Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations: Task Analysis of ATIS/CVO Functions

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Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations: Task Analysis of ATIS/CVO Functions

Research and Development
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McLean, Virginia 22101-2296

FOREWORD

This report is one of a series of eight reports 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). Among the topics discussed in the series are a functional description of ATIS-CVO, comparable systems analysis, identification and exploration of driver acceptance, and definition and prioritization of research studies.

This report analyzes the influence of using ATIS on driving tasks for both private and commercial vehicle operators. The task analyses that specify the tasks to be performed by the users as well as the information displayed in the ATIS are based on scenarios developed from previous project tasks.

Copies of this report can be obtained through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, telephone (703) 487-4650, fax (703) 321-8547.

A. George Ostensen, Director
Office of Safety and Traffic Operations
Research and Development

NOTICE

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16. Abstract

This working paper documents Task E of the present project, Task Analyses for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) systems. The goal of Task E is to conduct detailed analyses of the influence of using ATIS on driving tasks for both private and commercial vehicle operators. The task analyses specifying the tasks to be performed by the users as well as the information displayed in the ATIS (including IRANS, IMSIS, ISIS, and IVSAWS) are based on scenarios developed from previous project tasks. Information for the task analysis was obtained from a review of the literature, observations, and interviews of drivers and dispatchers using prototype and first-generation operational systems. The report organizes the tasks people and systems do while driving into three usable formats: (1) a graphical representation of the interactions that take place between driving and ATIS/CVO functions; (2) a diagram (i.e., an Operational Sequence Diagram [OSD]) of the sequence of task actions, the types of tasks involved, and the relationship between various human and non-human parts of the system; and (3) a description of each task in terms of its purpose, initiating conditions, task type, and performance considerations. General characteristics and performance considerations are examined for four types of tasks: setup, bridging, decision-making, and integrated. A summary of research issues and additional research needs are identified.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.765	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.785	cubic meters	m^3
NOTE: Volumes greater than 1000 I shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	so.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (oi "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lambefts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/In^2	poundforce par square inch	6.69	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C +32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m*	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E360.

(Revised September 1993)

EXECUTIVE SUMMARY

Task E focuses on the analysis of the tasks that drivers and other operators of Advanced Traveler Information Systems (ATIS) and advanced information systems for Commercial Vehicle Operations (CVO) will perform when using these systems. The task analysis includes a recognition that ATIS/CVO tasks will often take place in conjunction with other, perhaps more urgent, tasks of controlling a vehicle and doing so safely. Understanding how drivers and other system operators will actually interact with and use ATIS/CVO systems under normal driving conditions is an important element of developing human factors design guidelines.

The task analysis performed was limited to relatively broad assumptions about the design specifications of specific systems. In some cases, particularly with the analysis of tasks involving In-Vehicle Routing and Navigation Systems (IRANS) and In-Vehicle Motorist Services Information Systems (IMSIS), the task analysis was based on prototype or first-generation equipment. In other cases, the analysis was based on system design specifications as they commonly appear in Intelligent Vehicle-Highway Systems (IVHS) plans and concept papers.

Information for the task analysis was gathered from a variety of sources. These included a review of information gathered in previous tasks in the ATIS project as well as by other researchers. It also included observations and interviews of drivers and dispatchers using prototype and first-generation operational systems. Since not all of the major functions associated with ATIS/CVO are represented by prototype systems, information was also gathered by having subjects describe how they would operate these systems if they were available.

Since this was the first real opportunity within the ATIS project to examine the influence of driving on ATIS/CVO functions, Task E devoted a good deal of attention to this issue. This was done by two methods: (1) the analysis included functions and tasks that primarily involved vehicle operation, and (2) each of the analyses was based on realistic driving scenarios.

The primary work of a task analysis involves organizing the things people and systems do into a usable format that allows the analyst to identify various conditions or characteristics that are important. Task E used three methods to accomplish this organization. The first was to organize information from a specific scenario into a graphical representation of the interactions that take place between both driving and ATIS/CVO functions. The second was to organize the tasks required to successfully complete a specific scenario into a graphical representation (i.e., an Operational Sequence Diagram [OSD]) that will show the sequence of task actions, the types of tasks involved, and the relationship between various human and non-human parts of the system. The last method used to organize the information was to describe each task in terms of its purpose, initiating conditions, task type, and performance considerations. This task characterization was done in a table format. Each analysis is described in detail in appendix D.

There are many different ways to perform a task analysis (see appendix A for summaries of papers proposing potential methods). The systematic approaches used in Task E represent some of the most commonly used conservative techniques. The use of standard OSDs and tables that describe task characteristics ensures a more general understanding of the information. It has the further advantage of providing a commonly accepted foundation for more detailed expansion of the task analysis as systems are developed. More sophisticated advanced network techniques are described in appendix B.

To provide information of greater potential and general use than is possible from the detailed task analysis, the report contains a composite analysis of the four main types of tasks. These include:

- Tasks that are used to set up an ATIS function.
- Tasks that serve as bridges between two or more ATIS functions.
- Tasks that involve decision making by the driver or dispatcher.
- Tasks that are integrated with critical driving tasks.

Each of these types of tasks were then examined in terms of the general characteristics of each task type and the task performance considerations that are common to that type of task. Results of the composite analysis were used to develop recommendations concerning the development of human factors design guidelines that will reflect both task requirements and human limitations. Areas were identified where additional research needs to be done before effective guidelines can be developed.

While the main body of the text provides a general summary and compilation of recommendations and conclusions, the report includes several appendices that document the supporting details of these conclusions. In addition, these appendices form a useful reference that future tasks can draw upon. Specifically, appendix A includes summaries of several papers that discuss previous task analyses of driving, general task analysis methods, and issues that a task analysis should address. Appendix B contains the details of an analysis of information flows among functional characteristics of ATIS/CVO systems. To analyze the relationships between functional characteristics, a number of social network analyses and graphical theory techniques were adopted. This analysis examines the relative centrality of each functional characteristic and shows which functional characteristics fall into tightly coupled groupings (which groups of functional characteristics share information). This analysis helped identify ATIS/CVO functional characteristics that should be included in the driving scenarios used for the detailed task analysis (appendix D). Appendix C contains a comprehensive hierarchical catalog of driving and ATIS tasks. This hierarchical task listing is shown in text lists and graphically as block diagrams. Appendix D examines these tasks in detail, using tables and diagrams to describe tasks listed in appendix C in the context of driving scenarios. Thus, the appendices form the foundation for the approaches and conclusions generated in the main body of the report.

In addition to the task analysis, this report also includes an integrated summary of the findings, observations, and issues that were identified as a result of work conducted in Tasks A through E. This summary appears as appendix E. The summary is organized around the following 11 research issues:

- Issue 1. Existing status of research and development.
- Issue 2. Formatting of information.
- Issue 3. Driver capacity to assimilate information.
- Issue 4. Knowledge, skills, and abilities requirements.
- Issue 5. Information requirements of ATIS/CVO users.
- Issue 6. Driver acceptance of ATIS/CVO systems.
- Issue 7. Driver decision strategies for trip taking.
- Issue 8. Factors influencing the performance of drivers.
- Issue 9. Issues related to CVO system use.
- Issue 10. Interactions between ATIS use and driving.
- Issue 11. ATIS interactions.

Each research area is discussed in terms of combined findings and observations obtained from Tasks A through E. Following the summary, a list of recommendations for both human factors design guidelines and future research requirements is provided.

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LIST OF ABBREVIATIONS

ADIS . . . . Advanced Driver Information Systems
ARI . . . . Advisory, Restrictive, or Inhibitory
ATIS . . . . Advanced Traveler Information System
ATMS . . . . Advanced Traffic Management Systems
AVCS . . . . Advanced Vehicle Control Systems
AVI . . . . Automatic Vehicle Identification
AVL . . . . Automatic Vehicle Location
CAD . . . . Computer-Aided Dispatch
CB . . . . Citizens Band
CDM . . . . Critical Decision Method
CM . . . . Concept Mapping
CRT . . . . CathodeRay Tube
CTA . . . . Cognitive Task Analysis
CVO . . . . Commercial Vehicle Operations
DAWS . . . . Driver Alert Warning System
ERGS.. . . . . Electronic Route Guidance Systems
ETA. . . . . Estimated Time of Arrival
FHWA . . . . Federal Highway Administration
GPS . . . . Global Positioning System
IDA . . . . Information Decision Action
IMSIS . . . . In-Vehicle Motorist Services Information Systems
IRANS . . . . In-Vehicle Routing and Navigation Systems
ISIS . . . . In-Vehicle Signing Information Systems
IVHS . . . . Intelligent Vehicle-Highway System
IVNS . . . . In-Vehicle Navigation Systems
IVSAWS . . . . In-Vehicle Safety Advisory and Warning Systems
LCD . . . . Liquid Crystal Display
MDS . . . . Multi-dimensional scaling
OSD . . . . Operational Sequence Diagram
PVPA . . . . Prospective Verbal Protocol Analysis
TA . . . . TaskAnalysis
UTM . . . . Universal Traverse Mercader
VPA . . . . Verbal Protocol Analysis
WIM . . . . Weigh in Motion

CHAPTER 1. TASK ANALYSIS OF ATIS/CVO SYSTEMS

INTRODUCTION

Prior tasks in the Advanced Traveler Information Systems/Commercial Vehicle Operations (ATIS/CVO) project have concentrated on obtaining a description of what ATIS is likely to do; what role it is likely to play in terms of economics, safety, quality of life, and environmental concerns; and what functions it is likely to perform for private and commercial vehicle operations. These previous activities provided a description of ATIS and what people are likely to use it for without examining the way it will actually be accomplished. In addition, prior tasks concentrated on the ATIS without paying much attention to the driving context within which the systems will have to be used. Task E is intended to provide information related to how drivers and other users are going to interact with ATIS/CVO systems in the driving environment.

Goals of the Task Analysis of ATIS/CVO Systems

Task E has two primary goals:

- Develop an understanding of what users of ATIS/CVO systems are going to be required to do to use the system safely and effectively.

- Develop an understanding of the relationship between what ATIS/CVO system users are going to be required to do to use the system and what they are likely to be able to do.

Usefulness of a Task Analysis

A task analysis can be used to perform a number of useful functions depending on the needs of the user, the development stage of the system, and the type of system being described. The major goal of the ATIS project is to develop human factors design guidelines for ATIS/CVO systems. In this context, a task analysis provides an evaluation of the relationship between the way the user will need to interact with the system and the physiological and cognitive characteristics the user is likely to bring to the task.

Appendix A summarizes several papers that document important issues that a task analysis should address. In addition, this appendix reviews several papers that describe potential task analysis methods and thus provides the basis for selecting the methods used in this report.

The task analysis has several useful outcomes for both later tasks in the project and-the direct development of human factors design guidelines. These include:

- Identification of "basic" human tasks that will be required of ATIS regardless of the specific design adopted for a particular system.

- Identification of areas where an understanding of the impact of human limitations on a particular type of task is incomplete and will require further research.

- Development of a sequential description of the actions users of ATIS/CVO systems will need to perform to achieve functional goals.

- Identification of potential conflicts between ATIS/CVO tasks and driving tasks.

- Early identification of task demands that may exceed user characteristics for some portions of the population.

- Identification of general areas that will need to be addressed by the human factors design guidelines.

Constraints in the Task Analysis

The task analysis of ATIS/CVO systems was constrained by several conditions. The first condition is that the systems are not well developed. Although there are some reasonable prototypes of ATIS/CVO systems that perform some of the ATIS functions, common approaches to the design of such systems are a result of technological capability rather than any form of standardization or general agreement on how the systems should be designed. In the next 5 to 10 years there is reason to believe that technological limitations that presently constrain design considerations will be lifted and that there will be a multitude of possible approaches to deal with controls and display issues-the primary human factors issues of ATIS The lack of a mature or well-developed technology provides the task analyst with two possible alternatives. The analyst can use a system-specific approach limited to the existing technology, thus enabling a very detailed look at the tasks involved, but with the attendant risk of providing information that will be outdated when operational systems are released. The analyst can also develop the task analysis using a function-related approach that concentrates on the tasks that will need to be performed, regardless of design, to achieve the goals of the function. This type of approach is obviously less sensitive to specific design issues, but does have the advantage of being more applicable to developing technologies.

A second condition in a task analysis of ATIS/CVO systems is that these systems are being developed for use by a wide range of drivers. As a consequence, it is difficult to determine, with any certainty, what effect user characteristics will have on task performance. One approach to solving this problem would be to examine the relationship between task demands and user characteristics for several different user populations (e.g., commercial drivers, younger drivers, and older drivers). Such an approach would have significantly increased the complexity of the analysis without adding a great deal to its usefulness, particularly given the limited understanding of specific ATIS/CVO designs.

A third (and perhaps the most important) condition is the lack of information on the effect of secondary tasks, such as those represented by ATIS, on the primary task of driving. While secondary tasks are not new to driving (e.g., radios have been in cars since the 1920s), ATIS is probably the first major system that will represent a secondary task so closely integrated with the driving task. This integration is particularly noticeable with an ATIS that provides instructions to the driver, where the driver must not only comply with the instructions given by the system, but must maintain primary control of the vehicle as well.

DATA/INFORMATION COLLECTION

Task E was designed to provide a systematic, top-down analysis of the tasks performed by users of ATIS/CVO systems in order to meet the required functions for each system as identified in Task C (Battelle Research Center, 1992). The analysis was to be based on a combination of information gathered in earlier tasks and information specifically obtained in connection with the task analysis. Table 1 shows the contributions made by the earlier tasks.

These previous tasks provided a starting point or foundation from which it was possible to identify additional activities that would be necessary to perform the task analysis. These additional activities included:

- Conducting a short literature review aimed specifically at significant issues associated with the task analysis.
- Conducting focus groups to identify how ATIS comparable tasks are presently done and how drivers might use ATIS/CVO systems when they become available.
- Conducting site visits to obtain experiential and observational information on the use of prototype ATIS/CVO systems in “real-world” situations.
- Conducting Prospective Verbal Protocol Analyses (PVPA) with representative drivers on ATIS functions that do not have readily available prototypes.

The following sections of this report provide details of how these data/information collection activities were conducted.

Table 1. Contributions of previous tasks to the task analysis.

ATIS/CVO PROJECT TASK	CONTRIBUTIONS TO TASK ANALYSIS
Task A - Literature Review	· Prior task analyses that have been conducted for private and commercial driving tasks. · Prior function analyses that have been conducted for private and commercial vehicle operations. · ATIS descriptions and characteristics. · Advanced commercial vehicle system descriptions and characteristics.
Task B - Identify System Objectives and Performance Requirements	· ATIS/CVO system objectives. · ATIS/CVO system design characteristics (present and future). · ATIS/CVO performance specifications.
Task C - Define Functions	· Results of the function analyses of private/commercial vehicle functions (after comparison of system analysis). · Results of the investigation of technical constraints on private/commercial vehicle systems. · Results of the investigation of human constraints on private/commercial vehicle operators. · Data and observations from the evaluation of functions from the driving context for private/commercial vehicles.
Task F - Identify User Characteristics and Information Requirements	· Results of the determination of user physical and cognitive characteristics for private/commercial vehicle operators.

LITERATURE REVIEW

In order to perform a task analysis of ATIS/CVO systems that would reflect the goals of these systems and show accurately how they could be used, it was necessary to complete a literature review. The literature review had several functions. First, it served to identify existing techniques that have been developed to analyze systems that are still at the conceptualization phase. Second, the literature review helped to locate existing terminologies to describe driving behaviors and their associated tasks. In addition, the literature review also helped in identifying: (1) the cognitive demands imposed on drivers when using ATIS/CVO subsystems while driving, as well as (2) the human constraints that users bring with them when performing a task. Finally, the literature review examined drivers' behaviors when making use of similar techniques or when taking part in experiments that study some of the functional aspects/characteristics of these subsystems.

The literature review had an initial goal to identify and summarize task analysis methods or other similar techniques that have been used in the past to describe the user's task sequence for systems that exist only at the conceptualization stage. When systems are being conceptualized, rather than already having been built, it is difficult for future users to adequately describe the potential tasks that they will have to perform. Because ATIS/CVO subsystems are still at that particular stage of conceptualization, it was necessary to perform such a review. In fact, although In-Vehicle Routing and Navigation Systems (IRANS) and In-Vehicle Motorist Services Information Systems (IMSIS) have the privilege of having numerous comparable systems to illustrate their capabilities, In-Vehicle Signing Information Systems (ISIS) and In-Vehicle Safety Advisory and Warning System (IVSAWS) have very few examples from which to choose.

In order to perform a task analysis of IRANS and IMSIS, one could examine how present users of comparable systems (such as TRAVTEK and NAVMATE) accomplish the tasks associated with an ATIS. To describe how these drivers would use IRANS and IMSIS, it is necessary to extrapolate from their actual use of comparable systems. Such an extrapolation of the tasks to be performed on IRANS and IMSIS can be obtained through the use of Prospective Verbal Protocol Analysis (PVPA), the use of focus groups of drivers, and by observation of users accomplishing tasks on similar systems. As a consequence, the first goal of the literature review was to search for alternatives to the traditional task analysis methods. Some alternatives were identified and they include PVPA (Tolbert & Bittner, 1991); multi-dimensional scaling (Coury, Weiland, & Cuqlock-Knopp, 1992); thinking-aloud protocols (Denning, Hoiem, Simpson, & Sullivan, 1990); and cognitive task analysis (Drury et al., 1987; Redding, 1990).

The second goal for the literature review was to assist the task analysis breakdown in identifying terminologies associated with driving behaviors as well as ATIS-related tasks. In this regard, it was worth noting that most task analyses of driving behaviors are done at a level much finer than the one intended in this task. However, some of these task descriptions were considered useful. For example, the classic task analysis description by Miller (1953) served as a basis by providing the terminology that is relevant to any task domain. Some of the cognitive processes were derived from Miller's (1974) decision-making elements. Finally, most of the driving terminology was obtained from Moe, Kelly, and Farlow (1973) and MacAdam (1992).

In addition to these terminology listings, a description of drivers' tasks was obtained by reviewing their behavior with similar technologies. Studies such as simulation of driver route diversion and alternate route selection (Allen et al., 1991); pilot studies of IVSAWS driver-alert warning system design (Erlichman, 1992); and surveys of driver attitude concerning aspects of highway navigation (King, 1986), as well as the influence of car navigation map displays on drivers' performance, have contributed to a better understanding of drivers' future task demands and have helped to provide the terminology necessary to describe these future tasks.

The literature review also had a goal to identify cognitive demands and human limitations in using these ATIS/CVO systems. Some papers helped this identification by breaking down the driving task into various components and determining the drivers' information needs (Allen, Lunenfeld, & Alexander, 1971; Senders et al., 1967). Others focused on human factors considerations that dealt with driving and navigation tasks as well as with users and display characteristics (Petchenik, 1989; Wierville, Hulse, Fisher, & Dingus, 1988). Finally, others provided this information as well as cognitive/attentional demand requirements by looking at advanced systems in general (Roth, Bennett, 8z Woods, 1988; Smiley, 1989).

Appendix A provides a detailed summary of each citation included in the literature review. Each summary identifies the topic, type of article, and subject population used in empirical studies. The summaries also include the abstract, a description of the methodology used in the study, and a brief review that documents the utility of the article and the critical findings. The details of these summaries helped to identify appropriate task analysis methods and provided the descriptions of driving tasks that are included in appendix C and appendix D.

In summary, such a review was necessary in order to produce a task analysis that would accurately reflect the nature of the future systems and would achieve the goal of describing users' tasks.

SITE VISITS

Three site visits were conducted in connection with the task analysis. The site visits allowed the analysts to participate in or observe the use of prototype ATIS/CVO systems. Thus, these visits provided the analysts with an opportunity to observe the performance of ATIS/CVO tasks within the context of driving or dispatch.

Experiential Observations of IRANS and IMSIS

The Avis Rent-a-Car agency currently has five automobiles equipped with Zexel's NAVMATE system that are available for rent from their San Jose (CA) International Airport office. The NAVMATE system is an autonomous system that provides some of the primary functions of the IRANS and IMSIS subsystems described in the Task C functional description working paper. The available NAVMATE system incorporates the IRANS functions of trip planning, pre-drive route and destination selection, route guidance, route navigation, and the IMSIS function of the services/attractions directory. The IRANS functions are based upon a geographic data base that covers the greater San Francisco Bay area. Vehicle location is determined on the basis of both the global positioning system (GPS) and inertial guidance systems. The IMSIS directory provides a relatively complete listing of commercial establishments, government offices, schools and universities, and recreation areas. There is integration between the IMSIS and IRANS, providing the capability of selecting a destination for IRANS route planning using the IMSIS directory. A more thorough description of the NAVMATE system is in the Task D comparable systems analysis working paper.

Two members of the Task E project team traveled to San Jose and rented a NAVMATE-equipped vehicle from Avis for use during a 3-day period to familiarize themselves with the capabilities and operation of such a system. In preparation for this site visit, selected IRANS and IMSIS scenarios developed during Task B (system objectives and performance requirements) were formatted for use in guiding operational exercises conducted with the NAVMATE system. Upon arriving at the San Jose airport and renting the NAVMATE-equipped automobile, project staff installed a video camera in the back seat of the vehicle and wired the driver with a microphone to obtain a record of the operational exercises. The video camera's field of view included most of the windshield scene and the NAVMATE displays and controls. While driving the car, project staff verbalized their intentions, interpretations, and reactions to the NAVMATE system. The staff member who was the passenger controlled the video camera and maintained a written timeline record of events during each operational exercise.

Operational exercises, based upon a subset of five private vehicle ATIS scenarios, provided the framework within which project staff gained experience operating the IRANS and I&ISIS. At the beginning of each exercise, scenarios were selected and reviewed by the driver and passenger, then the driver operated the NAVMATE system and vehicle with minimal assistance from the passenger. Scenarios that were used to guide these exercises included the following from the Task B working paper:

Pl: Driver goes directly to the hotel located in the city X miles from the airport.

P2: Driver goes to multiple destinations (street addresses) all located within the city. (Modified by selecting multiple destinations and storing them in temporary system memory for retrieval during sequential portions of the trip.)

P3: Driver goes directly to a destination located in the city.

P4: Driver wants to go to a nearby restaurant (point of interest). Driver obtains two alternatives using IMSIS, compares travel times for the two alternatives using IRANS and drives to one of the restaurants. (Modified by comparing distance only.)

P5: Driver has an appointment in a large suburban area. However, before the appointment, the driver wants to go to a restaurant (point of interest) and to a service station. The driver uses IMSIS to select a restaurant near the present location, enters the restaurant and the next client's location on the IRANS, and requests the location of a service station on this route. (Modified by selecting multiple destinations and storing them in temporary system memory for retrieval during sequential portions of the trip.)

Exercises were conducted in both daylight and nighttime conditions for a total period of approximately 24 h. The exercises were conducted over much of the greater San Francisco Bay area, providing opportunities to travel in large and small cities, as well as suburban and rural settings. Following the site visit, videotapes were reviewed and edited, resulting in a 6-h set of edited videotapes that provided representative examples of different scenarios and activities illustrating particular issues in system operation. These videotapes were reviewed by appropriate project staff to help familiarize them with IRANS and IMSIS operation. Following the editing of the videotapes, the audio portion of the edited tapes was transcribed. No additional formal analyses or records of this site visit were made, although the site visit provided general experience that was drawn upon during later stages of the task analysis.

Observations of CVO, AVL, and Satellite Communications Systems

Two human factors specialists spent 1 day observing and interviewing drivers of combination vehicles from Tri-State Motor Freight as they moved hazardous materials from a shipping port to a port where the cargo would be loaded on ships for shipment overseas. Each vehicle was equipped with Qualcomm systems for automatic vehicle location (AVL) and communications with the dispatcher. In addition to the observations of the use of the AVL and communications systems, the observations allowed the specialists to view CVO interactions with State regulators and intermodal networks.

The observations started at the company terminal where the trucks and trailers were inspected and made ready for the trip. Prior to departing, the drivers initiated automatic status messages via the Qualcomm system to indicate to central dispatchers (located in another

State) that they were in service and beginning the trip. The trip to the port was made during the morning rush hour; thus, the trip included delays due to traffic, and the passing of information from one vehicle to another concerning traffic and road conditions ahead. The inter-truck communications were made using on-board citizens band (CB) radios.

Once at the port, the drivers needed to find out which gate they should enter. This was not clear from signs in the vicinity nor from the briefings they had been given by their dispatchers. Eventually, they were able to learn where they needed to be from other drivers. At the port, they were inspected and weighed. Their shipping papers were also checked by both the port authorities and customs officials. All of this was in order; however, the drivers expressed frequent concern that individual inspectors or others would require something that they did not have or that something would not exactly be as the inspector wanted it.

While at the port, the drivers received different instructions concerning how they were to handle the tarps covering the cargo (i.e., leave them with the cargo or take them back to the terminal). The Qualcomm system was used to obtain instructions from the dispatcher concerning this issue. In this case, the message was exchanged using free text and was entered using the keyboard. Both the message and the answer were received by the system and stored until the driver could view them. After the delivery was made, the drivers also received instructions concerning their next assignment over the Qualcomm system, although most also called the dispatcher from a truck stop to negotiate or verify these instructions.

Observations of Computer-Aided Dispatch, AVL, and IRANS for Emergency Vehicles

Two human factors specialists spent half a day observing and interviewing dispatchers and drivers of department vehicles in the Seattle Fire Department. The Seattle Fire Department has computer-aided dispatch (CAD), AVL, and text communication links to their vehicles. Vehicles are equipped with Travelpilot navigation systems.

During this visit, several managers were interviewed concerning the use of the system. Because the system affected dispatchers and drivers, the human factors specialists spoke with drivers and dispatchers and observed them as they operated the system. Most of these observations were made in the dispatch center, where four dispatchers were observed as they handled incoming calls and coordinated the activities of response vehicles.

Dispatchers use the CAD features of the system to identify the location and status of vehicles within a limited radius of the tire or aid request. If no vehicles are available to respond within that radius, the system initiates a search for appropriate equipment from among the nearest stations to the scene. In this function, the system keeps a comprehensive record of the location, status, and availability of all of the fire and aid equipment in the Seattle Fire Department. When a call is received and its location is entered into the system by a dispatcher, the system identifies equipment closest to the scene for the dispatcher, who then initiates the alarm notification at the firehouse or in the vehicle. Simultaneously, the dispatcher assigns the equipment to the incident within the CAD system, and text notification and a scene location icon are sent to the vehicle IRANS display. As the response develops, the system is updated both by the responses from the AVL and the status messages generated from the vehicle, and by the entries the dispatcher made as a result of either phone or radio messages. This information can be displayed on the dispatcher's screen along with a map that includes the vehicle location and incident scene. The map scale can be changed to provide an overall view of the city or a detailed view of the area around the scene. Both the map display and the information used by the system are limited to map orientation only and provide neither routing information nor traffic information to the dispatcher.

The contemporaneous record-keeping function performed by the CAD system provides a means for positioning the city's fire department assets when responding to a major fire or aid incident involving several different fire companies. This ensures that backup assets are available at the scene and that the city is covered as much as possible with the remaining assets. The CAD system also provides a consolidated record of the fire department response to a particular incident, including the locations of the equipment, their travel times, and their status throughout the incident.

The equipment used on the vehicles provides a small map display that includes the incident scene and the vehicle location. The scale can be adjusted, but does not include traffic or routing information. In addition to the map display, text information can be presented on the screen and "quick keys" are provided for the user to enter changes in status (e.g., arrival at the scene, free for assignment, in the station house, or out of service). Operation of the system is the responsibility of the co-driver, and, in most of the equipment, the screen is placed where it cannot be observed by the driver.

FOCUS GROUPS

Three focus groups were conducted in connection with the function and task analyses. Table 2 gives the composition and primary focus of each of the groups. Each of the focus groups consisted of between 15 and 25 participants. The focus groups in Seattle and Denver involved a full day of activities. The focus group in Bar Harbor, ME, was limited to half a day. Each of the focus group sessions was preceded by a description of ATIS/CVO to acquaint participants with the general characteristics and functions that each system would provide. To minimize the influence that specific design approaches might have on the way in which participants visualized the system, descriptions were based primarily on IVHS America's planning documents and published concepts. (IVHS stands for Intelligent Vehicle-Highway System.) The presentations were followed by sessions that concentrated on specific systems (i.e., IRANS, IMSIS, ISIS, IVSAWS, and CVO).

Table 2. Focus groups to gather information on ATIS functions and tusks.

LOCATION	REPRESENTATION	PRIMARY FOCUS AREAS
Seattle, Washington	Private Drivers Commercial Vehicle Drivers	Comparison between differences in the functions and tasks performed by private and CVO drivers and how these differences may or may not be reflected in the use of ATIS/CVO systems.
Denver, Colorado	Commercial Vehicle Drivers CVO Dispatchers	Function and task allocations between CVO drivers and dispatchers and how these allocations are likely to be affected by ATIS/CVO systems.
Bar Harbor, Maine	CVO Enforcement CVO Fleet Management	Fleet management and CVO regulatory enforcement are likely to be affected by ATIS/CVO systems.

Individual sessions for each ATIS/CVO system usually included having the participants involved in some exercise related to the system {e.g., a trip planning and route guidance exercise for IRANS), followed by facilitated discussions of the functions and tasks that participants felt would be involved in the use of the system. Participants were encouraged to describe not only how they might use ATIS/CVO, but also how they would presently perform the same functions and tasks. The discussions of each focus group were transcribed for later analysis.

PROSPECTIVE VERBAL PROTOCOL ANALYSIS

Background

A cognitive task analysis was performed using a prospective verbal protocol analysis (PVPA) approach that was delineated by Tolbert and Bittner (1991). Essentially, this PVPA was an extension of the classical Verbal Protocol Analysis (VPA) (Ericsson & Simon, 1984) that required drivers to “role play” through task steps of a selected scenario in the PVPA and to verbalize the strategy they would use to perform a task with a conceptually described system (described only in outline form). The resulting verbalizations can subsequently help identify human skills required to perform steps effectively and verify the essential correctness of task analysis results developed using expert judgment (e.g., Wheeler & Toquam, 1991).

Described in the following sections are elements of the method used for the PVPA. These include subjects, scenarios, and procedures.

Subjects

Three subjects participated in the PVPA (N=3). Two females (ages 31 and 43 years) and one male (age 32 years) participated. One subject participated as part of her job, while the other two volunteered their time. A description of the general nature of the study was presented, after which an informed consent was obtained from each subject.

Scenarios

The five scenarios used in the PVPA were extensions of scenarios developed as part of Task B (Pl, P8, and P12) or were created as part of the task analysis requirements (P16 and P22). These scenarios were modified slightly to capture all of the IVSAWS and ISIS subsystem functions. Descriptions of these scenarios are given in tables 3 through 7. The IVSAWS and ISIS functions were the focus of the PVPA because they were the two ATIS subsystems for which the data collection gathered the least amount of information. In fact, most of the existing systems (e.g., TravTek, NAVMATE) have capabilities that reflect some of the functional characteristics associated with IRANS and IMSIS, but have no or very limited ISIS or IVSAWS capabilities. The purpose, summary, system, and functional characteristics for the data scenarios are delineated below.

Table 3. Scenario Pl as used in the Prospective Verbal Protocol Analysis.

PURPOSE	This scenario was created to illustrate the various functions that a single system can perform and to show how these various functions occur in a sequenced fashion.
SUMMARY	A driver vacationing with his family in an urban setting arrives at the airport in mid-afternoon and rents a car with an IRANS device installed. The family's plan is to go directly to their hotel located in the city 10 miles (16.1 km) from the airport, The weather is good, but there is a substantial level of congestion on the major highways between the airport and the hotel due to normal commuting traffic. After receiving a brief orientation on using IRANS at the rental office, the driver identifies his destination on the IRANS and requests the fastest route. The IRANS recommends a route that the driver accepts and he begins his trip to the hotel.

SYSTEM	**FUNCTIONAL CHARACTERISTICS**
IRANS	Pre-drive route and destination selection Route guidance Route navigation

Table 4. Scenario P8 as used in the Prospective Verbal Protocol Analysis.

PURPOSE	**This scenario was developed to illustrate how several ATIS might work together and to show** the requirements that use of the systems might make on the driver,
SUMMARY	You are traveling in the suburbs of a major city that you are not familiar with during a heavy snowstorm at night. You have a 20-mile (32.2-km) drive from your hotel to your first destination. Unfortunately, the drive is not in a straight line, but rather there are a number of turns onto various arterial roads (no highways). The heavy snow is making visibility very poor and the roads icy.
SYSTEM	FUNCTIONAL CHARACTERISTICS
IRANS ISIS IVSAWS	Pre-drive route and destination selection Roadway guidance sign information Roadway notification sign information Roadway regulatory sign information Road condition information

Table 5. Scenario P12 as used in the Prospective Verbal Protocol Analysis.

PURPOSE	**This scenario was developed to illustrate the possible use of ATIS for safety-related driving functions.**
SUMMARY	You are visiting friends in Colorado for a vacation. You are traveling late at night on curvy mountain roads to get to their cabin. It's pouring rain and has been for the last 4 hours. However, because you are quite late for the dinner party, you are maintaining a fairly good speed. Unfortunately, at some point you are not as attentive as you should be, you hit a mudslide in a curve while driving at an excessive speed, and you run off of the roadway. The vehicle is slightly damaged and could be driven again, except that it is caught in the ditch. You have no injuries. The area is desolate.
SYSTEM	FUNCITONAL CHARACTERISTICS
ISIS IVSAWS	Roadway notification sign information Immediate hazard warning Road condition information Manual aid request

Table 6. Scenario P16 as used in the Prospective Verbal Protocol Analysis.

PURPOSE	This scenario was developed to illustrate the interaction between navigation and warning functions of ATIS.
SUMMARY	It is Thursday evening, you are on your way to pick up a friend to attend a concert. You are traveling on a major highway that extends across the entire city. While you are driving, an emergency vehicle approaches from behind. Moments later you notice an accident a few miles down the road.
SYSTEM	FUNCTIONAL CHARACTERISTICS
IRANS IVSAWS	Dynamic route selection Immediate hazard warning

Table 7. Scenario P22 as used in the Prospective Verbal Protocol Analysis.

PURPOSE	**This scenario was developed to illustrate potential automated emergency functions of ATIS.**	
SUMMARY	You are traveling in a rural area where there are several speed changes (ranging from 25 to 50 mi/h [40.2 to 80.5 km/h]) due to the presence of several small villages and towns. Also, road repairs are being made in several places in the area. As you near your destination, you gradually begin to reduce your speed. A vehicle suddenly emerges from a hidden crossroad. Your car cannot stop fast enough and collides with the other vehicle. Your car is severely damaged and you have lost consciousness.	
	SYSTEM	**FUNCTIONAL CHARACTERISTICS**
	ISIS IVSAWS	Roadway regulatory sign information Immediate hazard warning Automatic aid request Vehicle condition monitoring

As can be seen above, ISIS and IVSAWS functions were added or emphasized in the modifications. Table 8 summarizes the breakdown of the functional characteristics across the four data scenarios, showing that all facets were covered for ISIS and IVSAWS.

Procedure

The PVPA data collection sessions were conducted in two phases. During the "preliminary" phase, each subject was initially introduced to the nature of the project and to the PVPA technique. Subjects were then asked to fill out the informed consent form and the demographic survey. In order to become more familiar with ATIS concepts, the experimenter then had the subjects read about the following: (1) ATIS in the context of the overall project, (2) ATIS systems/subsystems, and (3) potential ATIS features/functions. The experimenter answered any questions the subjects may have had. Next, TravTek and NAVMATE/Zexel video examples (5 min illustrating actual use) were shown to subjects to provide a broad operational context for ATIS. The experimenter stated that the systems were being used for example purposes and that subjects might have other ideas on how the systems should operate. Subjects were told to express their ideas/conceptions of how the systems should operate.

Following the introductory material, a practice scenario (Pl) was used to familiarize subjects with the PVPA procedure. During this step (phase), subjects were given the general instruction "to imagine themselves in the context of the scenario and to relate everything they could think of to the experimenter." The practice scenario incorporated IRANS and IMSIS

Table 8. Functional characteristics used for the Prospective Verbal Protocol Analysis.

FUNCTION	SCENARIO 8	SCENARIO 12	SCENARIO 16	SCENARIO 22	TOTAL
IRANS					
5.1 Trip planning					
5.2 Multi-mode travel coordination					
5.3 Pre-drive route and destination selection	1				1
5.4 Dynamic route selection			1		1
5.5 Route guidance					
5.6 Route navigation					
5.7 Automated toll collection					
IMSIS					
6.1 Broadcast services/ attractions					
6.2 Services/attractions directory					
6.3 Destination coordination					
6.4 Message transfer					
ISIS					
7.1 Roadway guidance sign information	1				1
7.2 Roadway notification sign information	1	1			,
7.3 Roadway regulatory sign information	1			1	2
IVSAWS					
8.1 Immediate hazard warning		1	1	1	3
8.2 Road condition information	1	1			2
8.3 Automatic aid request				1	1
8.4 Manual aid request		1			1
8.5 Vehicle condition monitoring				1	1

functions and paralleled the NAVMATE video example. A portion of the practice scenario was read, then the experimenter asked the following questions:

- What would you do/be doing at this point?

- What would you expect the system to do?

The subjects' responses were recorded via microcassette (and in writing). Each portion of the scenario was read through, with the same set of questions asked after each portion. The experimenter did not try to ask additional questions at that time. After reading through the whole scenario one time and collecting the subjects' responses, the experimenter went back to the first portion of the scenario and asked the subjects to expand on their responses. This typically involved the experimenter asking for additional information as to how the subjects would "request information" and how the system would "provide information."

This basic procedure was used for the remaining responses for each portion of the scenario. When the practice scenario protocol was finished, the subjects had an opportunity to ask questions of the experimenter. Each of the remaining scenarios (P8, P12, P16, and P22) were then read in separate portions with the same set of initial questions being asked for each portion of each scenario.

Limitations of Using Prospective Verbal Protocol Analysis

Suitability of the technique. The technique used appeared suitable for a general idea of (1) what drivers would expect the system to do, and (2) what they might have to do to interact with it. However, subjects reported having some difficulties imagining how the systems would look, feel, and work, even with the introductory materials and videotapes. In this regard, it is pertinent to note, most subjects had strong initial opinions about how information should be presented (auditorially or visually). However, they were less sure of when the information should be presented or how they would specifically interact with the system (at the button-pressing level). Additionally, subjects mentioned very little about regular driving tasks that they would be doing while using ATIS. When asked about the lack of this information in their responses, their comments were, "I just assumed that I would be doing normal driving tasks," and "It's difficult to imagine what I would be doing while driving without actually doing it." Another subject alluded to the possibility that driving tasks are so automated that they aren't thought about and are not easily verbalized (expert knowledge difficult to verbalize). This latter comment (and to some extent earlier comments), it is noteworthy, is consistent with historical critiques of PVPA (cf., Ericsson & Simon, 1984). However, they are also inconsistent with earlier research using PVPA for assessing strategies used in performing a rapid, complex motor task (Triggs et al., 1990) and early success using PVPA (e.g. Zachary, Zaklad, & Davis, 1987; Zacklad, Deimler, Iavecchia, & Stokes, 1982). Significantly, subjects in the Triggs et al. study had recent extensive experience doing their task, and those in the earlier Zachary et al. and Zacklad et al. studies had hundreds of hours working with systems and scenarios similar to those being evaluated.

This suggests that PVPA may be most appropriate when subjects have more intimacy with the systems evaluated (e.g., ATIS) than could be achieved in the present study (albeit using video and other materials).

Problems concerning PVPA execution. Some concerns about the execution of the PVPA arose during the administration process. First, the materials used to familiarize the subjects with ATIS, both written and videotaped, may have biased subjects' responses toward what they learned from the materials (even though they were told these were examples and they might have other ideas regarding how systems could work). Second, the initial questions used to elicit subjects' responses were very general, which may have resulted in largely more general responses. More specific questions, however, might also have further biased subjects' responses. Third, greater bias was introduced by asking second-level protocol questions specifically related to each subject's first-level responses. By doing this, though, the subjects' responses stayed their own. This too suggests that PVPA may have been more appropriate when subjects are more familiar with the systems being evaluated (e.g., ATIS).

CHAPTER 2. TASK ANALYSIS PROCEDURE

The task analysis undertaken in conjunction with Task E followed a relatively classical task analysis technique. Since a task analysis can be performed in a multitude of ways, the specific procedure used represented a compromise between utilizing specific techniques that might have been of greater value in the determination of specific human factors issues and the more readily acceptable techniques having a greater application to the range of issues that must be considered in this project. The approach used included the following:

- Develop a hierarchical listing of tasks associated with driving and - functions.
- Develop descriptions of each task that characterize the task according to issues of potential importance to human factors design guidelines.
- Identify and characterize the driving tasks of importance to use of ATIS.
- Select from among all ATIS functions those that appear to be most representative of normal uses that will be made of ATIS.
- Select scenarios that represent potential "real-world" use of the most significant ATIS functions.

HIERARCHICAL TASK DESCRIPTION

One of the first things that needs to be done in a task analysis is to decide which tasks will be considered as part of the analysis. The basis for task descriptions was the information gathered during earlier tasks in the project and the information-collection activities undertaken during this task. Before developing a task list, the various functions associated with driving and ATIS were identified. Since Task C had identified the tasks associated with ATIS in both private and commercial operations, the results of this task were used to identify ATIS functions. Sources of information on driving functions and tasks were gathered primarily from previous driving task analyses (McKnight & Adams, 1970), to which functions were added for CVO operations based on discussions with people familiar with such operations.

Once functions were identified, the tasks necessary to carry out each function were developed. Tasks required to accomplish functional goals can be described at varying levels of detail. In order to keep the analysis within reasonable bounds, several rules were used to decide when the tasks had been broken down to an adequate level of detail. These rules were:

- Functions would be described by as few tasks as could reasonably achieve the intended purpose of the function.

- Tasks would be divided into subtasks and task activities only to the level necessary to describe the basic task type required, human limitations involved, and significant important issues related to the task.

- Tasks would not be divided below the level where task allocation between human and machine is likely to depend on a specific engineering design or a specific phase of IVHS development.

By using these rules, the expectation was to develop a task list and subsequent task characterization. Both the task list and task characterization would then focus on human factors design issues facing the development of the ATIS, thus possibly avoiding the inherent problems associated with developing detailed task descriptions that would reflect the technology currently available or expand the analysis to the broad range of future possibilities that might be afforded by future technologies.

Once the tasks, subtasks, and task activities were identified for each function, they were arranged in a hierarchical fashion. Figure 1 illustrates the hierarchy for the tasks involved in the IRANS function of pre-drive route and destination selection.

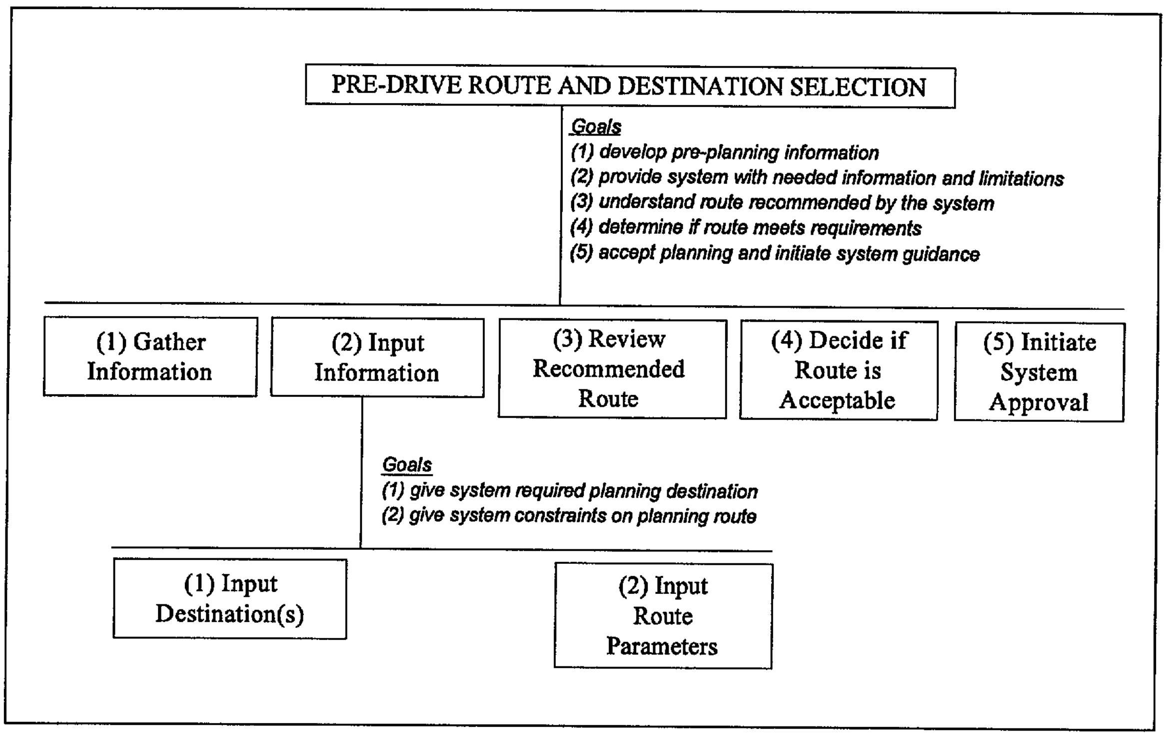


Figure 1. Hierarchy of tasks involved in IRANS function "pre-drive route and destination selection."

The hierarchical task list reflects the minimum detail (in terms of tasks, subtasks, and activities) necessary to adequately describe the performance of a function. Where possible, the sequence of tasks is maintained. In many cases, however, the order in which specific tasks would be performed is dependent entirely on system design. Therefore, while the order of task presentation may indicate temporal relationships, no attempt should be made to interpret the information presented for a specific function based solely on the order of the presentation. Appendix C contains this hierarchical task listing, which is organized around the driving functions presented at the start of the appendix. For each driving function, the appendix includes a complete list of its associated tasks arranged in an outline format:

- The first level represents tasks (e.g., 1.3 Auxiliary Systems).
- The second level represents subtasks (e.g., 1.3.1. Climate Control).
- Subsequent levels represent major task activities (e.g., 1.3.1.1 Set climate controls as necessary). Each driving function is also accompanied by a figure that shows the key tasks, the associated goals, and the function they serve.

After the hierarchical task list was developed for each function, the list was reviewed by a panel of human factors and CVO experts to determine if the tasks sufficiently described the tasks necessary for successful performance of a function in order to proceed with the detailed characterization of each task. The results of the panel discussion are reflected in the hierarchical task listings presented in appendix C and the detailed task analysis in appendix D.

OPERATIONAL SEQUENCE DIAGRAM (OSD)

Following the development of hierarchical task descriptions for each of the functions, operational sequence diagrams (OSDs) were developed for each scenario. The OSD provides a graphical method of task analysis aimed at "describ[ing] clearly the functions of the system integrating all potential hardware requirements" (Walley & Shepherd, 1992, 18ff.). Using standardized operation symbols (figure 2), the OSD provides a way to plot the sequential flow of information, decisions, and actions during the performance of a task or sequence of tasks (Meister, 1985). In addition to characterizing task performance, OSDs are useful (Baker, Johnson, Malone, & Malone, 1979) for:

- Evaluating human-machine interfaces and function allocations.
- Identifying critical task situations.
- Identifying overload and underload situations.
- Identifying critical decision/action points.

- Developing workspace design and evaluation criteria.
- Identifying points of high error likelihood.
- Developing operational procedures.

Of the breadth of OSD applications, our intent in using them was: (1) to characterize the interactions between ATIS and CVO features of IVHS, and (2) to identify critical situations, decision/action points, and other aspects that should be examined further as ATIS/CVO systems are developed. Characterizations of the interactions between system features, it should be noted, are integral to the later Detailed Task Analysis (appendix D). More specifically, each scenario analyzed in appendix D includes an OSD that illustrates driver interaction with different subsystems (IRANS, IMSIS, ISIS, IVSAWS, and CVO-specific) and the external environment. Broad considerations related to the critical feature-interactions can be found in chapter 5 (Recommendations). The OSDs should also provide a framework for other developmental applications as these critical-feature interactions are dealt with and ATIS/CVO systems are moved toward broad system use.

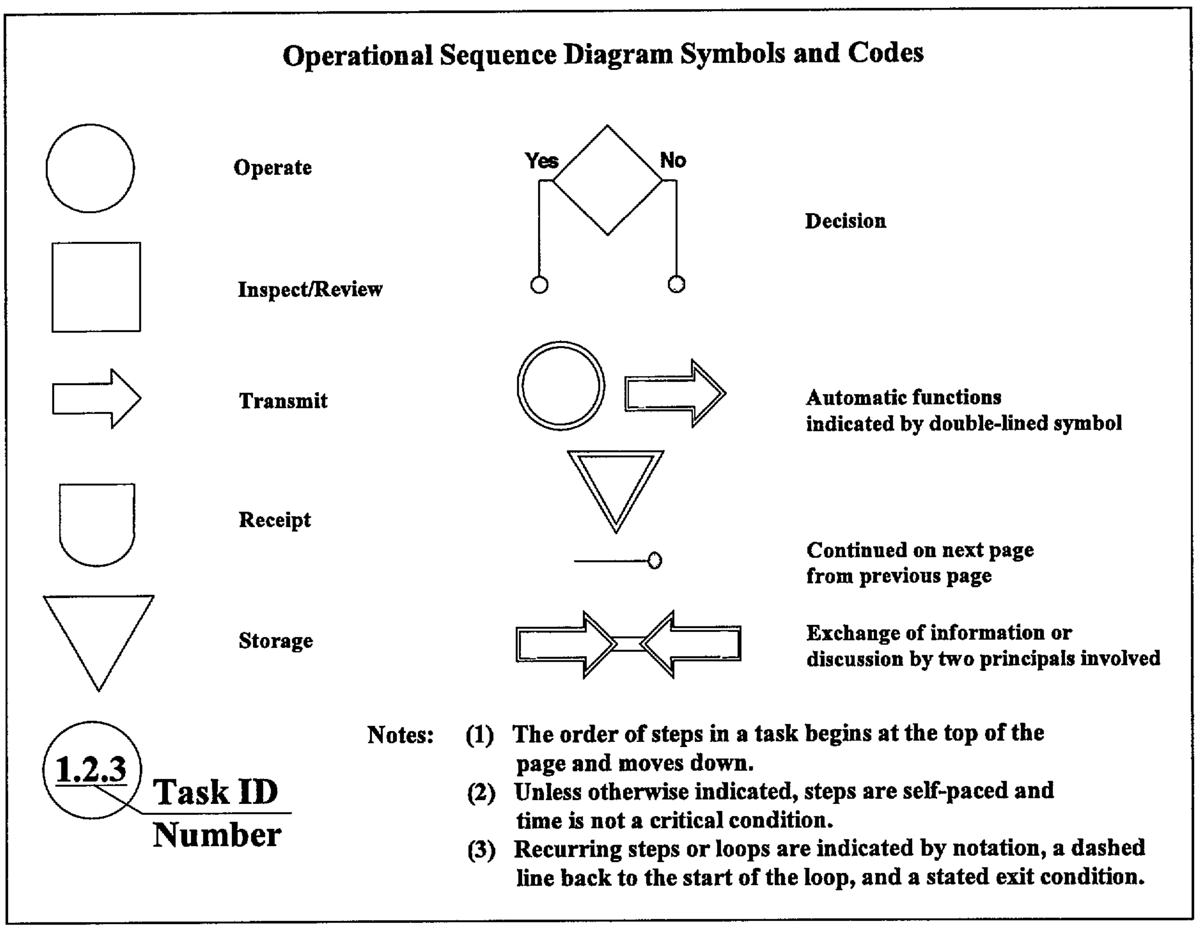


Figure 2. Standard operation symbols.

TASK CHARACTERIZATION

Although the development of a task list that adequately identifies the tasks necessary to achieve the purpose of a system function is important, it does not provide adequate information to the analyst to consider the requirements of a particular task or the implications of a task to human factors design guidelines. To do this part of the analysis, it is necessary to develop an understanding of the characteristics of each task. The next step in the analysis process, therefore, was the preparation of elements that would provide an adequate characterization or description of each task.

Since the major purpose of the ATIS project is the development of human factors design guidelines, the areas considered for the characterization concentrated on those things that would be important to determining the guidelines. Following traditional task description approaches, a variety of possible task characteristics was considered. Some were rejected (e.g., display indications, control actions) because they involved assumptions about the design of the systems, which the analysts were reluctant to make. Others were rejected (e.g., feedback, time available) because they required that the analysts make assumptions about the order of task completion or time required of a specific task that are not known at this time. The following categories were selected to characterize each task:

- Purpose-the purpose or goal of performing the task.
- Initiating Condition-the situation or condition that causes the driver or system to start performing the task.
- Decision Element (Task Type)-the type of action performed.
- Task Performance Considerations-considerations that must be made when designing the system to ensure successful performance by drivers on the task.

In addition to these categories, space was provided for other comments that the analyst believes are important to an understanding of the task within the context of the task analysis. Once the decision had been made to characterize the tasks using these four categories, taxonomies were selected or developed that would provide reasonable boundaries to the description of the tasks and allow comparisons of characteristics across tasks. Appendix D includes a detailed task characterization based on these four categories. Furthermore, the taxonomies that define each of these categories help identify constraints on task sequences and pertinent human limits associated with specific driving and ATIS tasks.

Characterizing the Purpose for the Function or Task

The reason for characterizing a task by its purpose is that by doing so the analyst will have an idea of the relationship between the task, the function that it supports, and the other tasks that are involved in the same function. To support such an understanding of task relationships, the taxonomy used to describe the purpose categories is described in table 9.

Characterizing the Initiating Conditions

The initiating conditions to start a task are essentially demands for task action. The description of the initiating condition, therefore, tells the analyst something about the sequence of events that precedes starting the task, the system demand characteristics associated with the task, and the urgency with which the task must be undertaken. A taxonomy was developed to describe the range of possible initiating conditions associated with the use of ATIS. Table 10 describes this taxonomy.

Characterizing Task Activities

One of the more important ways of characterizing a task is to identify the type of actions performed. Task C of the ATIS project reported the use of a taxonomy of decision elements that described the important actions necessary for each ATIS function. This same taxonomy works equally well in describing task activities and was adopted for use in this task as well. Table 11 provides a brief description of each of the decision elements (Lee et al., 1993).

When performing a characterization of the various tasks associated with ATIS/CVO systems, characterization of individual tasks was based on the most significant or highest level cognitive task performed by an operator. While it is recognized that complete decomposition of a task to the level that identifies individual decision elements might be desirable in identifying the relationship between human limitations and potential task requirements, such a detailed decomposition of tasks for conceptual systems would be overly ambitious and requires the analysts to make major assumptions about design configurations.

Characterizing Task Performance Considerations

One of the most important products of a task analysis is the identification of system design considerations that would affect the performance of human operators on a specific task. Task F of the ATIS project identified the physiological and cognitive characteristics of drivers that would influence the use of ATIS. Based on the physiological and cognitive characteristics of drivers developed in Task F and others who deal with human error, a listing was developed to indicate the significant system design considerations that would influence human performance on the task. Table 12 provides a brief description of the task performance considerations commonly associated with each decision element. The basis for each of these considerations is as follows:

- Audio signals must not be masked bv background noise (Detect). Human beings have both a limited range of normal hearing (approximately

Table 9. Purpose categories used to characterize functions and tasks.

PURPOSE	DEFINITION
Make a system ready to use	To provide the necessary actions to start a system and make it ready for use.
Provide system information	To provide a system with necessary information so that system functions can be executed.
Limit system considerations	To provide a system with parameters or information that limit system considerations and/or operation.
Narrow user considerations	To provide users with a subset of information to consider, usually based on parameters provided by the system.
Ensure input accuracy	To make sure that information provided by the system is accurate.
Obtain environment information	To gather information from the environment.
Obtain system information	To gather information from the system.
Understand system/ environmental information	To understand the information provided by the system or gathered from the environment.
Verify output meets expectations	To ensure that the output of the system meets the operator's expectations.
Approve system output and initiate next step	To approve a plan or proposed action by a system; approval usually enables the system to continue and to execute the first step of the plan.
Invoke system operation	To cause a system to begin an operation.
Evaluate system recommendation	To determine whether the system's advice should be adhered to.
Execute system recommendation	To conform to the guidance provided by the system by executing a maneuver with the vehicle.
Maintain safe distance from others	To keep a safe distance between a vehicle and obstructions or other vehicles.
Maintain safe speed	To maintain control of the speed of a vehicle.
Direct vehicle	To control the direction a vehicle will follow.

Table 10. Taxonomy of initiating conditions.

CONDITION	DEFINITION
Goal initiation	A condition that is necessary to begin the accomplishment of a separate goal of either a function or superior task.
System demand	Completion of an operation by the system requires the completion of this task.
Environmental change	A change in the environment has created a need for modification of the plans initiated by a system or individual.
Completion of previous step	Completion of a previous, sequential step has been made; continued operation of the function requires completion of this step.
Change in goals	A change in the purpose for executing tasks that leads to a change in tasks to be performed.

Table 11. Summary of decision-making elements that describes driver interaction with ATIS/CVO systems.

DECISION ELEMENT	SUMMARY DEFINITION
Detect	Determining if something has changed or exists.
Input Select	Selecting information to attend to next.
Filter	Eliminating irrelevant information.
Search	Looking for a specific item.
Identify	Associating a label with an event or item.
Interpret	Determining the meaning of a signal.
Code	Translating information from one form to another.
Plan	Matching resources to expectations.
Compute	Calculating the logical or mathematical answer to a problem.
Test	Comparing an event or item with expectations.
Decide/Select	Choosing a response to fit the situation.
Control	Selecting a control action or sending a message.
Monitor	Observing a process for deviations or events.

Table 12. Summary of decision-making elements and human task performance considerations.

DECISION ELEMENT	TASK PERFORMANCE CONSIDERATIONS
Detect	Audio signals must not be masked by background noise. Audio signals must be distinct enough in onset, frequency, amplitude, and duration to exceed a driver's threshold of noticeability. Visual signals must be sufficiently large to be seen by the driver. Visual signals must lie within the normal or peripheral scan of the driver. Visual signals should not be apportioned between different displays.
Input Select	Workload must be low enough to allow driver to make selection. Required input to be selected must not be masked by other tasks.
Filter	Relevant signals/information must be distinct from irrelevant information. Relevant signals/information that need to be considered must be similar to one another.
Search	Information presentations that require memorization must not exceed short-term memory capabilities.
Identify	Information presented must be consistent with user's knowledge base.
Interpret	Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals.
Code	Motor actions required must be within human capabilities. System input requirements must be compatible with user's knowledge base. System input requirements must not require user translation. System input actions must not exceed short-term memory limitations.
Plan	System requirements must allow adequate time for necessary execution. System must provide necessary information for user to make informed choices. System must allow sequential or organizational entry of planning information to avoid short-term memory limitations.
Compute	System requirements must limit user demands on short-term memory. System requirements must minimize user demands on long-term memory.
Test	System must provide output of recommendations in appropriate detail for user to identify compatibility with major constraints. System must provide output of recommendations without exceeding short-term memory limitations. System must avoid presenting recommendations in such a high level of detail as to significantly increase driver workload.
Decide/Select	System must provide adequate information for user to predict outcome of each option being considered. System recommendations must be consistent with driver's experience. System recommendations must not violate known conditions or limitations.
Control	System requirements must not exceed driver's response capabilities (i.e., reaction time, precision, and tracking). System must provide driver with indications of action completion. System must provide driver with indications that the system is responding to input.
Monitor	System must provide driver with indications of present state or condition. System must provide driver with indications of progress toward a planned goal.

20 to 22,000 Hz) and a limited ability to discriminate between competing tones. Both of these limitations are differentially affected by conditions such as age; prior exposure to damaging levels of noise, fatigue, and illness; and certain drugs. For an audio signal to be detected, it must be within the limits of perception (i.e., be loud enough and within the frequency band available to human hearing) and be separate from other noises that would hide or confuse the signal. For example, an audio signal lower in amplitude than the background noise created by the noise of the engine would not be detected easily by the operator. Likewise, an audio signal that was approximately the same frequency as that produced by a cooling fan in the cab of a truck would not be noticed by the driver unless it was of significantly higher amplitude than the noise produced by the fan.

- Audio signals must be distinct enough in onset, frequency, amplitude, and duration to exceed a driver's threshold of noticeability (Detect). The human auditory system is widely adaptable to accommodate normal changes in the environment. The rate of change, frequency, amplitude, and duration with which the change occurs must exceed this normal accommodation in order to be detected as a signal of interest. Signals that fall below this threshold are accommodated as normal conditions by the individual.

- Visual signals must be sufficiently large to be seen by the driver (Detect). Human beings have an ability to detect visual objects that represent approximately 0.05 degrees of the visual field. The specific size required for detection varies depending on the context of the signal (e.g., number, complexity, and proximity of other visual signals).

- Visual signals must lie within the normal or peripheral scan of the driver (Detect). To be detected, a visual signal must lie within the normal view of the driver or within the peripheral scan of the driver. The size of the signal, illumination requirements, color contrast, and movement effects of the signal will depend upon where within the visual scan the signal occurs.

- Visual signals should not be apportioned between different displays (Detect). Human beings rely on visual signals that are associated with one another in a single portion of the visual field. As a consequence, they are generally unable to readily detect signals that are presented on different displays. An example of such a signal in a car might be one where a head-up display would flash to indicate a warning, the color of the instrument panel would indicate the severity of the warning condition, and the text on a display beside the dash would indicate the specific condition.

- Workload must be low enough to allow driver to make selection (Input Select). When workload is high, the individual will focus on those signals interpreted to be relevant to specific tasks, usually selected on the basis of either order of presentation or for their obvious survival benefit. In periods of high workload, signals that are not perceived within as pertaining to one of these two conditions will be ignored. For example, a signal indicating that a left turn should be initiated is not likely to be noticed if, at the same time, a driver receives information on the name of the cross-street and the special sale going on at the nearby mall.

- Required input to be selected must not be masked by other tasks (Input Select). Human beings have a limited ability to attend to several different things at once. To be selected for attention, a signal must compete with other tasks that the operator is doing at the same time. When another task has similar characteristics to the signal task, there is a likelihood that the driver will ignore one or the other. For example, a synthesized voice signal notifying a driver of an engine overheating, followed by a flashing annunciator light notifying the driver of a transmission problem, might result in the driver dealing with the engine condition without noticing the transmission condition.

- Relevant signals/information must be distinct from irrelevant information Filter) Human Beings pay selective attention to signals and information based on a perception of the relevance of the information available to what is needed. If insufficient clues are available to determine which information is relevant, the driver will be unable to make a meaningful selection of the information. For example, if an IVSAWS provided warning of an emergency vehicle within a certain radius, but provided no indication of the direction or distance of the vehicle, the driver would not be able to use the information to determine what actions he or she should take, since the emergency vehicle could easily be on another street or moving away.

Relevant signals/information that need to be considered must be similar to one another (Filter). Human beings organize information elements based upon categorical relationships or learned associations among the information elements. For goal-relevant information to be filtered from non-relevant information, the relevant information should be presented within a structure that reflects meaningful distinctions between the information elements. In a practical way, this means that choices should be made between information elements that have already been organized into familiar groups or categories. For example, when presenting a list of possible restaurants on an IMSIS, the list normally would not consist of all restaurants within a 20-mile (32.2~km) radius. Rather, the various restaurants can be organized according to criteria that are likely to be of interest to the user when making a decision about a restaurant, such as cost, distance, or type of food.

- Information presentations that require memorization must not exceed short-term memory capabilities (Search). Human beings have a limited capacity to retain individual items in short-term memory from which the items can be transferred to long-term memory for comparison with expectations and decision making. The practical limit for human beings to search a list of items is approximately five to nine individual items. Beyond that number, individuals usually must go through multiple selection processes to reduce the items down to a reasonable number of choices.

- Information presented must be consistent with user's knowledge base (Identify/Interpret). Human beings identify and interpret signals based on their experience with similar signals in the past. To adequately interpret a signal, a driver must have encountered the signal or similar signals before. Signals for which the driver has no similar experience may cause alarm, but will not be labeled and processed as goal-oriented behavior. For example, the appearance of a new type of highway sign on the road with the word SLOW written in the center surrounded by a circle with a diagonal slash through it would very likely result in some portion of drivers going slower.

- Information presented must be consistent with user's understanding of system goals (Interpret). Human beings organize their interpretation of events based on mental models of the outcome (goals) and the way a system will operate. If the system provides information that is inconsistent with such a model, the driver will doubt the system or will be unable to properly interpret the signals presented. For example, an IMSIS might use the driver's date of birth to determine the appropriateness of a particular hospital within its data base. If, when seeking information about hospitals in the area, the system responded with a listing headed by the statement, "You are 57 years old today," the driver would likely be doubtful and, therefore, not be able to properly interpret the system output, particularly if he or she knew of a hospital nearby that was not listed.

- Motor actions required must be within human capabilities (Code). Human beings have limited capabilities for motor actions. These include limitations in the time necessary to respond to a signal (reaction time), to coordinate fine motor activities, and to maintain continuous controls within specified limits. These limitations vary from individual to individual depending on a wide variety of conditions, such as hand preference and genetic background. They also vary within individuals depending on conditions such as age, state of health, fatigue, and use of certain drugs. They are also affected by a variety of different environmental conditions, such as the presence of vibration, the need to perform controls while the arm is fully extended, the size of the control and its proximity to other controls, and the wearing of gloves.

- System input requirements must be compatible with user's knowledge base (Code). The information required of a system needs to be something that is known by the driver. The greater the capabilities of the system, the more knowledge the driver needs to effectively employ it. For example, a data base that holds only the location of restaurants in a local area might not require a driver to know the city in which the desired restaurant lies; however, to effectively use a nationwide data base, the driver would generally need to know that information. Similarly, a system that required a driver to enter the present latitude and longitude to update an IRANS would be dependent on the ability of the driver to obtain this information.

- System input requirements must not require user translation (Code). Human beings are limited in their ability to convert information from one unit of measure to another. For example, location information should not require that the driver enter offsets from map reference points (e.g., two blocks north and one block west of the junction of highways 305 and 27).

- System input actions must not exceed short-term memory limitations (Code). Human beings have a limited capacity to remember long lists of numbers and items. In coding information into a system, an operator is often required to observe one number or item, such as an address in a list, and to retain it in memory long enough to enter the information into the system. A good example of this problem is when someone uses a long distance calling card to make an unassisted international telephone call. The likelihood of successfully entering the appropriate company access code, telephone number, and charge card number on the first try is less than certain.

- System requirements must allow adequate time for necessary execution (Plan). Human beings require finite amounts of time to consider alternatives and to formulate decisions. The amount of time required depends on other tasks that need to be done, the amount of information that must be considered, and the willingness of the individual to act on incomplete information regarding likely outcomes. To successfully formulate plans, drivers must have sufficient notification of the need to plan so that they can consider the situation and its likely outcome.

- System must provide necessary information for user to make informed choices (Plan). Human beings involved in planning require information upon which to make judgments about the likely effect of their plans. For example, a driver planning a cross-country trip might need to know the distance and estimated travel times for alternative route segments before deciding where to spend the night.

- System must allow sequential or organizational entry of planning information to avoid short-term memory limitations (Plan). Human beings organize information according to several different possible structures. These include temporal or sequential association and similarity of the type of information. To effectively overcome short-term memory limitations, such organized information allows a driver to enter information in "chunks."

- System requirements must limit user demands on short-term memory (Compute). Human beings have a limited ability to retain multiple items in short-term memory. When computations are required of the driver, the number of items that the driver needs to use in the computation are limited. For example, a CVO system might require that the system know the total weight of the vehicle. If the vehicle has been weighed, this would require that the driver compute the total weight by adding the weight on each axle. If the axle weights were not known, the driver would need to compute the weight of the tractor empty, plus fuel capacity, minus fuel used, plus trailer weight empty, plus cargo. A system that would allow each of these weights separately would reduce the possibility of computation error.

- System requirements must minimize user demands on long-term memory (Compute). In computation, long-term memory (i.e., knowledge) provides a driver with the rules that are applied to information in short-term memory in order to arrive at a solution. Computational performance by human beings is at least partially dependent on how complex these rules are. Simple rules (i.e., limited demands on long-term memory) generally result in better performance than do more complicated rules. The difference can be illustrated by the difference in accuracy for a driver computing following distance based on a mnemonic, "One car length for every 10 miles per hour of speed," as opposed to one that says, "The following distance should be 17.5 feet times the speed, rounded to the nearest 10 miles per hour."

- System must provide output of recommendations in appropriate detail for user to identify compatibility with major constraints (Test). When testing possible alternatives, human beings make comparisons between the alternative and a series of expected features. If the system does not express the alternative in a way that allows such a comparison, a test cannot be made. For example, one of the criteria that a driver might have for selecting a proposed route through a city might be that it avoids certain areas of the city. If the output of the system was presented as street names and turn points, a driver would probably be unable to determine if this criteria had been met. If the route was shown as a map overview with major sections labeled, the driver would be better able to test the route to see if it was compatible with his or her requirements.

- System must provide output of recommendations without exceeding short-term memory limitations (Test). Human beings have a limited capacity to retain items in short-term memory for comparison with criteria held in long-term memory. The exact limits of such memory will depend on a number of individual and situational variables, such as age, workload, recall delay, the driver's familiarity with the information items, and the meaningfulness of the information items. If the system presentation of a recommendation involves the need to make more comparisons of information with criteria than can be held in short-term memory at that particular time, the driver will be unable to effectively test the recommendation.

- System must avoid presenting recommendations in such a high level of detail as to significantly increase driver workload (Test). Human beings make tests of possible alternatives based on a limited number of comparisons with criteria selection or rejection of the alternative. If a system provides too much information at too rapid a rate, the individual will not be able to effectively select the salient information from that which is unimportant. An example of such a possibility would be a system that presented a turn-by-turn recommendation for a dynamic route change while a driver was approaching an accident scene.

- System must provide adequate information for user to predict outcome of each option being considered (Decide/Select). Although human decision making involves many different possible approaches, it can be thought of as a weighing of costs and benefits to determine which of several alternatives will result in the greatest benefit at the least cost. To effectively decide on a course of action, a driver must have information concerning these costs and benefits. Without this information, the driver is only involved in guessing or risk taking.

- System recommendations must be consistent with driver's experience (Decide/Select). Drivers make decisions on recommendations based on their assessment of the likelihood that a given recommendation will have the desired outcome. Since decision making is a human process and not a machine process, drivers select or approve a particular recommendation based partly on the information associated with the recommendations (e.g., estimated travel time, predicted road conditions) and partly on their prior experiences with similar decisions (e.g., the last trip over a similar route took 3 h longer than expected, it feels like it's going to rain today).

- System recommendations must not violate known conditions or limitations (Decide/Select). The driver's confidence in a system recommendation depends in part on the perceived plausibility that the recommendation is an appropriate one. If a recommendation includes items that the driver knows are not possible (e.g., travel over a bridge that is under construction, travel the wrong way down a one-way street), he or she is likely to reject the recommendation altogether.

- System requirements must not exceed driver's response capabilities (i.e., reaction time, precision, and tracking) (Control). Drivers have limited ability to respond to system-required control actions. These include limitations in the time necessary to respond to a signal (reaction time), to coordinate fine motor activities, and to maintain continuous control within specified limits. These limitations vary from individual to individual depending on a wide variety of conditions, such as hand preference and genetic background. In addition, they vary within individuals depending on conditions such as age, state of health, fatigue, and use of certain drugs. They are also affected by different environmental conditions, such as the presence of vibration, the need to perform controls while the arm is fully extended, the size of 'the control and its proximity to other controls, and the wearing of gloves,

- System must provide driver with indications of action completion (Control). Human beings require indications that necessary control inputs have been accepted by the system in order to know when to stop making the input.

- System must provide driver with indications that the system is responding to input (Control). Human beings require periodic information on system functioning to know that a control action has not only been accepted by the system, but that the system is appropriately using the input.

- System must provide driver with indications of present state or condition (Monitor). Human beings need periodic information that a system performing properly and doing what it is intended to do. For example, when using a passive warning system such as IVSAWS, a driver will not have confidence in the system unless he or she has some indication that the system is on and that it is capable of receiving the necessary trigger conditions to issue a warning.

- Svstem must provide driver with indications of progress toward a planned goal (Monitor). Human beings involved in the use of automated systems such as IRANS may substitute instructions provided by the system for monitoring normal position and navigation tasks. Since they become dependent on the system to guide them, they need to have indications from the system that tell them how the planned route is progressing.

DRIVING FUNCTIONS

Identifying driving functions is a critical step in performing a task analysis of ATIS, whose primary purpose is to provide a broad perspective to guide the selection of which driving tasks to include in the task analysis. The driving functions aggregate many individual tasks to show how the individual tasks interact at a more global level. This more global perspective helps to focus the analysis on important issues and to define the scope of analysis.

In a hierarchical task description, the highest level of description defines driving in terms of general functions. Subfunctions and tasks associated with a common goal make up these general functions. For example, the tasks of steering wheel manipulation, accelerator control, and brake application support the subfunctions of maintaining speed, changing speed, and adjusting vehicle position relative to the roadway and other vehicles. These subfunctions all serve the general function of speed and position control. In many instances, subfunctions consist of sets of tasks associated with components of the ATIS. Task C described components of ATIS, and the task analysis identified tasks associated with those components. These ATIS-specific tasks form the basis of many subfunctions that support various driving functions. Thus, driving functions include subfunctions and tasks related specifically to driving and to the various components of ATIS. Appendix C provides a comprehensive listing of driving/ATIS/CVO tasks and begins with a listing of these driving functions. These functions can be used as an index to the listing of individual tasks, because appendix C contains a list of tasks associated with each function or system functional characteristic. In this way, appendix C provides a convenient catalog of tasks accessible through the index of driving functions.

Selection of Driving Functions

Table 13 shows the ATIS components associated with each driving function for private drivers, and table 14 shows this information for commercial drivers. Since these functions represent the highest level of a hierarchical description of driving tasks, a complex set of tasks is associated with each driving function in these tables. In addition, each function consists of driving-specific tasks and may also include tasks specific to interaction with ATIS. The selection of driving functions depended on two criteria. First, the scope of the task description must include tasks associated with all the ATIS functional characteristics identified in Task C. This ensures that the task description represented by the functions in tables 13 and 14 completely describe how drivers will interact with a potential ATIS and show all the ATIS elements described in Task C. Second, the driving functions must go beyond describing only the tasks associated with ATIS; they should also describe crucial driving tasks that may interact with ATIS-specific tasks. Driving functions that include all potential ATIS elements and a representative set of important driving-specific tasks help to ensure that the task analysis will address issues important to the design and implementation of ATIS.

Table 13. Driving functions and the associated ATIS functional characteristics for private drivers.

DRIVING FUNCTIONS	ATIS FUNCTIONAL CHARACTERISTICS (FROM TASK C)
1. PRE-DRIVE	
1.1 Inspection	
1.2 startup	
1.3 Auxiliary System	
1.4 Planning	5.1 Trip planning 5.2 Multi-mode travel coordination 5.3 Pre-drive route and destination selection 6.2 Services/attractions directory 6.3 Destination coordination
2. DRIVE	
2.1 Nayigation and Routing	
2.1.1 Wayfinding	5.5 Route guidance 5.6 Route navigation 7.1 Roadway guidance sign information
2.1.2 Route Modification	5.4 Dynamic route selection 6.1 Broadcast services/attractions
2.2 Guidance and Maneuvers	
2.2.1 Traffic Coordination	
2.2.2 Rule Compliance	5.7 Automated toll collection 7.3 Roadway regulatory sign information
2.2.3 Maneuvering	7.2 Roadway notification sign information
2.2.4 Hazard Observation	8.1 Immediate hazard warning 8.2 Road condition information
2.3 Control	
2.3.1 Speed Control	
2.3.2 Position Control	
2.4 Vehicle System Operations and Monitoring	6.4 Message transfer 8.5 Vehicle condition monitoring
2.5 Emergency Response	8.3 Automatic aid request 8.4 Manual aid request

Table 14. Driving functions and the associated ATIS functional characteristics for commercial drivers.

DRIVING FUNCTIONS	ATIS FUNCTIONAL CHARACTERISTICS (FROM TASK C)
1. PRE-DRIVE	
1.1 Inspection	
1.2 CVO-Administration	9.1 Fleet resource management 9.2 Dispatch 9.3 Regulatory administration 9.4 Regulatory enforcement
1.3 startup	
1.4 Auxiliary System	
1.5 Planning	5.1 Trip planning 5.2 Multi-mode travel coordination 5.3 Pre-drive route and destination selection 5.8 Route scheduling 6.2 Services/attractions directory 6.3 Destination coordination
2. DRIVE	
2.1 Navigation and Routing	
2.1 .1 Wayfinding	5.5 Route guidance 5.6 Route navigation 7.1 Roadway guidance sign information
2.1.2 Route Modification	5.4 Dynamic route selection 6.1 Broadcast services/attractions 7.4 Road restriction information
2.2 Guidance and Maneuvers	
2.2.1 Traffic Coordination	
2.2.2 Rule Compliance	5.7 Automated toll collection 7.3 Roadway regulatory sign information
2.2.3 Maneuvering	7.2 Roadway notification sign information
2.2.4 Hazard Observation	8.1 Immediate hazard warning 8.2 Road condition information
2.3 Control	
2.3.1 Speed Control	
2.3.2 Position Control	
2.4 Vehicle System Operations and Monitoring	6.4 Message transfer 8.5 Vehicle condition monitoring 8.6 Commercial vehicle and cargo monitoring
2.5 Emergency Response	8.3 Automatic aid request 8.4 Manual aid request

Identifying the driving functions of interest both limits the scope of the task analysis and indicates important interactions and issues. For this analysis, the driving functions included in the analysis were selected to address critical issues associated with ATIS-specific tasks and the interaction of information provided by ATIS and driving tasks. Specifically, the driving functions can be grouped into pre-drive and drive activities to highlight critical differences between tasks performed while the vehicle is motionless and those performed while it is moving. This distinction illustrates which ATIS-specific tasks compete with the drivers' attention to the dynamic control of a vehicle. Another critical issue that the selection of driving functions emphasizes is the interaction between driving functions associated with primary driving functions and functions associated with ancillary tasks. The ancillary functions include critical tasks (such as responding to emergencies) and interacting with other in-vehicle systems (such as adjusting climate controls, the radio, or scanning the ATIS listing of upcoming restaurants). Thus, the driving functions focus on the task analysis so that it is not a broad description of driving, but a description of driving and ATIS-specific tasks relevant to the design of ATIS.

Drive and Pre-Drive Driving Functions

The detailed description of the tasks associated with particular scenarios (appendix D) will reveal how ATIS may augment current driving tasks. In this comparison, the distinction between pre-drive tasks and driving tasks is particularly important. Pre-drive functions refer to sets of tasks completed while the vehicle is motionless. In this situation, the driver is primarily concerned with system configuration, inspection of the vehicle, and planning. As such, the driver has a single focus with minimal distractions. For example, the driver can focus attention on trip planning (e.g., finding information using the telephone directory, a map, or an ATIS) without the need to attend to other tasks concurrently. This contrasts with the tasks associated with the drive functions. In this instance, drivers must spread their attention across multiple tasks simultaneously. For example, drivers may need to assimilate information simultaneously from road signs while maneuvering through traffic and monitoring the ATIS for route guidance information. Additional tasks associated with pre-drive ATIS interactions are less likely to overwhelm the driver, compared to additional tasks ATIS may impose when the driver is also concerned with controlling the vehicle. Describing the driving-specific tasks will help to reveal important design differences between components of ATIS used before driving and those used while the vehicle is moving.

Primary and Ancillary Driving Functions

The distinction between primary driving and ancillary driving tasks may help show how an ATIS must integrate with drivers' tasks. Primary driving functions are those that are central to driving and without which moving a vehicle to a destination safely would not be possible. More specifically, the primary driving functions fall into three broad categories: navigation and routing, guidance and maneuvers, and control. Each of these groups of functions identifies tasks that a driver must perform. For instance, a driver must identify and follow a route, maneuver to change lanes and to turn from one street to another, and maintain control of the speed and position of the car relative to the roadway and other vehicles.

Ancillary driving tasks differ from primary tasks in that they are not a required aspect of routine driving. Ancillary driving functions include emergency response and monitoring and operating vehicle systems. In contrast with primary driving functions, the tasks associated with ancillary functions are of secondary importance to driving; however, they may go concurrently with driving. For example, a driver may adjust the radio (a task associated with the function of vehicle system operation and monitoring) while maneuvering the vehicle onto an entrance ramp. ATIS has the potential to increase the number of ancillary tasks and augment the driver's capability to cope with the primary driving tasks. In addition, an ATIS may automate many of the primary and ancillary tasks; thus, it is unclear whether ATIS will increase or decrease the driver's workload and efficiency. By identifying primary and ancillary driving functions and their associated tasks, a task analysis can determine how the tasks that are automated, added, or augmented by ATIS will interact with a driver's ability to attend to the primary task of driving. If many primary tasks are unchanged by ATIS, but more ancillary tasks are added, driver overload may become a serious threat.

In general, identifying driving functions was used to define the breadth of the analysis and to indicate which driving-specific tasks should be described in greater detail. In this way, the driving functions helped to guide the task analysis.

FUNCTION SELECTION

Task C identified a set of 19 functional characteristics for the private vehicle operations and as many as 26 for the CVOs. Creating a detailed task analysis for each functional characteristic and all its potential interrelationships with other functional characteristics would have generated an enormous amount of data that might obscure important relationships between ATIS/CVO functional characteristics and their associated tasks. As a consequence, an analysis examined interrelationships between functional characteristics to identify those that are most central to ATIS/CVO usage and those that form closely linked groups. This analysis identified interrelationships between functions by examining the information flows that link ATIS/CVO functional characteristics. For example, the functional characteristic pre-drive route and destination selection provides destination and route information to route guidance. Functions central to the operation of ATIS/CVO provide or require information from several other functional characteristics. The potential importance of these functions highlights the need to include them in any analysis. Identifying groups of functions, linked by information flows, reveals sets of functions that should be examined together. Detecting functional characteristics that appear central to ATIS/CVO systems and identifying those that form highly coupled groups provide a strong basis for validating and revising the scenarios created in Task B. These revised scenarios focus the task analysis on important ATIS/CVO functional characteristics and on important groupings of these functional characteristics.

The initial step for this function selection was to identify information flows that link each functional characteristic with other functional characteristics, either within one particular system (e.g., IRANS) or with the components of the other systems. Task C became the principal source of reference to accomplish this identification. By reviewing the description of each functional characteristic and the tables showing the interaction of a particular function with other functional characteristics, as well as the tables labeled “information flow and current sources supporting subsystem functional characteristics” (Lee et al., 1993), it was possible to generate a set of interrelationships between the various functions. For each functional characteristic, a chart was drawn depicting the various links between a particular function and other functions. Figure 3 shows one example of these charts. Upon completion of all the charts, each one was reviewed systematically to identify inconsistencies in the interaction patterns across the various functional characteristics. The information in these charts was then combined into a large matrix that shows the information flows among all the ATIS/CVO functional characteristics. Appendix B shows a matrix for both private and commercial ATIS/CVO systems.

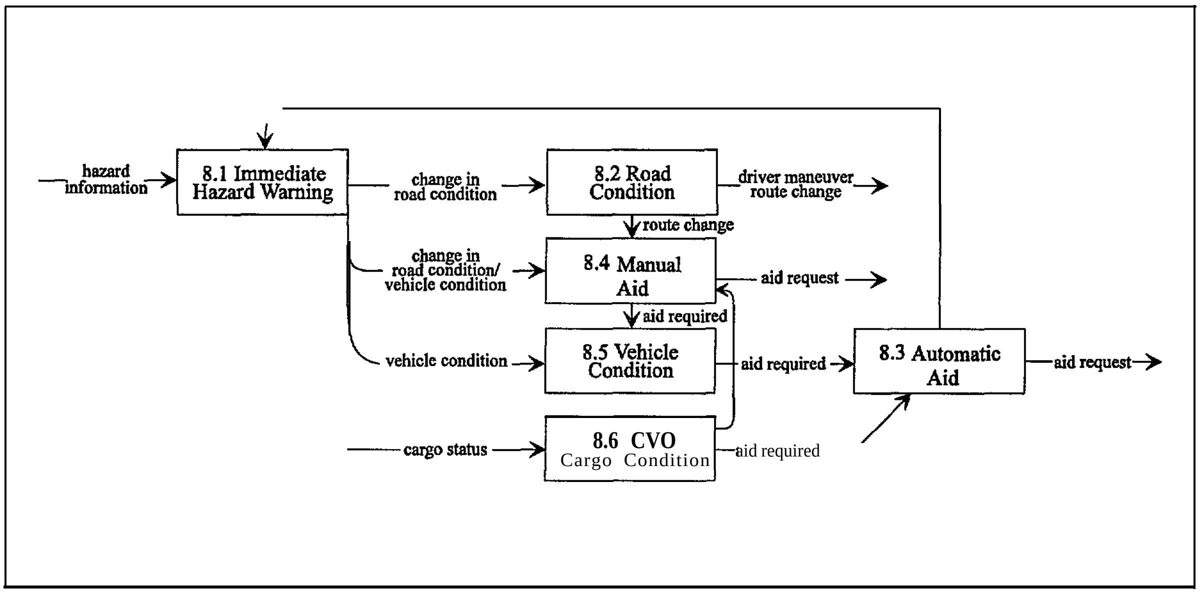


Figure 3. Interactions between the functional characteristic “immediate hazard warning” and other IVSAWS components.

These charts and the accompanying matrices served as the basis for several analyses. These analyses, reported in detail in appendix B, served two purposes: (1) to identify functional characteristics that are central to ATIS/CVO operation, and (2) to identify clusters of functional characteristics that form meaningful groupings based on the information that links them. To analyze the relationships among functional characteristics, a number of techniques traditionally used to examine social networks were adopted (Borgatti, Everett, & Freeman, 1992). These analyses include a frequency count that tabulates the number of times each function requires or provides information to other functions, a network analysis measure of centrality, and a cluster analysis that identifies groups of functional characteristics linked by information flows. Appendix B includes a summary of the frequency counts, estimates of centrality for each functional characteristic, and matrices showing groups of highly coupled functional characteristics. The results of these analyses form a strong basis for identifying which functional characteristics or groups of functional characteristics the scenarios need to include. The next section, Scenario Selection, shows how these functional characteristics and combinations of functional characteristics guide the selection of scenarios for the detailed task analysis.

SCENARIO SELECTION

The analysis of the information flows between functional characteristics helped to focus the task analysis by generating a subset of functional characteristics that, based on the information flow analysis, represented the most important aspects of ATIS/CVO systems. Tasks B and C provided a set of private and commercial scenarios that could form the basis for placing the tasks associated with ATIS/CVO use in the actual driving context. The previously generated scenarios and the analysis of information flow made it possible to select and, in some cases, modify scenarios that were representative of the combinations of functions that hold the greatest potential interest (see appendix B for a detailed discussion of the selection process). Generally, scenarios were selected to include functional characteristics that were determined to be central to ATIS/CVO, and to include combinations of functional characteristics that corresponded to highly coupled groups of functional characteristics. In addition, scenarios were selected to examine interactions between diverse functional characteristics and to investigate instances in which the driver may experience high workload.

Appendix B describes in detail the rationale used to choose each scenario. This description accounts for how the results of the information flow analysis guided the selection of particular scenarios. In addition, appendix B identifies each functional characteristic that occurs in each scenario and explains its importance given the context of each particular scenario. Appendix B summarizes each scenario in a table (see appendix B, tables 32 to 44) that includes the following information: (1) purpose, (2) summary, (3) systems involved (IRANS, IMSIS, ISIS, IVSAWS, and CVO-specific), and (4) functional characteristics that occur. The following scenarios are the output of the selection process described in appendix B, and they provide the basis for the detailed task analysis.

- Private Driving Scenario Pl

  A driver vacationing with his family in an urban setting arrives at the airport in mid-afternoon and rents a car with an IRANS device installed. The family's plan is to go directly to their hotel located in the city 10 miles (16.1 km) from the airport. The weather is good, but there is a substantial level of congestion on the major highways between the airport and the hotel due to normal commuting traffic. After receiving a brief orientation on using IRANS at the rental office, the driver identifies his destination on the IRANS and requests the fastest route. The IRANS recommends a route that the driver accepts and he begins his trip to the hotel.

- Private Driving Scenario P2

A real estate salesperson is meeting a couple at their residence. She plans on showing them several houses in a suburban area of a major city. She has selected houses in several different neighborhoods spaced around one side of the city. The neighborhoods can be reached by either highways or arterials. It is evening, there is a heavy rain, and there is an accident on one of the highways that could be taken. Two neighborhoods that would be reasonable starting points for the evening's viewing are approximately equidistant from the clients' current residence. The salesperson would like to go to the neighborhood that can be most easily reached first. Prior to picking up her clients, she enters the addresses of all of the houses in the IRANS. During the drive to her clients' house, she monitors the traffic congestion in the planned area of travel. When she arrives at the clients' residence, she requests a comparison of travel times and selects the route that is predicted to take the least time. She then reviews current traffic congestion. Finally, she picks up her clients and drives them to the first house.

- Private Driving Scenario P6

A driver is on an extended driving vacation. He has stopped approximately 50 miles (80.5 km) from his destination to review motel options for the evening at his destination point. He accesses the IMSIS directory for the town he will be staying in, reviews several alternative motels, and selects three that are located in one specific area and that look interesting. Before proceeding toward his destination, he makes a reservation using ATIS.

- Private Driving Scenario P8

A business traveler is driving in the suburbs of a major city he is not familiar with during a heavy snowstorm at dinner time. He has selected a 20-mile (32.2-km) drive, recommended by ATIS, from his hotel to his first destination, which is predominantly on arterial roads. In fact, the drive is not a straight line, but rather a series of turns to various arterial roads (no highways). The heavy snow is making visibility poor and the roads icy. He requests that the ATIS provide him with street signs and interchange graphics as well as stop signs and lane-use control information. Halfway to his destination, he is informed of an accident and of his need to select an alternate route. As he is examining two alternatives, the ATIS warns him of an approaching emergency vehicle. He slows down, pulls over, and enters his route choice. After the emergency vehicle passes, he continues traveling to his destination.

- Private Driving Scenario P14

A driver commutes between her home and the office. The commute requires coordination between three different modes of transportation. She drives the first 10 miles (16.1 km) and then has to decide between taking the ferry across the Bay or driving around the Bay Area. Once she is on the other side of the Bay, she has to drive for another 5 miles (8.0 km) to a park-and-ride lot where she takes a bus to the office. However, she can choose to reject the bus option and drive an additional 10 miles (16.1 km) if the traffic is light, It is a cold winter day and the roads are icy. She needs to get to work in the shortest amount of time possible. She uses the ATIS to plan her trip to the office and to coordinate the travel between the different modes of transportation. After taking the ferry and paying the toll, and while traveling to the bus stop, her ATIS informs her of icy conditions on the road and of bus delays. She selects an alternate route and continues her drive to work.

- Private Driving Scenario P16

A driver uses the ATIS to travel from her hotel to a restaurant on the outskirts of town. While traveling, she receives notification that the engine's temperature is increasing. Fearing engine damage, she pulls off the road. The driver then identifies a service station close by. She requests the assistance of a tow truck and cancels her dinner reservation. She also communicates with her friend to inform her of the misadventure with the vehicle and to ask to be picked up at the service station.

- Private Driving Scenario P20

It is Friday afternoon and a driver is following the IRANS guidance in traveling back to her hotel from an appointment with a client. As she drives, she receives the broadcast signal of a nearby winery. She debates between continuing to her hotel or visiting the winery. She uses the ATIS to verify if the winery is open and makes a reservation for the next guided tour. Moments later, she requests a dynamic route change to proceed toward the winery.

- Private Driving Scenario P22

A driver travels on a secondary road where there are numerous speed changes due to the presence of several small towns. As he is driving, the IVSAWS detects a malfunction of the car's brakes. The driver takes notice of the message and continues to his destination. Later on, he receives another message of road construction ahead. The driver applies the brakes, but it is too late; the car collides with a construction vehicle merging from the side of the road. The ATIS activates the aid request to provide assistance to the driver, who is unconscious.

- Commercial Driving Scenario C4

  A young interstate truck operator is traveling at night on a narrow, two-lane road. As he is traveling, his IVSAWS provides advance warning of the road closure due to a new construction zone ahead. Because the road closure occurs just prior to a planned refueling stop, the driver uses his ATIS to determine the nearest service station. Having selected one, he requests a dynamic route change to proceed to the station and the help of the ISIS to provide speed limit transitions, street signs, and merge signs.

- Commercial Driving Scenario C 11

  An experienced interstate truck operator is passing between two States at nighttime. Prior to reaching the inspection point, her weigh-in-motion (WIM) system advises her to move to the right-hand lane, where her vehicle is weighed while traveling at normal speeds. Simultaneously, a sensor reads the truck's electronic credentials to validate safety records and debit the trucking company's account for road taxes. Finally, the driver's electronic credentials are verified to ensure that her driver's license and permits are up to date and that her operating hours have been within the legal limits. The driver receives notification that all transactions have been performed successfully, and she proceeds at normal speed past the inspection point.

- Commercial Driving Scenario C 12

  It is Friday evening, during rush hour traffic, just before a holiday. The commute is slow because it is snowing and several accidents obstruct the traffic circulation. A central dispatcher for medical aid vehicles in a large metropolitan area is working her normal evening shift. She receives two concurrent emergency calls for aid required at a freeway accident and at a private residence. The dispatcher enters the locations of the emergencies into her routing system and the system determines the appropriate medical aid vehicle stations to call and the appropriate routes to take, based on the fastest predicted travel time under current traffic and road conditions. Upon receipt of that information, she informs the appropriate drivers of the new destination and route to take. The drivers enter the routing into their ATIS and activate IVSAWS to provide them with updated road condition information. As one of the drivers is driving to the residential call, he is informed of severe icing along the route. He requests a route change from his ATIS and continues to the residence.

- Commercial Driving Scenario C 13

  A central dispatcher coordinates the progress of 20 separate vans that provide door-to-door airport transportation in one suburban section of a major metropolitan area. Service is provided on demand so that calls are responded to within a specified period of time. If the caller is not picked up within the specified time, the cost of the ride is reduced by 50 percent and a report must be filed by the driver and dispatcher. A dispatcher is also rewarded for making the maximum use of available vans, as determined by the fleet routing system. The dispatcher prepares the first pickup schedule of the day and transmits this information to the drivers.

Commercial Driving Scenario C 15

An interstate truck operator is traveling on the interstate early Sunday morning. As he is driving, his "cargo/vehicle condition monitoring" informs him of a malfunction with one of the trailer's axles. The driver pulls over, checks it, and determines that help is needed. Using the ATIS, he selects a service station that is open at that time and requests their assistance.

CHAPTER 3. AN OVERVIEW OF DRIVING AND ATIS TASKS

AN INTEGRATED DESCRIPTION OF DRIVING AND ATIS TASKS

The task analysis presented in this report consists of a hierarchical description of operational sequence diagrams and task characterization tables associated with using an ATIS and with driving. As such, tasks are described in substantial detail. Appendix D consists solely of this description and includes many tables describing individual tasks. While this detailed description of individual driving tasks provides insight into specific ATIS tasks, this representation may not convey how specific tasks or a series of tasks combine with others in a more general description of driving with an ATIS. Therefore, a more simplified description of the driving tasks is needed to summarize the complex and detailed task listing, making the more detailed description understandable. Specifically, a summary of driving and ATIS functions will help to place the detailed description of individual tasks in a meaningful context. Figure 4 summarizes individual tasks as driving functions and provides an index to the task description in appendix D. Each analysis in appendix D is preceded by a similar figure to help identify general sequences of driving functions that might occur in driving scenarios. Since the names of the nodes correspond to functions in the analysis, a sequence of driving functions in figure 4 can quickly be traced to specific tasks.

Figure 4 provides a summary of driving tasks by showing the driving functions that make up the top levels of the hierarchical task description. Each function is composed of subfunctions and tasks that have a common goal embodied by the function. Thus, the network of functions shown in this figure summarize driver activities. The tasks associated with each driving function include tasks specific to driving, such as manipulating the steering wheel. In addition, the driving functions include tasks specific to ATIS, such as entering the desired destination into the route guidance system. Thus, the functions shown in figure 4 summarize and integrate ATIS-specific and driving-specific tasks.

Linking Groups of Tasks

In summarizing the detailed task descriptions with driving functions, figure 5 shows the links between driving functions. These links, drawn as arcs on the figure, reveal sequential dependencies and interactions between functions. Similarly, the arcs connecting driving functions represent triggering conditions that initiate functions and their respective tasks. For example, “vehicle safety verified” designates the arc labeled “A,” which connects Inspection with Startup, and shows that Startup occurs only after the vehicle has been inspected and its condition verified. Other functions may require several triggering events to initiate the underlying tasks. For example, Maneuvering depends on Traffic Coordination and Wayfinding. Thus, the arcs serve two purposes. First, they show the sequential dependencies between tasks and functions. Second, the arcs show how changes in system state and information flow link driving functions. These links become particularly useful when

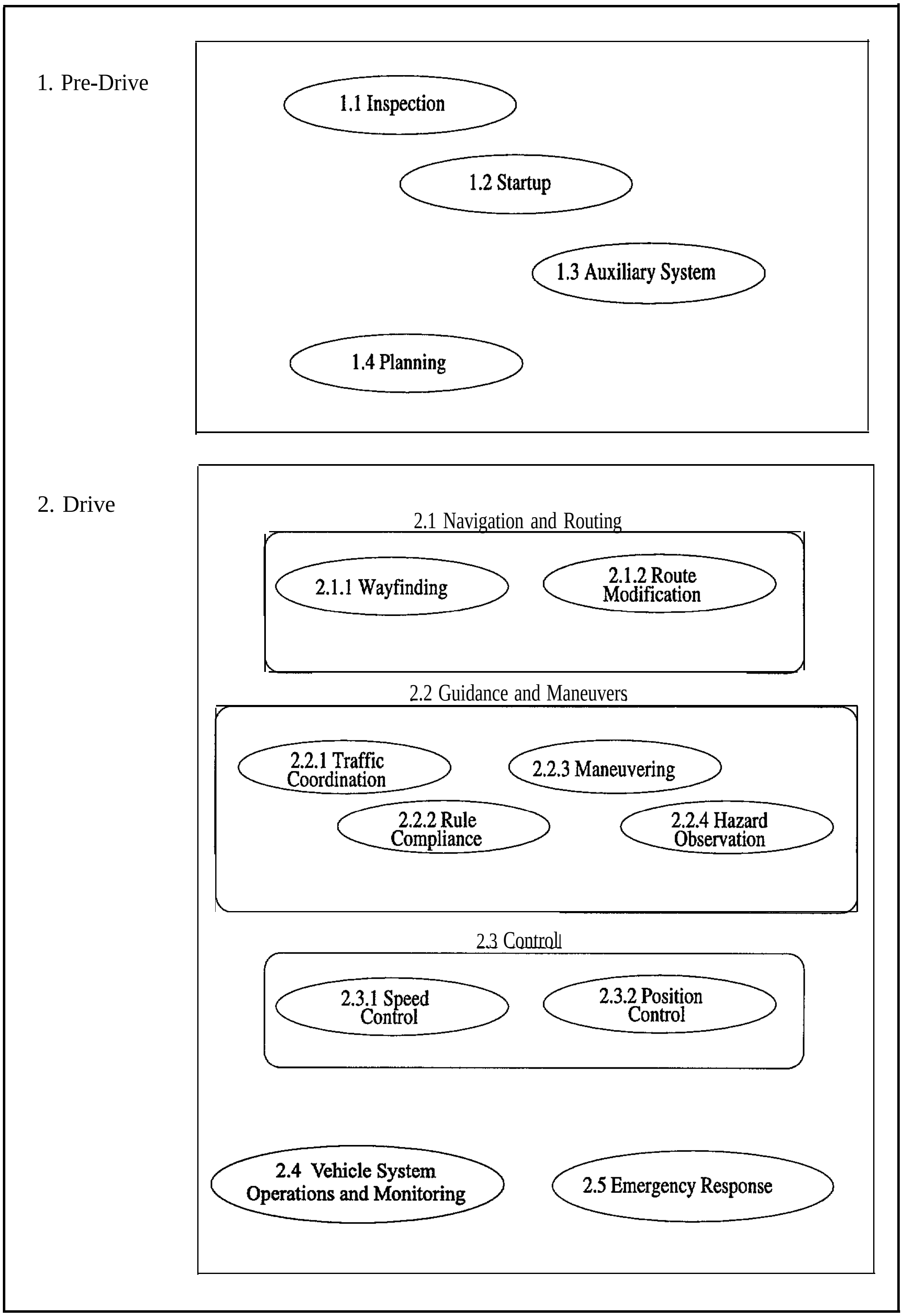
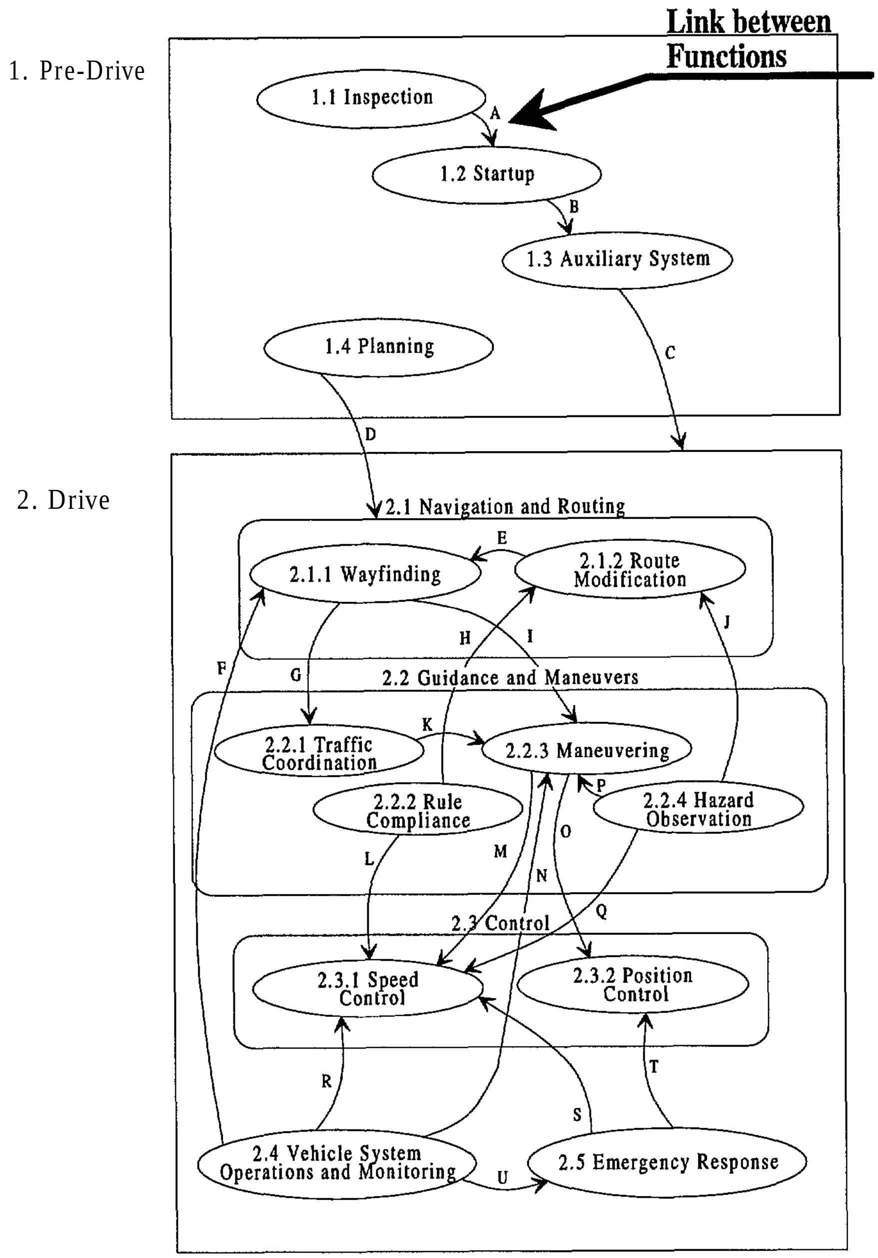


Figure 4. Example of nested driving functions.



A Vehicle safety verified
B Vehicle initiated
C Auxiliary systems initiated
D Destination and route selected
E Route change identified
F Vehicle service required
G Maneuver required
H Regulatory limits on roadway
I Maneuver required
J Potential hazards identified in upcoming roadway
K Identification of safe path through trafic
L Deviation from regulations
M Requires speed increase/decrease
N Failure requires change in speed/ position
O Requires change in lane position
P Hazard identified
Q immediate hazard identified
R Vehicle failure
S Conditions requiring immediate response
T Conditions requiring immediate response
U Minimize injury/damage

Figure 5. Example of functional links.

examining how drivers act on ATIS information in the context of the other driving tasks because they show how information from an ATIS initiates and changes driver behavior. This becomes particularly important when drivers must coordinate ATIS-recommended actions with environmental constraints, such as traffic conditions and roadway configurations. In general, the driving functions and the arcs that link them provide a summary of the information flows and initiating events that link general driving functions that might be lost in a more detailed view of individual driving tasks.

Integrating ATIS-Specific and Driving-Specific Tasks

The focus of this project is a task analysis of ATIS; however, a meaningful analysis of ATIS must also examine ATIS in the more general context of driving. In particular, an analysis that examines only ATIS-specific tasks would fail to address the critical issue concerning which ATIS functions can be used while driving. Ignoring driving tasks would also fail to address the question of how drivers might assimilate ATIS advice that may help guide their driving maneuvers. The task description, summarized in figure 6, achieves this objective by placing ATIS-specific tasks in the driving context. This is possible because the driving functions shown in this network include both driving-specific and ATIS-specific tasks.

The ATIS-specific tasks were identified by analyzing the potential elements of ATIS. More specifically, a hierarchical task description enumerated tasks associated with each of the functional characteristics identified in Task C. Figure 6 illustrates how ATIS-specific tasks integrate with the driving tasks by annotating the network of driving functions with labels for ATIS functional characteristics. Positioned below each driving function are labels that show which functional characteristics and their associated tasks support each of the driving functions. This places the description of ATIS, developed in Task C, in the context of the more general driving tasks. For example, figure 6 shows that the tasks associated with pre-drive route and destination selection and destination coordination would be associated with the trip planning function. Thus, the labels show how ATIS-specific tasks integrate with the driving functions and the driving-specific tasks. Combining the ATIS-specific tasks associated with the functional characteristics of Task C with the driving-specific tasks provides an integrated description of driving with ATIS.

INTERACTIONS BETWEEN TASKS

The integrated description of driving and ATIS tasks, summarized in the figure preceding each scenario-based task analysis (appendix D), highlights several important interactions that might be ignored by an analysis that focuses solely on individual tasks. These interactions fall into three categories. One category describes how ATIS-specific tasks interact with each other. Another category describes how drivers incorporate information from the ATIS to modify their driving behavior. The third category of interaction addresses how drivers must share their attention with both ATIS-specific and driving-specific tasks.

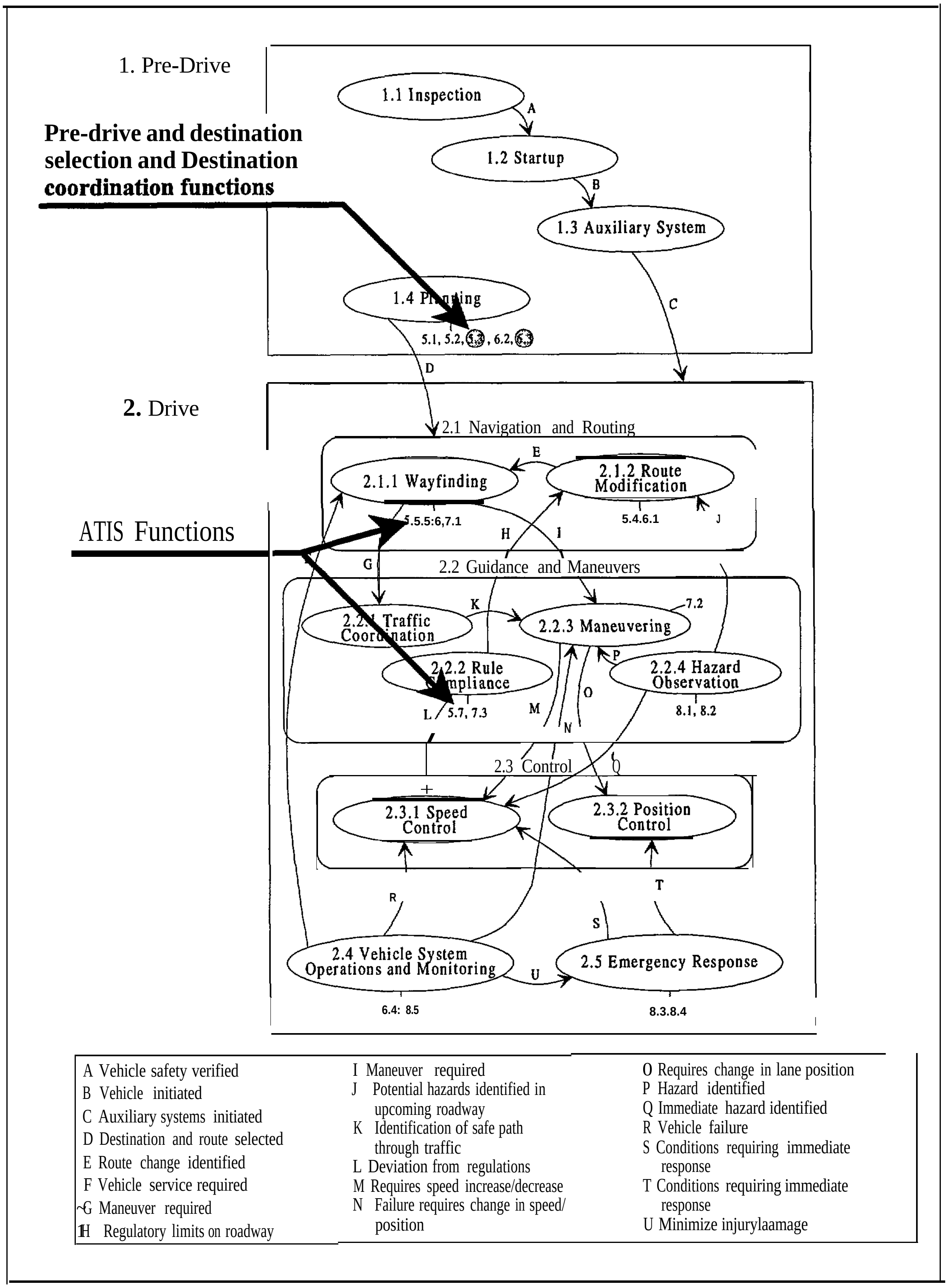


Figure 6. Example of integrated ATIS-specific and driving-specific tasks.

Interactions Between ATIS-Specific Tasks

Interactions between ATIS-specific tasks are an important consideration because they can lead to unnecessary tasks (i.e., entering data manually that could be transferred from function to function automatically). By examining the information flows and requirements, unnecessary tasks can be eliminated by facilitating the transfer of information through ATIS. Interactions between functional characteristics also are important because combinations of ATIS functional characteristics may overwhelm the driver with information or tasks. Alone, each element of ATIS may provide the driver with information that can easily be assimilated and acted upon. In combination, however, each element of ATIS may contribute to an information flow that could overwhelm the driver. Thus, identifying potential interactions between elements of the ATIS will help to eliminate unnecessary tasks associated with transferring information through the system and avoid overwhelming the driver with information from a large number of disparate sources.

The functional description of ATIS identified information flows that define some of the interactions between elements of ATIS. These interactions were defined in a context that was independent of the driving tasks. However, when seen in the broader driving context, the nature of these interactions may change slightly, and what initially appeared to be seemingly disparate ATE-specific tasks might now be linked together. For example, although the functional description does not indicate a link between message transfer and route navigation, figure 7 shows how these functional characteristics might interact. Message transfer (6.4) is an ATIS function that needs to be monitored by the driver and, as a consequence, is linked to the driving function Vehicle System Operations and Monitoring. Similarly, route navigation (5.6) is an ATIS function that helps the driver to find a route and, as a consequence, is tied to the driving function Wayfinding. These two ATIS functions could interact together given a particular situation. For example, a driver could be monitoring her vehicle's component and to be informed by the message transfer ATIS function that her appointment with a client is cancelled. She could then use the route navigation ATIS function to alter her route to drive to another appointment.

Thus, in many cases, the tasks of driving may link functional characteristics of ATIS in ways that are different from those based solely on the information flow between functions. Ignoring the links between elements of ATIS that are generated by driving tasks might lead designers to ignore potentially important interactions between functional characteristics. Such interactions need to be considered to minimize unnecessary tasks and limit the potential for driver overload.

Attending to Driving While Attending to ATIS

Besides the interactions of ATIS-specific tasks, the interactions between ATIS-specific tasks and driving-specific tasks are critical in defining a system that a driver can use safely and efficiently. Specifically, examining how drivers may share their attention with the ATIS and the primary task of driving may reveal potential driver overload. If the driver must spend a significant amount of time attending to ATIS-specific tasks, then performance will likely

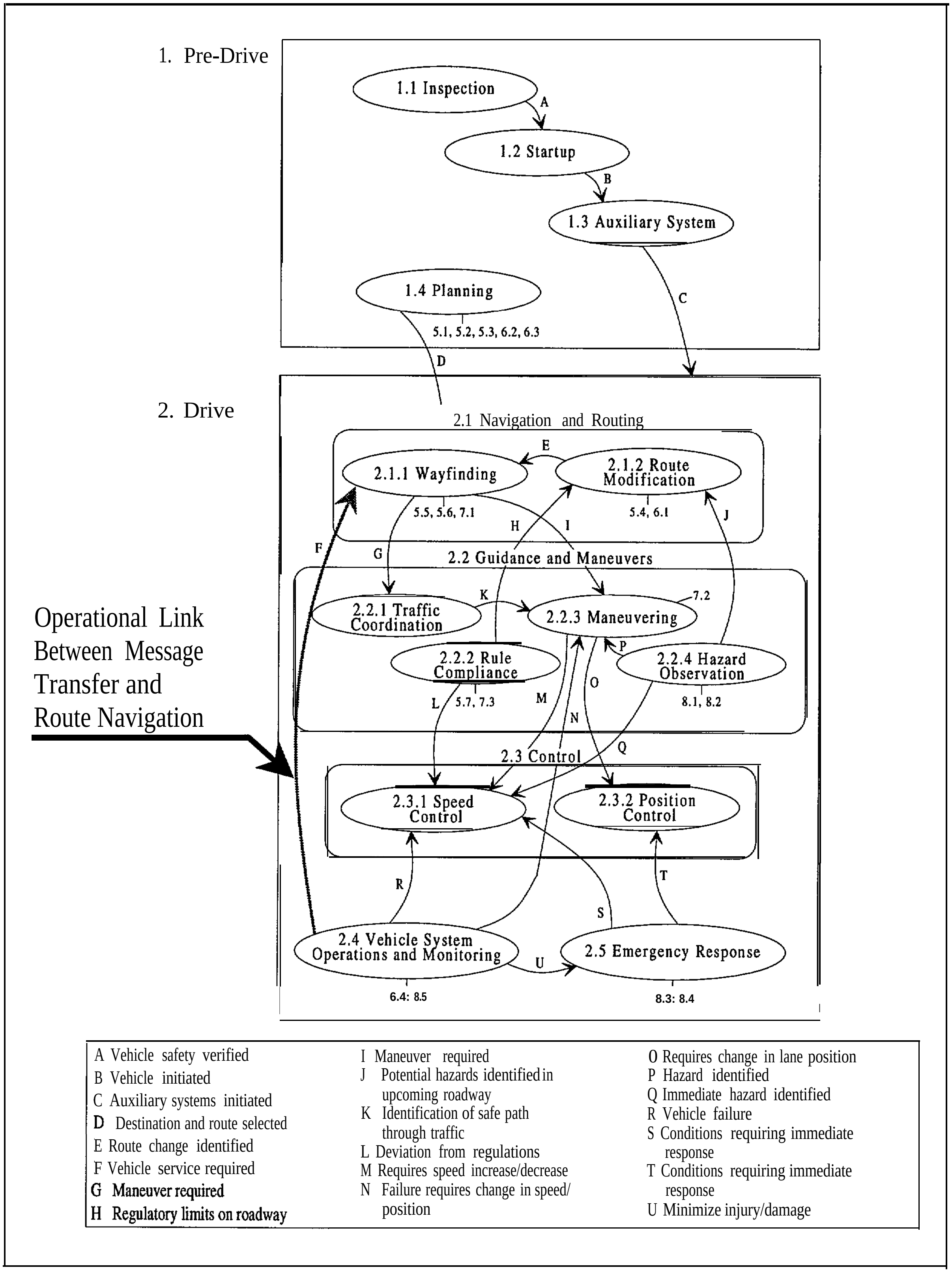


Figure 7. Example of interactions between ATIS-specific tasks.

suffer. Thus, a clear description of the driving-specific tasks must parallel the description of ATE-specific tasks to document the degree that ATIS demands driver attention.

In many cases, ATIS may add tasks that the driver would not otherwise perform while driving. For instance, a driver may select alternate destinations using a data base of local attractions while simultaneously maintaining the position of the vehicle on the road. In other instances, ATIS may augment the driver's capabilities and reduce the number of driving-specific tasks to which the driver must attend. For example, ATIS may eliminate the need to scan the roadside for speed limit signs and then compare the posted speed to the actual vehicle speed. An ATIS could include the posted speed as a marker on the speedometer, directly revealing to the driver any discrepancy between the actual and posted speed. Placing ATIS-specific tasks in the context of figure 4 explicitly demonstrates that the driver must share ATE-specific tasks with driving-specific tasks. Within this framework, the detailed description of individual tasks documents instances where ATIS increases driver workload with additional tasks and where ATIS may simplify or eliminate some of the driver's tasks.

Integrating ATIS Information and Commands into Driving Behavior

While the issue of sharing the driver's limited attention between driving-specific tasks and ATE-specific tasks represents a critical issue for the design of ATIS, how the driver integrates ATIS information and commands to guide his or her behavior reveals another important issue. Figure 8 illustrates this general issue through the labeled arcs representing events that initiate driving functions. In general, these initiating events represent driver interpretation of information regarding changes in the position or state of the vehicle relative to the driver's goal. As such, the driver plays an active role filtering, selecting, and interpreting information from the system; the driver does not passively obey the commands of the system. Because the driver plays an active role in processing information from the ATIS, the interaction between driving-specific tasks and ATIS-specific tasks is important. Thus, it becomes important to perform a detailed examination of the factors that a driver must consider when acting on information provided by ATIS. Several factors drive this requirement, including the uncertainty of ATE-generated information, the need to accommodate traffic dangers when complying with ATIS commands, and the need to coordinate compliance with ATIS commands with roadway constraints and the driver's more general requirements and objectives.

Technological limits associated with map data base accuracy and estimates of future traffic density provide specific examples of two factors that force the driver to evaluate and verify the information provided by ATIS. The arc linking Wayfinding and Maneuvering shows the outcome of this verification process, as does the arc linking Route Modification and Wayfinding. In each of these situations, the driver must evaluate the quality of ATIS information by comparison to external environment. Ideally, the system would provide the driver with information that could easily be integrated with the driver's own perceptions so that the maximum advantage can be gained from both the driver's perceptions and the power

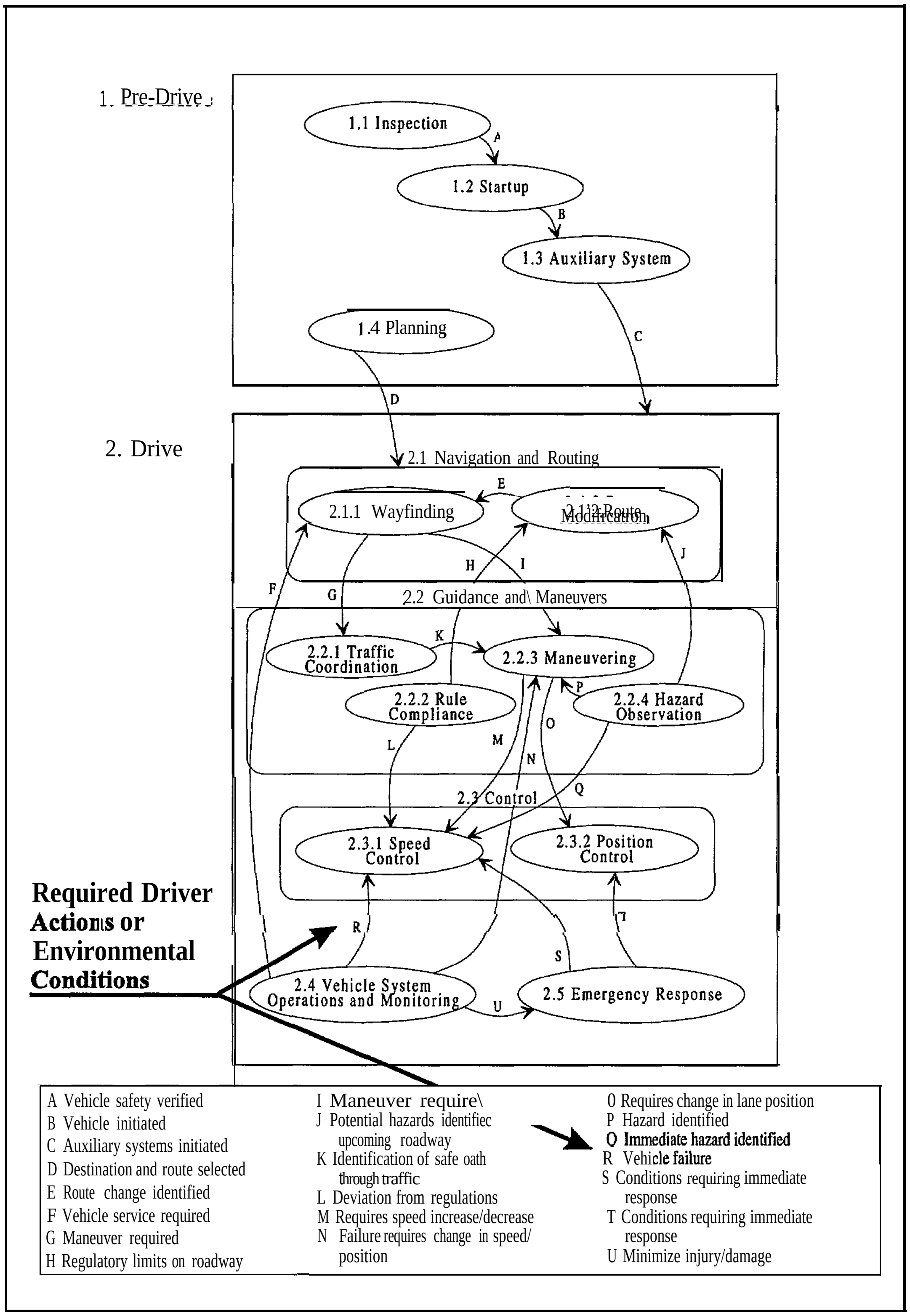


Figure 8. Example of integrating ATIS information and commands into driving behavior.

of the ATIS For example, a visual representation of traffic density on an electronic map may provide the driver with an understanding of the traffic patterns that can augment the driver's direct perception of traffic density and experience. In this situation, the driver's knowledge of specific events or contingencies could augment the inherent limits of ATIS. On the other hand, if the system provides only turn-by-turn route guidance (which is generated to accommodate traffic patterns), the driver has no way of detecting instances where the estimate of traffic density provided by ATIS diverges from reality. Figure 8 highlights the need to support the driver in the verification of ATIS information by showing the events and information that link driving functions. If ATIS provides the information depicted on the arcs to augment driving functions, then it is important to support the driver's interpretation of this information to take advantage of the driver's inherent adaptability that ATIS does not possess.

Even if the ATIS provided correct data that did not require the driver's confirmation, drivers could not simply follow the directives of the ATIS; drivers must consider the feasibility of making any maneuver in the context of other vehicles in the immediate area. For example, if an ATIS provides route guidance suggesting a particular turn, the driver must coordinate with other traffic before making a turn. Thus, it is not enough to discuss only the tasks directly associated with ATIS; the tasks associated with evaluating the feasibility of an ATIS directive must also be examined. Similarly, drivers cannot act on ATIS information without considering the constraints of the roadway or the impact on their overall goals. One-way streets, medians, and divided highways represent constraints of the road network that a map data base may not include. Attending to these constraints is part of the routine driving task, and its interaction with ATIS information may have important consequences for how and when the ATIS presents information. The arcs leaving driving functions that draw upon ATIS functional characteristics illustrate the need to coordinate ATIS directives with external events. These arcs highlight the need to consider the interactions between ATIS-specific and driving-specific tasks in coordinating directives provided by ATIS with the more general tasks of driving.

Like roadway constraints, drivers may have a variety of goals and requirements that represent important factors governing their routing and navigation decisions. Without an ATIS, drivers may implicitly attend to these factors when planning and executing a trip. With an ATIS, drivers will need to verify whether ATIS information is consistent with these goals and requirements. For instance, drivers may endeavor to avoid areas they suspect of having high levels of crime. Using an ATIS, drivers will likely use their perceptions of the ability of ATIS to meet these objectives in order to evaluate whether they should act upon the information provided by ATIS. Unlike coordinating ATIS commands with the constraints imposed by other vehicles and roadway geometry, no particular arc or node in figure 8 illustrates the evaluation of ATIS information in the context of driver goals and requirements. Instead, the evaluation may incorporate the results of a series of driving functions, including the dynamic re-evaluation as the driver proceeds along a chosen route. Therefore, some tasks associated with traditional means of navigation and routing may occur in parallel with ATIS-specific tasks. Because drivers may retain and apply pre-ATIS navigation and routing strategies, an understanding of these strategies may ensure that the ATIS provides information consistent with their goals and requirements. Development of such a system requires the relatively detailed description of a broad range of routine driving tasks.

SUMMARY

The detailed task analysis presented in this report includes a large number and wide variety of tasks. The analysis describes these tasks in great detail and the resulting description provides a very detailed, but complicated, view of driving with an ATIS. This section and the figure preceding each detailed analysis (see appendix D) summarize and simplify the complex tasks by describing driving in terms of several general functions, which are composed of many individual tasks. The functions and their interconnections provide a summary of the more detailed analysis that highlights interactions, information flows, and triggering events that may be obscured by the more detailed analysis in chapter 4 and in appendix D.

The most important feature of figures 4 through 8 is that they embed a description of ATIS-specific tasks in a description of the more general tasks of driving. Combining ATIS-specific tasks with driving-specific tasks reveals links between elements of an ATIS that emerge when they are considered in the context of routine driving tasks. In addition, figure 8 illustrates several different types of interactions between ATIS-specific tasks and driving-specific tasks. For example, the issue of sharing attention between the primary task of driving and interaction with the ATIS places strict limits on what interactions a driver can have with an ATIS while the vehicle is moving. Likewise, drivers do not respond to information and directives produced by the ATIS in isolation. They interpret, filter, and coordinate this information and the activity it implies with other driving constraints and tasks. Thus, the summary shown in the figure preceding each detailed task analysis in appendix D embeds the task analysis of ATIS within a description of the more general driving tasks. As a result, the figures help to identify issues and design considerations that depend on considering the effects of ATIS in the broad context of how it may affect the general nature of driving.

CHAPTER 4. TASK ANALYSIS RESULTS

APPROACH TO THE TASK ANALYSIS

Appendices C and D present the detailed task analyses conducted of the ATIS/CVO functions and scenario-based activities. Appendix C provides hierarchical task descriptions for each of the ATIS private and CVO functions. As such, appendix C provides a comprehensive listing of tasks that might confront the driver, organized hierarchically to show which tasks support the various driving and ATIS functions. While appendix C does not provide any information about potential task sequences or decision points, it shows the driver goals associated with each task and how the tasks combine to serve the overall driving and ATIS functions. Appendix D complements appendix C by describing tasks in the context of realistic driving scenarios. This description includes information about task sequences and decision points as well as a more detailed description of each task. Although the task description in appendix D occurs in the context of specific scenarios, the position of each task within the hierarchical task description can be easily identified. Each task in appendix D has a unique number that corresponds to the numbering scheme of the hierarchical task listing in appendix C. The specific content of the scenario-based analyses of appendix D includes:

- A description of the scenario, its system components, and the major ATIS functions.
- Graphical depiction of the interaction between the driving and ATIS functions.
- Graphical depiction of the sequence of task steps involved in performing the scenario.
- Tables characterizing each task step in terms of task demands and related information.

The summary presented in this section was developed using the detailed task analysis found in appendices C and D. The purpose of this summary is to identify common task requirements among the various situations represented by the scenarios.

In preparing the analysis in appendix D, each scenario was first described in terms of its functional interaction within the pre-drive and drive operational phases of both vehicle and ATIS/CVO use. This provided a link between the earlier function analysis conducted in Task C and the more detailed analysis that follows. It also served the purpose of establishing the scenario functions associated with ATIS/CVO within the larger context of driving.

The functional level description of the scenario is followed by an operational sequence diagram (OSD) of the tasks that would be performed to achieve the goals of the scenario.

The OSD provides a graphical description of the relationship between tasks, individuals, or systems that perform each task and the sequence in which the tasks might take place, The OSD provides the primary means for the analysis to evaluate how tasks relate to one another and how task activities might be shared between the user and various systems. Thus, the OSD provides a way for the analyst to evaluate the dynamic qualities of task performance within the scenario.

Accompanying each OSD is a Task Characterization (TC) table containing the detailed task characterization for each task represented by the OSD. The task characterization provides additional information to the analyst, which is of particular importance when evaluating the performance required of an individual when doing that specific task. Figure 9 illustrates the process used to develop this analysis.

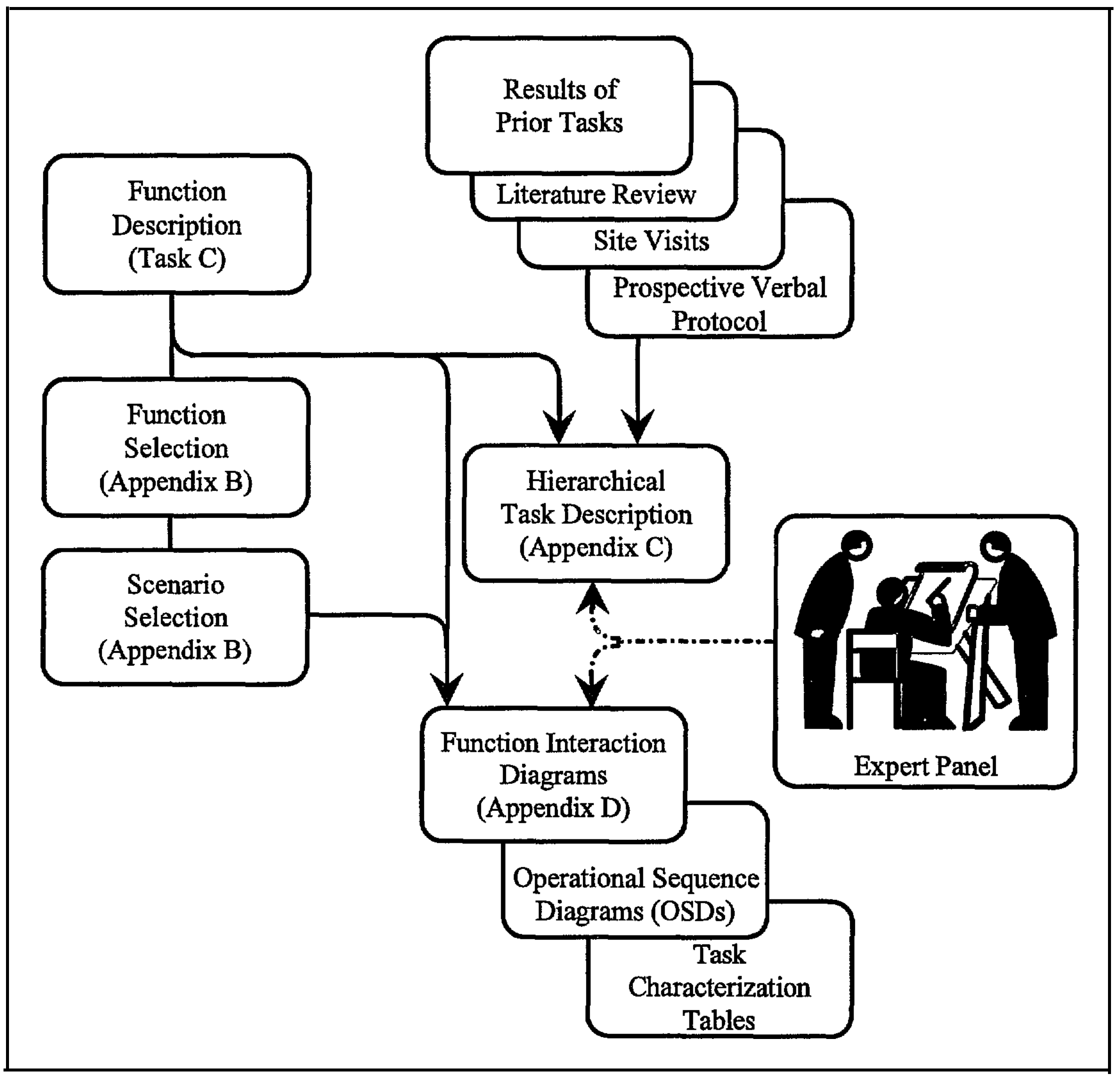


Figure 9. Results of prior tasks.

ASSUMPTIONS USED IN THE ANALYSIS

Advanced Traveler Information Systems (ATIS) are intended to provide a relatively broad range of different services in the context of virtually all possible driving situations. Since the practical environment for ATIS/CVO use is so broad, care must be taken to avoid over-specifying how an individual might use ATIS systems in almost any given situation. Unlike a task analysis of an objective system where it would be possible to identify both the limits of functional use and the way that each function would be carried out, this analysis was done on systems that have not yet been built and lack a fully specified functional allocation. Therefore, the analysis makes assumptions (see table 15) about both functional allocation and task requirements, the extent of which far exceed what would normally be expected of a task analysis.

Table 15. Summary of assumptions used in the task analysis.

ASSUMPTION	SUMMARY
Integrated System	IRANS, IMSIS, ISIS, IVSAWS, and CVO systems are integrated and able to pass information from one to another with minimum human action.
Minimal Use	ATIS functions would only need to be set up by the driver when required for the driving scenario.
Prior Task Completion	Tasks required for system operation prior to those needed for the scenario would have been successfully completed.
Complete Infrastructure Support	ATIS would have all the necessary support to successfully complete the scenario.
Normal System Behavior	All equipment, except as noted in the scenario, including ATIS/CVO functions, would be operating normally.

Assumption of an Integrated System

Advanced Traveler Information Systems have been defined as encompassing four distinctly different types of information systems (i.e., BANS, IMSIS, ISIS, and IVSAWS). Each of these systems could be developed separately and might be purchased and installed by a driver on an optional basis. However, there is sufficient overlap in the functions provided by each of the systems that the use of entirely separate systems would result in redundancy in both display and control of each of the systems. An assumption of entirely independent system functions, presentation, and control would result in both an unrealistic and overly complicated task analysis. For example, such an assumption would require separate entry actions for both destinations requested under the IMSIS and IRANS, an unnecessary and probably unrealistic condition if both systems are in a vehicle. Similarly, completely separate IRANS “and ISIS systems would result in route guidance information being presented in addition to cross-street information being provided from ISIS.

Due to the obvious value of having ATIS integrated to share information, suppress redundant information, and minimize the presentation of redundant or unnecessary information, the task analyses of driving scenarios assumed reasonable integration of the ATIS.

Assumption of Minimal Use

Advanced Traveler Information Systems are envisioned to provide functions for a wide range of driver needs. While it would be possible to exercise all or most of the functions in any trip, such use would neither be consistent with driver needs nor a reasonable assessment of the cost/benefit trade-off that using the function would have for a particular scenario. For example, it is probably unrealistic to assume that a driver will initiate the full capabilities of IRANS, including route planning and guidance, when he or she is driving to a familiar location within a local area. It might be equally unrealistic to assume that a driver would tolerate the presentation of all roadway information signs from an ISIS system when driving to work over a familiar route.

Due to the likelihood that drivers will only use systems that they need in a particular circumstance, the task analysis assumes that only those systems needed to perform a set of tasks associated with a particular scenario would be used.

Assumption of Prior Task Completion

The scenarios used in the analysis represent the possibility of creating a list of tasks from the inception of a trip until its completion. Such a representation would have been unnecessarily complicated and lengthy. In addition, such an analysis would have tended to diminish the focus on particular functions as intended by the choice of the scenario. Therefore, the analysis confined itself to a description of the tasks that supported the functions of importance in the scenario and assumed that common preliminary tasks (e.g., turning on equipment and deciding where one wanted to go) were not of central importance to the analysis and thus could be assumed to have been performed.

Assumption of Complete Infrastructure Support

Advanced Traveler Information Systems are going to require a significant amount of infrastructure support. The availability of this support was assumed to be complete in the task analysis. It was further assumed that information necessary to fully support the system function under analysis would be available.

Assumption of Normal System Behavior

Although it is certainly possible to perform a task analysis that includes an analysis of what drivers might do in the event of an ATIS malfunction, doing so significantly complicates the analysis when the specific system design and modes of failure are not yet known. For this task analysis, the assumption was made that the ATIS would have no failures. In the analysis, no failures or related problems were assumed beyond those specified in the scenario.

TASK ANALYSIS RESULTS

Using the results of the task descriptions, as reflected in the Operational Sequence Diagrams (OSDs) and Task Characterization (TC) tables presented in appendix D, task analyses were completed for four different types of tasks:

- Tasks that are used to set up an ATIS function. (SETUP TASKS)
- Tasks that serve as bridges between two or more ATIS functions. (BRIDGING TASKS)
- Tasks that involve decision making by the driver or dispatcher. (DECISION-MAKING TASKS)
- Tasks that are integrated with critical driving tasks. (DRIVING TASKS)

Each type of task represents specific types of activities that are critical to the proper operation and use of the ATIS and aspects of system use that will need to be considered in the design.

As a consequence, the task analysis results are divided into four main sections, each describing one of the four tasks in greater detail. For each one of the task types, the analysis is subdivided into four parts. First, the *Function* section provides an operational definition of the type of task involved. The second part, *Characteristic,* is a description of the general characteristics of the task, including the likely interactions with precursor and successor tasks; but more specifically, it describes the nature of the task in terms of its demands on cognitive and motor processes. Following characterization of the task, the *Human Factors Design Implications* are discussed, for both general and specific implications. Finally, a summary table presents the main findings described in the previous paragraphs.

Analysis of Setup Tasks

Tasks that are used to provide information to the ATIS were the first types of tasks analyzed. An understanding of such tasks is essential to the development of appropriate driver input devices and approaches.

Function of Setup Tasks

Input tasks are generally defined as tasks that have the purpose to gather and provide information needed by an ATIS to begin or complete necessary processing. Examples of various setup tasks include:

- A commercial vehicle driver initiates an IMSIS to present a listing of services that will allow him to select a service station where he can get fuel (see appendix D, Scenario C4, Task 6.2.1).
- A real estate salesperson enters the destinations of several houses she intends to show to customers into an IRANS while planning her meeting with the customers (see appendix D, Scenario P2, Task 5.1.2.1).
- A driver sets the parameters of the broadcast function of an IMSIS to the nearest service station from the present position (see appendix D, Scenario P16, Task 6.1.2).

Setup tasks appear to perform four different functions related to the use of ATIS/CVO systems. These four different functions are summarized in table 16.

Table 16. Function and description of setup tasks.

FUNCTION	DESCRIPTION	EXAMPLES
1. Initiation of System Operation	Turn the system on or otherwise prepare the system to perform a designated function, such as route planning or receiving roadside hazard information.	• Figure 10.
2. Entry of System-Critical Information	Provide information to the system that is critical to the performance of the system function.	• Figure 11. • Appendix D, Scenarios Pl OSD, P2 OSD, P14 OSD, Cl2 OSD, and Cl3 OSD.
3. Entry of Preference Criteria Information	Enter parameter information that establishes driver or dispatcher preferences for how an IRANS will perform a planning function.	• Figure 13. • Appendix D, Scenarios Pl OSD, P2 OSD, P6 OSD, and P14 OSD.
4. Confirmation of Proper System Operation	Confirm that the system is correctly set up. These tasks would usually involve a review of the input provided or the recommendations developed from that input.	• Figure 14. • Appendix D, Scenarios Pl OSD, P2 OSD, P6 OSD, P14 OSD, P16 OSD, P20 OSD, C4 OSD, and Cl5 OSD.

For this analysis, setup tasks were limited to tasks performed by a driver or dispatcher to initiate system functional operation, to provide goal-related information (e.g., destination location), or to limit considerations of the system.

General Characteristics of Setup Tasks

Of the 165 driver and dispatch-centered tasks examined in detail (see appendix D), approximately 42 percent were tasks associated with setting up an ATIS/CVO system.

Setup tasks involve both cognitive and motor activities that need to be considered in connection with the likelihood of good task performance. Since setup tasks involve several different types of activities and perform different functions in the use of ATIS/CVO, they may involve different performance considerations.

The tasks associated with turning the system on or preparing the system to perform a design function (see figure 10) are likely to be among the least demanding tasks associated with the use of ATIS, particularly since many of the setup initiation tasks would be performed during the pre-drive phase of a trip. One notable exception to this would be when a driver executes a dynamic route change (see appendix D, Scenarios P20 OSD, C4 OSD, and Cl2 OSD). In such circumstances, the setup is usually performed in conjunction with a series of decision-making actions and may often be performed while driving.

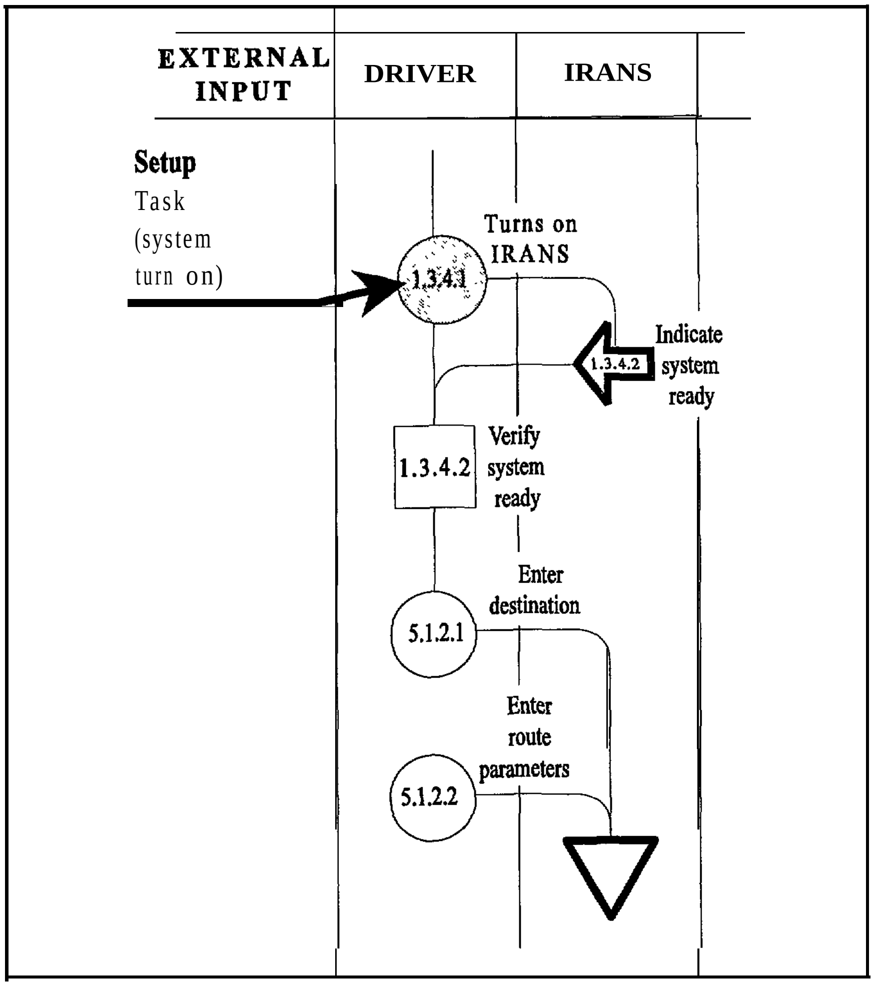


Figure 10. Example of setup task (system turn on).

Setup tasks that are <u>critical to performing a function</u> (see figure 11) usually involve complex cognitive and relatively complicated motor processes. Representative of these types of setup tasks are those that involve identifying and entering a destination. This type of information often involves a complicated series of steps that depend on the driver's long-term memory and knowledge of specific information about the destination (i.e., street address, town name, or cross-street).

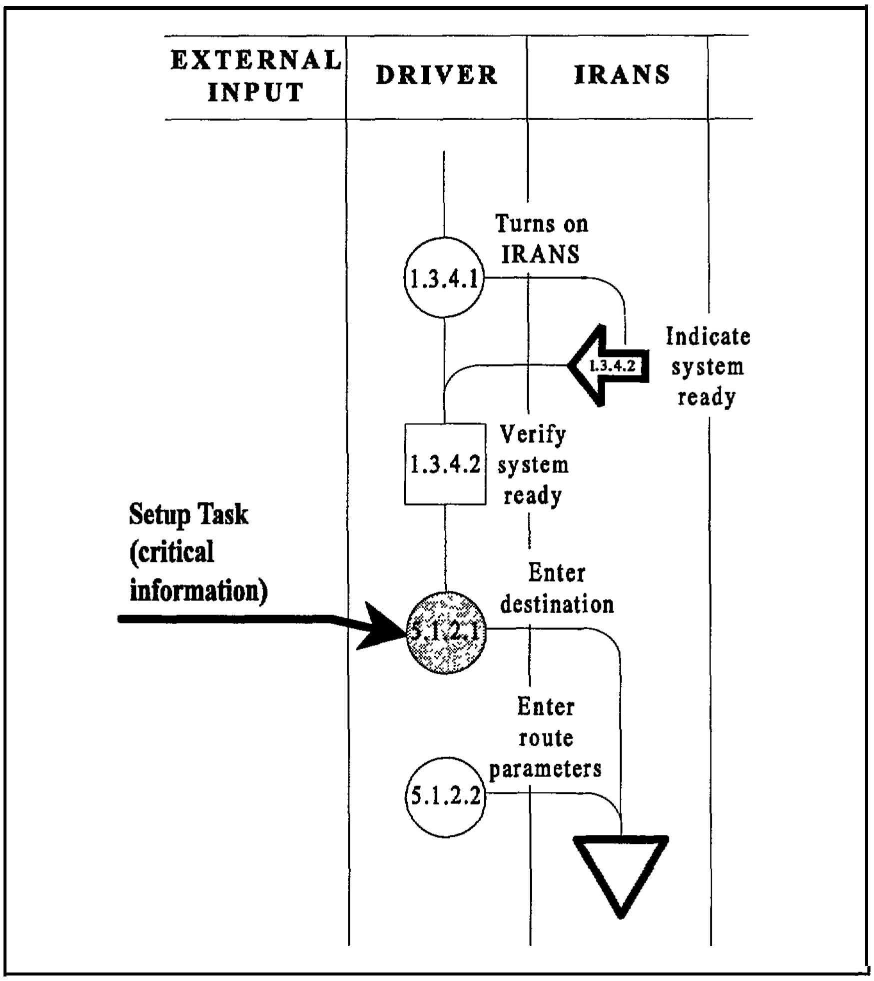


Figure 11. Example of setup task (critical information).

In addition to the task elements of collecting the information required by the system, the setup task also involves entering the information. Assuming that the destination includes a normal address, the detailed entry process likely to be required when performing a setup task of a flexible destination indicates that workload and attention requirements of the task might preclude it being done while moving.

Aside from setup tasks involving flexible destinations, it would also be possible to have the system pre-programmed for destinations that are frequently used (e.g., work, home, and selected destinations frequently used). Such destinations would allow the driver to select them from a limited destination menu when setting up IRANS systems and thus eliminate much of the normal destination setup activities (see appendix D, Scenario P14 OSD). The same would also be true of the entry of pre-programmed destinations that might be obtained from technologies such as address bar coding on newspaper advertisements or business cards.

In addition to flexible destination setup tasks used with IRANS, there are setup tasks associated with cataloged destinations such as public buildings, businesses, and significant landmarks (see appendix D, Scenarios P6 OSD, P16 OSD, C4 OSD, and Cl5 OSD) that could be accessed via multiple menu windows (see figure 12). While a menu-driven sequence does not require the same degree of cognitive preparation and information-entry expertise that is required to set up a flexible destination, the tasks involved do include the necessity that the driver focus a great deal of attention on the ATIS equipment and are thus likely to be incompatible with the primary task of driving.

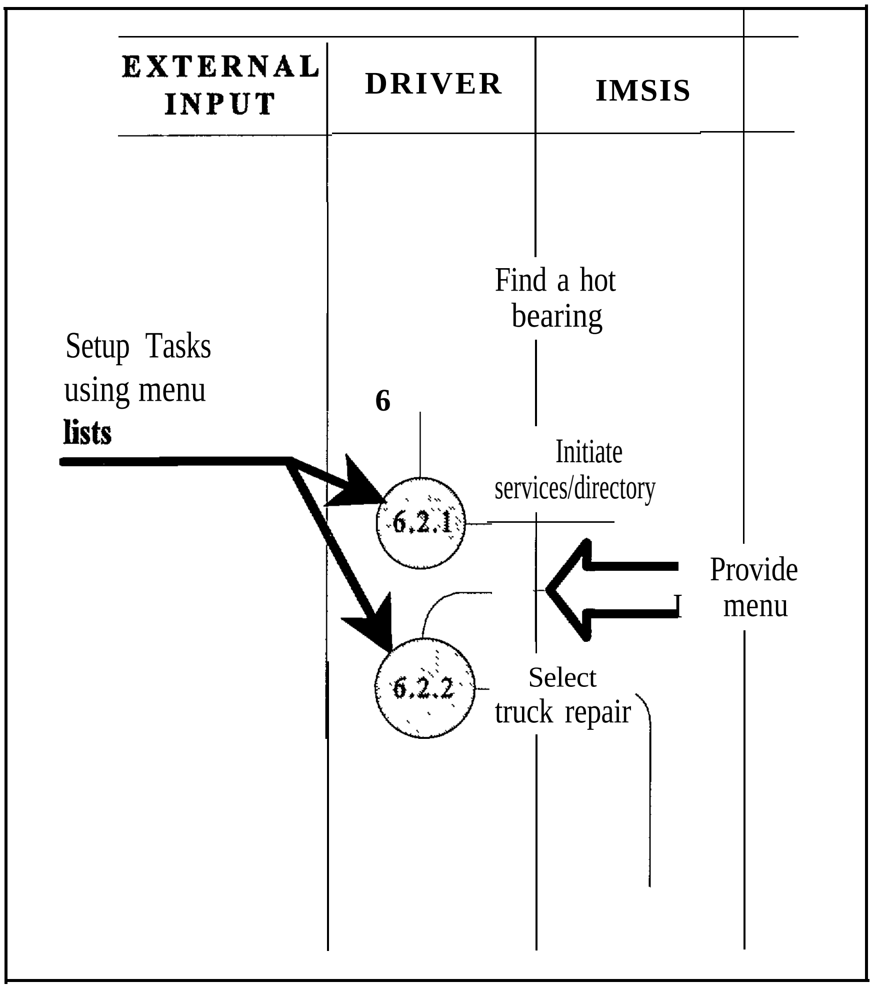


Figure 12. Example of setup task using menu lists.

The task of entering parameter information for driver or dispatcher preferences for how an IRANS will perform a planning function, will most likely use a menu-driven approach, due to the limited number of parameters that are likely to be important for a particular function. These types of functions (see figure 13) may also be suitable for automatic or semi-automatic settings depending on driver preferences, vehicle design, and other conditions that would automatically set the system up and, therefore, would be transparent to the driver.

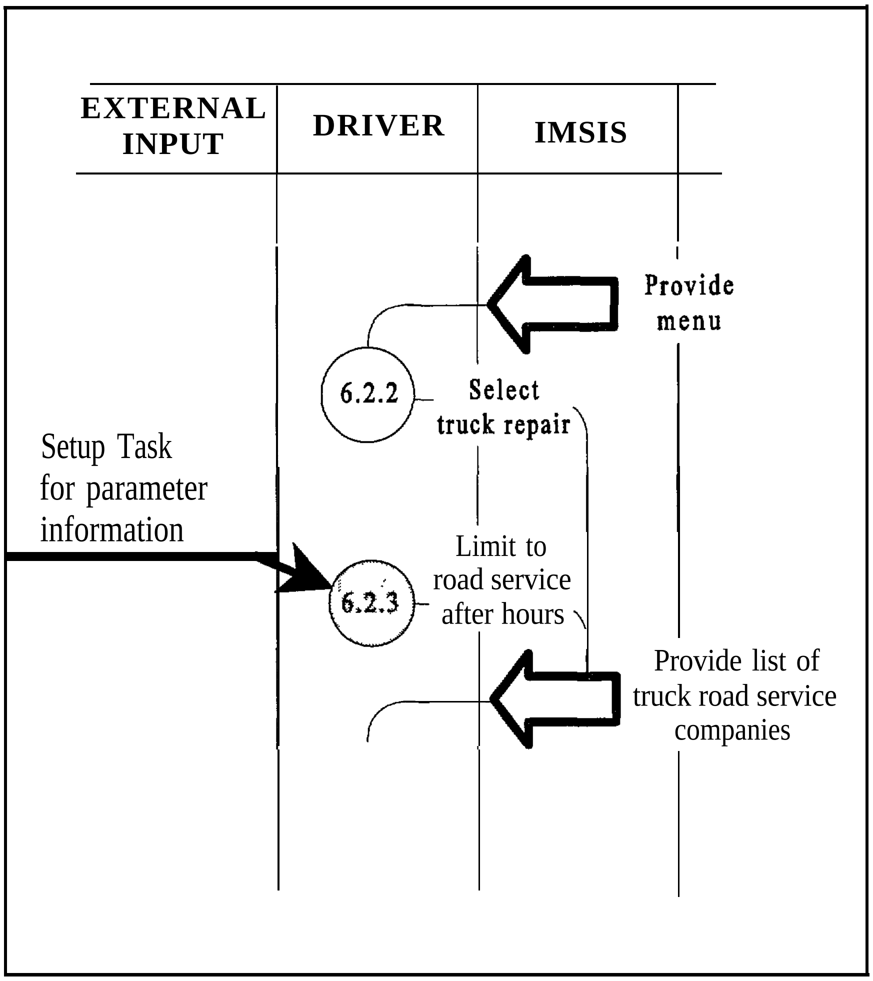


Figure 13. Example of setup task for parameter information.

The last type of setup task is made up of those tasks that are used to confirm that the system is correctly set up (see figure 14). These tasks would usually involve a review of the input provided or the recommendations developed from that input. The method for presenting this information may be quite complex and detailed. In these instances, the complicated review tasks probably would preclude their being performed while also performing the primary task of driving.

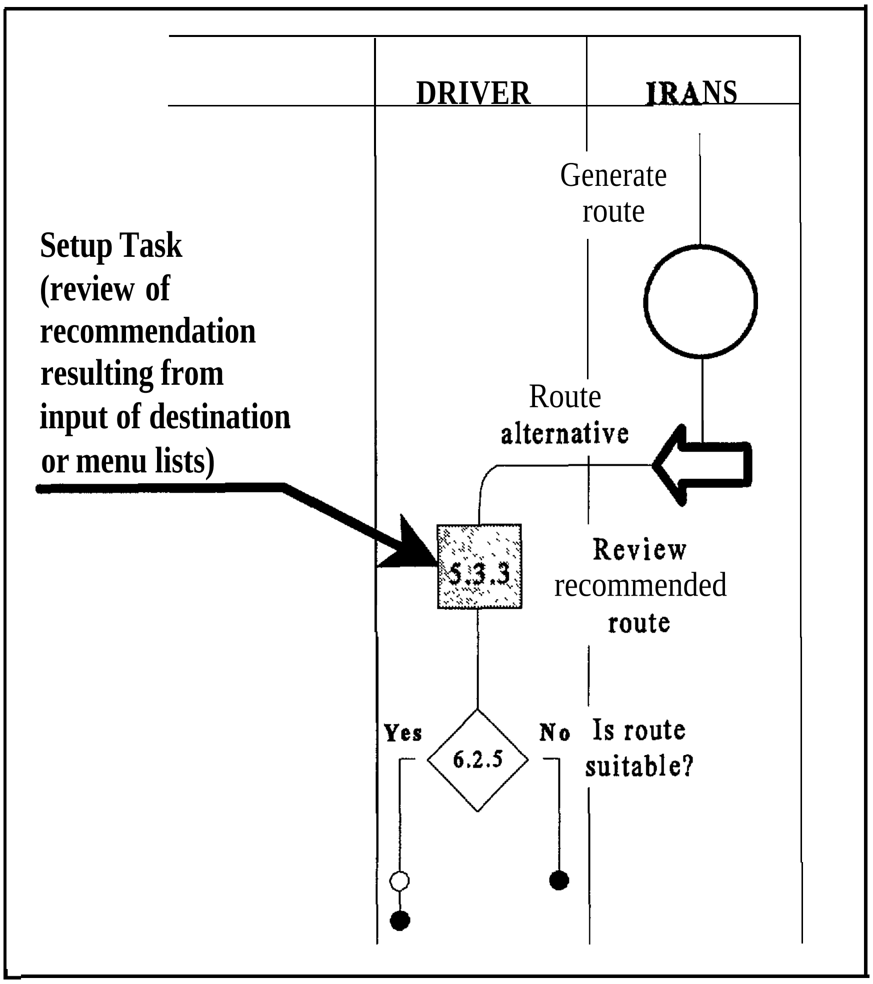


Figure 14. Example of setup task (review of recommendation).

<u>Human Factors Design Implications (General and Specific)</u>

Human factors design implications, be they general or specific, will depend on the purpose or actual function of the system, For the setup tasks, there were four different types of functions identified. For each one of these functions, there might be different human factors design implications. The following paragraphs summarize these design implications for each one of the setup tasks.

First of all, the primary task performance characteristics for turning on or initiating the ATIS are likely to be that the controls required are within easy reach of the driver, are large enough to be easily controlled, and provide positive feedback to the driver that the system or function has been initiated (see appendix D, Scenario P20 TC).

Representative of these types of setup tasks are those that involve identifying and entering a destination. This type of information often involves a complicated series of steps that depend on the driver knowing specific information about the destination (i.e., street address, town name, or cross-street). The attributes of such information may depend a good deal on the size of the map data base used by the system, as well as the nature of political and geographic divisions in a particular part of the country. The first and perhaps most important characteristic of this type of setup task is that it requires the driver or dispatcher to have an accurate and precise description of the destination that is also compatible with the data base used by the system. Therefore, system design needs to be consistent with the most likely way that people identify the locations they drive to. For example, street mailing addresses are probably more useful for ATIS systems than some other destination reference system would be (e.g., latitude and longitude or Universal Traverse Mercader [UTM]).

Aside from the problem of having the proper information to correctly specify a destination, the driver must also correctly communicate this information to the ATIS. This task can obviously be done in a variety of different ways. For example, a destination address may be entered using either a keyboard, touch screen menu, or some combination of the two. Assuming that the destination includes a normal address, the entry must provide the system with both numerical and alphabetical information in a series that is likely to exceed 20 to 30 characters. This implies the necessity for an entry device that:

- Has an ability to enter at least 26 unique alphabetical characters and 10 numerical characters, plus an unspecified number of special characters.
- Minimizes the number of steps required to enter a specific character.
- Provides a trace of the characters entered so the driver will know where he or she is in the entry process.

Other alternatives to data entry techniques include having an abbreviated menu of pre-planned destinations (e.g., office, home, and frequently visited friends). Use of a pre-planned personal destination menu would greatly simplify the setup task for those destinations. Other means of entering individual destinations might include the use of programmed “smart cards” that would allow planning a series of destinations prior to beginning a trip. Perhaps the most obvious use of such “smart cards” would be for commercial applications, such as small package delivery, where a support system could be set up to prepare the card.

The task performance considerations associated with setting up destinations from cataloged information, such as might be available from IMSIS, vary slightly from those needed for entering non-cataloged information. Such a task would almost certainly be based on using a hierarchically organized menu-driven system to arrive at a listing of alternative services and then to select the desired alternative from that list. The first performance characteristic that is likely to be associated with such actions is going to depend on the user’s knowledge of the structure of the categories used by the system and the ability to correctly place the desired destination or class of services within the appropriate category. Efficient use of the directory will depend in large part on the knowledge that the user has of the categories used by the system. This could, of course, be improved by the development of a standardized taxonomy of services presented in the ATIS Aside from needing to know the structure of data base categorization, performance will depend on the ability of a driver to recognize an appropriate match between the requirements that they have for services and the services listed in the menu. In most cases, this ability will be dependent on the type of services needed and the number of options available (e.g., a driver will have less difficulty selecting post offices than Chinese restaurants).

The tasks associated with establishing parameters for system use are similar to those required for all menu-driven systems, with the exception that these parameters are likely to represent a smaller set of choices than the driver can make.

Finally, the task of confirming proper system operation is likely to involve much more than simply verifying the mimic of the information needed to be entered, but also, the much more complex process of determining if the system recommendations are reasonable and appropriate for the circumstances. This involves not only verifying that the information was correctly entered in the system, but also that the information was correct at its inception. Such checking also involves making a determination that the basic information the system uses (i.e., the data base and the computational assumptions) is correct and appropriate. This type of verification involves the user in a combination of cognitive activities that include the use of previous experience, knowledge, and the assessment of multiple sources of information that might have a bearing on the outcome of a particular recommendation.

Finally, since it can be assumed that many destination entry tasks will involve, at least partially, the use of long-term memory, an ATIS might also include intelligent evaluation of destination input that would provide logical as well as direct matching of the driver's input with the data base. For example, if a driver enters an address that does not exist in the data base for a specific area, the system might respond with suggestions of possibly correct alternatives in a manner similar to that used by spell check features used in word-processing programs.

Table 17 summarizes the general characteristics and considerations associated with setup tasks.

Table 17. Summary of the general characteristics and considerations associated with setup tasks.

TASK TYPE	Setup tasks			
FUNCTION	Gather and provide information to an ATIS system that is needed by the system to begin or complete necessary processing.			
SUBFUNCTIONS	CHARACTERISTICS	HUMAN FACTORS DESIGN IMPLICATIONS		CAUTIONARY NOTES
		GENERAL	Specific	
1. Initiation of System Operation	• These tasks are the least demanding if they are accomplished during the pre-drive.		• Controls within easy reach. • Controls of sufficient size. • Controls provide positive feedback.	
2. Entry of System-Critical Information	* These tasks involve complex cognitive and relatively complicated motor processes. • Menu-driven entries focus driver's attention inside the vehicle.	• Size and nature of data base affects driver's data entry process. • Data entry process requirements have to be consistent and natural with driver's expectations. - System needs to prompt and aid for display entry.	• Data entry requires alphanumerical, numerical, and special characters. . Minimal input steps required. - Character input trace required.	. These tasks might be precluded from being performed while driving.
3. Entry of Preference Criteria Information	• These tasks could be transparent to the driver if the system is automatically setup. • Menu-driven approach focuses the driver's attention in the vehicle.	- Menu-driven entries should have hierarchically organized categories that are compatible with driver's expectations. . Menus should be based on standardized taxonomies.	• Abbreviated menu of preplanned destination. • Programmed smart cards.	• Menu-driven options should be compatible with driver's expectations to avoid driver being lost in menus. • Performance on menu-driven choices depends on. driver's ability to recognize appropriate categories and match.
4. Confirmation of Proper System Operation	. These tasks require complex cognitive processes.	• Need for intelligent evaluation system of destination input.		• These tasks might be precluded from being performed while driving.

Analysis of Bridging Tasks

Tasks that serve as an information or procedural "bridge" between two or more functions are the second type of tasks analyzed. An understanding of such tasks is necessary because they bring together the various systems of ATIS into an integrated and functional whole.

Function of Bridging Tasks

Tasks that serve as a bridge between two or more functions provide the procedural link that integrates the output of one function with the input requirements of another. Bridge tasks include those that provide information from one function to another. They also include those that initiate or set up tasks in functions other than the ones found in the initial setup tasks. Examples of bridging tasks include:

- A driver of an aid car modifies his route to an accident scene based on information received on route conditions. The IRANS provides guidance information for the new route and position, and routing information to the computer-aided dispatch system in the dispatcher's office (see appendix D, Scenario P12, Task 56.1).

- A driver selects a motel from an IMSIS directory and, after obtaining a reservation, initiates route guidance to a restaurant using the IRANS (see appendix D, Scenario P6, Task 5.3.2.1).

Most bridging tasks are preceded by a decision task. The outcome of the decision task may be based on one of two basic conditions. The ATIS has provided the driver with a satisfactory destination or route as part of the planning function. For example, the system has been asked to plan a route from the present location to the nearest hardware store, and a route is suggested that the driver considers suitable. If either the environmental or other conditions surrounding the route have changed, the driver may initiate a change in ATIS functions. For instance, if a driver were preceding on a route to a restaurant and suddenly realized that she needed to get some money at an Automated Teller Machine (ATM), she would initiate a change in functions to locate the nearest ATM along the proposed route.

In general, bridging tasks perform four different functions. These functions are summarized in table 18.

Table 18. Function and description of bridging tasks.

FUNCTION	DESCRIPTION	EXAMPLES
1. Provider of a link between planning and execution functions	This function applies mostly to IRANS and IMSIS. Following a successful completion of various planning actions, this function enables the system to start the execution of these plans.	- Figure 15. . Appendix D, Scenarios Pl OSD, P2 OSD, PI4 OSD, P16 OSD, and C4 OSD.
2. Initiation of coordination of destination requirements	Following a decision process, this function tells the system to initiate destination requirements that may include reservations at a restaurant or motel or, for example, warehouse loading dock activities. This function will most likely be a secondary function of the ATIS.	• Figure 16. • Appendix D, Scenarios P6 OSD, PI6 OSD, and P20 OSD.
3. Initiation of functions as a consequence of a change in plans	This function is always the result of a decision process. This function directs the driver to the next set of actions to be performed. These new actions can occur within the same system or can be initiated by a different system.	• Figure 17. • Appendix D, Scenarios P14 OSD, P16 OSD, and Cl2 OSD.
4. Execution of a function developed and accomplished by two different parts of a system	This function is the result of coordination between different parts of the ATIS system, one of which is usually external to the vehicle. The function usually involves some part of the infrastructure supporting the system.	• Figure 18. • Appendix D, Scenarios Cl2 OSD and Cl3 OSD.

General Characteristics of Bridging Tasks

Of the 165 driver and dispatch-centered tasks examined in detail, approximately 18 percent involved actions that either shifted information from one system to another or from one function to another within a single system.

The most common ATIS bridging task is probably found in the link between planning functions and execution functions associated with IRANS and IMSIS (see figure 15). Such a task is likely to require little more than a single control action indicating acceptance of the system recommendations and simultaneous approval to begin the guidance phase of the trip. In some cases, such as when planning is done in advance of the trip, the bridging task might involve only indicating that the driver is prepared to begin the trip. Since the bridging task itself is relatively simple, there is no real reason that it could not be accomplished safely while the vehicle was moving under most conditions. The most often used ATIS bridging tasks (i.e., those that bridge planning and execution functions as well as planning and destination coordination functions) present few problems to adequate task performance. In the integrated system assumed by this analysis, performing such a task would be, for all practical purposes, a transparent activity in the operation of the system.

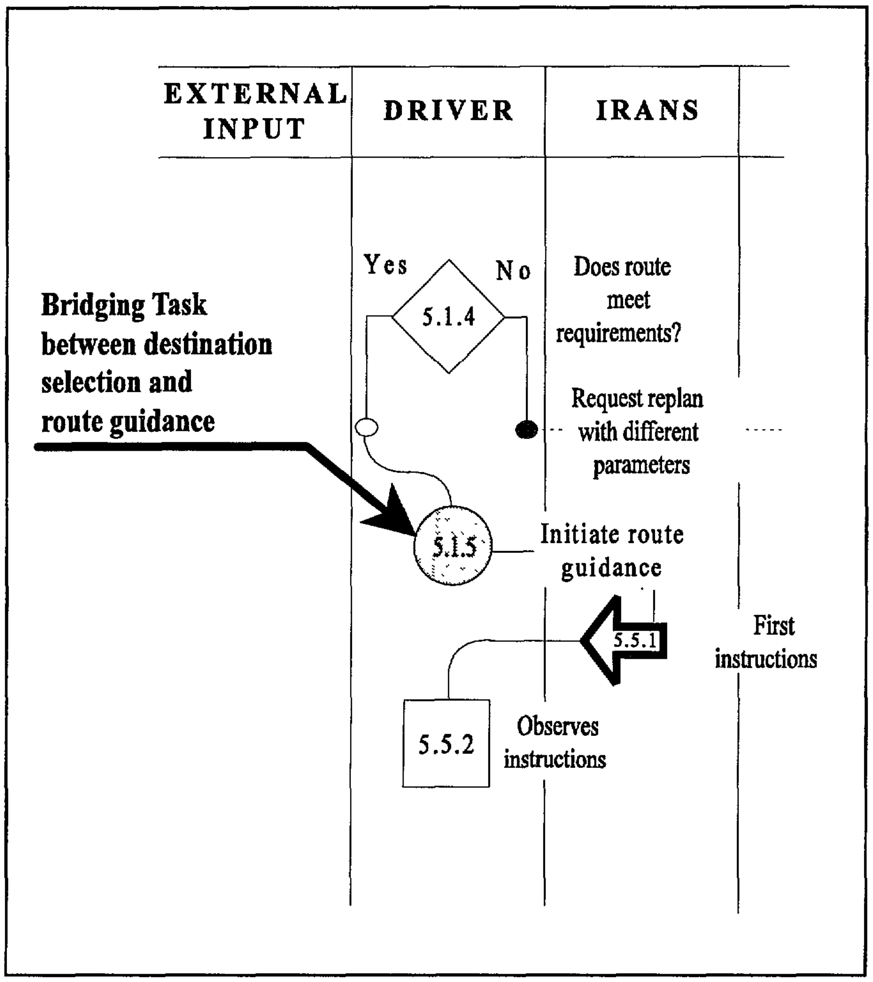


Figure 15. Bridging task between destination selection and route guidance.

A second potential use of ATIS bridging tasks is likely to be when coordinating destination requirements such as reservations at a restaurant, motel, or warehouse loading dock (see figure 16; also see appendix D, Scenarios P6 OSD, P16 OSD, and P20 OSD). Such coordination is likely to be a secondary function of the ATIS and one not likely to involve the driver beyond indicating that reservations are desired and acknowledging that they have been made. This type of task could be accomplished either immediately after confirmation of the plan or destination selection or, if desired, at some later time. Of course, if confirmation of the availability of space is important to the selection of a particular destination, this task would need to be done before initiating route guidance to the destination.

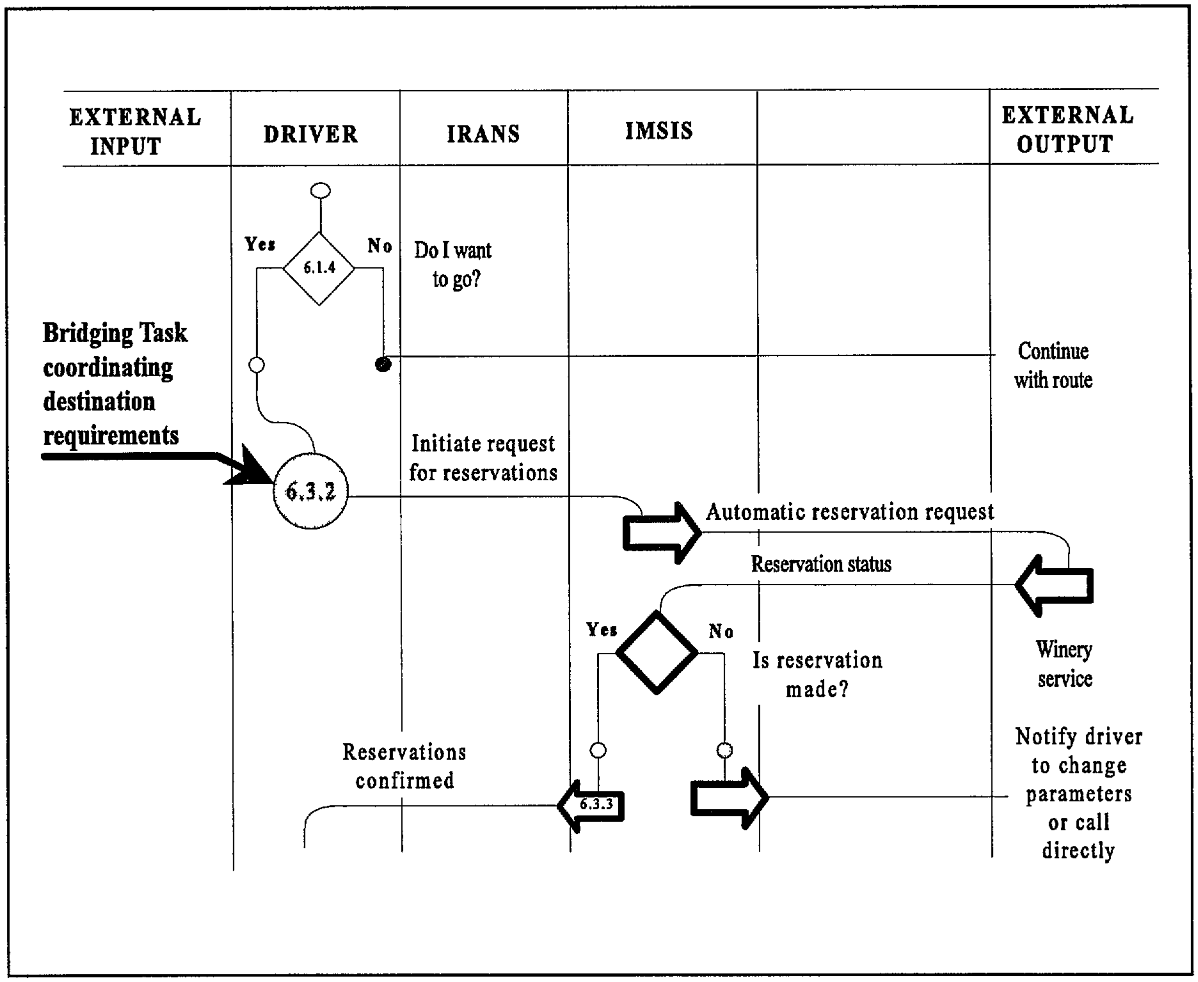


Figure 16. Bridging task coordinating destination requirements.

A third potential use of ATIS bridging tasks is as a result of recognizing that conditions may require a change in plans or their execution (see figure 17; also see appendix D, Scenarios P14 OSD, P16 OSD, and C12 OSD). This type of bridging task may involve more complex behavior than the previously discussed tasks. The initiation of new functions as a result of changed conditions often involves making changes in a route while under way or similar activities that are likely to require that the driver either enter new destination or routing parameters or that he or she review suggested route changes generated by the system. It can be anticipated that such tasks may be required while driving and, furthermore, that the circumstances requiring the change (e.g., traffic congestion or hazardous road conditions) will simultaneously increase the need for the driver to concentrate on the driving task. Such task demands undoubtedly will require that the system be designed to minimize the workload exerted on the driver, while at the same time allowing the necessary actions to be performed to initiate the new function.

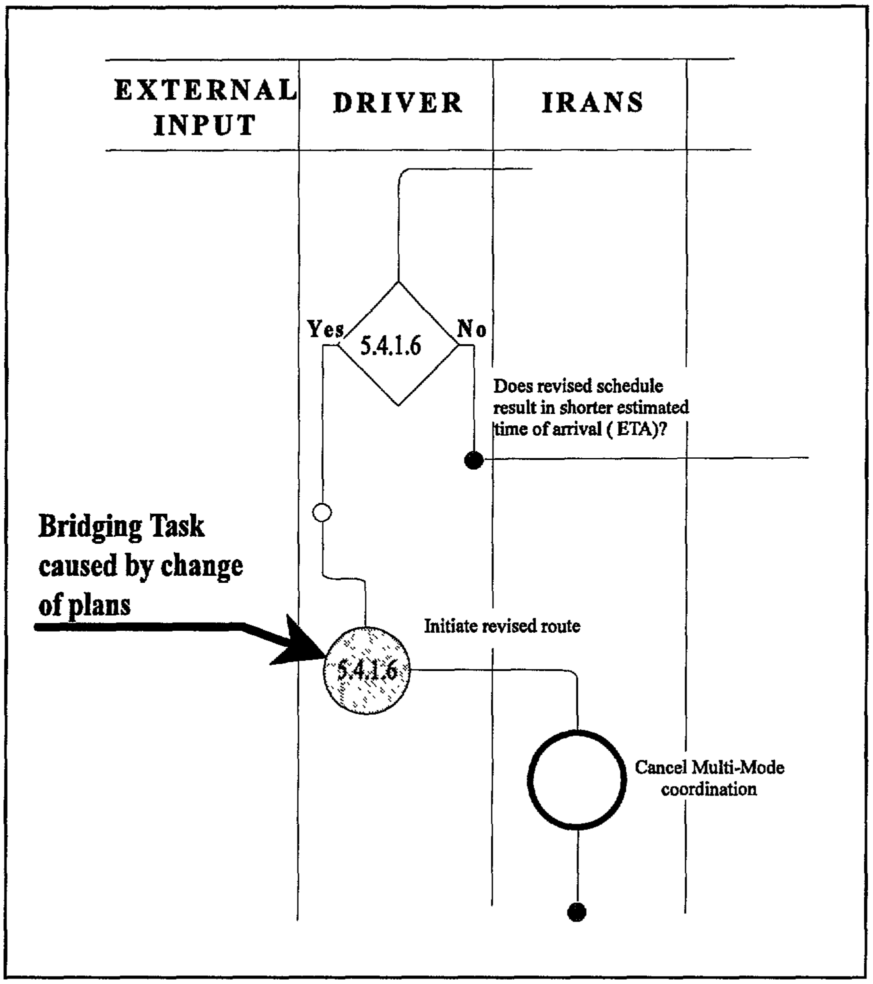


Figure 17. Bridging task caused by change of plans.

The last examined use of ATIS bridging tasks involves the execution of a function (see figure 18) that was developed by one part of the system (e.g., dispatch) but was used by another part (e.g., drivers) (see appendix D, Scenarios C12 OSD and C13 OSD). Such a task potentially involves all of the characteristics of human communications, including the inherent limitations on the accuracy of such communications.

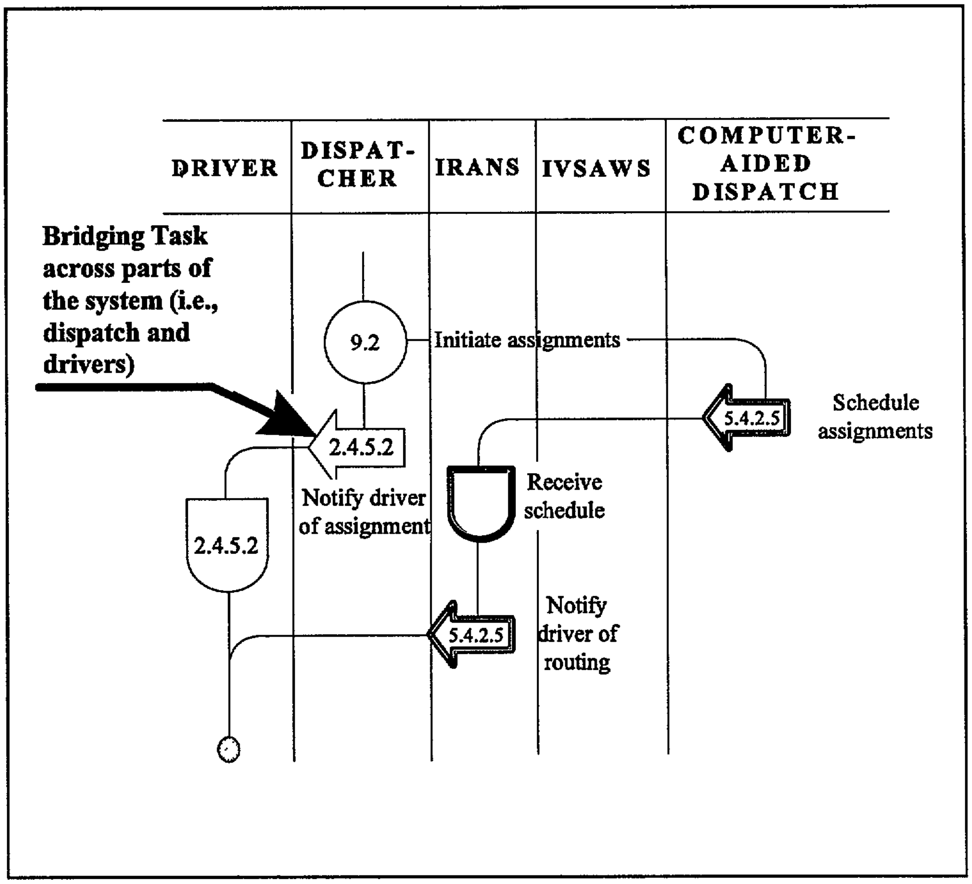


Figure 18. Bridging task across parts of the system (i.e., dispatch and drivers).

<u>Human Factors Design Implications (General and Specific)</u>

Bridging functions are, for the most part, transparent to the driver. However, in most cases, the driver still has to acknowledge his or her acceptance of the system's recommendations. The exact method of doing so will depend on system technical design. Such a design could range from manual switch activation through voice recognition. It might also include passive acceptance or acknowledgment (i.e., performing the first required action).

In most cases, following the driver's acceptance of a specific system's recommendation, the system will automatically initiate the actions. As a consequence, such activities will be transparent to the driver and will not require any specific human factors recommendations.

However, if there is a need for the system to interrogate the driver to his or her next course of actions, these interrogations should satisfy some human factors guidelines. Text presented to the driver should be made up of short sentences, should use standard terminology, and should include one request at a time.

Finally, to minimize the driver's workload, it is essential that these system's requests be limited to a small number of steps. If it becomes impossible to reduce the number of system's requests, such as in a change of plans, the system should prompt the driver with a statement indicating the need to pull over in order to continue the process.

Table 19 summarizes the general characteristics and considerations associated with bridging tasks.

Table 19. Summary of the general characteristics and considerations associated with bridging tasks.

TASK TYPE	Bridging Tasks			
FUNCTION	• Tasks that serve as an information or procedural "bridge" between two or more functions. • These tasks provide the procedural link that integrates the output of one function with the input requirement of another.			
SUBFUNCTIONS	**CHARACTERISTICS**	**HUMAN FACTORS DESIGN IMPLICATIONS**		**CAUTIONARY NOTES**
		General	**Specific**	
1. Provider of a link between planning and execution functions	• Minimal cognitive and motor processes required. • Tasks are almost transparent to the driver. • These tasks need to be preceded by a decision task.	• Need to provide a way for the driver to approve/reject system's recommendations.	• Simple control switch or minimal input steps required. • Controls within easy reach, of sufficient size, and providing positive feedback.	
2. Initiation of coordination of destination requirements	• Minimal cognitive and motor processes required. • Tasks are almost transparent to the driver.	• Need to provide a way for the driver to initiate and acknowledge system's actions.	• Simple control switch or minimal input steps required. • Controls within easy reach, of sufficient size, and providing positive feedback.	
3. Initiation of functions as a consequence of a change in plans	• Extensive cognitive and motor processes are required. • These tasks need to be preceded by a decision task.	• Input actions need to minimize workload demands on the driver.	• Short sentences and standard taxonomy are needed. • Reduced number of actions to be performed.	
4. Execution of a function developed and accomplished by two different parts of a system	• These tasks imply extensive and accurate communication capabilities across systems. • These tasks need to be preceded by a decision task.	• Accurate and extensive communication capabilities across systems. • System design needs to be compatible across systems.		

Analysis of Decision-Making Tasks

Decision making is an important part of any information system, including ATIS. The analysis of decision-making tasks is intended to provide an understanding of this type of activity with regards to ATIS.

Function of Decision-Making Tasks

Decision-making tasks provide the most important human activity in the use of ATIS. These tasks include activities where the driver or dispatcher compares alternatives against expectations, verifies that system recommendations are appropriate, and ensures that following system recommendations can be done safely. Decision-making tasks inherently involve the comparison of two conditions (e.g., system output and expected output). They also inherently result in following one of two possible (and often divergent) task sequences. Examples of decision tasks associated with ATIS include:

- A driver, who intends to take a ferry as part of his trip, reviews **a** planning schedule that includes his estimated arrival time at the ferry terminal along with when the ferry is likely to be at the same point (see appendix D, Scenario P14, Task 5.4.1.6).

- An aid car driver has planned an alternate route based on receiving indications that his selected route is congested. He decides if the alternate will actually save him time (appendix D, Scenario C12, Task 5.4.1.6).

Table 20 describes the decision-making tasks identified in the task analysis that serve several functions.

Table 20. Function and description of decision-making tasks.

FUNCTION	DESCRIPTION	EXAMPLES
1. Decision about system's plans and recommendations	• Decide if the plans and recommendations of a particular system activity, such as planning a route, are what the driver or dispatcher intended. • Give the user an opportunity to include considerations in his or her planning process that the ATIS is unable to make. • Provide the driver an opportunity to correct information or assumptions made by the system that are manifestly inappropriate. • Primarily associated with IRANS and IMSIS planning functions.	Figure 19; Appendix D, Scenarios Pl OSD, P2 OSD, P6 OSD, P8 OSD, P14 OSD, PI6 OSD, P20 OSD, and C4 OSD.

Table 20. Function and description of decision-making tasks (continued).

FUNCTION	DESCRIPTION	EXAMPLES
2. Verification of accuracy of a system's guidance recommendation	• Verify that a specific recommendation is appropriate when it is presented during the IRANS route guidance instruction.	Figure 20; Appendix D, Scenarios P1 OSD, P2 OSD, P16 OSD, P20 OSD, and C4 OSD.
3. Evaluation of system's information in regard to the driving task	• Evaluate the relevance of ISIS and IVSAWS notices and warnings as they relate to driving. • Initiated when either ISIS or IVSAWS detects a condition that lies within the notification parameters selected by the driver or system.	Figure 21; Appendix D, Scenarios P8 OSD, P14 OSD, P16 OSD, P22 OSD, and C15 OSD.
4. Recognition of a need for a change in situation.	• Recognize some change in the situation, other than that presented by ATIS, which might necessitate a change in plans or behavior. • Involve comparing the expected results of the plan currently being followed with some sort of "what if" analysis for another plan.	Figure 22; Appendix D, Scenarios P14 OSD and C12 OSD.

General Characteristics of Decision-Making Tasks

Of the 165 driver or dispatch-centered tasks examined in detail, approximately 21 percent were decision-making tasks. The decision-making tasks identified in the task analysis serve several functions. The first is that they are used to decide if the plans and recommendations of a particular system activity, such as planning a route, are what the driver or dispatcher intended (see figure 19; also see appendix D, Scenarios P1 OSD, P2 OSD, P6 OSD, P8 OSD, P14 OSD, P16 OSD, P20 OSD, and C4 OSD). Such decisions are important to the use of the ATIS because they provide the user an opportunity to include considerations in his or her planning process that the ATIS is unable to make. They also provide the driver an opportunity to correct information or assumptions made by the system that are manifestly inappropriate. This sort of decision task is normally associated with IRANS and IMSIS planning functions and would probably be performed when it could be done without interfering with the primary task of controlling the vehicle. The outcome of this task usually will be either to have the system develop another plan or to use the plan as presented.

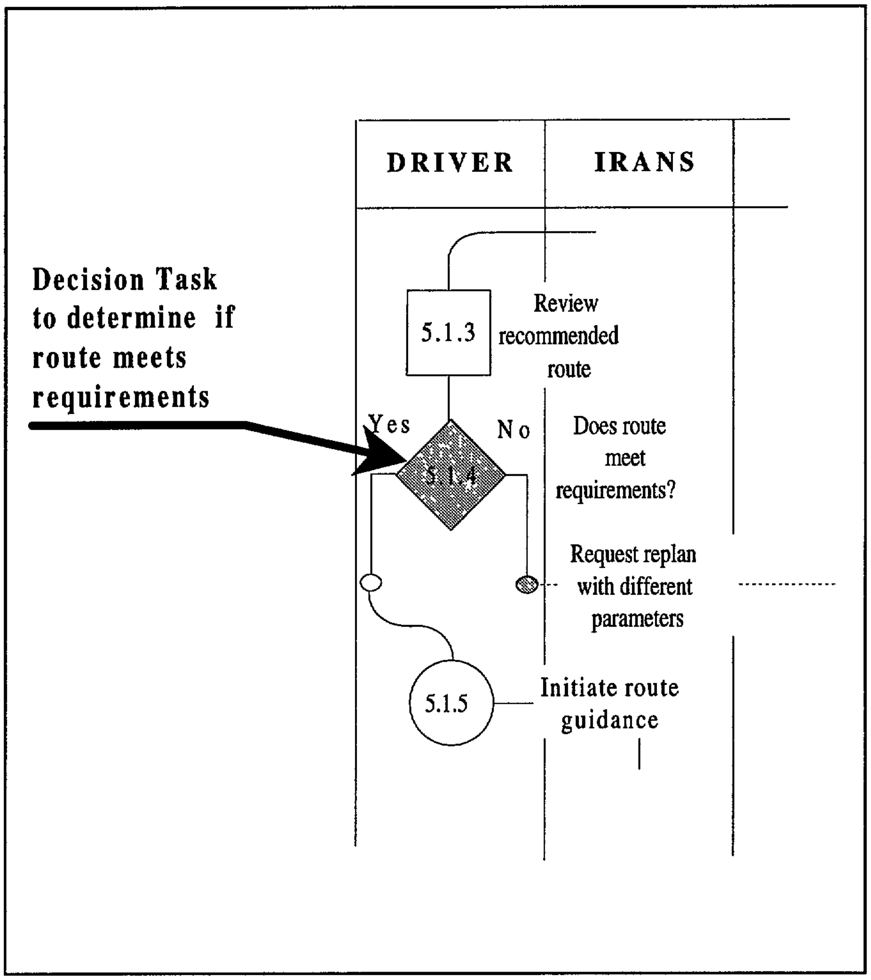


Figure 19. Decision task to determine if route meets requirements.

Another type of decision task involves verifying that a specific recommendation is appropriate when it is presented during the IRANS route guidance instruction (see figure 20; also see appendix D, Scenarios P1 OSD, P2 OSD, P16 OSD, P20 OSD, and C4 OSD). Usually such decision tasks must be performed while also controlling the vehicle, thus requiring the driver to gather information upon which to make the decision from a variety of different areas (e.g., personal experience, observations of the road configuration, and observations of other traffic).

The results of this type of task usually are to follow the recommendations presented by the system or to ignore the recommendations and revert to driving without using the system until the discrepancy between the driver's perception of the situation and system recommendations can be corrected.

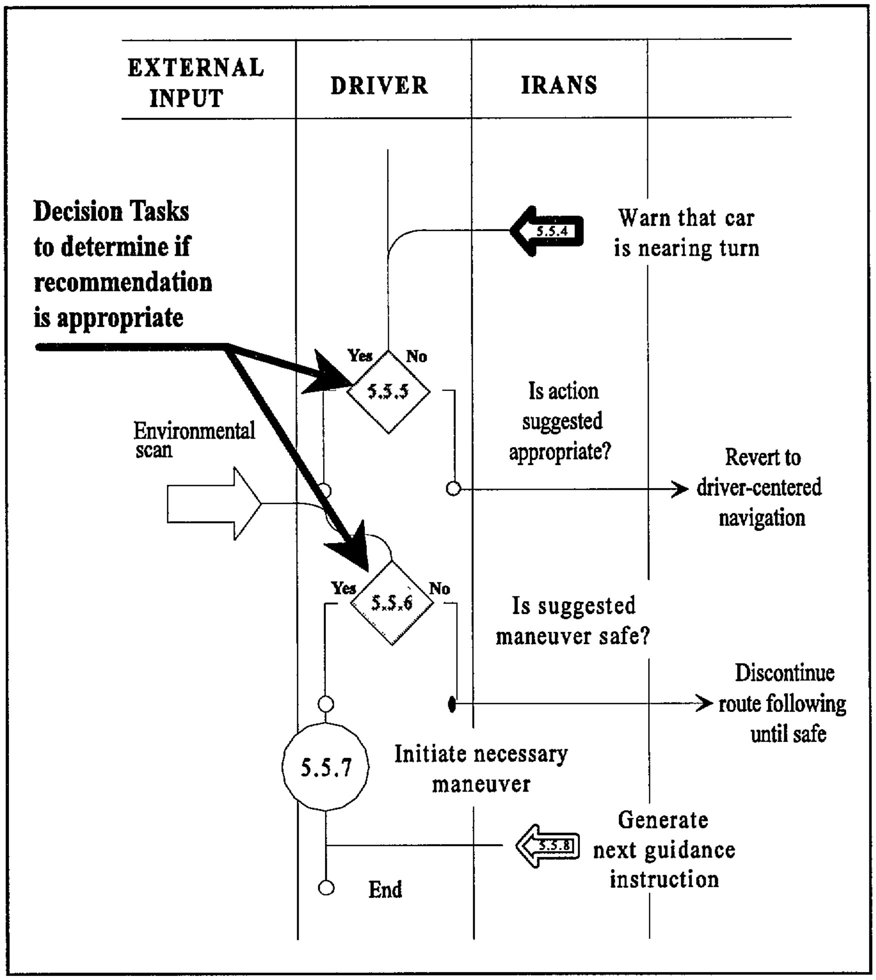


Figure 20. Decision task to determine if recommendation is appropriate.

A third type of decision task is an evaluation of the relevance of ISIS and IVSAWS notices and warnings as they relate to driving (see figure 21; also see appendix D, Scenarios P8 OSD, P14 OSD, P16 OSD, P22 OSD, and C15 OSD). Such tasks are initiated when either ISIS or IVSAWS detects a condition that lies within the notification parameters selected by the driver or system. In most cases, notification will be made as a result of the vehicle coming within a certain distance of the condition, thus requiring the driver to perform this task while controlling the moving vehicle. The outcome of a decision task of this nature may be either to ignore the notification or to modify the driving behavior or planned routing.

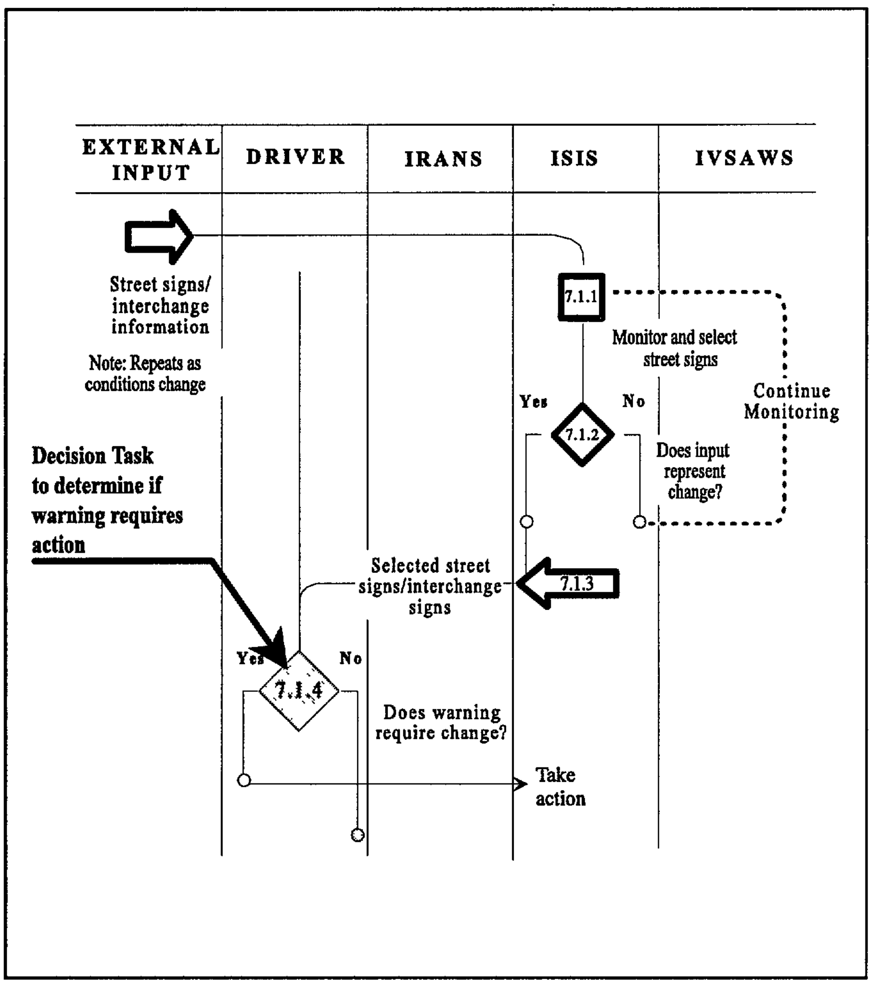


Figure 21. Decision task to determine if warning requires action.

One remaining type of decision task is evident in the detailed task analyses. This is a decision task that recognizes some change in the situation, other than that presented by ATIS, which might necessitate a change in plans or behavior (see figure 22; also see appendix D, Scenarios P14 OSD and C12 OSD). This type of task usually involves comparing the expected results of the plan currently being followed with some sort of "what if" analysis for another plan. The steps required to make such an evaluation are likely to be fairly complex as they would normally require that the driver have information on two, or possibly more, potentially competing plans. Generating those plans would normally require that the driver provide the system with different sets of parameters for developing the plans. Decision tasks of this type might be performed either while moving or when stopped. However, the need to provide the ATIS with alternative planning information would probably indicate that such decisions are most likely to be made when the vehicle is stopped, such as in a traffic backup.

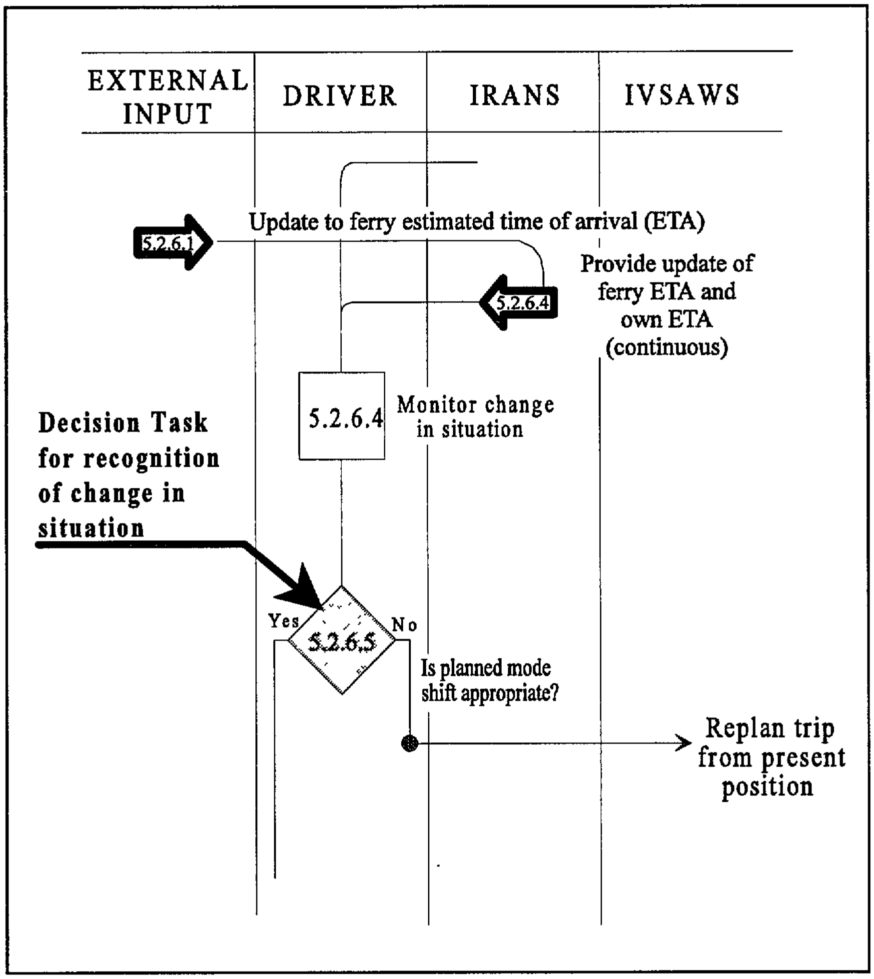


Figure 22. Decision task for recognition of change in situation.

Human Factors Design Implications (General and Specific)

Decision-making tasks such as those associated with using ATIS/CVO essentially involve comparisons between presented information and some criteria, such as knowledge, experience, or expected outcome. Although not presented in the detailed analysis due to limitations of space and the uncertainties associated with specific design possibilities, decision tasks involve a complex and often repeated series of gathering information, interpreting its meaning, and selecting from among possible alternatives. Performance on such tasks depends on the accuracy of the information as well as the thoroughness with which the driver can examine the problem presented.

Many of the decision-making tasks associated with ATIS planning functions will probably be done during the pre-drive phase of a trip, and thus afford the driver a reasonable opportunity to gather and evaluate whatever information is necessary to perform the task. Decision tasks that involve planning while also controlling the vehicle would significantly increase the workload required of the driver, both due to the intensive interaction that would be necessary to obtain information from the system and due to the cognitive load imposed by the amount of information that would be required.

Decision tasks associated with executing ATIS recommendations present similar workload concerns for the driver as when following directions given by a passenger. In both cases, the driver has to evaluate whether the instructions are appropriate and whether he or she can execute them safely. The performance characteristics of such tasks, while not at all unusual in driving without the ATIS, are of considerable importance and warrant further investigation, particularly as they are at least partially based on the driver's perception of the error rates of the system and the degree to which the driver has come to rely on system instructions.

Performance characteristics of decision tasks associated with ISIS and IVSAWS notifications and warnings are likely to be a little different than those now encountered when faced with roadside signs or hazard warnings. The principal difference is that the advanced warning that such systems can provide a driver will allow him or her more time to take appropriate action. Unlike conditions such as the IRANS planning and guidance that involve more complex decision-making processes, decisions based on ISIS and IVSAWS are likely to be straightforward and the required action is more likely to be based on a simple heuristic model (e.g., "ice = slow down" and "speed below limit = speed up").

General human factors considerations for the design of ATIS that result in decision tasks include the following:

- The system design should facilitate the review of the system's plans so that the driver can compare them with his or her mental representation of the situation.

- The system should be designed to provide a clear preview of the entire trip and this feature should be selected by the driver.

- The system should be designed so that the driver can suspend his or her use of ATIS for a period of time and resume using it without the need to restart the system.

- The system should provide a means for aiding the driver's situational awareness by allowing him or her to obtain a review of the present position or situation with regard to the plan being followed from the ATIS. The system should have the capability to constantly monitor the vehicle's position and provide an update if requested.

- The system should be designed to allow a driver to enter and modify parameters that the system uses in constructing route and other recommendations, thus limiting the range of decisions that the driver needs to consider.

- The system should present accurate and reliable information so as to limit the risk considerations that a driver needs to make when reviewing system recommendations.

- The system should provide a driver with the ability to select features that he or she can monitor (e.g., distance to go, traffic density, projected time to destination) in order to support the driver's personal decision criteria.

Specific human factors design considerations for ATIS that result in decision tasks include the following:

- The design should allow shifting between display screens or modes.

- The design should minimize the number of input steps required to obtain information needed to make or confirm decisions.

- The design should provide clear and simple representation of the system's recommendations.

- Information density should be made low through the use of appropriate icons, short sentences, and standard taxonomies.

Table 21 provides a summary of the general characteristics and considerations of decision-making tasks associated with the use of ATIS.

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Table 21. Summary of the general characteristics and considerations of decision-making tasks associated with the use of

TASK TYPE	Decision-Making Tasks			
FUNCTION	· Tasks where the driver or dispatcher compares alternatives against expectations, verifies that system recommendations are appropriate, and ensures that following system recommendations can be done safely.			
SUBFUNCTIONS	**CHARACTERISTICS**	**HUMAN FACTORS DESIGN IMPLICATIONS**		**CAUTIONARY NOTES**
		General	**Specific**	
• Decision about system's plans and recommendations	- Requires extensive cognitive skills.	• Need to facilitate the review of system's plans and its comparison with driver's mental representation of the situation. • Must present accurate information.	• Ease of navigation between screens. . Simple control switch or minimal input steps required. - Clear and simple representation of system's decisions. • Use of standard taxonomies.	These tasks might be precluded from being performed while driving.
• Verification of accuracy of a system's guidance recommendation	• Requires extensive cognitive skills. • Good knowledge of tasks to be executed. - Needs to be performed while also controlling the vehicle. • Need for the driver to gather information from a variety of areas.	• Need to facilitate the review of system's plans and its comparison with driver's mental representation of the situation. • Need to provide a clear and accurate overview of the entire trip. • Ability to stop the system's actions, revert to driving only, and eventually come back to the system's suggestions. • Ability to constantly monitor vehicle's position and provide an update if requested.	• Ease of navigation between screens. • Simple control switch or minimal input steps required to approve or reject plan. • Clear and simple graphical map illustration. • Simple control switch or minimal input steps to obtain an update of vehicle's position and route.	

Table 21. A summary of the general characteristics and' considerations of decision-making tasks associated with the use of ATIS (continued).

TASK TYPE	Decision-Making Tasks			
FUNCTION	• Tasks where the driver or dispatcher compares alternatives against expectations, verities that system recommendations are appropriate, and ensures that following system recommendations can be done safely.			
SUBFUNCTIONS	CHARACTERISTICS	HUMAN FACTORS DESIGN IMPLICATIONS		CAUTIONARY NOTES
		General	Specific	
• Evaluation of system's warning information in regard to the driving task	• Requires little cognitive skills. • Driver has a good appreciation of the driving task. • Needs to be performed while also controlling the vehicle.	• Must present accurate and reliable information. • Ability to ignore notification or to modify driving behavior or the planned routing. • Ability to select features to be monitored by the system.	. Close link with external sensors or other type of equipment in the driving environment. • Simple control switch to cancel messages or a system that makes message cancellation transparent to the driver. • Short sentences and use of standard taxonomy.	
• Recognition of a need for a change in situation	• Requires extensive cognitive skills. • Implies that the driver has a good situational awareness. • Driver has more than one plan of action.	• Ability for driver to provide the system with a different set of parameters.		These tasks might be precluded from being performed while driving.

Analysis of Tasks Integrated with Critical Driving Functions

The value and usefulness of the ATIS are found largely in the driving environment. An understanding of the interaction of ATIS/CVO tasks with the primary tasks associated with driving during critical periods is an important factor in the development of human factors design guidelines for ATIS.

Function of Tasks Integrated with Critical Driving Functions

Tasks associated with ATIS/CVO use include some that must take place in close proximity to driving tasks, such as scanning for pedestrians or obstacles, controlling the vehicle in speed and direction, and coordinating the position of the vehicle in relation to other vehicles on the road. Such tasks are of particular importance to an understanding of the design requirements necessary for ATIS/CVO systems to be used safely on the road. Examples of such tasks include:

- A driver receives guidance instructions from IRANS requiring a turn. Before making the turn, the driver must check to ensure that there are no obstacles that would prevent making the turn safely (see appendix D, Scenario P1, Task 5.5.6).

- A commercial driver receives notification that he is to get in the right-hand lane of traffic to complete weigh in motion (WIM) and other CVO regulatory information transfers (see appendix D, Scenario Cl 1, Task 7.4.3).

General Characteristics of ATIS Tasks Integrated with Critical Driving Functions

Of the 165 driver or dispatch-centered tasks examined in detail, approximately 13 percent directly involved the integration of ATIS/CVO system tasks with driving. This should not be construed in any way as an indication of the likely distribution of the various tasks that would be encountered in operational systems. Such a distribution will obviously depend on the specific design of the system and how drivers actually use it.

Although ATIS may provide information to drivers that is of interest, the real importance of ATIS use is found in the execution of the ATIS recommendations on driving behavior. In the scenarios evaluated as part of the task analysis, tasks that integrate ATIS functions with driving functions are based on two different types of requirements:

- Driving behavior responding to ATIS recommendations.

- Driving behavior resulting from ATIS notifications and warnings.

Tasks that integrate the results from the IRANS route guidance tasks with driving behavior lead to the driver maneuvering the vehicle to follow a planned route (see figure 23; also see appendix D, Scenarios P1 OSD, P2 OSD, P16 OSD, P20 OSD, and C12 OSD). Such tasks are preceded by a decision task that determines that the recommended action is safe and appropriate; they are usually followed by a resumption of the ATIS tasks.

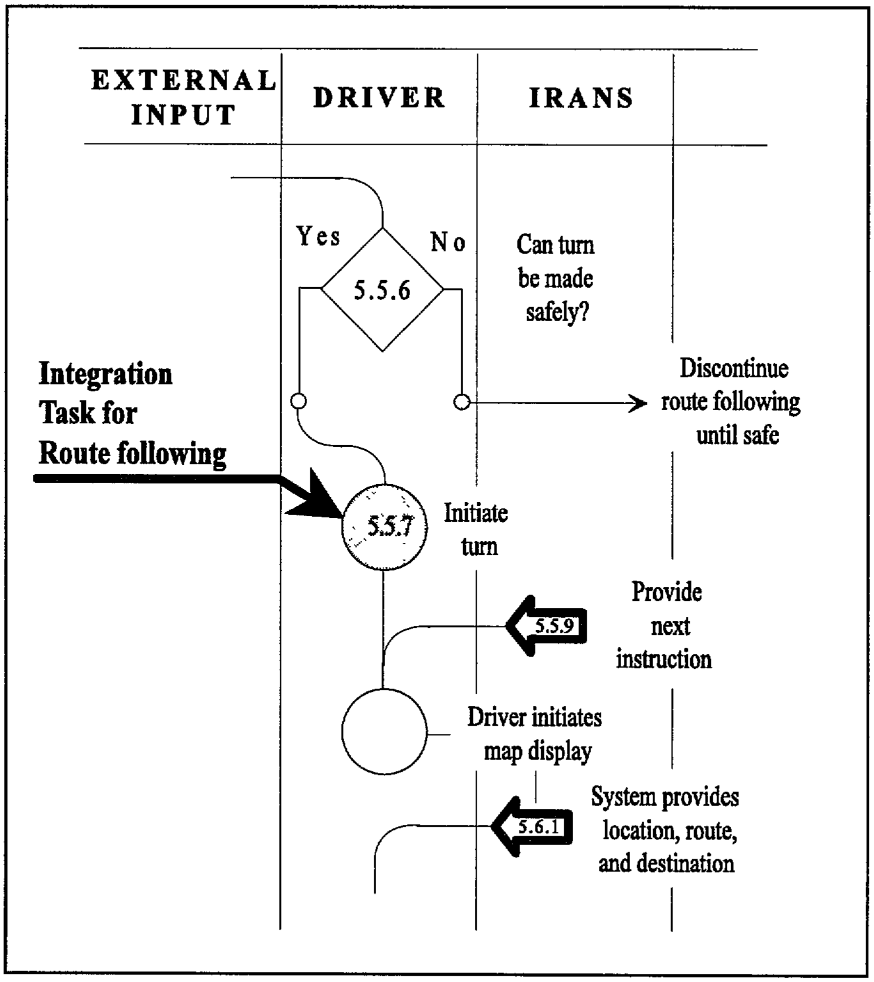

Figure 23. Integration task for route following.

Tasks that integrate the results of ISIS and IVSAWS notification and warning tasks with driving behavior result in the driver taking action based on experience and training (see figure 24; also see appendix D, Scenarios P8 OSD, P14 OSD, P22 OSD, C4 OSD, C11 OSD, and C15 OSD). Such tasks are preceded by a decision that the notification or hazard requires immediate action, and they are usually followed by modification of the planned trip.

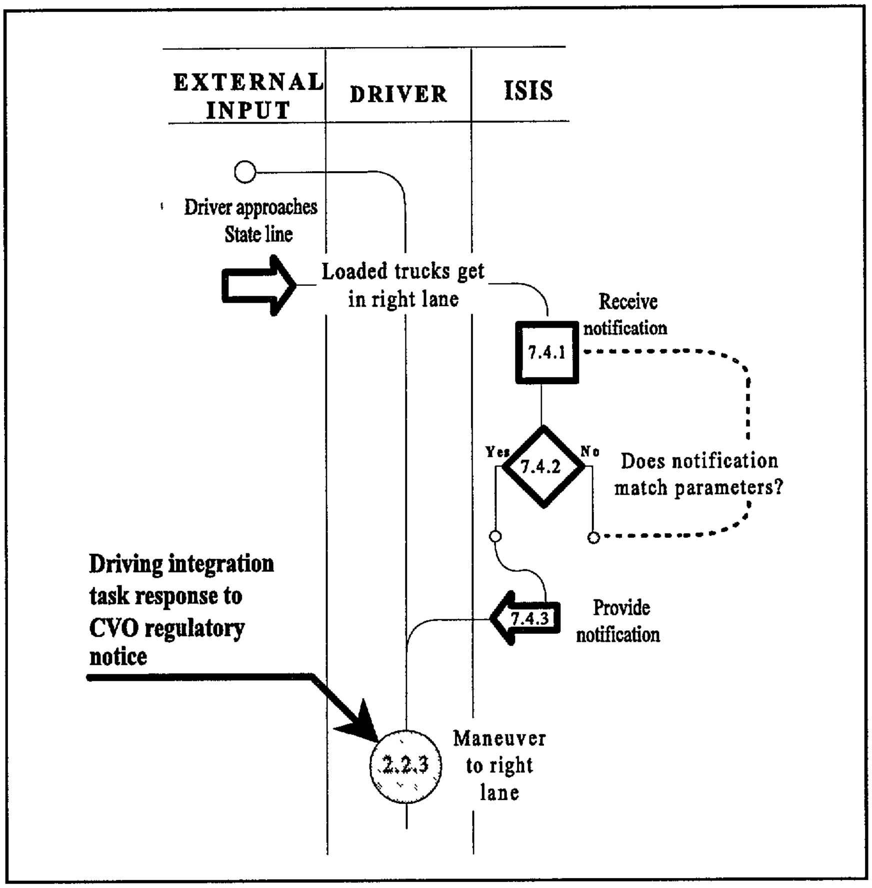

Figure 24. Driving integration task response to CVO regulatory notice.

For ease of understanding, these two sets of functions for tasks integrated with critical driving functions have been summarized in table 22.

Table 22. Summary of tasks integrated with critical driving functions.

FUNCTION	DESCRIPTION	EXAMPLES
1. Response to ATIS recommendations	The system provides a set of actions for the driver to do. These actions must be preceded by a decision task in which the driver determines if the recommended action is safe and appropriate.	• Figure 23. • Appendix D, Scenarios P1 OSD, P2 OSD, P16 OSD, P20 OSD, and C12 OSD.
2. Result from ATIS notifications and warnings	The system gives notifications and warnings to the driver who must then decide on an action based on his or her experience and training. In some circumstances, the planned trip needs to be modified.	• Figure 24. • Appendix D, Scenarios P8 OSD, P14 OSD, P22 OSD, C4 OSD, C11 OSD, and C15 OSD.

Human Fatitors Design Implications (General and Specific1

In the sequence of actions involving ATIS tasks integrated with critical driving functions, ATIS initially informs the driver of a recommendation or provides warnings or notifications of an event. In order for the recommendation or notification to be effective, it is essential that the driver be able to receive and process this information.

Upon receiving and processing this information, the driver must make a decision. This decision task must determine whether an immediate action is needed or not, or in other instances, whether the ATIS-recommended action is safe and appropriate.

Upon deciding what action to take, the driver must proceed with his or her driving tasks. Tasks that integrate ATIS functions with driving are basically vehicle control tasks. As such, when the decision has been made to execute the tasks, they both become the primary focus of the driver's attention and are within the normal range of driver performance.

Table 23 summarizes the general characteristics and considerations associated with integration tasks that involve both driving and ATE use.

Table 23. Summary of the general characteristics and considerations associated with integration tasks that involve both driving and ATIS use.

TASK TYPE	Driving Tasks			
FUNCTION	• Provide a close link between ATIS-recommended actions and the actual task of driving a vehicle.			
SUBFUNCTIONS	**CHARACTERISTICS**	**HUMAN FACTORS DESIGN IMPLICATIONS**		**CAUTIONARY NOTES**
		General	**Specific**	
1. Response to ATIS recommendations	- The driver must be able to receive and evaluate ATIS's recommendations. • Requires some cognitive processes.	• Need to provide the driver with a means to evaluate a specific recommendation in light of the entire sequence of actions. • Need to provide a window of opportunity for the driver to be able to perceive, decide, and react to the information presented.	• Ease of navigation between screens. • Simple control switch or minimal input steps required to cancel the ATIS recommendations.	
2. Result from ATIS notifications and warnings	• These tasks imply that the driver is alert and can evaluate quickly the actions to be performed.	• The information presented needs to be timely and accurate. - Need to provide a window of opportunity for the driver to be able to perceive, decide, and react to the information presented.	• Present verbal information. • Use of short sentences and standard taxonomy.	

CHAPTER 5. DISCUSSION AND RECOMMENDATIONS

DISCUSSION

The scenario task characterization process involved the systematic integration of task analysis information into operational sequence diagrams (OSDs). This process, as could be anticipated (e.g., Meister, 1985, p. 68; Baker, Johnson, Malone, & Malone, 1979), focused the attention of the task analysis participants on ATIS/CVO-related design issues. Among the most prominent of these were issues related to: (1) adverse user responses to ATIS/CVO features, and (2) molecular and molar system architecture. Considerations of these are followed by a general discussion of the identified issues and recommendations for addressing them in future work.

User Responses to ATIS/CVO Features

The task analysis process repeatedly suggested opportunities for users to respond to ATIS/CVO in ways that could have adverse consequences. Most prominent among these were opportunities for users to over-rely on the system functions:

- Blindly rely on/follow system recommendations.
- Experience transitioning difficulties when the system is inadequate for problems at hand.

The first of these overreliance problems, it is important to note, has long been known to happen with the introduction of work-aiding automation. Kletz (1985), illustrating a simple example, considers the result of providing an automated flow-cutoff valve. Pertinently, this addition was made after a tank overflow incident when an inattentive worker failed to observe that an indicator had reached “full.” This intuitively attractive automation initially appeared to provide for reducing the probability of an overfill (as the system would serve as a backup for the worker). Workers, however, began to divert their attention to other matters as they relied on the automated cutoff.

More relevant blind-following of automation can be found in other domains, particularly commercial aviation (e.g., Bittner, Kantowitz, & Bramwell, 1993). Based in part on these examples of “blind-following,” the potential for their occurrence with ATIS/CVO appears certain (unless otherwise addressed). In Scenario P6 (appendix D), for example, the task analysis team observed the possibility of a driver blindly following routes selected by IRANS into high-crime areas of an unfamiliar city. Blind-following is one user response that points toward careful considerations of the appropriate way to automate functions (cf., Kantowitz, 1993).

Transitioning difficulties, the second of the overreliance problems, can be as problematical as the first. Bittner, Kantowitz, and Bramwell (1993), again in the context of automated cockpits, point out numbers of incidents where the transition from automation to manual task accomplishment proved difficult. Among the difficulties noted were problems of even deciding when to stop relying on dysfunctional automation. Analogous ATIWCVO failures, it is noteworthy, were not specifically addressed during the present task analysis because of the astronomical numbers of modes of possible occurrence. Other transitioning difficulties occurred when pilots were required to become more involved in the control task after a long period where automation carried the decision-making load (i.e., transitioning from low workload to high workload). Alertness entering a city after driving a long open-road stretch using IRANS could, analogously, be more of a problem than currently is the case (given IRANS reductions in the navigational workload). These transitioning difficulties also require early consideration in future ATIS/CVO developments because of their profound safety implications. Fortunately, there is existing guidance for such user-centered considerations (e.g., Kantowitz, 1993).

System Architecture Issues

The task analysis process repeatedly revealed both molecular and molar architecture issues. Most prominently among the molecular issues were those concerning the nature of interfaces and coordination between ATIS/CVO elements. Regarding the interface issue, some task analysts (based in part on system proposals) could envision interfaces with linear key-entry input approaches. Others, in contrast, could envision more graphical trackball or analogous entry methods. Regardless of the arguments for and against one entry method versus another, analysts agreed that:

- Different interface natures would call on different user capabilities.

- The nature of interfaces should be common across all of the elements of ATIS/CVO.

Clearly, resolving the nature of the ATIS/CVO interfaces is a major issue for their successful implementation and remains to be addressed in future work. The results of the present task analysis efforts should prove useful in future work aimed at resolving the interface issue, as they were conducted at the level just above where the interface nature is specified.

The task analysis process repeatedly identified a second molecular issue regarding the coordination between ATIS/CVO elements. Illustrating this, for example, are the transitions between IMSIS and IRANS in Scenario P6 (appendix D). If, as could be the case, the information from IMSIS (e.g., potential places to spend the night) could not readily be transferred to IRANS, then the driver would have to externally record the relevant information and reenter it into IRANS (for assistance in navigating). This, of course, would require a good deal of driver effort and thereby severely reduce the utility of IMSIS and IRANS. However, the results of the present task analysis efforts should also prove useful in future work aimed at ensuring coordination across system interfaces. The transitions between ATIS/CVO elements (e.g., &ISIS to IRANS) are clearly seen in the scenario descriptions (OSDs) and could be used to identify information that should be passed between system components.

Most prominent of the molar design issues were those concerning overall system architecture. First, much as it was clear that the nature of interfaces should be common across all of the elements of ATIS/CVO, it was also clear that the overall architecture needs to be consistent. Changes in architecture, albeit with nominally consistent interfaces, can be expected to result in subtle differences in the way that users must interact with separate system elements. From cockpit automation experiences, such subtleties have been found to lead to hazardous conditions (particularly if not consistent across differing vehicle models used by an operator) Bittner, Kantowitz, & Bramwell, 1993. Second, in addition to overall system consistency, it was also clear that there is a requirement for overall hierarchical information resolution/integration across the various components. For example, to begin to appreciate this second requirement, consider the relatively simple problems of overlapping information regarding an approaching intersection:

- ISIS provides sign-notification information (e.g., cross-street name).

- IRANS provides present location information (i.e., conflicting cross-street name) from a different data base.

Compounding this, moreover, may be a further cacophony of additional overlapping and related intersection information; for example:

- IVSAWS warning of a construction area and an accident at the construction site.

- IRANS providing information regarding an associated traffic backup (resulting from the accident).

- IVSAWS alerting of an on-coming emergency vehicle (ambulance in response to accident injuries).

Clearly, handling this bulk of information in a way that will not overwhelm drivers is a challenging issue. Consequently, not broadly addressing this second issue could, like the first, result in a significant reduction in the utility of ATIS/CVO These two molar architecture issues together have an impact on the molecular issues discussed earlier and should be considered as part of future ATIS/CVO developmental efforts.

Conclusions

The scenario task characterization process, as seen above, has led to the identification of a number of significant issues affecting the future success of ATIS/CVO. Among these were issues regarding adverse user responses to ATIS/CVO features and molecular and molar system architecture. Although not commonly documented, such issue identification results from the task characterization processes were expected (Meister, 1985; Baker, Johnson, Malone, & Malone, 1979). Indeed, the task characterization team strove to capture these significant issues as they emerged, in keeping with the unique system requirements concerns (e.g., Bittner, Kantowitz, & Bramwell, 1993).

Efforts were also made during task analysis team deliberations to capture recommendations for addressing issues as they emerged. For example, after delineating the issue of information coordination between ATIS/CVO elements, further considerations were captured on how transitions (apparent in the OSDs) could be employed to identify information requiring such coordination.

RECOMMENDATIONS CONCERNING HUMAN FACTORS DESIGN GUIDELINES

The results of the task analysis highlighted several areas that should be addressed in the human factors design guidelines for ATIS. These were gleaned primarily from the summary analysis that was done of all the task analyses. They are as follows:

- Access to functions and features should be based on an assessment of the combined workload requirements of each feature and the likely driving conditions that would encourage use of the function.

- Both the information requested of the system and the display provided when making system recommendations should be compatible with other demands on the driver at the time, even though this might mean that system recommendations would be less than optimal.

- Use of preference profiles for individuals and situations should be encouraged to reduce setup time for the driver.

- Preferences set by the driver should be designed to require drivers to select a preference rather than exclude a preference. This would reduce the number of features, notifications, and warnings presented to the driver.

- Setup features that involve entry of specific information by the driver, such as street names and addresses, should include checking functions that will assist the driver in identifying errors and correcting the entry. Since the driver may or may not have precise information available when initiating the system, this checking function should provide logical alternatives to an error, when available.

- Setup features for IRANS should include the ability to enter and retain short lists of destinations and routes frequently used (e.g., work, home, etc.).

- Destination selection should include the possibility of the driver using successive approximation approaches to destination selection. Such an approach would allow the driver to receive guidance to a general area (e.g., a downtown district) and then to use IMSIS broadcast services or the services directory to select a final destination.

- Route review and approval requirements should be supported by a display that depicts the whole or large parts of the recommended route on a single display.

- Alternative methods for entering destination information (e.g., bar coding of business cards, cross-referenced with telephone numbers and pre-loaded smart cards) other than direct entry by the driver should be supported and encouraged.

- A standard taxonomy of IMSIS categories should be developed and used throughout the data bases.

- System design should include positive indications to the driver that a change of function (e.g., shift from planning to route guidance, or change in destination routing) has occurred following driver actions that initiate such a change.

- Provisions should be made in the system to allow the driver to not only review a proposed route, but to review the assumptions made by the system to establish that route.

RECOMMENDATIONS CONCERNING EMPIRICAL RESEARCH

The task analysis helped identify areas where insufficient information is available on the way that drivers are likely to perform using ATIS/CVO The following issues are considered important areas for future research concerning ATIS/CVO use:

- The effect of ATIS/CVO route guidance instructions on maintenance of driver vigilance for obstacles and recognition of inappropriate instructions (e.g., directed the wrong way on a one-way street) is unknown.

- Navigation strategies used for ATIS route guidance that focus on the destination are different than those normally used by drivers who tend to focus on the successive process of approaching a destination by using a series of recognizable waypoints. How the prolonged use of destination-focused approaches will affect driver reliance, comfort, and use of ATIS/CVO needs to be explored both in terms of driver acceptance and driver stress.

- Under some conditions, ATIS/CVO requirements are likely to exceed the availability of the driver to do them (e.g., a driver is unable to make a required turn due to traffic). Since efficient use of ATIS will depend on an understanding of the best strategies for recovering from this type of event, it is important to understand how drivers deal with such events now and how ATIS might be used to improve such strategies.

- ATIS/CVO devices may require significant visual attention, leading drivers to attend to in-vehicle sources of information at the expense of environmental information. The time and attention demands of various ATIS tasks must be quantified relative to that required for driving. The task analysis illustrated that little is known about the time and attention requirements of ATIS devices.