ATIS functions including those that provide travelers with information regarding alternative modes of transportation, such as bus, rail, air, and ride-sharing. Issues directly related to reducing congestion will be more critical.

Table 4. Criterion definition (continued).

CRITERIA	DEFINITION
Safety	lTS technology is seen as providing an opportunity to improve safety by reducing crashes, contrasted with the traditional approach of increasing "crash worthiness." The basic strategies identified for improving safety center around avoiding areas of congestion, being warned of hazards, reducing levels of congestion (that are associated with a higher incidence of accidents). Another possible positive aspect of ATIS would be the reduction in frequency of drivers simultaneously holding a map while driving a vehicle. ATIS may also jeopardize safety. Specifically, concerns include erroneously directing drivers down one-way streets the wrong direction, reducing the time spent by drivers monitoring the roadway, and reducing reaction time to unanticipated hazards due to high levels of mental workload. Issues closely related to driver safety will be more critical.
Mobility	The objective of increased and higher quality mobility is used to refer to a broad range of associated performance requirements that address the traveler's well being, comfort, enjoyment, and access to travel. Well being, comfort, and enjoyment requirements range from reducing the general level of stress while driving to increasing access to scenic and recreation areas. Access to travel requirements include both improved automobile access, as well as improved access to alternative modes of travel. Finally, this objective is commonly referred to when noting the requirement to increase the mobility of the elderly, disabled, and economically disadvantaged segments of the population. Critical issues will directly relate to enhanced mobility.
Environment	The objective of environmental quality includes improved energy efficiency and other benefits such as reduced noise pollution, reduced travel, and shifts in the mode of travel. Improved environmental quality and energy efficiency will be accomplished by decreasing traffic congestion, diverting travelers from single-occupancy vehicles, accommodating smoother more evenly distributed traffic flow, reducing travel time, and demand management based on road pricing. Issues closely related to furthering the environment should be rated highly.
Economic	The objective of improved economic productivity has consequences for both commercial and private drivers. From the institutional perspective, this objective can be achieved by reducing total institutional expenditures for the transportation infrastructure. From the individual and CVO perspective, improved economic productivity relates to specific gains by individuals and commercial operators. A closely-related objective is improved energy consumption, which translates into cost savings for all components of the economy. Issues closely related to furthering the economic improvement goals of lTS should be rated highly.
Existing data	Although human factors research from other applications may help resolve many issues associated with ATIS development, placing advanced ATIS technology in cars and trucks involves a number of unique issues. The most critical issues on the list are those for which no previous research exists and so studies that resolve questions that no existing data address should receive high ratings.
Guidelines	The purpose of this project is to develop human factors design guidelines for ATIS, not to simply examine how driver behavior may change as a result of these systems. Therefore, studies/issues that directly address potential design alternatives and would support designers' data base of human limits and abilities should receive high ratings.
Older drivers	Older drivers present a particular challenge to ATIS design. They have special needs and limits that if addressed will help ensure a flexible system that can be adjusted to meet the special needs of a variety of populations. Because of the need to devote special attention to the needs of older drivers, studies particularly well suited should receive high ratings.
Younger drivers	Younger drivers have highest accident rates and so special attention should be paid to enhancing their safety through ATIS designs.

2. METHOD

RATERS

Eight human factors experts, highly familiar with ITS and ground transportation, provided the raw data. Six raters were drawn from key authors of the working papers (Dingus-University of Iowa, Kantowitz-Battelle, Landau-GM Hughes, Lee-Battelle, McCauley-Monterey Technologies, Wheeler-Battelle). In addition, two distinguished university faculty also completed the lengthy questionnaire (Professors Moray-University of Illinois and Triggs-Monash University). Since they did not participate in writing the working papers it was hoped that their ratings would not reflect any possible biases potentially acquired by Battelle team members during the course of their intense collaboration on this project.

PROCEDURE

The rating forms (appendix B) were created by concatenating tables 2 and 3. Thus each form contained 2,184 cells (91 issues by 24 criteria). Since the 8 raters completed all cells, there are a total of 17,472 rating entries in the data set. A 5-point scale was used for ratings (appendix B). Completing the rating form took approximately 8 h. Raters were self-paced.

After the ratings were scored, raters were given three new lists of candidate issues to evaluate. List A (appendix B) contained the highest rated 16 issues for the entire data set, weighted as described later in this paper. List B contained the highest rated 16 issues based only on the data for the individual rater but using the same weighting scheme. Thus, eight unique List B forms were generated, one for each rater. List C (appendix B) contained a stratified random sample of 16 candidate issues with 4 issues drawn from each quartile, again with the same weighting scheme. Raters were told to treat each list independently and were not informed how the lists were created. For each list, raters were instructed to delete as many issues as they wished if they believed a particular issue was either not important or not practical given resource limits of the project. They could also add one issue to each list.

3. RESULTS

Our analysis of the rating data is divided into four parts. First, we consider the criteria in table 3 one at a time. Second, we use a linear model to combine ratings on several criteria. Third, we perform a sensitivity analysis to determine the effects of imperfect weightings in the linear model. Fourth, we validate the combination model used.

SINGLE CRITERIA

This section contains several tables with the highest 20 studies/issues ranked on one criterion only. Tables 5 through 9 contain the ITS America criteria rankings. Tables 10 through 13 contain the other criteria rankings. In the tables below, tied items are given the same rank rather than average ranks. This procedure will have no effect on the sensitivity analyses and gamma calculations discussed later in this section. Labels from table 2 are shown in brackets, e.g., [Hl]. The Methodology ratings are not considered singly because there is little gained by having an optimal method for an unimportant issue.

It is clear from these tables that the Safety criterion is most important from a human factors perspective. Table 14 contains all studies/issues with a mean rating of 4.50 or greater. Thirteen issues are related to the Safety criterion, 6 issues are related to the Guidelines criterion, 3 issues are related to the Older Driver criterion, and two issues are related to the Existing Data criterion. Only two studies/issues were rated above 4.50 on two criteria: Al - Safety and Existing Data, and E3 - Safety and Older Drivers. No issues were rated 4.50 or greater on three or more criteria.

MULTIPLE CRITERIA

A linear psychometric model (Dawes & Corrigan, 1974) was used to combine ratings into a single score for each rater. While giving each criterion an equal weighting would be an obvious way to combine data, this would be a poor choice since all criteria are not equally important. The following section on Sensitivity compares the weighting used, based upon the relative importance of the criteria, to the equally-weighted case.

Table 14 was used to generate weights for all but the Methodology items. If all the Methodology items had been considered equally, the resultant score would favor issues amenable to more than a single methodology. Instead, we calculated the single methodology, be it Laboratory, Field, or Survey, that had the highest score for any issue. This Maximum Methodology score was given a weight of 15 percent when combined with the other important criteria in table 14. The weights for these criteria were Safety (53 percent), Guidelines (18 percent), Older Driver (9 percent) and Existing Data (6 percent). Other weightings that maintained this ordering (e.g., Safety most important, etc.) do not produce dramatic differences in final rankings of weighted scores (table 15).

Table 5. Top 20 ranked issues for Congestion.

RANK	RATING	STUDY/ISSUE
1	4.38	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [H1].
2	4.00	Investigate information requirements associated with driver "way-finding" and destination selection strategies [H3].
3	3.88	Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment [G7].
4	3.75	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews [D20].
4	3.75	Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems [G1].
4	3.75	Evaluate acceptability of different types of In-Vehicle Routing and Navigation Systems maps, symbols, and icons [G5].
4	3.75	Investigate factors that influence driver's perception of the effectiveness of automatic routing [H2].
8	3.63	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatchers to ensure effective decision making [A8].
8	3.63	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial [B6].
8	3.63	Determine the information content of maps to support different ATIS/CVO functions [H5].
11	3.50	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
11	3.50	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS [C4].
11	3.50	Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers [C8].
11	3.50	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events [F2].
11	3.50	Identify measures comprehensive enough to allow metacomparisons with existing research [K2].
16	3.38	Identify information drivers need and want from in-vehicle road sign (ISIS) and warning systems (IVSAWS) [B2].
16	3.38	Identify how ATIS information prioritization can enhance driving performance and response to ATIS information [C3].
16	3.38	Identify how display characteristics, such as modality, influence driver comprehension of advisory system information [D3].
16	3.38	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection [D7].
20	3.25	Observe actual driving behavior to reveal the need to integrate functions in ways that were not identified in the analytic approach. These observations should not be bound by current ATIS technology [A3].

Table 6. Top 20 ranked issues for Safety.

RANK	RATING	STUDY/ISSUE
1	**5.00**	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [Al].
1	5.00	Examine how attention to different types of ATIS information influences the primary task of driving [Fl].
3	4.88	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
3	4.88	Examine the workload implications of requiring drivers to transform and enter information into the system [A5].
3	4.88	Assess how the fatigue that plagues CVO drivers (e.g., 8 to 12 h shift) might interact with complex in-vehicle systems to degrade driver performance [D16].
3	4.88	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving [E3].
7	4.75	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS [C4].
7	4.75	Identify potential for overload of specialized CVO drivers such as emergency vehicle operators [E13].
9	4.63	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
9	4.63	Examine how in-vehicle road sign information (e.g., ISIS) affects workload, especially under nighttime, poor weather, and other reduced visibility conditions [El4].
11	4.50	Examine the effect on driver performance of integrating non-ATIS/CVO equipment (radar/laser detectors, laptop computers, cellular phones) with ATIS equipment [A7].
11	4.50	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information [C6].
11	4.50	Identify the performance implications of inconsistent display formats across ATIS subsystems [D1]
11	4.50	Evaluate the types of information suitable for a HUD display [D9].
11	4.50	Evaluate the effectiveness of multimodality displays, such as voice in combination with text [D12].
11	4.50	Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment [E7]
11	4.50	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS [E9].
11	4.50	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events [F2].
19	4.38	Identify features that will benefit/require standardization across many types of ATIS Systems and functions [D2].
19	4.38	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels [D4].

Table 7. Top 20 ranked issues for Mobility.

RANK	RATING	STUDY/ISSUE
1	3.63	Investigate information requirements associated with driver "way-finding" and destination selection strategies [H3].
2	3.50	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [H1].
2	3.50	With mass market penetration, identify methods to evaluate and predict consequences of ATIS/CVO system use [K3].
4	3.25	Identify how ATIS information prioritization can enhance driving performance and response to ATIS information [C3].
4	3.25	Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience [E6].
4	3.25	Determine the information content of maps to support different ATIS/CVO functions [H5].
4	3.25	Identify measures comprehensive enough to allow metacomparisons with existing research [K2].
8	3.13	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [A1].
8	3.13	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
8	3.13	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
8	3.13	Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers [C8].
8	3.13	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews [D20].
8	3.13	Identify ATIS functions a driver might need or want to use during the various driving activities, such as driving, parking, and stopping [E5].
8	3.13	Evaluate how driver acceptance may decline when the driver is forced to interact with multiple subsystems, particularly when this interaction is exacerbated by demanding road conditions [G3].
8	3.13	Evaluate acceptability of different types of In-Vehicle Routing and Navigation Systems maps, symbols, and icons [G5].
16	3.00	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatchers to ensure effective decision making [A8].
16	3.00	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.) [B1].
16	3.00	Identify what types of ATIS information should be available upon request [B5].
16	3.00	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS [E9].
16	3.00	Examine how in-vehicle road sign information (e.g., ISIS) affects workload, especially under nighttime, poor weather, and other reduced visibility conditions [E14].

Table 8. Top 20 ranked issues for Environment.

RANK	RATING	STUDY/ISSUE
1	3.50	With mass market penetration, identify methods to evaluate and predict consequences of ATIS/CVO system use [K3].
2	3.38	Identify measures comprehensive enough to allow metacomparisons with existing research [K2].
3	3.13	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [H1].
4	3.00	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews [D20].
4	3.00	Investigate information requirements associated with driver "way-finding" and destination selection strategies [H3].
6	2.88	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatchers to ensure effective decision making [A8].
7	2.75	Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers [C8].
7	2.75	Determine how learning about ITS systems and increased experience with them over time affects acceptance of ATIS/CVO [G9].
7	2.75	Investigate factors that influence driver's perception of the effectiveness of automatic routing [H2].
10	2.63	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial [B6].
10	2.63	Identify how and when information related to weather conditions and availability of specialized fuel services should be provided to CVO drivers [C7].
10	2.63	Examine how to display information such as "weight-in-motion" to promote regulatory compliance, especially if the information is different than expected [D19].
10	2.63	Examine how to display CVO-specific highway safety information (e.g., bridge clearance, width, and restrictions) with minimum interference in attention to the roadway [F5].
10	2.63	Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment [G7].
15	2.50	Observe actual driving behavior to reveal the need to integrate functions in ways that were not identified in the analytic approach. These observations should not be bound by current ATIS technology [A3].
15	2.50	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
15	2.50	Identify how ATIS information prioritization can enhance driving performance and response to ATIS information [C3].
15	2.50	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS [C4].
15	2.50	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information [C6].
15	2.50	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection [D7].

Table 9. Top 20 ranked issues for Economic.

RANK	RATING	STUDY/ISSUE
1	4.00	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatchers to ensure effective decision making [A8].
1	4.00	Examine the cost/benefit trade-off associated with training CVO drivers to accommodate more ATIS information [I5].
3	3.88	Examine how to display information such as "weight-in-motion" to promote regulatory compliance, especially if the information is different than expected [D19].
4	3.75	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial [B6].
4	3.75	Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers [C8].
4	3.75	Examine the requirements to support the complex onboard data management requirements that commercial vehicle drivers experience [E12].
4	3.75	Identify measures comprehensive enough to allow metacomparisons with existing research [K2].
8	3.63	Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment [G7].
8	3.63	With mass market penetration, identify methods to evaluate and predict consequences of ATIS/CVO system use [K3].
10	3.50	Assess how the fatigue that plagues CVO drivers (e.g., 8 to 12 h shift) might interact with complex in-vehicle systems to degrade driver performance [D16].
10	3.50	Examine how the accuracy of information pertaining to availability and current deployment of resources affects dispatcher acceptance and interaction with the system [G10].
12	3.38	Identify how priorities specific to CVO information compare to other ATIS information [C1].
12	3.38	Identify how and when information related to weather conditions and availability of specialized fuel and services should be provided to CVO drivers [C7].
12	3.38	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews [D20].
12	3.38	Examine how to display CVO-specific highway safety information (e.g., bridge clearance, width, and restrictions) with minimum interference in attention to the roadway [F5].
12	3.38	Determine system characteristics that eliminate or minimize training needs [I1].
17	3.25	Investigate the effect of dynamic route scheduling on the perceived quality of worklife and corresponding CVO driver acceptance [G6].
17	3.25	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [H1].
17	3.25	Investigate information requirements associated with driver "way-finding" and destination selection strategies [H3].
20	3.13	Identify features that will benefit/require standardization across many types of ATIS systems and functions [D2].

Table 10. Top 20 ranked issues for Existing Data.

RANK	RATING	STUDY/ISSUE
1	4.50	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [A1].
1	4.50	Identify how ATIS information flow might be managed to capitalize on the dynamic nature of driver workload [E8].
3	4.38	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately [C5].
3	4.38	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver [J1].
3	4.38	Investigate the design process to identify designer needs for guideline content and format [J3].
6	4.25	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
6	4.25	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS [E9].
6	4.25	Examine the requirements to support the complex onboard data management requirements that commercial vehicle drivers experience [E12].
6	4.25	Examine how in-vehicle road sign information (e.g., ISIS) affects workload, especially under nighttime, poor weather, and other reduced visibility conditions [E14].
6	4.25	Investigate alternate guideline presentation formats (e.g., expert systems, electronic data base, standard data base) so as to be compatible with designer needs [J2].
11	4.13	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatchers to ensure effective decision making [A8].
11	4.13	Identify information drivers need and want from in-vehicle road sign (ISIS) and warning systems (IVSAWS) [B2].
11	4.13	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
11	4.13	Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment [E7].
11	4.13	Examine how attention to different types of ATIS information influences the primary task of driving [F1].
11	4.13	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events [F2].
11	4.13	Determine whether drivers' reliance upon navigational cues outside the vehicle influences their observation of external hazards, compared to when they rely on navigational cues presented by an ATIS [F3].
11	4.13	Evaluate driver acceptance of "lock-out" designs that only allow the driver access to functions under certain circumstances [G3].
11	4.13	Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment [G7].
11	4.13	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [Hl].

Table 11. Top 20 ranked issues for Guidelines.

RANK	RATING	STUDY/ISSUE
1	5.00	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver [J1].
2	4.88	Investigate alternate guideline presentation formats (e.g., expert systems, electronic data base, standard data base) so as to be compatible with designer needs [J2].
2	4.88	Investigate the design process to identify designer needs for guideline content and format [J3].
4	4.63	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [H1].
5	4.50	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately [C5].
5	4.50	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels [D4].
7	4.38	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
7	4.38	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection [D7].
9	4.25	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [A1].
9	4.25	Identify information drivers need and want from in-vehicle road sign (ISIS) and warning systems (IVSAWS) [B2].
9	4.25	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial [B6].
9	4.25	Identify features that will benefit/require standardization across many types 0f ATIS systems and functions [D2].
9	4.25	Evaluate the types of information suitable for a HUD display [D9].
9	4.25	Identify the relationship between icon characteristics and information types that maximize icon effectiveness and salience [D13].
9	4.25	Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway [E2].
9	4.25	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving [E3].
9	4.25	Examine the requirements to support the complex onboard data management requirements that commercial vehicle drivers experience [E12].
9	4.25	Evaluate acceptability of different types of In-Vehicle Routing and Navigation Systems maps, symbols, and icons [G5].
19	4.13	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
19	4.13	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatchers to ensure effective decision making [A8].

Table 12. Top 20 ranked issues for Older Drivers.

RANK	RATING	STUDY/ISSUE
1	4.63	Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience [E6].
2	4.50	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.) [B1].
2	4.50	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving [E3].
4	4.38	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [A1].
4	4.38	Examine how attention to different types of ATIS information influences the primary task of driving [F1].
6	4.25	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
6	4.25	Identify how message length and wording for voice-based interfaces affect driving performance and message comprehension [D14].
8	4.13	Examine the workload implications of requiring drivers to transform and enter information into the system [A5].
8	4.13	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS [C4].
8	4.13	Evaluate the effectiveness of multimodality displays, such as voice in combination with text [D12].
8	4.13	Examine how in-vehicle road sign information (e.g., ISIS) affects workload, especially under nighttime, poor weather, and other reduced visibility conditions [E14].
8	4.13	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events [F2].
13	4.00	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
13	4.00	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels [D4].
13	4.00	Determine what factors influence synthesized voice message intelligibility [D15].
13	4.00	Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway [E2].
17	3.88	Examine the physical demands placed on the driver by the need to transition from one ATIS function to another [A2].
17	3.88	Identify how display characteristics, such as modality, influence driver comprehension of advisory system information [D3].
17	3.88	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection [D7].
17	3.88	Identify a subset of environmental factors that interacts with ATIS to influence driver workload levels [E1].

Table 13. Top 20 ranked issues for Younger Drivers.

RANK	RATING	STUDY/ISSUE
1	4.00	Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience [E6].
1	4.00	Examine how attention to different types of ATIS information influences the primary task of driving [F1].
3	3.88	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc [B1].
3	3.88	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events [F2].
5	3.75	Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment [E7].
6	3.63	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS [C4].
7	3.50	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving [E3].
7	3.50	Determine whether drivers' reliance upon navigational cues outside the vehicle influence their observation of external hazards, cornpared o when they rely on navigational cues presented by and ATIS [F3].
9	3.38	Observe actual driving behavior to reveal the need to integrate functions in ways that were not identified in the analytic approach. These observations should not be bound by current ATIS technology [A3].
9	3.38	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].
9	3.38	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].
9	3.38	Identify factors that may influence drivers to defer to the "Expert System" and fail to recognize a hazard when one is present [F4].
9	3.38	Identify what training techniques could be incorporated into the operation of the different subsystems [I3].
14	3.25	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [A1].
14	3.25	Examine the workload implications of requiring drivers to transform and enter information into the system [A5].
14	3.25	Identify what types of ATIS information should be available upon request [B4].
14	3.25	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels [D4].
14	3.25	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection [D7].
14	3.25	Identify a subset of environmental factors that interacts with ATIS to influence driver workload levels [E1].
14	3.25	Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems [G1].

Table 14. Studies/Issues rated 4.50 or greater on single dimensions.

RATING	STUDY/ISSUE	CRITERIA
5.00 **4.50**	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another [A1].	Safety Existing Data
5.00	Examine how attention to different types of ATIS information influences the primary task of driving [F1].	Safety
4.88	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system [A4].	Safety
4.88	Examine the workload implications of requiring drivers to transform and enter information into the system [A5].	Safety
4.88	Assess how the fatigue that plagues CVO drivers (e.g., 8- to 12-h shift) might interact with complex in-vehicle systems to degrade driver performance [D16].	Safety
4.88 **4.50**	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving [E3].	Safety Older Drivers
4.75	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS [C4].	Safety
4.75	Identify potential for overload of specialized CVO drivers such as emergency vehicle operators [E13].	Safety
4.63	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior [B3].	Safety
4.63	Examine how in-vehicle road sign information (e.g., ISIS) affects workload, especially under nighttime, poor weather, and other reduced visibility conditions [E14].	Safety
4.50	Examine the effect on driver performance of integrating non-ATIS/CVO equipment (radar/laser detectors, laptop computers, cellular phones) with ATIS equipment [A7].	Safety
4.50	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information [C6].	Safety
4.50	Identify the performance implications of inconsistent display formats across ATIS subsystems [D1].	Safety
4.50	Evaluate the types of information suitable for a HUD display [D9].	Safety
4.50	Evaluate the effectiveness of multimodality displays, such as voice in combination with text [D12].	Safety
4.50	Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment [E7].	Safety
4.50	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS [E9].	Safety
4.50	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events [F2].	Safety
4.50	Identify how ATIS information flow might be managed to capitalize on the dynamic nature of driver workload [E8].	Existing Data
5.00	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver [J1].	Guidelines
4.88	Investigate alternate guideline presentation formats (e.g., expert systems, electronic data base, standard data base) so as to be compatible with designer needs [J2].	Guidelines
4.88	Investigate the design process to identify designer needs for guideline content and format [J3].	Guidelines

Table 14. Studies/Issues rated 4.50 or greater on single dimensions (continued).

RATING	STUDY/ISSUE	CRITERIA
4.63	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability [H1].	Guidelines
4.50	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately [C5].	Guidelines
4.50	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels [D4].	Guidelines
4.63	Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience [E6].	Older Drivers
4.50	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.) [B1].	Older Drivers

Table 15 shows the final weighted rankings for all studies/issues. Ratings varied from 4.34 for the most important study/issue [Al] to 2.96 for the least important issue [G5]. The last column of table 15 shows the Methodology with the maximum score for each issue. In general the Laboratory Methodology was most preferred (55 issues), followed by Survey Methodology (23 issues) and On-Road Field Study (16 issues).

Table 15. Final weighted rankings.

RANK	STUDY/ISSUE	LABEL	RATING	METHOD
1	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another.	A1	4.34	Laboratory
2	Examine the workload implications of requiring drivers to transform and enter information into the system.	A5	4.31	Laboratory
3	Examine how attention to different types of ATIS information influences the primary task of driving.	F1	4.29	Laboratory
4	Identify features that will benefit/require standardization across many types of ATIS systems and functions.	D2	4.25	Laboratory /Survey
5	Identify specific concerns regarding how display formats and modality impact CVO driver workload.	D17	4.21	Laboratory
6	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhance the potential for an improper response to ISIS/IVSAWS.	C4	4.21	Laboratory
7	Identify how the dynamic characteristics of driver workload interact with the form of the ATIS interface.	E11	4.20	Laboratory
8	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior.	B3	4.19	On-road
9	Evaluate the effectiveness of multimodality displays, such as voice in combination with text.	D12	4.16	Laboratory

Table 15. Final weighted rankings (continued).

RANK	STUDY/ISSUE	LABEL	RATING	METHOD
10	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels.	D4	4.14	Laboratory
11	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system.	A4	4.13	Laboratory
12	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.	C5	4.13	Laboratory
13	Examine how display design might aid the dynamic allocation of driver visual and cognitive resources.	D21	4.12	Laboratory
14	Identify the compensatory actions drivers take to moderate their workload, and how ATIS/CVO systems might affect those actions.	E10	4.11	On-road
15	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information.	C6	4.10	Laboratory
16	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events.	F2	4.08	Laboratory
17	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS.	E9	4.05	Laboratory
18	Examine how in-vehicle road sign information (e.g., ISIS) affects workload especially under nighttime, poor weather, and other reduced visibility conditions.	E14	4.04	On-road
19	Identify information drivers need and want from in-vehicle road sign (ISIS) and warning systems (IVSAWS).	B2	4.03	Survey
20	Identify which functions to "lock out" during in-transit and provide only during zero-speed and pre-drive conditions.	E4	4.02	Survey
21	Identify how ATIS information flow might be managed to capitalize on the dynamic nature of driver workload.	E8	4.00	Laboratory
22	Determine how interface form and modality influences driver interpretation of ISIS and IVSAWS features.	D10	4.00	Laboratory
23	Evaluate how input device characteristics might need to vary across subsystems.	D5	3.99	Laboratory
24	Generate rules to pair types of information with display modality, for individual displays and for combinations of displays.	D11	3.98	Laboratory
25	Identify the display design characteristics required to support ATIS/CVO systems in large, noisy, and vibration prone commercial vehicles.	D18	3.97	On-road
26	Identify the performance implications of inconsistent display formats across ATIS subsystems.	D1	3.96	Laboratory
27	Assess how the fatigue that plagues CVO drivers (e.g., 8- to 12-h shift) might interact with complex in-vehicle systems to degrade driver performance.	D16	3.96	Laboratory
28	Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment.	E7	3.96	Laboratory

Table 15. Final weighted rankings (continued).

RANK	STUDY/ISSUE	LABEL	RATING	METHOD
29	Identify ATIS functions a driver might need or want to use during the various driving activities, such as driving, parking, and stopping.	E5	3.94	Survey
30	Examine the effect on driver performance of integrating non-ATIS/CVO equipment (radar/laser detectors, laptop computers, cellular phones) with ATIS equipment.	A7	3.94	Laboratory
31	Determine whether drivers' reliance upon navigational cues outside the vehicle influence their observation of external hazards, compared to when they rely on navigational cues presented by an ATIS.	F3	3.93	On-road
32	Identify a subset of environmental factors that interacts with ATIS to influence driver workload levels.	El	3.93	On-road
33	Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems.	Gl	3.92	Laboratory
34	Identify what types of ATIS information should be available upon request.	B5	3.92	Survey
35	Examine the requirements to support the complex onboard data management requirements that commercial vehicle drivers experience.	El2	3.91	Survey
36	Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway.	E2	3.87	Laboratory
37	Identify how ATIS information prioritization can enhance driving performance and response to ATIS information.	C3	3.87	Laboratory
38	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews.	D20	3.86	Survey
39	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial.	B6	3.85	Survey
40	Identify what types of ATIS information should be displayed to drivers automatically.	B4	3.85	On-road
41	Determine what factors influence synthesized voice message intelligibility.	D15	3.85	Laboratory
42	Examine how to display CVO-specific-highway safety information (e.g., bridge clearance, width, and restrictions) with minimum interference in attention to the roadway.	F5	3.83	Laboratory
43	Identify factors that may influence drivers to defer to the "Expert System" and fail to recognize a hazard when one is present.	F4	3.80	Laboratory /On-road
44	Identify how display characteristics, such as modality, influence driver comprehension of advisory system information.	D3	3.78	Laboratory
45	Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience.	E6	3.77	Laboratory
46	Investigate the effect of dynamic route scheduling on the perceived quality of worklife and corresponding driver acceptance.	G6	3.76	On-road

Table 15. Final weighted rankings (continued).

RANK	STUDY/ISSUE	LABEL	RATING .	METHOD
47	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver.	Jl	3.76	Survey
48	Investigate factors that influence acceptance of non-verbal and verbal alerts and messages, such as repeat cycle frequency.	G4	3.74	Laboratory
49	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.).	B1	3.74	Survey
50	Identify how message length and wording for voice-based interfaces affect driving performance and message comprehension.	D14	3.74	Laboratory
51	Observe actual driving behavior to reveal the need to integrate functions in ways that were not identified in the analytic approach. These observations should not be bound by current ATIS technology.	A3	3.72	On-road
52	Examine the physical demands placed on the driver by the need to transition from one ATIS function to another.	A2	3.71	Laboratory
53	Evaluate the types of information suitable for a HUD display.	D9	3.71	Laboratory
54	Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving.	E3	3.71	Laboratory
55	Evaluate driver acceptance of "lock-out" designs that only allow the driver access to functions under certain circumstances.	G2	3.71	Laboratory
56	Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers.	C8	3.70	Survey
57	Determine system characteristics that eliminate or minimize training needs.	11	3.69	Laboratory
58	Determine the information content of maps to support different ATIS/CVO functions.	H5	3.67	Laboratory /Survey
59	Evaluate how driver acceptance may decline when the driver is forced to interact with multiple subsystems, particularly when this interaction is exacerbated by demanding road conditions.	G3	3.66	Laboratory
60	Evaluate driver perception and control characteristics such as hand-finger coordination and touch accuracy that might influence ATIS design.	D6	3.64	Laboratory
61	Identify the relationship between icon characteristics and information types that maximize icon effectiveness and salience.	D13	3.64	Laboratory
62	Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment.	G7	3.63	On-road
63	Identify how and when information related to weather conditions and availability of specialized fuel and services should be provided to CVO drivers.	c7	3.61	Survey
64	Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability.	Hl	3.59	Laboratory

Table 15. Final weighted rankings (continued).

RANK	STUDY/ISSUE	LABEL	RATING	METHOD
65	Examine how the accuracy of information pertaining to availability and current deployment of resources affects dispatcher acceptance and interaction with the system.	G10	3.59	On-road
66	Identify potential for overload of specialized CVO drivers such as emergency vehicle operators.	E13	3.58	Survey
67	Investigate how best to support driver performance when the ATIS fails due to unreliable GPS signals or other anomalous circumstances.	C2	3.58	Laboratory
68	Investigate alternate guideline presentation formats (e.g., expert systems, electronic data base, standard data base) so as to be compatible with designer needs.	J2	3.57	Survey
69	Examine how the interface form (e.g., text versus graphic, touch screen versus steering wheel controls) should change from pre-drive to drive and park modes.	D8	3.55	Laboratory
70	Examine how the reliability and priority of regulatory information affect CVO driver workload.	C9	3.53	Laboratory
71	Examine how to support sharing information (e.g., status, location, availability of resources) among dispatches to ensure effective decision making.	A8	3.51	On-road
72	Generate multivariate constructs to measure driver capacity and workload.	K1	3.51	Laboratory
73	Investigate information requirements associated with driver "way-finding" and destination selection strategies.	H3	3.49	Laboratory
74	Identify how priorities specific to CVO information compare to other ATIS information.	C1	3.48	Survey
75	Examine the driver acceptance implications of requiring drivers to transform and enter information into the system.	A6	3.47	Laboratory
76	Identify what training techniques could be incorporated into the operation of the different subsystems.	I3	3.47	Laboratory
77	Examine how to display information such as "weight-in-motion" to promote regulatory compliance, especially if the information is different than expected.	D19	3.47	On-road
78	Investigate the design process to identify designer needs for guideline content and format.	J3	3.46	Survey
79	Examine the cost/benefit trade-off associated with training CVO drivers to accommodate more ATIS information.	I5	3.44	Laboratory
80	Examine the effect of display form (e.g., text versus graphic) on driver decision making and problem solving during route planning and selection.	D7	3.41	Laboratory
81	Evaluate the effect of destination-focusing navigational strategies on driver stress and driver acceptance.	H4	3.40	On-road
82	Develop methods to link driver performance to more global measures of system performance, such as specified by the ITS goals.	K4	3.38	Survey

Table 15. Final weighted rankings (contiuued).

RANK	STUDY/ISSUE	LABEL	RATING	METHOD
83	Investigate factors that influence driver's perception of the effectiveness of automatic routing.	H2	3.35	Laboratory
84	Examine how training might enhance driver acceptance of routing suggestions.	I2	3.30	On-road
85	Identify measures comprehensive enough to allow metacomparisons with existing research.	K2	3.30	Survey
86	Determine whether CVO drivers will accept a "lock-out" design which limits access to all or selected functions while moving.	G8	3.27	Survey
87	With mass market penetration, identify methods to evaluate and predict consequences of ATIS/CVO system use.	K3	3.19	Survey
88	Examine how best to develop videotape-based training to illustrate ATIS functions.	I4	3.10	Laboratory
89	Determine how learning about ITS systems and increased experience with them over time affects acceptance of ATIS/CVO.	G9	3.10	Survey
90	Develop a set of consistent subjective measures across experiments so that rating scales are common across experiments.	K5	3.02	Survey
91	Evaluate acceptability of different types of In-Vehicle Routing and Navigation Systems maps, symbols, and icons.	G5	2.96	Laboratory

SENSITIVITY ANALYSIS

Figure 2 shows the effect of increasing the weight for the Safety criterion with the set of nine criteria (Methodology excluded). Goodman's/Kruskal's gamma (Reynolds, 1977) is a measure of association, that ranges from +1.O to - 1.0, suitable for ordinal data. The baseline for calculating gamma has all nine criteria weighted equally. Figure 2 shows how gamma decreases when the weighting of the Safety criterion is increased. When Safety has a weight of one (not shown in figure 2) gamma = 1.0. As the weight for Safety increases, gamma decreases slightly until it asymptotes at .46 when Safety is the only criterion (e.g., all eight other criteria assigned a weight of zero). Thus, there is only a modest change in rankings for the linear model when the importance of the Safety criterion is varied. There is no effect on either the sensitivity analysis nor the gamma calculation associated with the method of calculating ranks shown in tables 5 through 13.

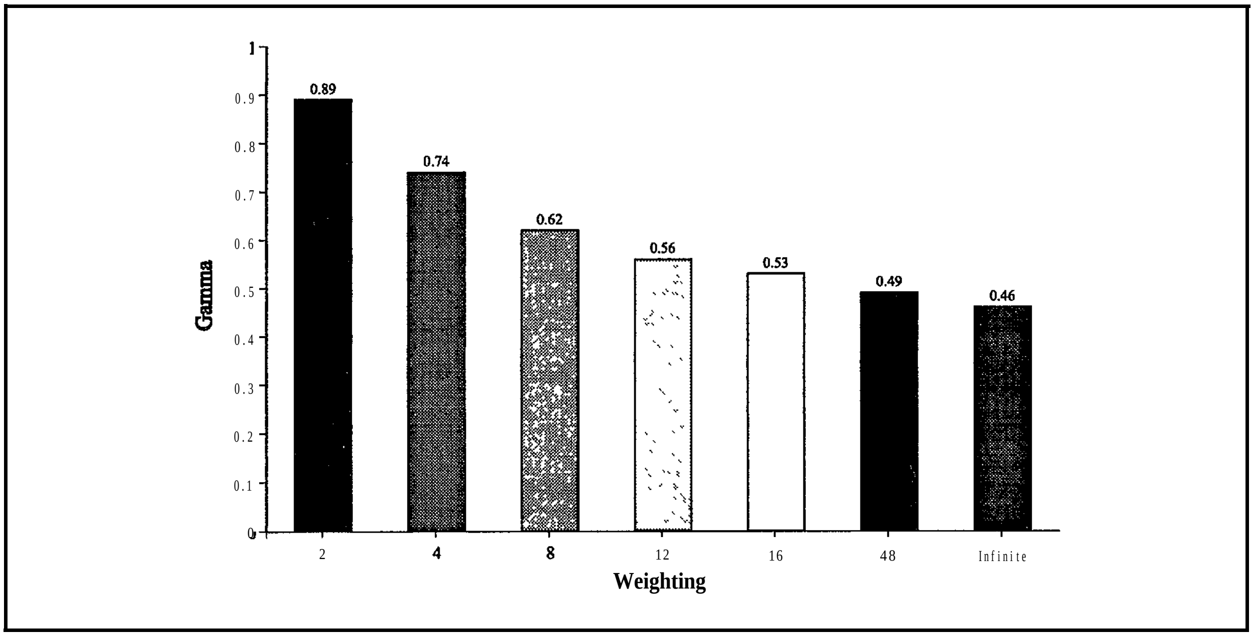


Figure 2. Goodman's/Kruskal' s Gamma as a function of Safety weighting.

Figure 3 shows the asymptotic value of Goodman' s/Kruskal' s gamma for all nine criteria. The Economic criterion changes the most, implying that from a human factors perspective it is a less valuable dimension. The Existing Data, Guidelines and Older Drivers criteria offer the same sensitivity as the Safety criterion. Thus, the sensitivity analysis confirms that the linear psychometric model is robust so that changes in individual weights used to produce table 15 will not greatly alter the rankings of table 15.

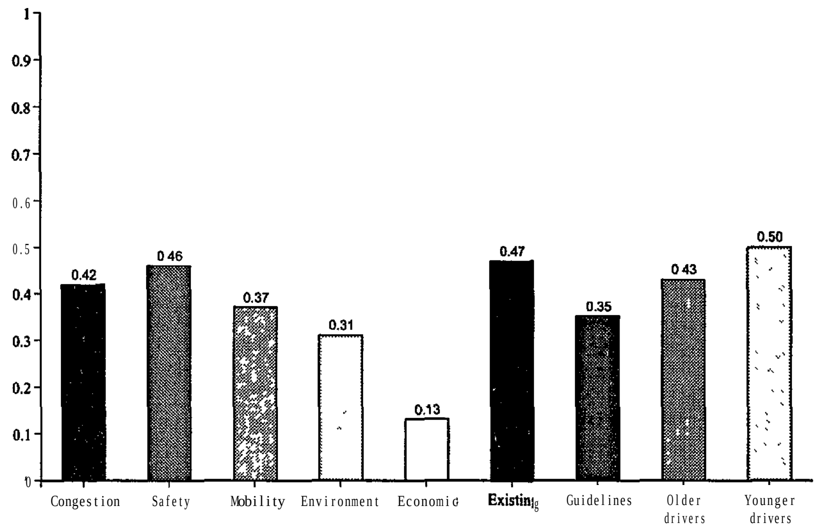


Figure 3. Goodman's/Kruskal' s Gamma for each criterion.

VALIDATION

Table 16 shows the number of studies/issues deleted by the raters for Lists A, B, and C. List A (appendix B) used the rankings in table 15. List B used the same weights as table 16, but applied only to the data of the individual rater. List C (appendix B) was a stratified random sample (appendix B) with four studies/issues from each quartile. If the rating methodology used in this study is valid, raters should have rejected more items from List C (appendix B). This was indeed the case, $F(2,14) = 15.1$, $p < .001$. List C (appendix B) differs from both Lists A and B, $ts(14) > 7.28$, $ps < .001$. Lists A and B do not differ, $t(14) = 1.62$, $p > .05$.

Table 16. Number of studies/issues deleted by raters by list.

RATER	LIST A	LIST B	LIST C
N. M.			
T. D.	2	1	5
B. K.			
J. L.			
W. W.	5	6	7
M. M.	1	4	5
F. L.			
T. T.	0	1	2
MEAN	1.50	2.00	4.25

Table 17 shows the eight studies/issues added to List A (appendix B) by the raters. Each rater was allowed to add only one issue. Table 18 shows issues deleted by two raters. No issue was deleted by more than two raters. In general, issues were deleted because raters thought studies would not be practical given time and resource limits of this project.

Table 17. Studies/Issues added to List A by raters.

LABEL	STUDY/ISSUE
B1	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc).
B6	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial.
D16	Assess how the fatigue that plagues CVO drivers (e.g., 8- to 12-h shift) might interact with complex in-vehicle systems to degrade driver performance.
D17	Identify specific concerns regarding how display formats and modality impact CVO driver workload.
D20	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews.
E2	Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway.
E11	Identify how the dynamic characteristics of driver workload interact with the form of the ATIS interface.
G1	Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems.

Table 18. Studies/Issues deleted from List A by two raters.

LABEL	STUDY/ISSUE
A5	Examine the workload implications of requiring drivers to transform and enter information into the system.
E11	Identify how the dynamic characteristics of driver workload interact with the form of the ATIS interface.
El4	Examine how in-vehicle road sign information (e.g., ISIS) affects workload especially under nighttime, poor weather, and other reduced visibility conditions.
Fl	Examine how attention to different types of ATIS information influences the primary task of driving.

4. DISCUSSION

HIGHEST PRIORITY STUDIES/ISSUES

Table 19 lists the 9 most vital studies/issues followed by the 12 most important remaining studies/issues. Table 19 was built by combining List A (appendix B) with tables 16, 17 and 18. Items are not ranked within the two groups because differences within each group are quite small. These are the key issues that will guide future research.

Table 19. Most vital studies/issues.

LABEL	STUDY/ISSUE
A1	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another.
A4	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system.
B3	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior.
C4	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhance the potential for an improper response to ISIS/IVSAWS.
C5	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.
D2	Identify features that will benefit/require standardization across many types of ATIS systems and functions.
D4	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels.
D12	Evaluate the effectiveness of multimodality displays, such as voice in combination with text.
D17	Identify specific concerns regarding how display formats and modality impact CVO driver workload.
B1	Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.).
B2	Identify information drivers need and want from in-vehicle road signs (ISIS) and warning systems (IVSAWS).
B6	Describe the specific information needs/wants of CVO drivers for various situations, such as local versus long distance, urban versus rural, and emergency response versus commercial.
C6	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information.
D16	Assess how the fatigue that plagues CVO drivers (e.g., 8- to 12-h shift) might interact with complex in-vehicle systems to degrade driver performance.
D20	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews.
D21	Examine how display design might aid the dynamic allocation of driver visual and cognitive resources.
E2	Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway.
E10	Identify the compensatory actions drivers take to moderate their workload, and how ATIS/CVO systems might affect those actions.

Table 19. Most vital studies/issues (continued).

LABEL	STUDY/ISSUE
F2	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events.
Gl	Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems.
J1	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver.

BRIEF DESCRII'TIONS OF STUDIES/ISSUES

Tasks J and L will elaborate these issues in precise operational terms by developing workplans. To the extent possible these workplans will propose experiments that combine several issues in table 19 efficiently. There is not sufficient time to limit each experiment to a single issue. Thus, the following brief descriptions will be considerably expanded in Tasks J and L.

Al. Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another.

The Task C working paper discusses many ATIS/CVO functions and explains how certain subsets naturally are linked. Thus, at least two kinds of cognitive demands can be studied: those transitions that occur within a natural set of ATIS and those that cross set boundaries. Using a part-task simulator in a laboratory we can investigate effects in both classes of function transition. The simulator will provide objective measures of cognitive demands such as driver accuracy and latency. If necessary, results can be described by quantitative models such as the theory of signal detection and information theory.

A4. Identify how complex ATIS interactions among ATIS functions might affect driver understanding and response to the system.

This issue is closely related to Al above and the same methodology can be used to study it. However, the main focus of interest is not transitions across functions but steady-state operation of one function that is related to other functions. This issue also includes potential problems associated with unexpected behavior of functions when a change in one function disrupts smooth operation of another function. It should be possible to combine issues labeled Al and A4 into a single set of laboratory experiments.

B3. Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior.

This study will be performed on-road as part of Tasks L and M. Information that is presented to a driver must go through three mental stages. First, it needs to be perceived correctly. Second, a cognitive decision about how the information might alter the driver's goals must be formulated.

Third, this mental plan must be translated into action, such as taking an alternate route. The on-road study will try to investigate the effects of ISIS and IVSAWS upon all three intervening stages.

C4. Examine how information reliability (e.g., false alarms) influences driver adaptation and enhance the potential for an improper response to ISIS/IVSAWS.

Systems often provide inaccurate information to drivers. False alarms in particular alter mental criteria for decision making. There have been documented cases where operators turned off system warning devices due to high false alarm rates. This is also related to issue Gl, consumer acceptance of unreliable ATIS/CVO devices. A laboratory simulator will be used to control the reliability and accuracy of presented information. Both objective measures (e.g., driver performance) and subjective measures (e.g., trust in system) will be recorded.

C5. Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.

Operators can often get lost in a system that presents too many messages simultaneously. This has been dramatically illustrated in nuclear power plants when a system fault causes an entire message-tile mosaic to illuminate. The "quiet dark cockpit" used in Boeing airplanes is one way transportation systems deal with this potential problem. For drivers the issue is whether the system should be quiet and dark or should it continually be updating the driver, even when he or she is not requesting information. The answer to this question may also depend upon driver demography. A driving simulator will be used to combine the driving task with a secondary ATIS task. Dependent variables will include both driving performance as well as comprehension of multiple messages.

D2. Identify features that will benefit/require standardization across many types of ATIS systems and functions.

This study is similar to research on control-display compatibility. It is best conducted in two phases. First, a survey will be used to measure driver population stereotypes. This may vary with driver demography. Then a laboratory simulation will be used to validate the stereotypes by confirming that popular mappings are used more effectively than unpopular mappings.

D4. Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels.

The concept of divided attention and its effects upon operators have been studied intensely since the seminal limited-channel model of Broadbent in 1958. The advantages and disadvantages of separate input channels depend upon the perceptual aspects of the inputs as well as its complexity. Even with simple inputs, such as dichotic pairs of digits, rate of presentation determines if ear by ear (channel by channel) is better than pair by pair (message by message). So we should not expect a simple answer to this question, especially when driver demography is also considered. This will be tested in a laboratory part-task simulator using both visual and auditory message presentation.

D12. Evaluate the effectiveness of multimodality displays, such as voice in combination with text.

This issue is closely related to issue D4 above and both will be tested in the same series of experiments. Redundancy usually improves message comprehension. But this may interact with the nature of the message (e.g., ISIS versus IVSAWS). A laboratory part-task simulator will be used to determine empirically what these tradeoffs are.

D17. Identify specific concerns regarding how display formats and modality impact CVO driver workload.

The CVO driver has special needs in addition to those of the private driver. For example, he might need warnings about low bridges and weight restrictions that would require mental calculations and planning. Some display formats and modalities might make such cognitive activities easier or more difficult. It is especially important to prevent such mental workload from impeding the safe operation of commercial vehicles. The Battelle Heavy Vehicle Simulator will be used to study this. This research is related to other section D issues in table 18 so that careful planning will be needed to coordinate studies. It might be prudent to delay D17 until some initial results with private vehicle drivers have been obtained.

CONCLUSIONS

Task I evaluated 1 year of research that produced 8 large reports with a total of over 2,600 pages. Filtering all these results to obtain a prioritized list of key research topics was not a simple task. Producing the final list required a psychometric analysis of 17,472 data points generated by 8 human factors experts. Analyzing a set of issues that has already been selected from a very large set of reports is technically difficult, because the selected issues form a narrow range of items: inappropriate items have already been weeded out by the selection process itself. Nevertheless, the validation study showed that this psychometric analysis was successful. Thus, we can have great confidence that the final prioritized list is well-suited to guide future research. The key issues listed here must be addressed if human factors as a discipline is to make a substantial technical contribution to the development of ATIS and CVO components of ITS.

APPENDIX A: STUDY/ISSUE SOURCES

NINE MOST VITAL STUDIES/ISSUES

Below, we provide more comprehensive descriptions of the nine most vital studies/issues identified in this effort. These descriptions have been adapted from previous project reports.

AI Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another. [Task C]

Few of the subsystem functional characteristics associated with ATIS/CVO will operate in the absence of others. Instead, most ATIS/CVO systems will contain several functional characteristics. To the extent that these systems represent an integrated set of functional characteristics, they will be more likely to enhance driver performance compared to independently installed functional characteristics. Therefore, as part of the description of each functional characteristic, we must consider the potential interactions between functional characteristics that may inhibit or facilitate their effectiveness.

Interactions between functional characteristics might stem from the information requirements of each function or from human cognitive characteristics. For example, route selectionrequires information concerning the location of the destination, and a services/attractions directory provides information about potential destinations. Therefore, these functions would facilitate each other. In other circumstances, human information-processing limits may introduce interactions between functional characteristics that might inhibit their effectiveness. For example, the display of commercial information may overwhelm drivers with information and inhibit the effective communication of emergency or warning information. In contrast, careful integration of several functions may minimize redundant information that might otherwise overwhelm drivers. For example, integrating in-vehicle guidance signs with route guidance information might minimize extraneous information, while better supporting the driver's navigation on an unfamiliar route. This situation represents a case where a pair of functions might either inhibit or facilitate each other, depending on the final system design.

A4 Identify how complex interactions among ATIS functions might affect driver understanding and response to the system. [Tasks C, A]

Few of the subsystem functional characteristics associated with ATIS/CVO will operate in the absence of others. Instead, most ATIS/CVO systems will contain several functional characteristics. To the extent that these systems represent an integrated set of functional characteristics, they will be more likely to enhance driver performance compared to independently installed functional characteristics. Therefore, as part of the description of each functional characteristic, we must consider the potential interactions between functional characteristics that may inhibit or facilitate their effectiveness.

Interactions between functional characteristics might stem from the information requirements of each function or from human cognitive characteristics. For example, route selection requires information concerning the location of the destination, and a services/attractions directory provides information about potential destinations. Therefore, these functions would facilitate each other. In other circumstances, human information-processing limits may introduce interactions between functional characteristics that might inhibit their effectiveness. For example, the display of commercial information may overwhelm drivers with information and inhibit the effective communication of emergency or warning information. In contrast, careful integration of several functions may minimize redundant information that might otherwise overwhelm drivers. For example, integrating in-vehicle guidance signs with route guidance information might minimize extraneous information, while better supporting the driver's navigation on an unfamiliar route. This situation represents a case where a pair of functions might either inhibit or facilitate each other, depending on the final system design.

One must zoom in/out and pan to various locations to plan a route prior to starting the drive. However, particularly for complex or long routes, it is difficult and time consuming to plan a route in this manner. What generally happens is that drivers, after inputting a desired destination, drive immediately and plan the route in large part as they travel. This strategy increases the attention demand of the composite driving task, since pre-drive planning has now been allocated as an in-transit task (Antin et al., 1990). Dingus et al. (1989) therefore recommend that a provision for route selection be provided as part of navigation and information systems. Another advantage to providing a route selection algorithm as part of navigation system features is that many more options are available for information presentation. If no route is provided, an area map must be displayed to accurately navigate. If a route is provided, the navigation information can be displayed aurally and/or visually, textually or spatially; the information can also be displayed in a turn-by-turn graphic format or an entire route graphic format.

B3 Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSA WS) might influence behavior. [Tasks D, F]

There is not a good understanding of which pieces of information about a traffic problem are necessary and useful to drivers. Specifically, it is not clear whether knowing about lane closures, or the cause of a congestion problem, will cause drivers to modify their behavior. Perhaps it is beneficial to suppress clarification of a spectacular incident like a fire, as it could encourage gawkers to travel to the scene. On the other hand, it also alerts drivers to the possibility of emergency vehicles in the area.

There are a variety of ways to express the severity of a congestion problem. Terms like "heavy traffic," "sluggish traffic," "a one minute delay," "bumper to bumper," "stop and go," "slow and go," and "merging delay" are used in traffic reports broadcast by radio stations. Radio traffic reports also occasionally provide an estimate of the length of a congestion queue. More research is needed, however, to determine how drivers use an estimate of a backup queue; whether it can be reliably estimated; and how best to describe it to drivers: in miles, or number of traffic signals, or from street X to street Y. The word "congestion" itself may be ambiguous; Do drivers interpret it consistently as slow traffic, or can congestion also refer to a heavy volume of traffic moving at the posted speed? The location of a traffic problem can also be expressed in various ways. Can the relevance of the problem be assessed more easily by the driver if its location is described relative to the vehicle or in absolute terms?

Onboard computer-generated traffic advisories can provide information on demand which is filtered for relevance to a given vehicle location/route. Some issues which arise when filtering for relevance strategies are considered include the criteria which are applied to determine relevance; the upper limit on the amount of information which should constitute an on-demand traffic report; and the possibility of giving drivers the ability to tailor traffic reports to their own needs and interests (Means, et al., 1992).

c 4 Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSA WS. [Tasks B, A]

ATIS devices must provide accurate and reliable real-time information. Specific issues that have been raised in this regard include: (1) the tolerance of private vehicle drivers' for congestion data that is out of date, (2) the need to decrease the current time between the occurrence of congestion and the incorporation of that information into in-vehicle systems, (3) the possible utility of providing confidence levels for estimated travel times, and (4) providing the driver with the data upon which alternate routes are recommended.

In general, ATIS research is lacking for IVSAWS and ISIS applications. Although these ATIS systems will probably not have particularly complex user interfaces, they present unique human factors and safety issues. IVSAWS will be an alarm type of display; therefore, issues of timing, modality false alarms, and potential operator reaction must be addressed.

C5 ***Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately. [Task F]***

In this context, information refers to the mathematical construct discussed by Fitts and Peterson (1964) and is analogous to the reduction in uncertainty that accompanies a choice among the alternatives. A specific example in the context of an ATIS system might address the effects of a proliferation of warning icons that warn of hazardous road conditions. As the number of icons and warning messages increases, the time to respond will increase as a linear function of the information content of the warning icons. At one extreme, many equally likely alternatives will maximize information content, increasing response time, while a single choice minimizes information content and minimizes response time.

D2 ***Identify features that will benefit/require standardization across many types of ATIS systems and functions. [Tasks D, F]***

Driver interfaces must be consistent. Information communicated to the driver in visual displays should be consistently located within the display. Vocabulary used in auditory speech displays should use a consistent syntax and sequence of information.

Similar to population stereotypes and innate response tendencies, automatic response developed through experience with a consistent interface design can enhance performance, while an inconsistent interface design can lead to increased errors and response times. Like population stereotypes, interface design consistency affects performance because of learned expectancies rather than innate characteristics of the users. In contrast to population stereotypes, the effects of interface design consistency are specific to a narrow domain (such as computer operating systems or vehicle controls), while population stereotypes span a wide variety of domains (e.g., red frequently signifies danger in a wide variety of settings). Consistency associated with design standards facilitates understanding of new systems based on experience with other systems, and promotes efficient performance through well practiced, consistent stimulus-response mappings. Schneider and Shiffrin (1977) showed that after extended practice with consistent stimulus-response pairings, subjects developed automaticity in their responses and were able to respond with little conscious effort. Inconsistent mappings did not promote automaticity as reflected by less accurate performance. The development of automaticity for searching displays takes somewhat longer in older than young adults (Fisk & Rogers, 199 l), suggesting that performance even with well-designed, compatible displays will be less effective for older drivers.

D4 ***Examine the performance differences associated with focusing all ISIS and IVSA WS information through either single or multiple display channels. [Task G]***

Wickens (1987) emphasizes the importance of coding display information redundancy in different modal formats. Redundant presentation of information in the auditory and visual modalities will accommodate transient shifts in noise within the processing environment (e.g., visual glare, background noise, verbal distractions), which may influence one format or another. Display format redundancy also accommodates the strengths of different ability groups in the population (e.g., high spatial ability versus high verbal ability).

Unfortunately, no specific guidelines for tactile displays can be given. It can only be stated that an effort should be made to encode manual controls with tactile information. This will enhance feedback and enable drivers to manipulate controls without taking their eyes off the road. Designers of in-vehicle systems should seriously consider the use of tactile feedback displays. There is a great need to perform research relevant to the use of tactile displays, in order to further define their value.

D12 Evaluate the effectiveness of multimodality displays, such as voice in combination with text. [Tasks A, F, G]

The implications of employing multimodal displays to aid map interpretation and navigation while driving are largely unknown. In particular, the driver's ability to read and understand navigation information from maps, symbols, and text, in various combinations is of interest.

While hearing does not play as central a role in driving as does vision, its importance may increase as sound is used to convey information to the driver without jeopardizing the driver's view of the road. In particular, sound offers an alternative to HUD's and other visual displays because it does not compete for visual attention. For example, Walker et al. (199 1) report that drivers using auditory navigation devices drove more safely than those using visual devices. Subjects using visual devices missed more gauge changes, had longer reaction times, and drove more slowly than subjects using auditory devices. Although auditory information avoids the human limitations of vision, human hearing has a number of limits that may have significant implications for ATIS systems.

Driver overload has consistently been identified as a concern associated with the use of multimodal displays. If the limits of working memory must be exceeded to display all of the necessary information, the system should include a method of recalling or re-presenting the information at a later time. Displaying this information both visually and aurally would in many cases enable the driver to receive the information without adding to the visual attention load. In addition, the information could be recalled at a later time if it is forgotten or misunderstood. It is very important to minimize the complexity of displays in a signing system, because the system will be functioning almost entirely while the vehicle is in motion. Any unneeded information that is displayed will require more attention by the driver that could create an unsafe condition.

D17 Identify specific concerns regarding how display formats and modality impact CVO driver workload. [Tasks C, A, G]

There are a number of concerns associated with CVO driver overload. First, CVO's typically have more components involved in the operation of their vehicle. For example many trucks have power take-off assemblies or refrigerator units. Thus, the required monitoring may be more complex because of the additional systems that require monitoring. Therefore, when designing the interface, the complexity of information presented to the CVO driver must be considered.

Second, it is unclear what sensory display modes and what associated information format and density are most appropriate for each of the ITS functions. Information from visual displays should be coded to allow for aggregation from successive glances. Timing of information presentation includes speed, control activation, traffic density, headway, weather, driver characteristics such as age and ability.

Third, a combination of a HUD and a centrally located video dashboard display may provide the optimal method of displaying visual ATIS information. Despite its advantages, this display option will be the most expensive to include in the automotive environment. In the case where such cost is beyond the constraints of a given design, either a HUD or centrally located dashboard display are attractive choices. An issue that still remains with respect to any of these options is visual display format selection. In addition to the format issues described in the above section, HUD's need to be analyzed for their compatibility with the display format that is chosen and the quantity of information provided. The current state of HUD technology does not allow the effective display of the amount of detailed information found on full route maps. Information requirements that are simpler and require more frequent glances, such as icons and alphanumerics, are more suited to display on a HUD. Information that requires more display resolution and possibly color coding should be allocated to display on a video screen.

APPENDIX B: STUDY/ISSUE RATING FORMS

INSTRUCTIONS FOR RATING ATIS/CVO STUDIES/ISSUES

Previous tasks of this project have identified a broad range of concerns which human factors research does not address. For example, a technical basis for ATIS/CVO (Advanced Traveler Information System/Commercial Vehicle Operations) is not covered within human factors guidelines. To develop a technical basis for human factors guidelines, the Battelle team will conduct a series of laboratory, survey, and on-road studies. However, the number of potential issues that could be studied far exceeds the resources to conduct those studies. Therefore, to maximize the benefit of the studies, the issues require prioritization. Issue priority depends upon a weighted average of several criteria.

To support this prioritization process we ask you to use the attached sheets to rate all studies/issues according to all the criteria. The left side of the rating sheet begins with a one-sentence description of the research issue/study. Immediately to the right is a series of criteria associated with the ITS America objectives and other criteria associated with how well the studies would support guideline development. Please rate each of these nine criteria using the rating scale shown in the upper left corner of the rating sheet. The larger the value, the more closely studies/issues meet the criteria. For example, a study to examine the effects of a route guidance system on freeway congestion might receive a “5” under the “Congestion” criteria. A study that goes beyond all existing data would receive a “5” for “Existing data.” ***Please enter a rating for all studies/issues.***

Criteria for rating the feasibility of the study associated with each issue lie on the right hand side of the rating sheet. These criteria address the cost, time, practicality, generality, and suitability associated with potential laboratory, field, and survey studies. Please rate all criteria for the different types of studies (laboratory, field and survey studies). Scales for these ratings lie at the far right of the rating sheet. The cost rating scale applies to the “Cost” criteria for the laboratory, field, and survey methodologies. The larger the number, on a 3-point scale, the more expensive the study. The time rating scale applies to the “Time” criteria for laboratory, field, and survey methodologies. Larger values correspond to longer experiments, as measured in months to complete. The practicality, generality, and suitability criteria are rated with a scale on the lower right of the rating sheet. The more practical, general, or suitable the study and methodology the larger the rating. For example, laboratory studies will never be able to replicate the complete driving experience and so will not be able to address many issues. In these situations “Suitability” under “Laboratory Methodology” would receive a rating of “1.” ***Please enter a rating for all criteria, even if a one or more methodologies appear completely unsuitable.***

The issues shown on the rating sheets are a composite of lists and summaries provided by several scientists. Many of whom, alas, neglected to supply the requested cross-reference to project working papers. As such, the reference to specific tasks may be ambiguous. However, we would like you to note the task that might contain the issue. Even better, if you know a page number please include it as well. We do not expect anyone to fill in references for all issues, but we would like benefit from the broad perspective of the group by identifying where these issues originated. Thus, where possible, please insert the initial of the form from where the issue came in the far right column. For example, insert "E298" to signify that the issue originated from page 298 of the Task E working paper.

Thank you very much for your patience with this task; we appreciate your help in rating all criteria for all studies/issues. Your ratings will provide a valuable resource in determining the priority of the ATIS human factors studies that will follow.

The following pages describe the general categories of studies/issues and the criteria used to judge them. The descriptions of issue/study categories augment the single sentence explanations on the rating sheets. Following the descriptions of issue/study categories each criterion is described in more detail.

STUDIES/ISSUES

The issues fall into 11 general categories to make the diverse set of issues more comprehensible. The range of issues includes the need to identify the factors that govern how drivers adapt to ATIS, the need to understand how best to present human factors guidelines to designers so that human factors concerns are addressed in future ATIS, and the need to develop sound experimental methodologies to study ATIS. The 11 general categories are defined below.

Coordination of Multiple ATIS Functions

ATIS will, in all likelihood, include a wide variety of functions that range from route planning, services/attractions direction and route guidance to automatic aid requesting and vehicle condition monitoring. The human factors issues in this category address the need to understand the cognitive and physical demands associated with transitions between these functions.

Driver Function and Information Requirements

Because potential ATIS applications have only recently emerged, the precise driver information requirements are only vaguely understood. Issues in this category address the need to understand how information requirements differ between types of drivers (commercial/private, experienced/novice) and types of environments (rural/urban, familiar/unfamiliar). These issues also include questions concerning what information should appear automatically and what information drivers should request manually.

Reliability, Timing, and Priority of Information

ATIS can provide drivers with a large amount of information not currently available to drivers, and it is unclear how drivers will adapt their behavior to this information. Issues in this category address how to present and prioritize information so that drivers safely perceive and respond. Also, the inherent difficulties in obtaining consistently reliable information concerning traffic and road conditions suggest that it may be important to understand how drivers react to inaccurate information.

Interface Form and Modality

ATIS development can draw upon a wide variety of display and input device technology; however, a clear understanding of how to match this technology to driver requirements has not been developed. Interface form refers to the physical characteristics and configuration of the interface, and does not describe the information content. For example, interface form differentiates between touch screens and keypads, and between analog and digital displays. Issues associated with interface form and modality include the effect of different display devices on warning message comprehension and perceived criticality, and the need to identify appropriate display devices for the different types of information provided by an ATIS.

Time Sharing, Attention, and Workload

Introducing ATIS devices to the driver has the potential to provide the driver with an overwhelming amount of information that could escalate workload above acceptable levels. At the same time, in-vehicle systems may reduce workload by providing advance warning of dangerous situations. Issues in this section focus on identifying when drivers should use various ATIS functions, and how interaction with ATIS can be structured to minimize detrimental effects and maximize beneficial effects on driving performance.

Effect of ATIS on Driving Performance

Because ATIS devices may increase driver workload and draw driver attention away from the roadway, they have the potential to adversely affect driver performance. One potential effect of these systems is their tendency to draw driver attention into the vehicle and away from the roadway. This may lead to a failure to detect potentially important external events. Over reliance on ATIS hazard warnings may also lead drivers to blindly accept potentially erroneous warning information. This could lead, for example, to excessive speeds on icy roadways.

Driver Acceptance

Because the success of nearly all ATIS functions depends on driver acceptance and willing cooperation, it is critically important to develop a better understanding of how system designers can avoid jeopardizing driver acceptance of these systems. A general issue in this category involves how “lock out” designs that limit the range of function available to the driver while in motion influence driver acceptance. Other general issues in this category address driver tolerance for inaccurate information and driver preference for various interface characteristics (e.g., types of map symbols and repetition frequency of verbal warnings).

Navigation and Route Selection Strategies

A large component of ATIS involves aiding drivers trip planning, routing selection, and navigation, so understanding how drivers will adapt to these features is an important consideration in developing new systems. For instance, if an ATIS provides a non-intuitive route a driver might not appreciate the time savings that it generates, and so may not see any advantage in using the system. Similarly, the utility of automatic routing systems depends on the drivers' abilities to specify useful routing parameters and algorithms. Routing parameters and algorithms refer to the mathematical operations that guide the system's choice of route. Potential routing parameters include fastest route, shortest route, safest route, fewest number of turns. These parameters may vary dramatically with driver characteristics, such as age, familiarity with the area, current goals (e.g., sight seeing, commuting journey).

Training and Education

Since it is unlikely that drivers will choose to engage in much training, systems should be developed to minimize training requirements. To address remaining training requirements, it may be possible to include help functions and incorporate training directly into system operation. Research needs to establish exactly how these techniques might enhance driver operation of ATIS/CVO systems. Research has shown a strong relationship between understanding of system functions and increased acceptance, so training may be an effective way to promote greater acceptance for system capabilities.

Design and Presentation of Human Factors Design Guidelines

The end product of this project is a set of design guidelines to ensure human factors considerations are addressed in new systems. To be successful, these guidelines must be more than a list of human limits, they must be tailored to the needs of the designers. To develop guidelines that designers will actually use requires a deep understanding of the design process. This understanding can help identify an appropriate structure (e.g., relationships between information in the guideline compilation) and format (e.g., computer-based hypertext, traditional paper-based, or an expert system).

Research Strategies and Methods

Executing and interpreting human factors studies requires a commitment to rigorous research strategies and methods. This is particularly true for a comprehensive program that must combine results into a unified product. Measures of driver workload provide a good example of how a robust experimental method, based on a multivariate construct of workload, could avoid potential confusion of apparently conflicting results. Developing comprehensive measures is another example. Broad, comprehensive measures of driver acceptance and workload could provide a link between studies in this project and research elsewhere.

CRITERIA

To identify the criticality of each issue, we request a rating on each of several criteria. These criteria include: 1) the role of the issue in achieving ITS goals, 2) how likely a study will address unresolved issues related to developing ATIS human factors guidelines, and 3) the feasibility of the associated experimental methodology.

The ITS America Strategic Plan (Intelligent Vehicle-Highway Society of America, 1992, Task B working paper) identified five major goals which ITS should support. Because ATIS design guidelines should help designers create systems that achieve these goals the criticality of any issue depends on how closely it relates to each ITS goal. The following short definitions describe the five ITS America goals.

Congestion

Decreased traffic congestion has been identified as the primary goal of ITS. Major benefits include better use of roadway capacity by shifting traffic from congested roadways to routes with excess capacity. Benefits to both private and commercial vehicle operators are seen as directly related to reduced travel time. Decreased traffic congestion may result from a variety of ATIS functions including those that provide travelers with information regarding alternative modes of transportation, such as bus, rail, air, and ride-sharing. Issues directly related to reducing congestion will be more critical.

Safety

ITS technology is seen as providing an opportunity to improve safety by reducing crashes, contrasted with the traditional approach of increasing “crash worthiness.” The basic strategies identified for improving safety center around avoiding areas of congestion, being warned of hazards, reducing levels of congestion (that are associated with a higher incidence of accidents). Another possible positive aspect of ATIS would be the reduction in frequency of drivers simultaneously holding a map while driving a vehicle. ATIS may also jeopardize safety. Specifically, concerns include erroneously directing drivers down one-way streets the wrong direction, reducing the time spent by drivers monitoring the roadway, and reducing reaction time to unanticipated hazards due to high levels of mental workload. Issues closely related to driver safety will be more critical.

Mobility

The objective of increased and higher quality mobility is used to refer to a broad range of associated performance requirements that address the traveler’s well being, comfort, enjoyment, and access to travel. Well being, comfort, and enjoyment requirements range from reducing the general level of stress while driving to increasing access to scenic and recreation areas. Access to travel requirements includes both improved automobile access, as well as improved access to alternative modes of travel. Finally, this objective is commonly referred to when noting the requirement to increase the mobility of the elderly, disabled, and economically disadvantaged segments of the population. Critical issues will directly relate to enhanced mobility.

Environment

The objective of environmental quality includes improved energy efficiency and other benefits such as reduced noise pollution, reduced travel, and shifts in the mode of travel. Improved environmental quality and energy efficiency will be accomplished by decreasing traffic congestion, diverting travelers from single-occupancy vehicles, accommodating smoother more evenly distributed traffic flow, and reducing travel time demand management based on road pricing. Issues closely related to furthering the environment should be rated highly.

Economic

The objective of improved economic productivity has consequences for both commercial and private drivers. From the institutional perspective, this objective can be achieved by reducing total institutional expenditures for the transportation infrastructure. From the individual and CVO perspective, improved economic productivity relates to specific gains by individuals and commercial operators. A closely-related objective is improved energy consumption, which translates into cost savings for all components of the economy. Issues closely related to furthering the economic improvement goals of ITS should be rated highly.

Beyond the relationship to the ITS goals, the criticality of issues depends on several other criteria that address how well studies will support a technical basis for human factors guideline development. These criteria include how far a study extends beyond existing data, potential to support guideline development, relevance to issues concerning older drivers and younger, inexperienced drivers.

Existing Data

Although human factors research from other applications may help resolve many issues associated with ATIS development, placing advanced ATIS technology in cars and trucks involves a number of unique issues. The most critical issues on the list are those for which no previous research exists and so studies that resolve questions that no existing data address should receive high ratings.

Guidelines

The purpose of this project is to develop human factors design guidelines for ATIS, not to simply examine how driver behavior may change as a result of these systems. Therefore, studies/issues that directly address potential design alternatives and would support designers' data base of human limits and abilities should receive high ratings.

Older Drivers

Older drivers present a particular challenge to ATIS design. They have special needs and limits that if addressed will help ensure a flexible system that can be adjusted to meet the special needs of a variety of populations. Because of the need to devote special attention to the needs of older drivers, studies particularly well suited should receive high ratings.

Younger Drivers

Younger drivers have highest accident rates and so special attention should be paid to enhancing their safety through ATIS designs.

Besides the issues related to the development of ATIS design guidelines, the criticality of the issues depends on the feasibility of the studies they imply. The feasibility of each study is assessed considering potential choices of methodologies. The same criteria apply for laboratory experiments, field experiments, or surveys. These criteria include the cost and length of the experiment, the practicality, the generality of the results, and the suitability of the methodology for the particular study.

Cost

To complete this rating, the rating scale corresponds to rough estimates of how much the study will cost using a particular methodology. For instance, a simple laboratory study may cost $25,000 and should receive a low rating of "1." A complicated on-road study may cost much more and may deserve a rating of "3." The rough estimates should include staff time and materials associated with data collection, analysis, and report preparation.

Time

This rating reflects the anticipated duration of the experiment with larger ratings corresponding to greater time requirements. As with cost estimates, this rating should be based on a rough estimate of the resource requirements of each study, using a particular methodology. For instance, a laboratory study to examine a simple issue may require less than 3 months, and a large survey study may take more than a year. The time estimate should span the entire duration of the experiment, from data collection to analysis and report preparation.

Practicality

This rating reflects the anticipated likelihood of success of the study. A practical study, given the constraints of the methodology and resources, is likely to resolve the issue in question. A simple issue, easily resolved with the given methodology, should receive a high rating of practicality.

Generality

Some issues address specific problems associated with single ATIS functions, while others address general human limits. General human limits may have more general implications for the design of many ATIS functions. A rating of high generality would result from a methodology that combines with an issue to provide information that applies to a wide variety of circumstances. For instance, a study that identifies a method for predicting driver workload could have benefits for a wide number of applications and should receive a "5."

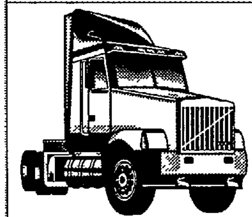
Suitability

Suitability refers to how well a particular methodology applies to resolving the issue. Laboratory, field and survey studies all have limits and benefits and their suitability depends on how well they match the particular issue. For example, laboratory studies will never completely replicate the driving experience and so may not be suitable to address many issues. When the capabilities of the methodology match the requirement of the issue, suitability should receive a rating of "5."

CRITERIA RATING SCALE
1 Not at all critical, useful, practical
2 Interesting
3 Important
4 Necessary
5 Essential and imperative

STUDY/ISSUE	IVHS AMERICA CRITERIA RATINGS					OTHER CRITERIA RATINGS			
	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
COORDINATION OF MULTIPLE ATIS FUNCTIONS									
Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another.									
Examine the physical demands placed on the driver by the need to transition from one ATIS function to another.									
Observe actual driving behavior to reveal the need to integrate functions in ways that were not identified in the analytic approach. These observations should not be bound by current ATIS technology.									
Identify how complex interactions among ATIS functions might affect driver understanding and response to the system.									
Examine the workload implications of requiring drivers to transform and enter information into the system.									
Examine the driver acceptance implications of requiring drivers to transform and enter information into the system.									
Examine the effect on driver performance of integrating non-ATIS/CVO equipment (radar/laser detectors, laptop computers, cellular phones) with ATIS equipment.									
Examine how to support sharing information (e.g., status, location, availability of resources) among dispatches to ensure effective decision making.									
DRIVER FUNCTION AND INFORMATION REQUIREMENTS									
Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.).									

Name:
Affiliation:




LABORATORY METHODOLOGY					FIELD METHODOLGY					SURVEY METHODOLOGY					
COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	TASK

COST RATING SCALE
1 Low ($0-$50K)
2 Medium ($51-$100K)
3 High (>$100K)

TIME RATING SCALE
1 0-3 Months
2 4-6 Months
3 7-9 Months
4 10-12 Months
5 > 12 Months

CRITERIA RATING SCALE
1 Not at all practical, general, suitable
2 Interesting
3 Important
4 Necessary
5 Essential and imperative

CRITERIA RATING SCALE
1 Not at all critical, useful, practical
2 Interesting
3 Important
4 Necessary
5 Essential and imperative

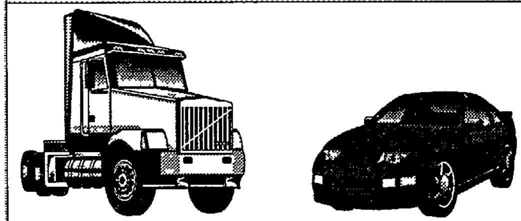
STUDY/ISSUE	IVHS AMERICA CRITERIA RATINGS					OTHER CRITERIA RATINGS			
	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Identify information drivers need and want from in-vehicle road sign (ISIS) and warning systems (IVSAWS).									
Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior.									
Identify what types of ATIS information should be displayed to drivers automatically.									
Identify what types of ATIS information should be available upon request.									
Describe the specific information needs/wants of CVO drivers for various situations, such as local vs. long distance, urban vs. rural, and emergency response vs. commercial.									

RELIABILITY, TIMING, AND PRIORITY OF INFORMATION

STUDY/ISSUE	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Identify how priorities specific to CVO information compare to other ATIS information.									
Investigate how best to support driver performance when the ATIS fails due to unreliable GPS signals or other anomalous circumstances.									
Identify how ATIS information prioritization can enhance driving performance and response to ATIS information.									
Examine how information reliability (e.g. false alarms) influences driver adaptation and enhance the potential for an improper response to ISIS/IVSAWS.									
Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.									

LABORATORY METHODOLOGY					FIELD METHODOLGY					SURVEY METHODOLOGY					
COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	TASK

Name:
Affiliation:



COST RATING SCALE
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3 High (>$100K)

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CRITERIA RATING SCALE
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2 Interesting
3 Important
4 Necessary
5 Essential and imperative

CRITERIA RATING SCALE
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STUDY/ISSUE	IVHS AMERICA CRITERIA RATINGS					OTHER CRITERIA RATINGS			
	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information.									
Identify how and when information related to weather conditions and availability of specialized fuel and services should be provided to CVO drivers.									
Since commercial vehicles have limited maneuverability, identify the most effective type and timing of information to present to CVO drivers.									
Examine how the reliability and priority of regulatory information affect CVO driver workload.									
INTERFACE FORM AND MODALITY									
Identify the performance implications of inconsistent display formats across ATIS subsystems.									
Identify features that will benefit/require standardization across many types of ATIS systems and functions.									
Identify how display characteristics, such as modality, influence driver comprehension of advisory system information.									
Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels.									
Evaluate how input device characteristics might need to vary across subsytems.									
Evaluate driver perception and control characteristics such as hand-finger coordination and touch accuracy that might influence ATIS design.									

LABORATORY METHODOLOGY					FIELD METHODOLGY					SURVEY METHODOLOGY					
COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	COST	TIME	PRACTICALITY	GENERALITY	SUITABILITY	TASK

Name:
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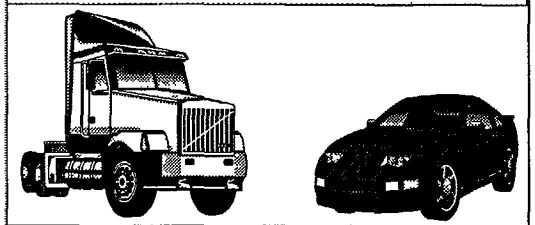

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STUDY/ISSUE	IVHS AMERICA CRITERIA RATINGS					OTHER CRITERIA RATINGS			
	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Examine the effect of display form (e.g., text vs. graphic) on driver decision making and problem solving during route planning and selection.									
Examine how the interface form (e.g., text vs. graphic, touch screen vs. steering wheel controls) should change from pre-drive to drive and park modes.									
Evaluate the types of information suitable for a HUD display.									
Determine how interface form and modality influences driver interpretation of ISIS and IVSAWS features.									
Generate rules to pair types of information with display modality, for individual displays and for combinations of displays.									
Evaluate the effectiveness of multi-modality displays, such as voice in combination with text.									
Identify the relationship between icon characteristics and information types that maximize icon effectiveness and salience.									
Identify how message length and wording for voice-based interfaces affect driving performance and message comprehension.									
Determine what factors influence synthesized voice message intelligibility.									
Assess how the fatigue that plagues CVO drivers (e.g., 8-12hr shift) might interact with complex in-vehicle systems to degrade driver performance.									
Identify specific concerns regarding how display formats and modality impact CVO driver workload.									
Identify the display design characteristics required to support ATIS/CVO systems in large, noisy, and vibration prone commercial vehicles.									

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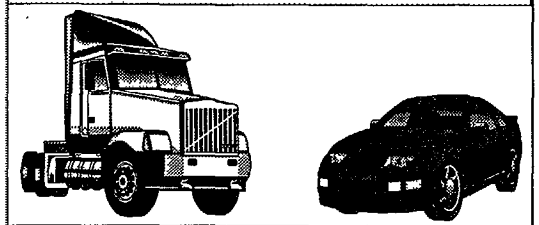

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STUDY/ISSUE	IVHS AMERICA CRITERIA RATINGS: CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	OTHER CRITERIA RATINGS: EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Examine how to display information such as "weight-in-motion" to promote regulatory compliance, especially if the information is different than expected.									
Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews.									
Examine how display design might aid the dynamic allocation of driver visual and cognitive resources.									
TIME SHARING, ATTENTION, AND WORKLOAD									
Identify a subset of environmental factors that interacts with ATIS to influence driver workload levels.									
Evaluate how different types of information, displayed using a HUD, affect cognitive attention devoted to the roadway.									
Examine the limits of visual and cognitive attention concerned with receiving information from ATIS when driving.									
Identify which functions to "lock out" during in-transit and provide only during zero-speed and pre-drive conditions.									
Identify ATIS functions a driver might need or want to use during the various driving activities, such as driving, parking, and stopping.									
Examine whether availability of information and functions should depend on individual differences such as age, gender, and experience.									
Identify the allowable functions of ATIS/CVO systems under conditions of driver impairment.									

LABORATORY METHODOLOGY					FIELD METHODOLGY					SURVEY METHODOLOGY					
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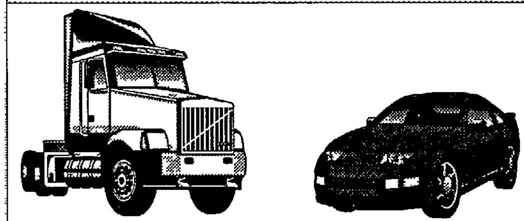

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STUDY/ISSUE	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Identify how ATIS information flow might be managed to capitalize on the dynamic nature of driver workload.									
Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS.									
Identify the compensatory actions drivers take to moderate their workload, and how ATIS/CVO systems might affect those actions.									
Identify how the dynamic characteristics of driver workload interact with the form of the ATIS interface.									
Examine the requirements to support the complex on-board data management requirements that commercial vehicle drivers experience.									
Identify potential for overload of specialized CVO drivers such as emergency vehicle operators.									
Examine how in-vehicle road sign information (e.g., ISIS) affects workload especially under nighttime, poor weather, and other reduced visibility conditions.									
EFFECT OF ATIS ON DRIVING PERFORMANCE									
Examine how attention to different types of ATIS information influences the primary task of driving.									
Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events.									
Determine whether drivers' reliance upon navigational cues outside the vehicle influence their observation of external hazards, compared to when they rely on navigational cues presented by an ATIS.									

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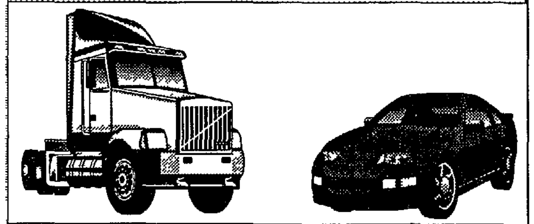

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Identify factors that may influence drivers to defer to the "Expert System" and fail to recognize a hazard when one is present.									
Examine how to display CVO-specific highway safety information (e.g., bridge clearance, width, and restrictions) with minimum interference in attention to the roadway.									
DRIVER ACCEPTANCE									
Evaluate the effect of information reliability and inaccuracies on driver acceptance and use of ATIS/CVO systems.									
Evaluate driver acceptance of "lock-out" designs that only allow driver to access functions under certain circumstances.									
Evaluate how driver acceptance may decline when the driver is forced to interact with multiple subsystems, particularly when this interaction is exacerbated by demanding road conditions.									
Investigate factors that influence acceptance of non-verbal and verbal alerts and messages, such as repeat cycle frequency.									
Evaluate acceptability of different types of In-Vehicle Routing and Navigation Systems maps, symbols, and icons.									
Investigate the effect of dynamic route scheduling on the perceived quality of worklife and corresponding driver acceptance.									
Examine the effectiveness of destination approach guidance for CVO in a congested, reduced sight distance, and increased pedestrian traffic environment.									

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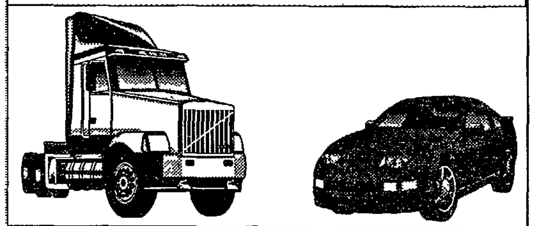

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STUDY/ISSUE	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Determine whether CVO drivers will accept a "lock-out" design which limits access to all or selected functions while moving.									
Determine how learning about IVHS systems and increased experience with them over time affects acceptance of ATIS/CVO.									
Examine how the accuracy of information pertaining to availability and current deployment of resources affects dispatcher acceptance and interaction with the system.									
NAVIGATION AND ROUTE SELECTION STRATEGIES									
Investigate how ATIS interface designs and parameters of routing algorithms (e.g., optimize for safety, time, distance) affect route acceptability.									
Investigate factors that influence driver's perception of the effectiveness of automatic routing.									
Investigate information requirements associated with driver "way-finding" and destination selection strategies.									
Evaluate the effect of destination-focusing navigational strategies on driver stress and driver acceptance.									
Determine the information content of maps to support different ATIS/CVO functions.									
TRAINING AND EDUCATION									
Determine system characteristics that eliminate or minimize training needs.									

LABORATORY METHODOLOGY					FIELD METHODOLGY					SURVEY METHODOLOGY					
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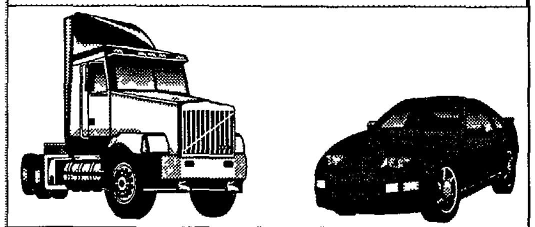

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STUDY/ISSUE	IVHS AMERICA CRITERIA RATINGS					OTHER CRITERIA RATINGS			
	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
Examine how training might enhance driver acceptance of routing suggestions.									
Identify what training techniques could be incorporated into the operation of the different subsystems.									
Examine how best to develop videotape-based training to illustrate ATIS functions.									
Examine the cost/benefit trade-off associated with training CVO drivers to accommodate more ATIS information.									
DESIGN AND PRESENTATION OF HUMAN FACTORS DESIGN GUIDELINES									
Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver.									
Investigate alternate guideline presentation formats (e.g., expert systems, electronic database, standard database) so as to be compatible with designer needs.									
Investigate the design process to identify designer needs for guideline content and format.									
RESEARCH STRATEGIES AND METHODS									
Generate multivariate constructs to measure driver capacity and workload.									
Identify measures comprehensive enough to allow meta-comparisons with existing research.									

LABORATORY METHODOLOGY					FIELD METHODOLOGY					SURVEY METHODOLOGY					
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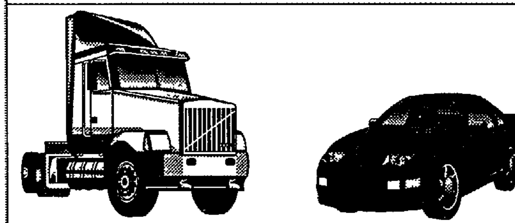

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	CONGESTION	SAFETY	MOBILITY	ENVIRONMENT	ECONOMIC	EXISTING DATA	GUIDELINES	OLDER DRIVERS	YOUNGER DRIVERS
With mass market penetration, identify methods to evaluate and predict consequences of ATIS/CVO system use. Develop methods to link driver performance to more global measures of system performance, such as specified by the IVHS goals. Develop a set of consistent subjective measures across experiments so that rating scales are common across experiments.									

LABORATORY METHODOLOGY					FIELD METHODOLGY					SURVEY METHODOLOGY					
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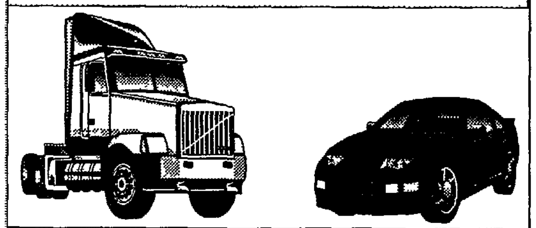

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VALIDATION RATING FORMS

Table 20. Validation rating forms-List A.

A l	Examine the cognitive demands placed on the driver by the need to transition from one ATIS function to another.
A4	Identify how complex interactions among ATIS functions might affect driver understanding and response to the system.
A5	Examine the workload implications of requiring drivers to transform and enter information into the system.
B2	Identify information drivers need and want from in-vehicle road sign (ISIS) and warning systems (IVSAWS).
B3	Identify how the information drivers need and want from road sign (ISIS) and warning systems (IVSAWS) might influence behavior.
C 4	Examine how information reliability (e.g., false alarms) influences driver adaptation and enhances the potential for an improper response to ISIS/IVSAWS.
C5	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.
C6	Examine how the timing of ISIS and IVSAWS information, with respect to the location of the incident, influences driver reaction to the information.
D2	Identify features that will benefit/require standardization across many types of ATIS systems and functions.
D12	Evaluate the effectiveness of multimodality displays, such as voice in combination with text.
D21	Examine how display design might aid the dynamic allocation of driver visual and cognitive resources.
El1	Identify how the dynamic characteristics of driver workload interact with the form of the ATIS interface.
E14	Examine how in-vehicle road sign information (e.g., ISIS) affects workload, especially under nighttime, poor weather, and other reduced visibility conditions.
Fl	Examine how attention to different types of ATIS information influences the primary task of driving.
F2	Examine how route guidance systems might adversely influence driver detection and recognition of unusual roadway events.
Jl	Investigate how to structure design guidelines to help designers address human factors issues in ATIS designs which support the needs of the driver.

DELETE: _____

ADD (Maximum of 1 entry): _____

Table 21. Validation rating forms-List C.

B1	"Identify how specific information needs vary as a function of driver characteristics (e.g., age, gender, etc.)."
B5	Identify what types of ATIS information should be available upon request.
C1	Identify how priorities specific to CVO information compare to other ATIS information.
C5	Investigate how to display multiple ISIS and IVSAWS messages so that drivers can identify relevant information and react appropriately.
C9	Examine how the reliability and priority of regulatory information affect CVO driver workload.
D4	Examine the performance differences associated with focusing all ISIS and IVSAWS information through either single or multiple display channels.
D7	"Examine the effect of display form (e.g., text vs. graphic) on driver decision making and problem solving during route planning and selection."
D13	Identify the relationship between icon characteristics and information types that maximize icon effectiveness and salience.
D18	"Identify the display design characteristics required to support ATIS/CVO systems in large, noisy, and vibration prone commercial vehicles."
D20	Examine how information can be displayed to dispatchers to support the complex decision-making process associated with allocation of emergency response crews.
E8	Identify how ATIS information flow might be managed to capitalize on the dynamic nature of driver workload.
E9	Identify how estimates of real-time driver workload can be used to avoid overload by moderating information from ATIS.
El2	Examine the requirements to support the complex onboard data management requirements that commercial vehicle drivers experience.
62	"Evaluate driver acceptance of "lock-out" designs that only allow driver to access functions under certain circumstances."
610	Examine how the accuracy of information pertaining to availability and current deployment of resources affects dispatcher acceptance and interaction with the system.
K4	Develop a set of consistent subjective measures across experiments so that rating scales are common across experiments.

DELETE:

ADD (Maximum of 1 entry):

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