U.S. Department
of Transportation
**Federal Highway
Administration**

Publication No. FHWA-RD-95-176
November 1996

# 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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## 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

Technical Report Documentation Page

| 1. Report No. FHWA-RD-95-176 | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle<br><br>DEVELOPMENT OF HUMAN FACTORS GUIDELINES FOR ADVANCED TRAVELER INFORMATION SYSTEMS AND COMMERCIAL VEHICLE OPERATIONS: TASK ANALYSIS OF ATIS/CVO FUNCTIONS | | 5. Report Date<br><br>November 1996 |
| 7. Author(s)<br><br>W. Wheeler, J. Lee, M. Raby, R. Kinghom, A. Bittner, M. McCallum | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br><br>Battelle<br>4000 41st Street NE<br>Seattle, Washington 98105 | | 10. Work Unit No. (TRAIS)<br><br>3B2C<br><br>11. Contract or Grant No.<br><br>DTFH61-92-C-00102 |
| 12. Sponsoring Agency Name and Address<br><br>Office of Safety and Traffic Operations R&D<br>Federal Highway Administration<br>6300 Georgetown Pike<br>McLean, VA 22101-2296 | | 13. Type of Report and Period Covered<br><br>TECHNICAL REPORT<br>June - November 1993<br><br>14. Sponsoring Agency Code |
| 15. Supplementary Notes<br><br>Contracting Officer's Technical Representative (COTR) - Joseph Moyer, HSR-30 | | |

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.

| 17. Key Words<br><br>Advanced Traveler Information System (ATIS); Commercial Vehicle Operations (CVO); Intelligent Vehicle-Highway Systems (IVHS) | | 18. Distribution Statement<br><br>No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161. | |
|---|---|---|---|
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>434 | 22. Price |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

# 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 $m^3$.

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **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.<br>· Prior function analyses that have been conducted for private and commercial vehicle operations.<br>· ATIS descriptions and characteristics.<br>· Advanced commercial vehicle system descriptions and characteristics. |
| Task B - Identify System Objectives and Performance Requirements | · ATIS/CVO system objectives.<br>· ATIS/CVO system design characteristics (present and future).<br>· ATIS/CVO performance specifications. |
| Task C - Define Functions | · Results of the function analyses of private/commercial vehicle functions (after comparison of system analysis).<br>· Results of the investigation of technical constraints on private/commercial vehicle systems.<br>· Results of the investigation of human constraints on private/commercial vehicle operators.<br>· 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.

<u>Observations of CVO, AVL, and Satellite Communications Systems</u>

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<br>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<br>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<br>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<br>Route guidance<br>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<br>ISIS<br>IVSAWS | Pre-drive route and destination selection<br>Roadway guidance sign information<br>Roadway notification sign information<br>Roadway regulatory sign information<br>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<br>IVSAWS | Roadway notification sign information<br>Immediate hazard warning<br>Road condition information<br>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<br>IVSAWS | Dynamic route selection<br>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<br>IVSAWS | Roadway regulatory sign information<br>Immediate hazard warning<br>Automatic aid request<br>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.

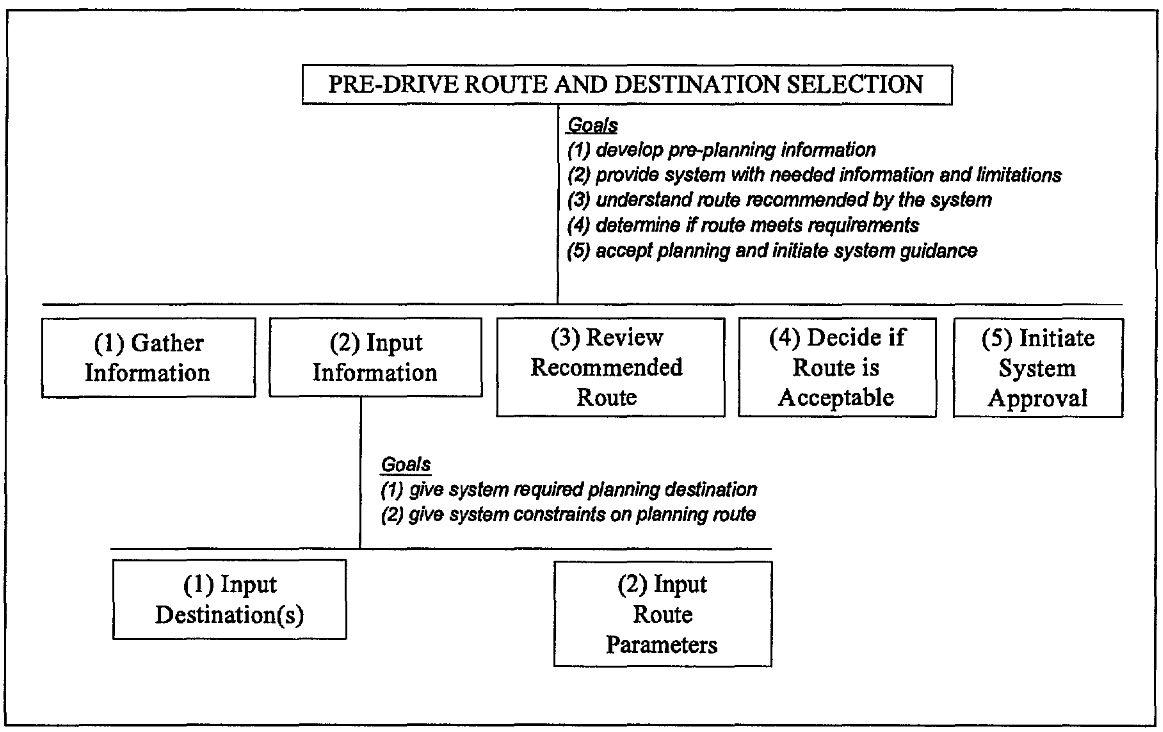



**Figure 1. Hierarchy of tasks involved in IRANS function "pre-drive route and destination selection."**

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.

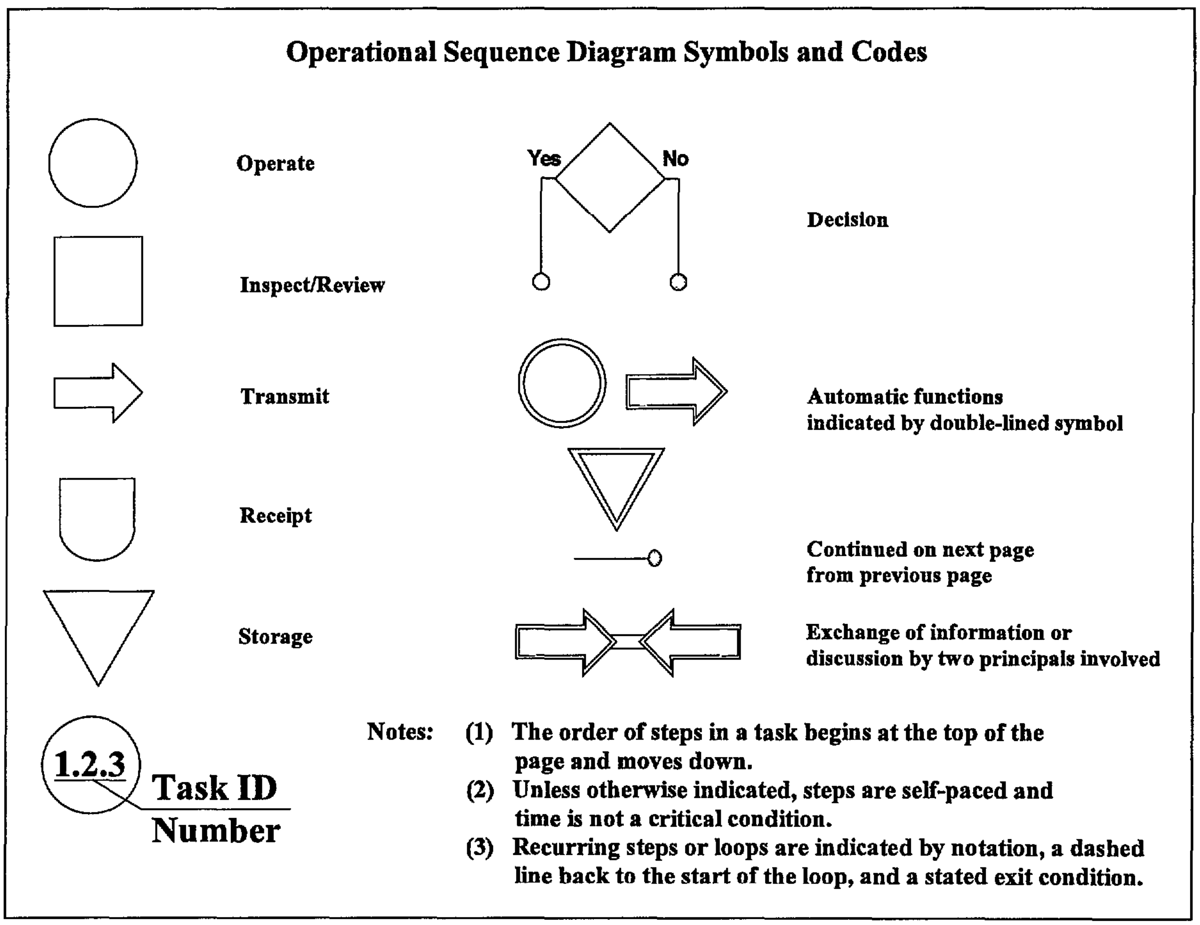



**Figure 2. Standard operation symbols.**

## 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.<br>Audio signals must be distinct enough in onset, frequency, amplitude, and duration to exceed a driver's threshold of noticeability.<br>Visual signals must be sufficiently large to be seen by the driver.<br>Visual signals must lie within the normal or peripheral scan of the driver.<br>Visual signals should not be apportioned between different displays. |
| Input Select | Workload must be low enough to allow driver to make selection.<br>Required input to be selected must not be masked by other tasks. |
| Filter | Relevant signals/information must be distinct from irrelevant information.<br>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.<br>Information presented must be consistent with user's understanding of system goals. |
| Code | Motor actions required must be within human capabilities.<br>System input requirements must be compatible with user's knowledge base.<br>System input requirements must not require user translation.<br>System input actions must not exceed short-term memory limitations. |
| Plan | System requirements must allow adequate time for necessary execution.<br>System must provide necessary information for user to make informed choices.<br>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.<br>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.<br>System must provide output of recommendations without exceeding short-term memory limitations.<br>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.<br>System recommendations must be consistent with driver's experience.<br>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).<br>System must provide driver with indications of action completion.<br>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.<br>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.

- <u>Audio signals must be distinct enough in onset, frequency, amplitude, and duration to exceed a driver's threshold of noticeability (Detect)</u>. 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.

- <u>Visual signals must be sufficiently large to be seen by the driver (Detect)</u>. 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).

- <u>Visual signals must lie within the normal or peripheral scan of the driver (Detect)</u>. 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.

- <u>Visual signals should not be apportioned between different displays (Detect).</u> 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.

- <u>Workload must be low enough to allow driver to make selection (Input Select).</u> 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<br>5.2 Multi-mode travel coordination<br>5.3 Pre-drive route and destination selection<br>6.2 Services/attractions directory<br>6.3 Destination coordination |
| 2. DRIVE | |
| 2.1 Nayigation and Routing | |
| 2.1.1 Wayfinding | 5.5 Route guidance<br>5.6 Route navigation<br>7.1 Roadway guidance sign information |
| 2.1.2 Route Modification | 5.4 Dynamic route selection<br>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<br>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<br>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<br>8.5 Vehicle condition monitoring |
| 2.5 Emergency Response | 8.3 Automatic aid request<br>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<br>9.2 Dispatch<br>9.3 Regulatory administration<br>9.4 Regulatory enforcement |
| 1.3 startup | |
| 1.4 Auxiliary System | |
| 1.5 Planning | 5.1 Trip planning<br>5.2 Multi-mode travel coordination<br>5.3 Pre-drive route and destination selection<br>5.8 Route scheduling<br>6.2 Services/attractions directory<br>6.3 Destination coordination |
| 2. DRIVE | |
| 2.1 Navigation and Routing | |
| 2.1 .1 Wayfinding | 5.5 Route guidance<br>5.6 Route navigation<br>7.1 Roadway guidance sign information |
| 2.1.2 Route Modification | 5.4 Dynamic route selection<br>6.1 Broadcast services/attractions<br>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<br>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<br>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<br>8.5 Vehicle condition monitoring<br>8.6 Commercial vehicle and cargo monitoring |
| 2.5 Emergency Response | 8.3 Automatic aid request<br>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.

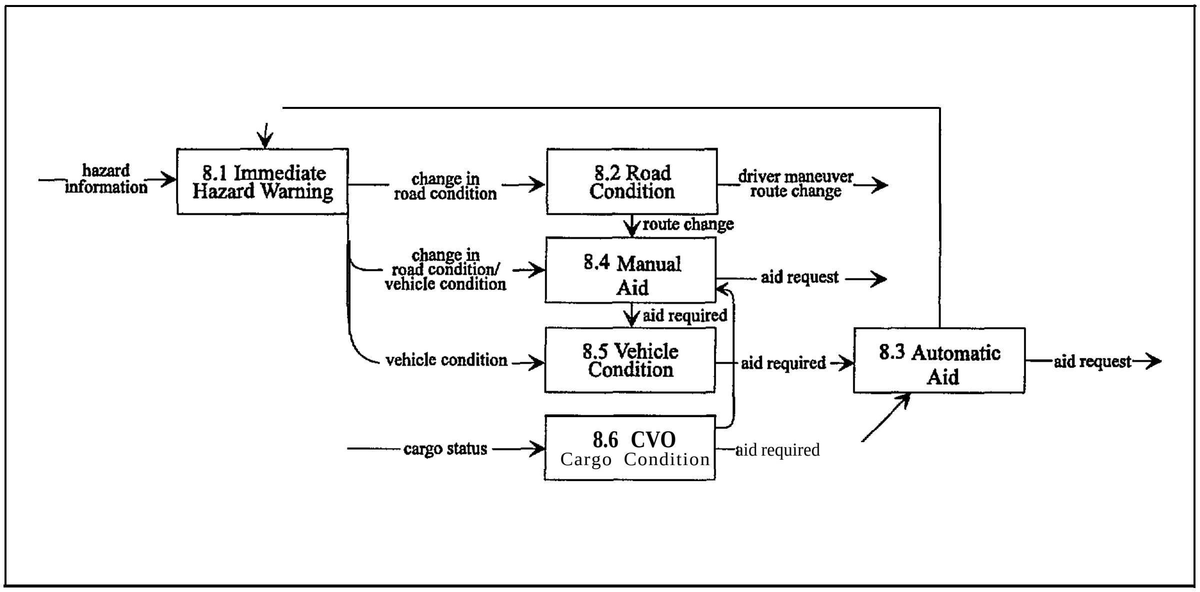



**Figure 3. Interactions between the functional characteristic “immediate hazard warning” and other IVSAWS components.**

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.

- <u>Private Driving Scenario Pl</u>

  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

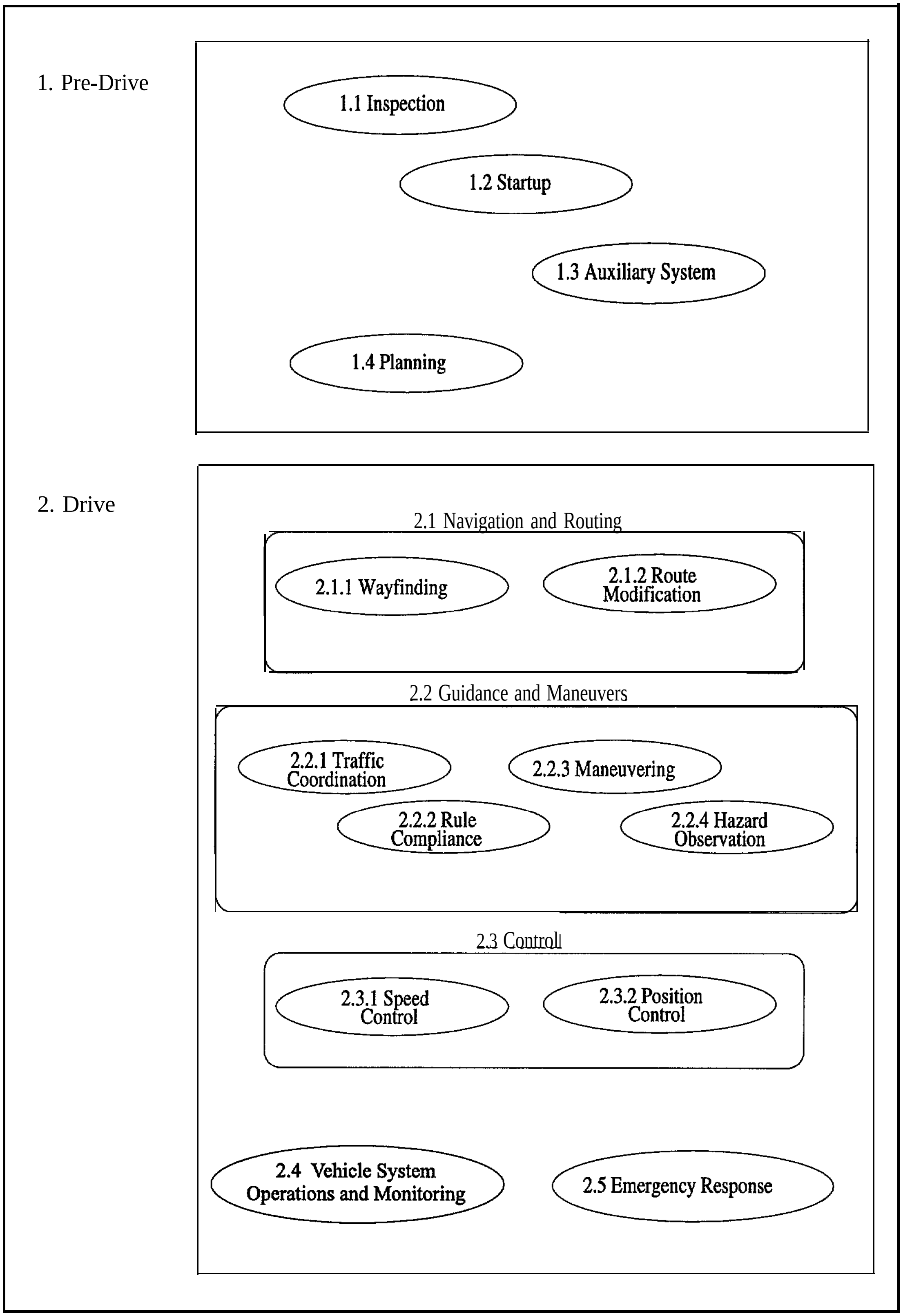
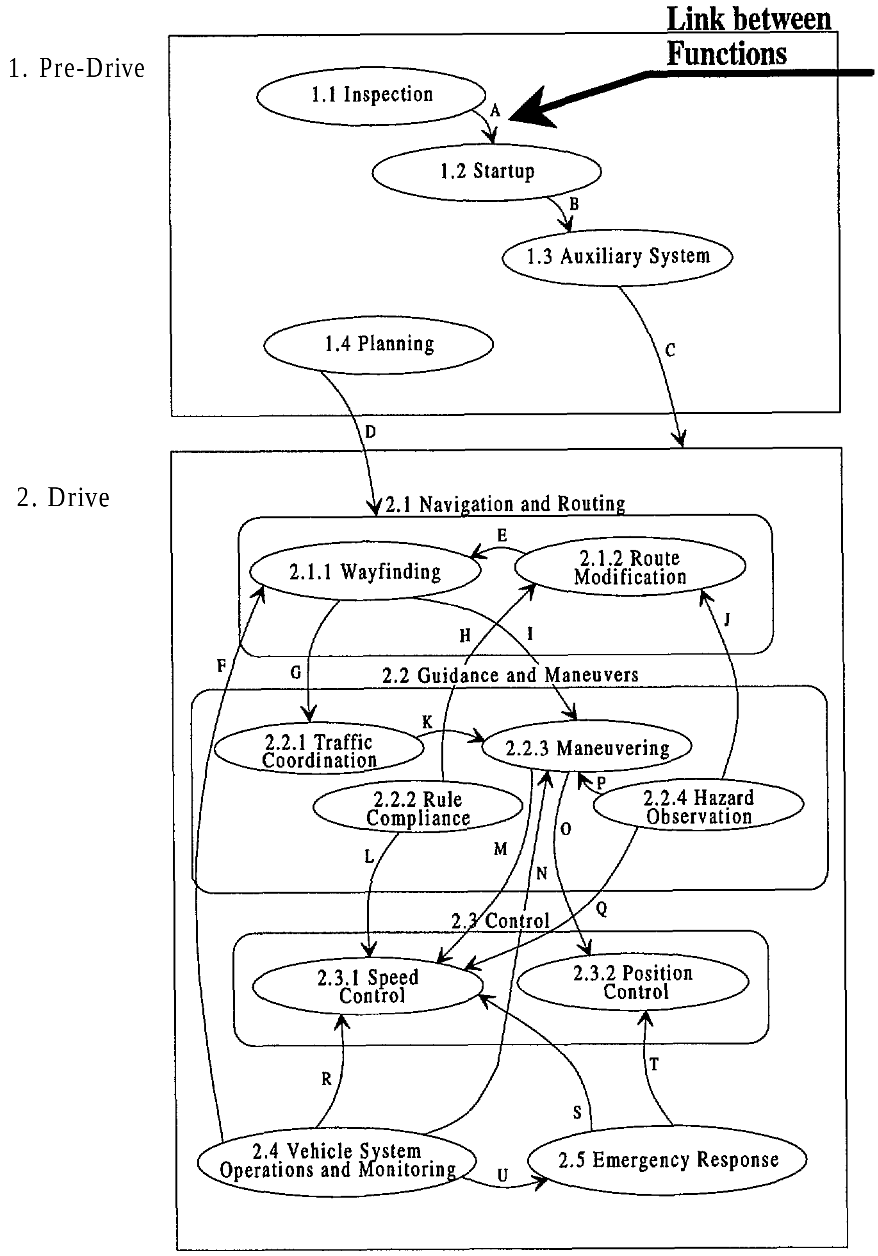



**Figure 4. Example of nested driving functions.**




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.

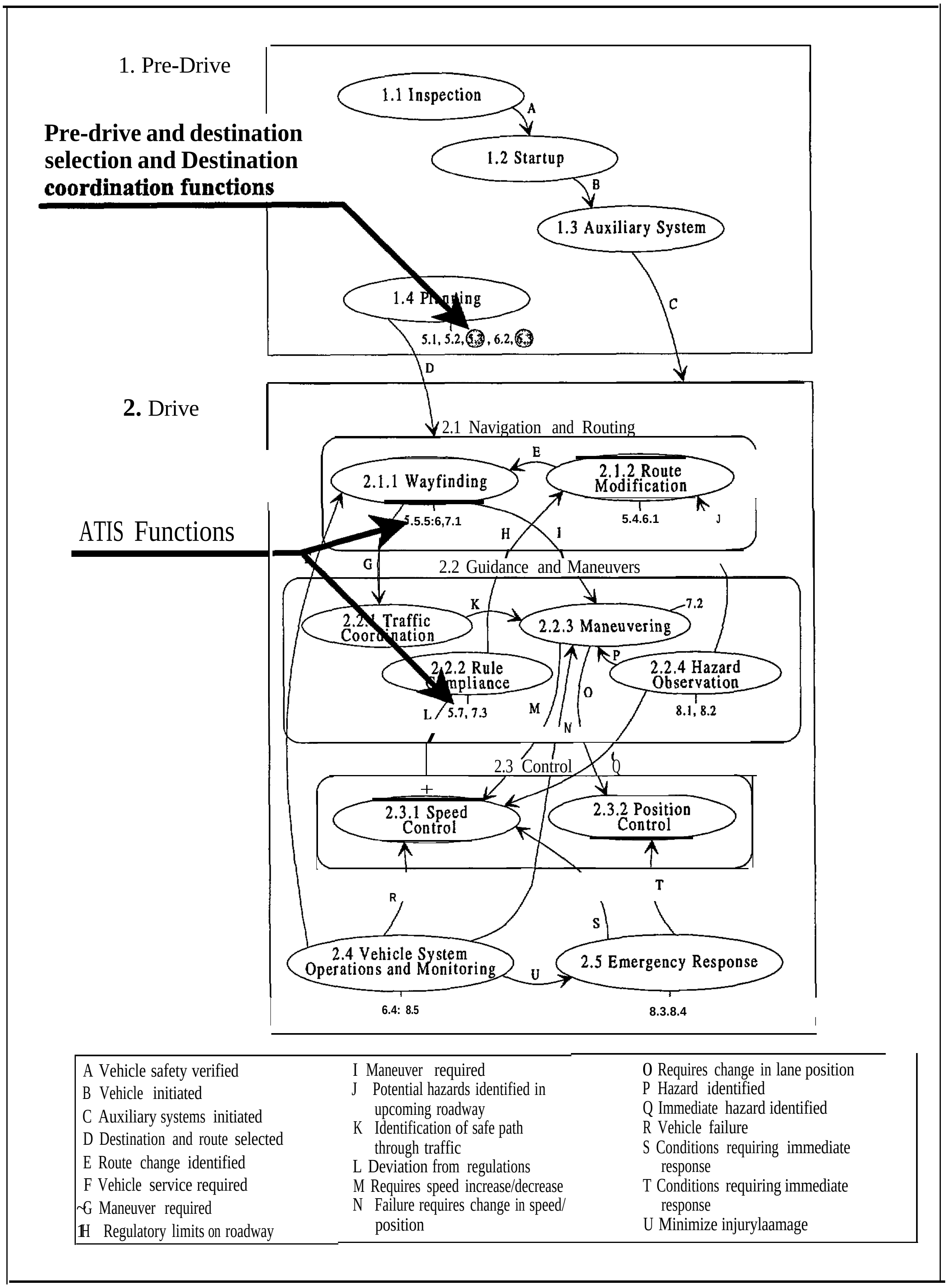



**Figure 6. Example of integrated ATIS-specific and driving-specific tasks.**

## Interactions Between ATIS-Specific Tasks

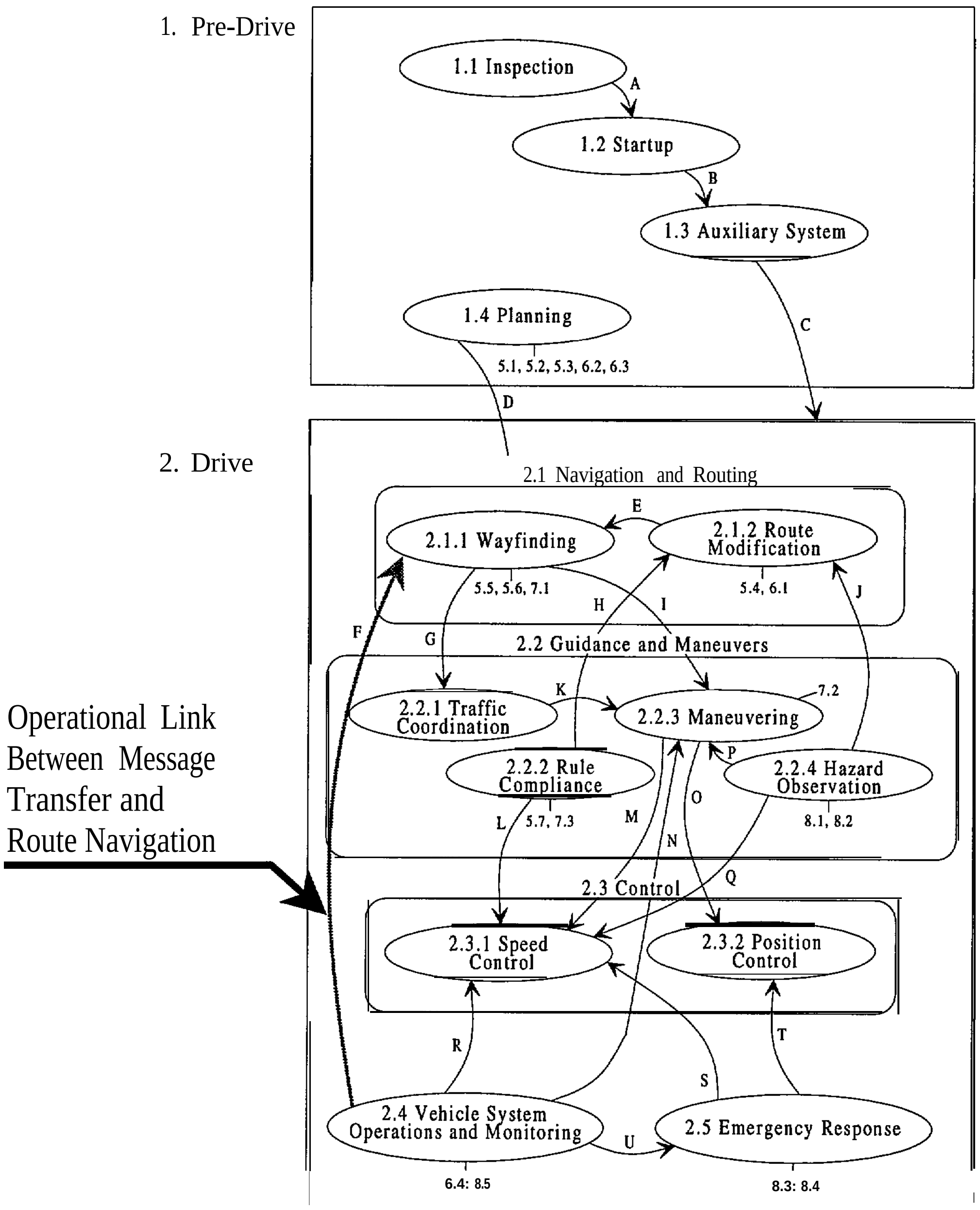
Interactions between ATIS-specific tasks are an important consideration because they can lead to unnecessary tasks (i.e., entering data manually that could be transferred from function to function automatically). By examining the information flows and requirements, unnecessary tasks can be eliminated 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




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 traffic
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 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

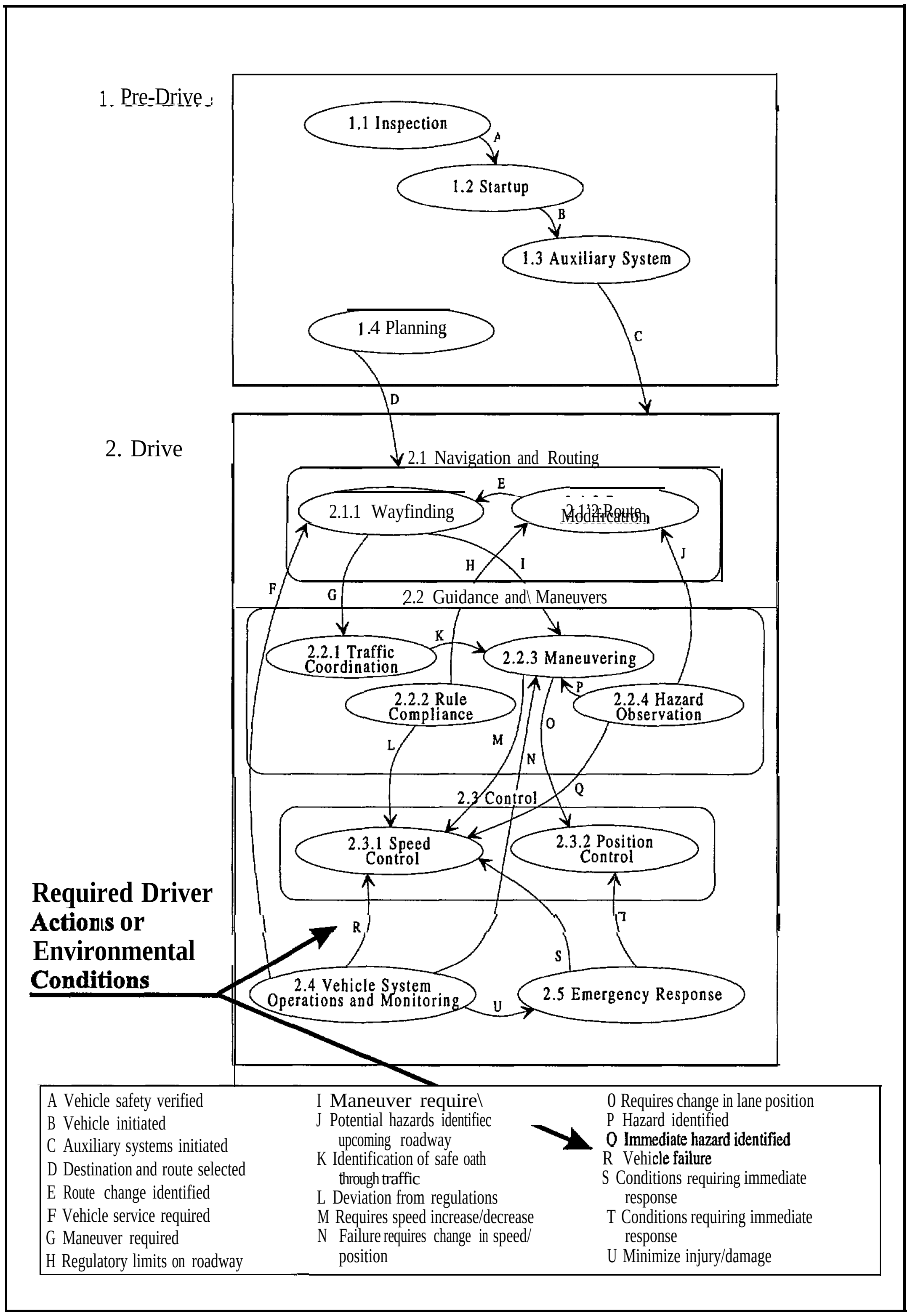



**Figure 8. Example of integrating ATIS information and commands into driving behavior.**

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.

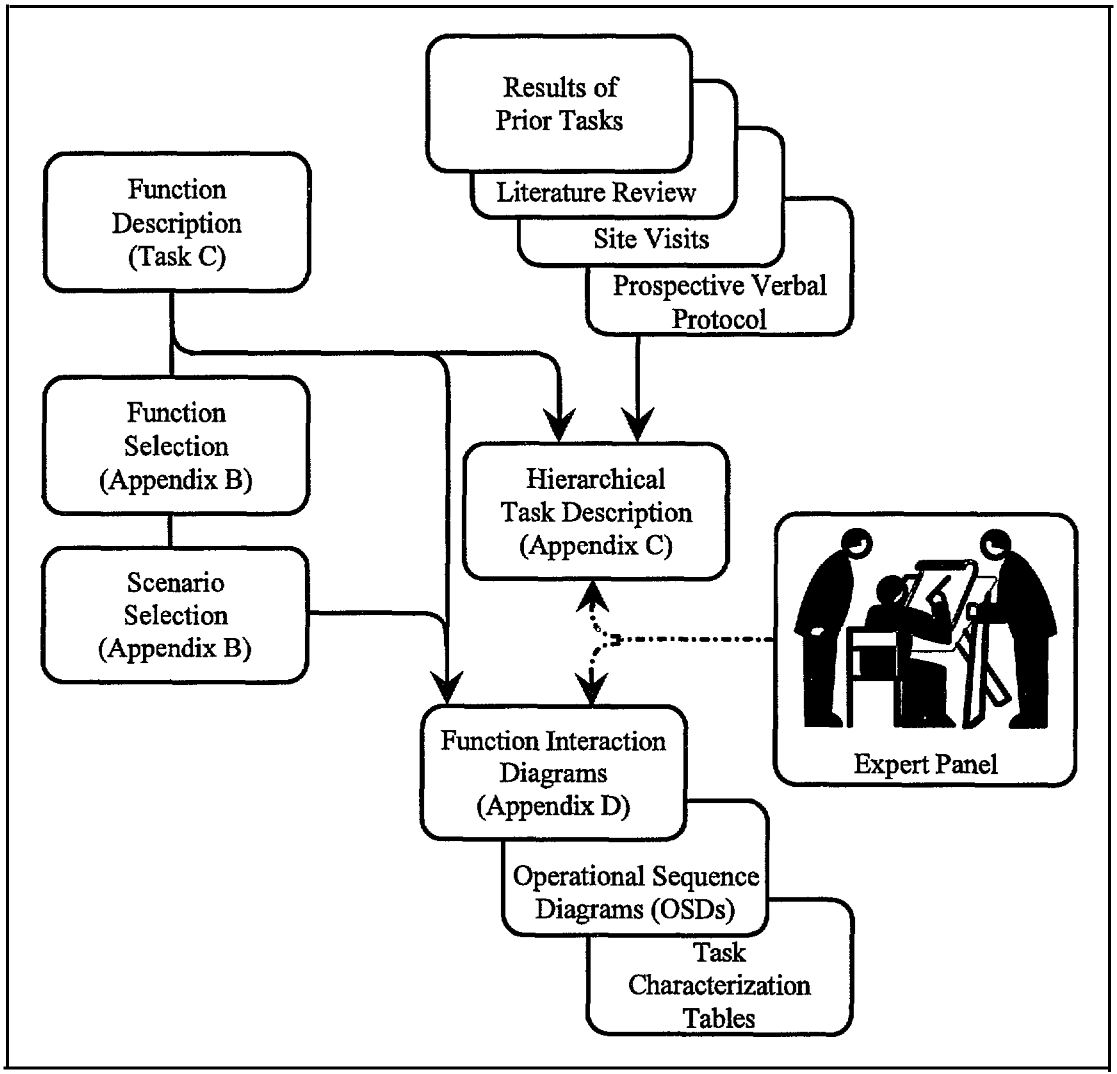



**Figure 9. Results of prior tasks.**

## 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.<br>• 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.<br>• 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.<br>• 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.

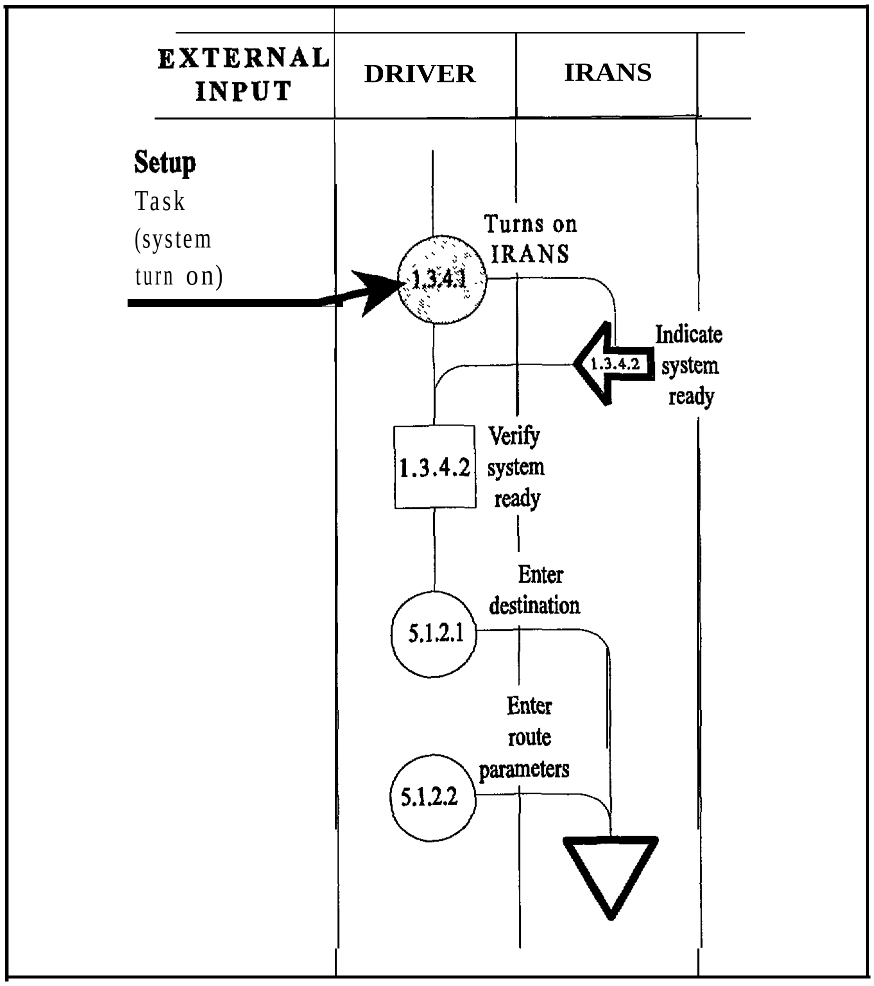



**Figure 10. Example of setup task (system turn on).**

Setup tasks that are critical to performing a function (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).

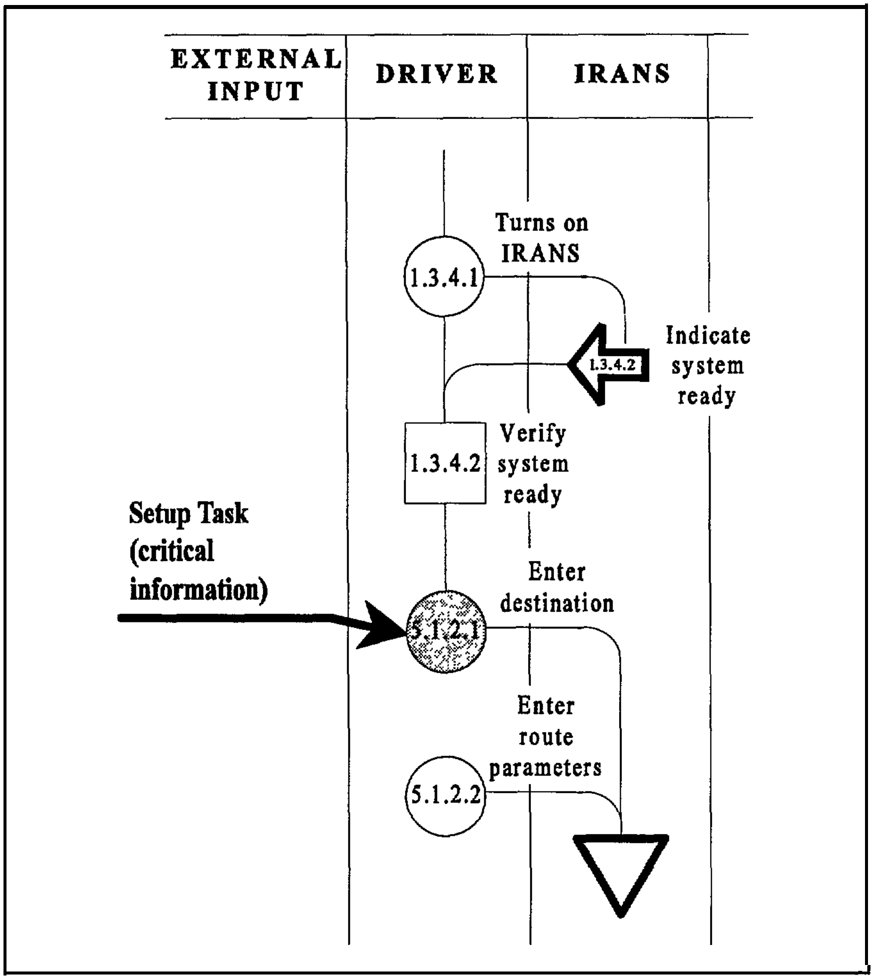



**Figure 11. Example of setup task (critical information).**

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.

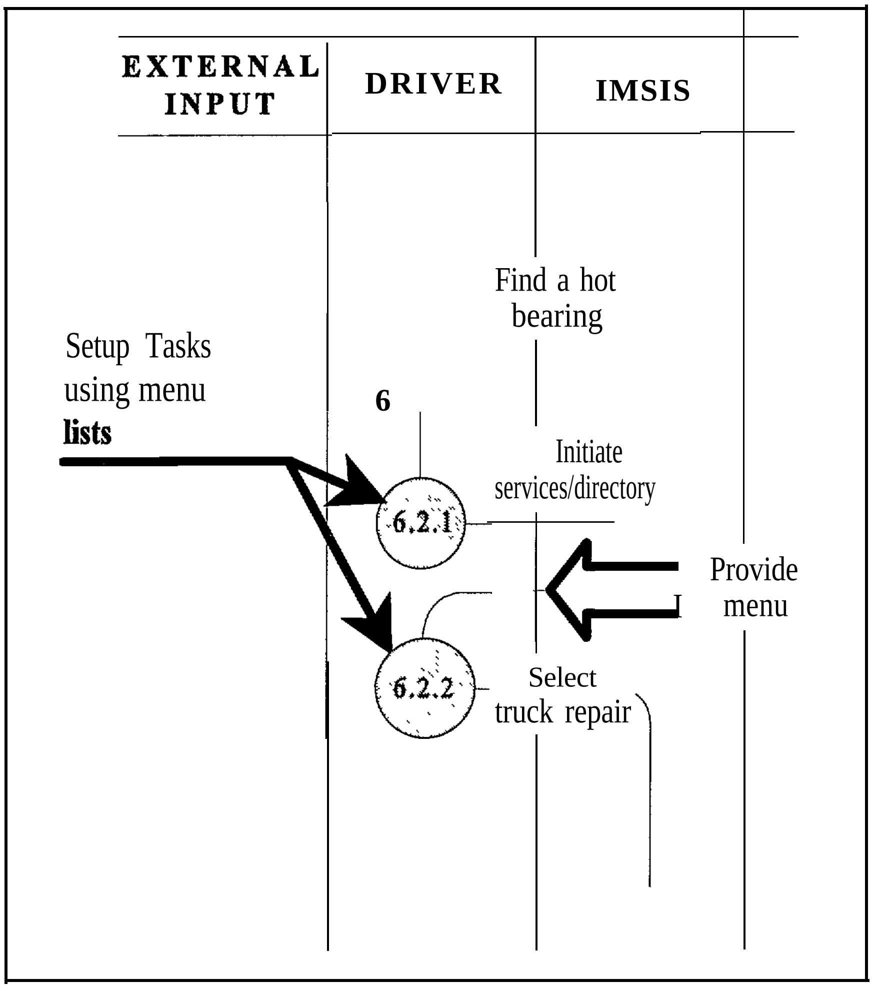



**Figure 12. Example of setup task using menu lists.**

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.

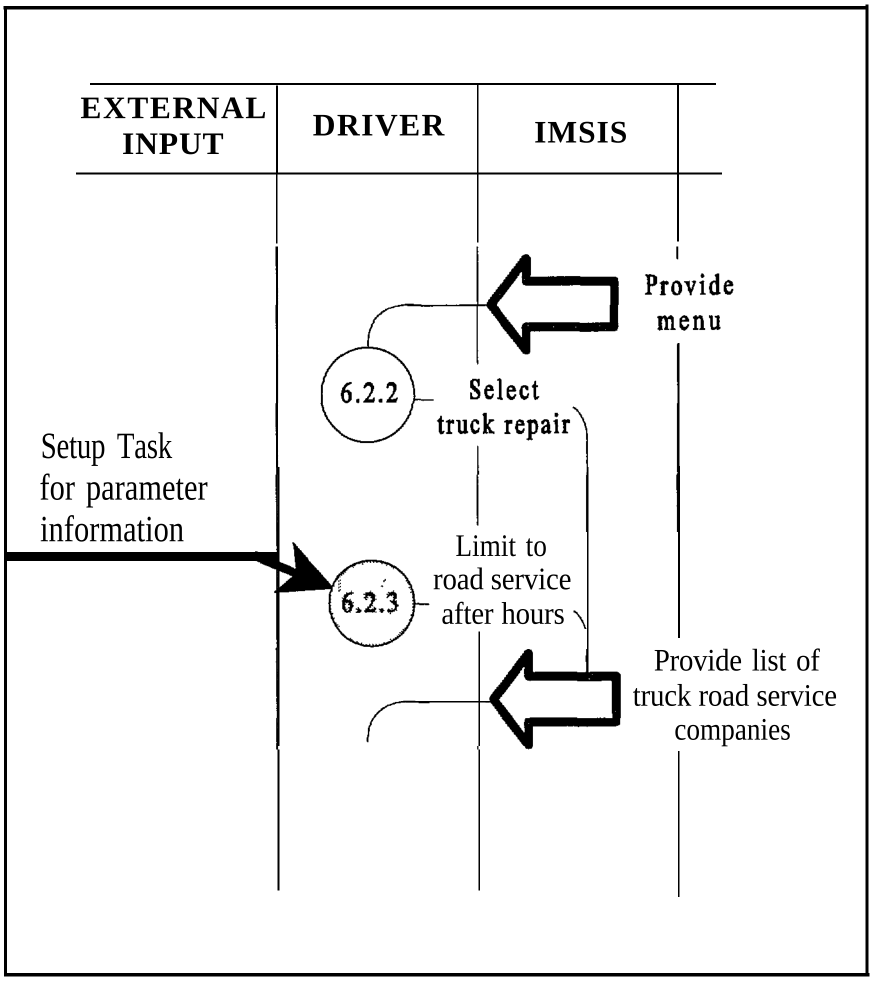



**Figure 13. Example of setup task for parameter information.**

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.

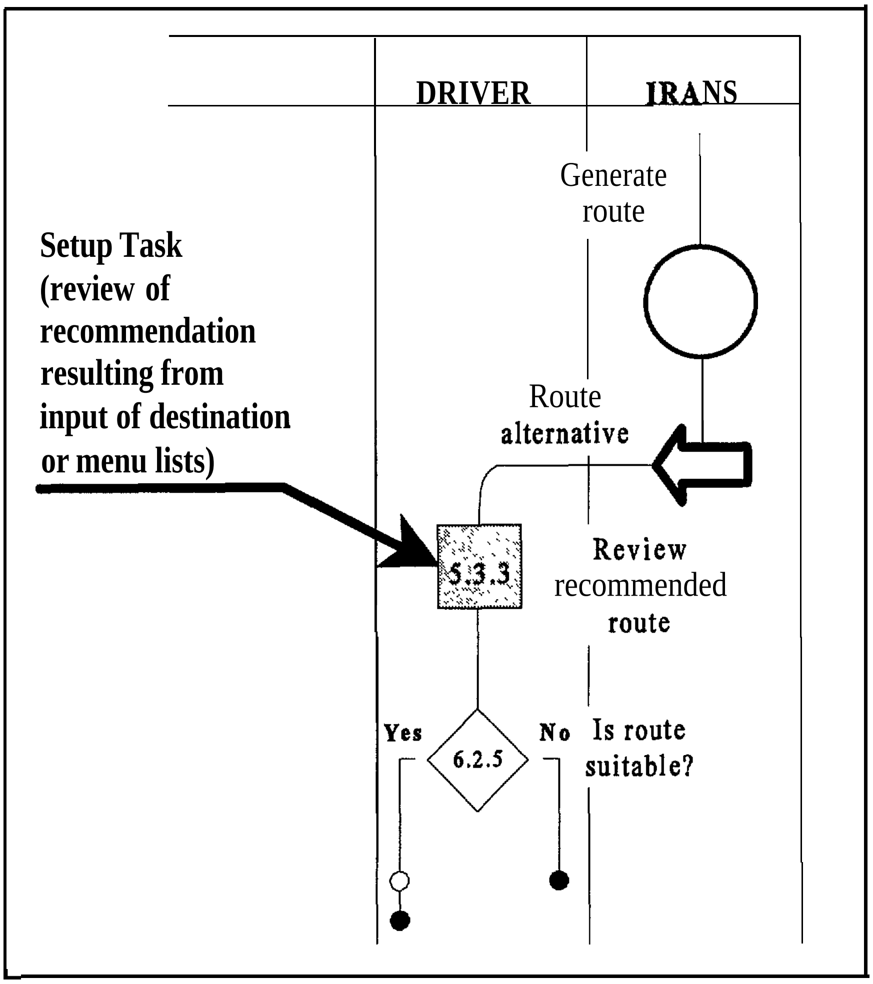



**Figure 14. Example of setup task (review of recommendation).**

Human Factors Design Implications (General and Specific)

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.<br>• Controls of sufficient size.<br>• Controls provide positive feedback. | |
| 2. Entry of System-Critical Information | * These tasks involve complex cognitive and relatively complicated motor processes.<br>• Menu-driven entries focus driver's attention inside the vehicle. | • Size and nature of data base affects driver's data entry process.<br>• Data entry process requirements have to be consistent and natural with driver's expectations.<br>- System needs to prompt and aid for display entry. | • Data entry requires alphanumerical, numerical, and special characters.<br>. Minimal input steps required.<br>- 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.<br>• 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.<br>. Menus should be based on standardized taxonomies. | • Abbreviated menu of preplanned destination.<br>• Programmed smart cards. | • Menu-driven options should be compatible with driver's expectations to avoid driver being lost in menus.<br>• 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.<br>. 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.<br>This function will most likely be a secondary function of the ATIS. | • Figure 16.<br>• 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.<br>• 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.<br>• 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.

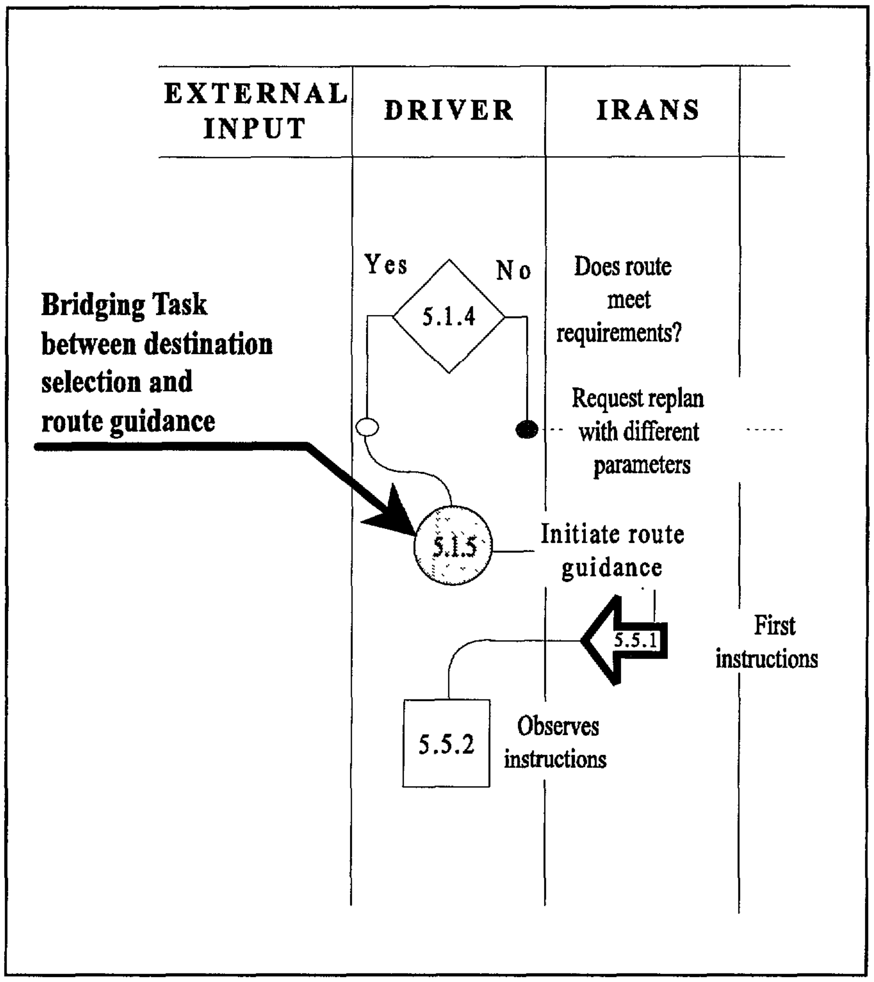



**Figure 15. Bridging task between destination selection and route guidance.**

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.

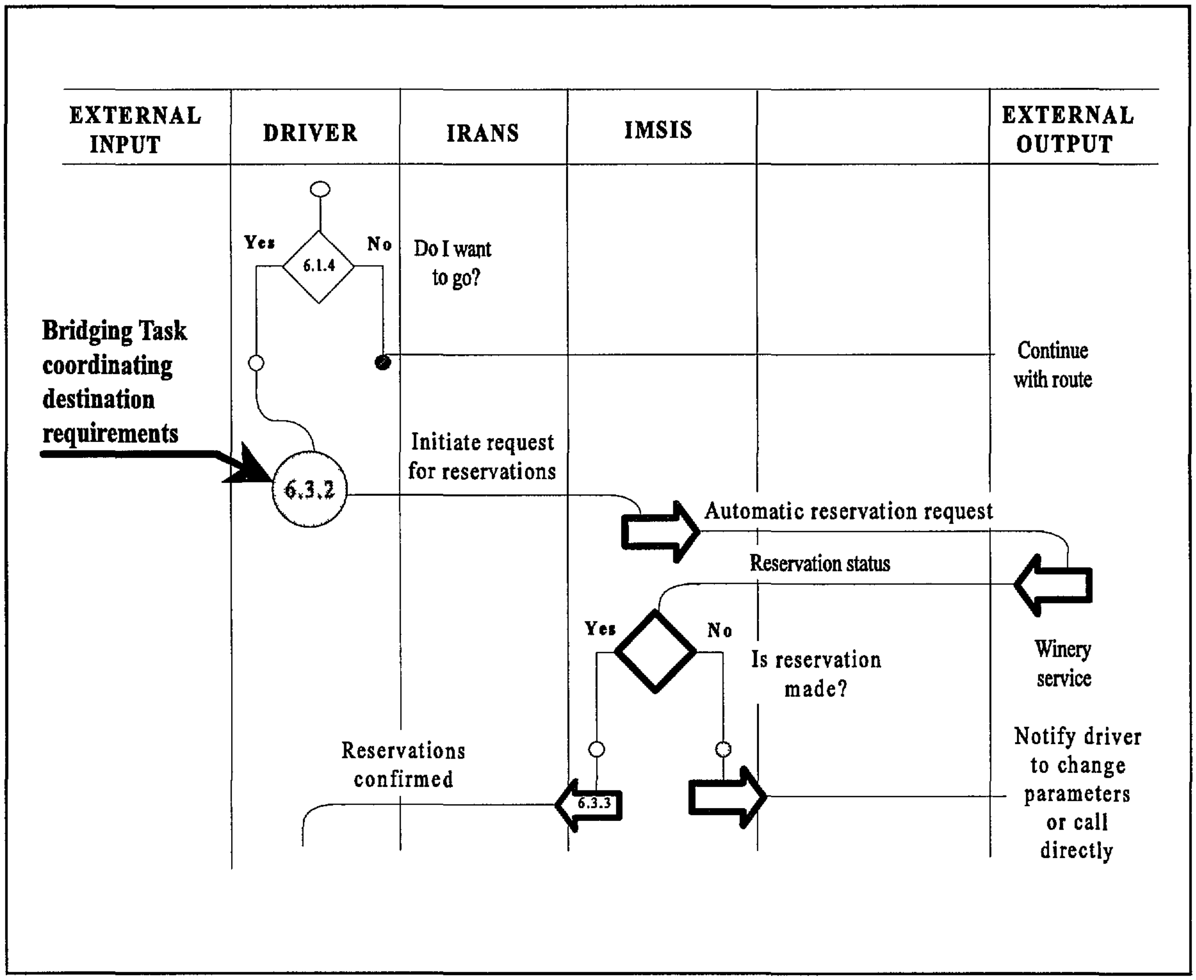



**Figure 16. Bridging task coordinating destination requirements.**

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.

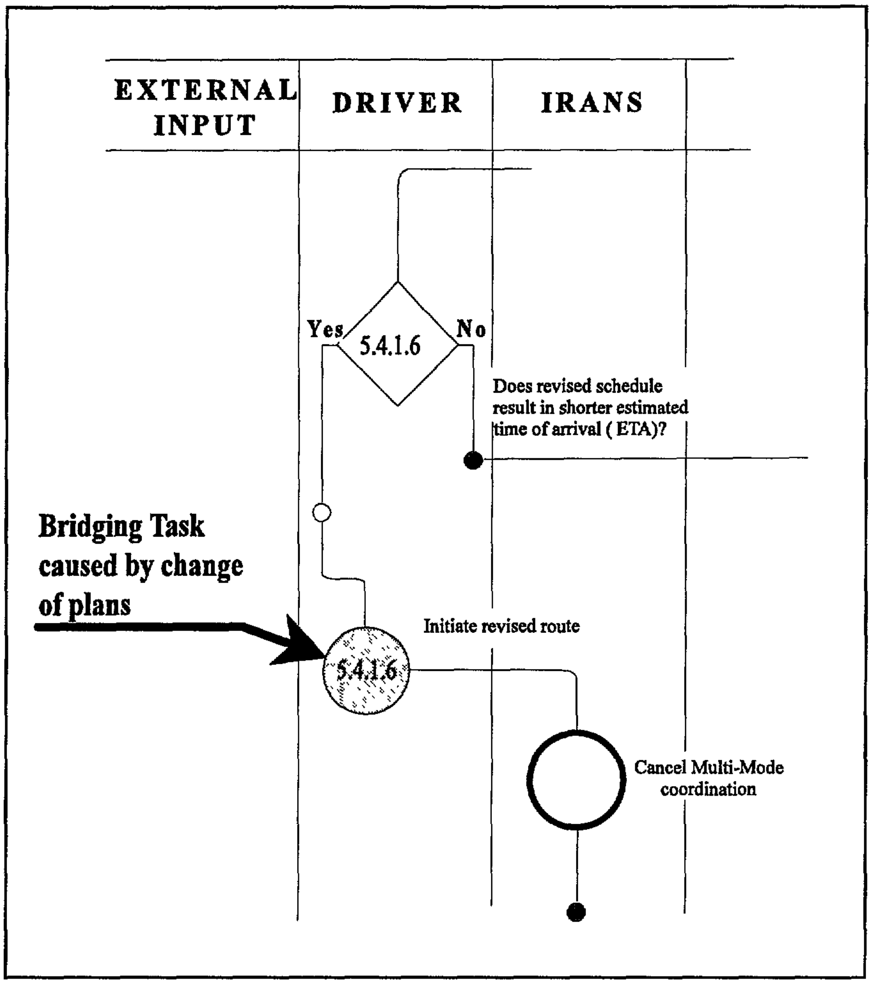



**Figure 17. Bridging task caused by change of plans.**

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.

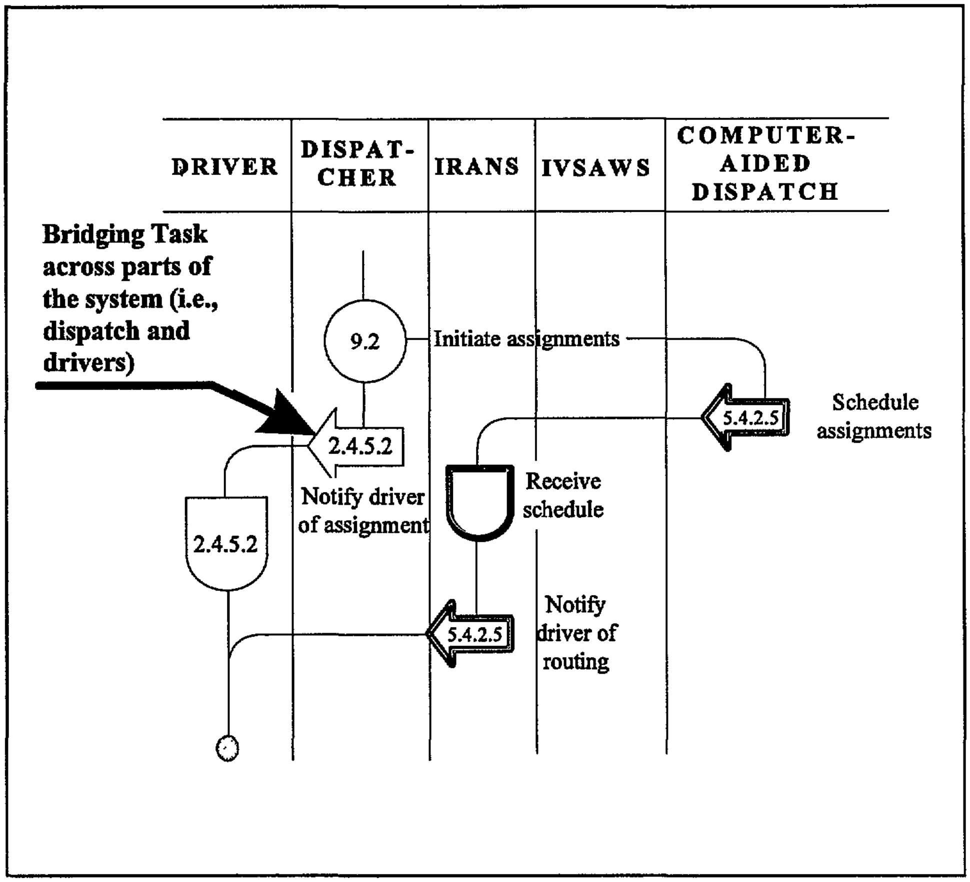



**Figure 18. Bridging task across parts of the system (i.e., dispatch and drivers).**

<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.<br>• 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.<br>• Tasks are almost transparent to the driver.<br>• 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.<br>• Controls within easy reach, of sufficient size, and providing positive feedback. | |
| 2. Initiation of coordination of destination requirements | • Minimal cognitive and motor processes required.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• These tasks need to be preceded by a decision task. | • Accurate and extensive communication capabilities across systems.<br>• 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.<br>• Give the user an opportunity to include considerations in his or her planning process that the ATIS is unable to make.<br>• Provide the driver an opportunity to correct information or assumptions made by the system that are manifestly inappropriate.<br>• 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.<br>• 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.<br>• 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.

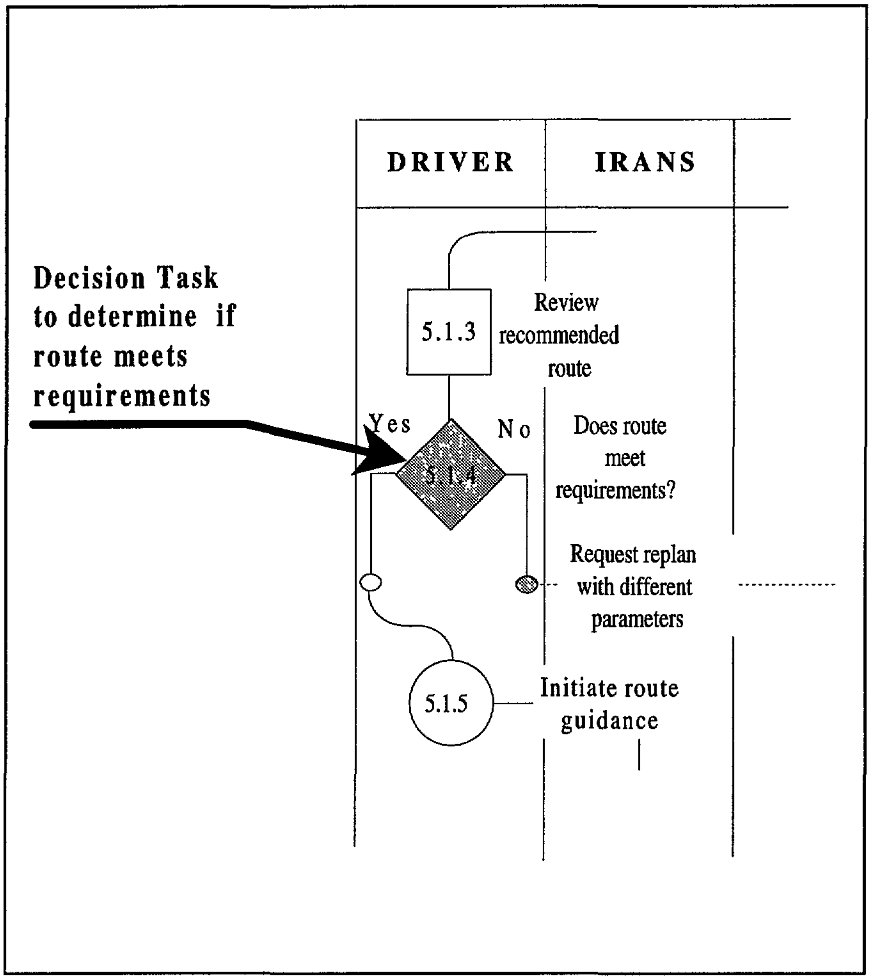



**Figure 19. Decision task to determine if route meets requirements.**

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.

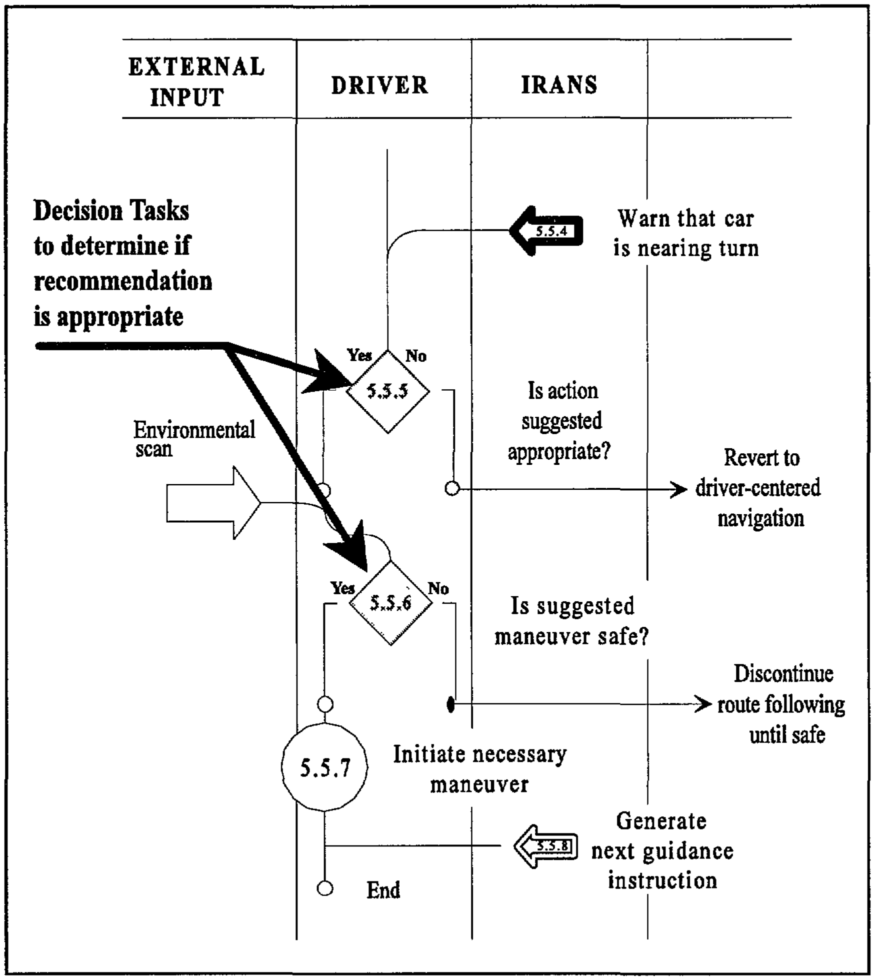



**Figure 20. Decision task to determine if recommendation is appropriate.**

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.

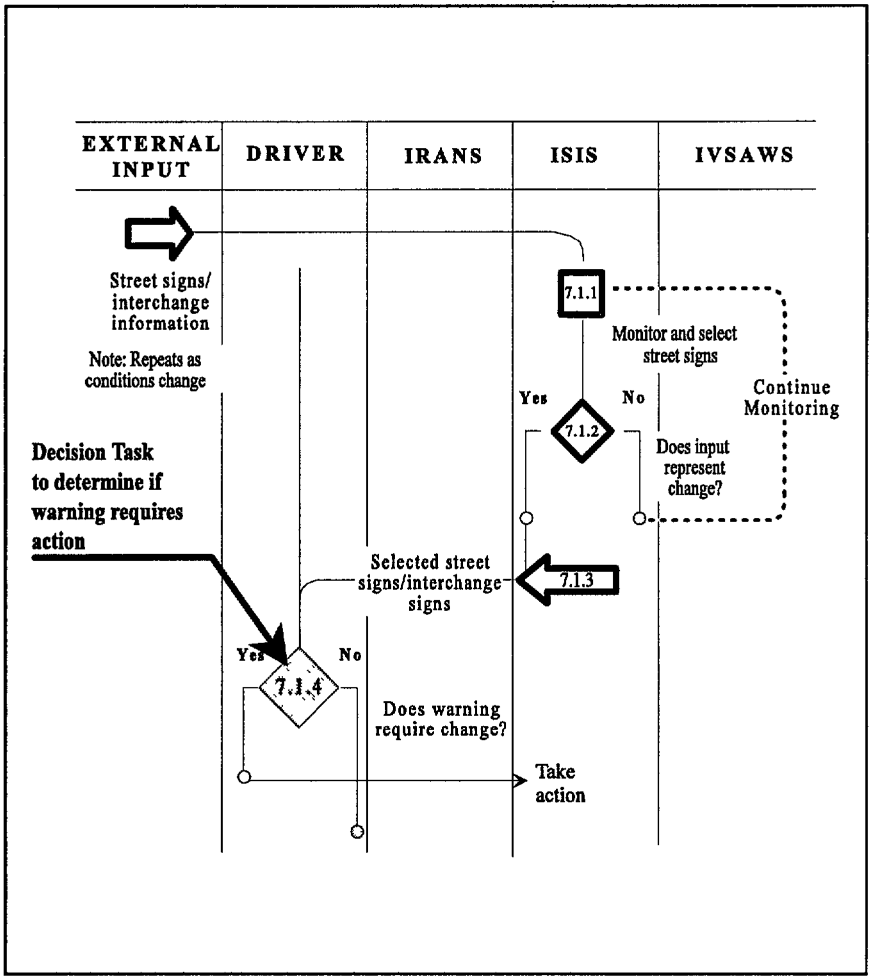



**Figure 21. Decision task to determine if warning requires action.**

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.

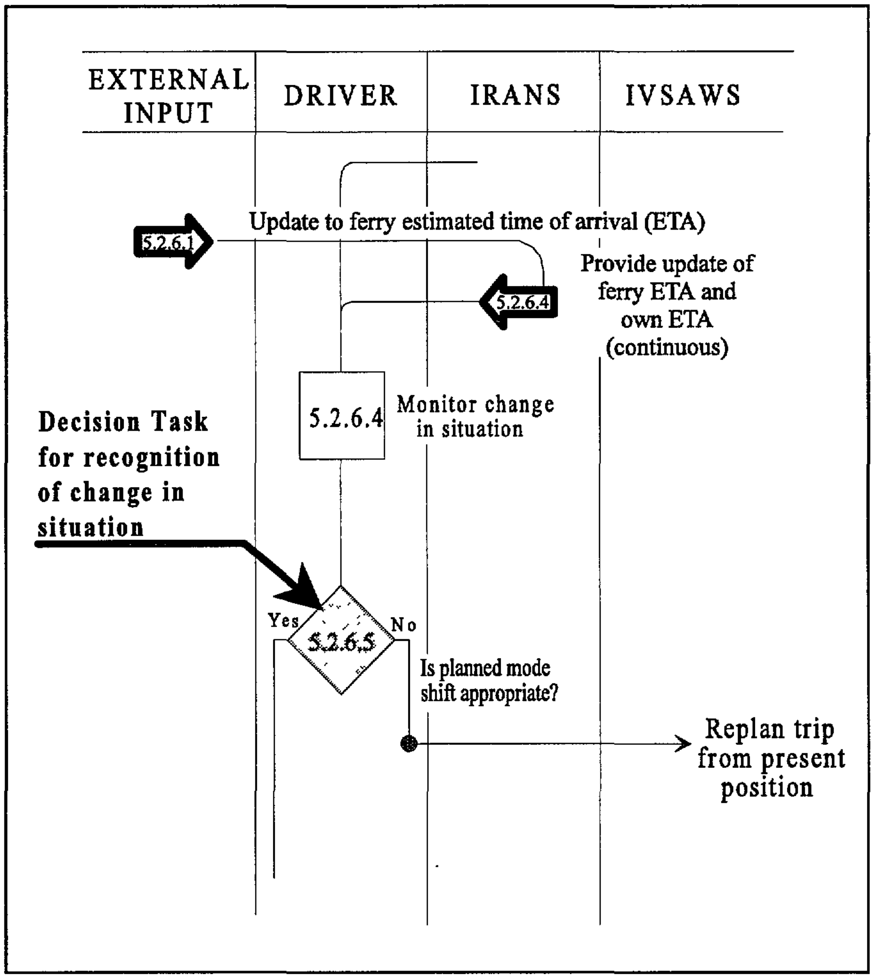



**Figure 22. Decision task for recognition of change in situation.**

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

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.

I..

**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.<br>• Must present accurate information. | • Ease of navigation between screens.<br>• Simple control switch or minimal input steps required.<br>• Clear and simple representation of system's decisions.<br>• 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.<br>• Good knowledge of tasks to be executed.<br>• Needs to be performed while also controlling the vehicle.<br>• 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.<br>• Need to provide a clear and accurate overview of the entire trip.<br>• Ability to stop the system's actions, revert to driving only, and eventually come back to the system's suggestions.<br>• Ability to constantly monitor vehicle's position and provide an update if requested. | • Ease of navigation between screens.<br>• Simple control switch or minimal input steps required to approve or reject plan.<br>• Clear and simple graphical map illustration.<br>• 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.<br>• Driver has a good appreciation of the driving task.<br>• Needs to be performed while also controlling the vehicle. | • Must present accurate and reliable information.<br>• Ability to ignore notification or to modify driving behavior or the planned routing.<br>• Ability to select features to be monitored by the system. | . Close link with external sensors or other type of equipment in the driving environment.<br>• Simple control switch to cancel messages or a system that makes message cancellation transparent to the driver.<br>• Short sentences and use of standard taxonomy. | |
| • Recognition of a need for a change in situation | • Requires extensive cognitive skills.<br>• Implies that the driver has a good situational awareness.<br>• 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.

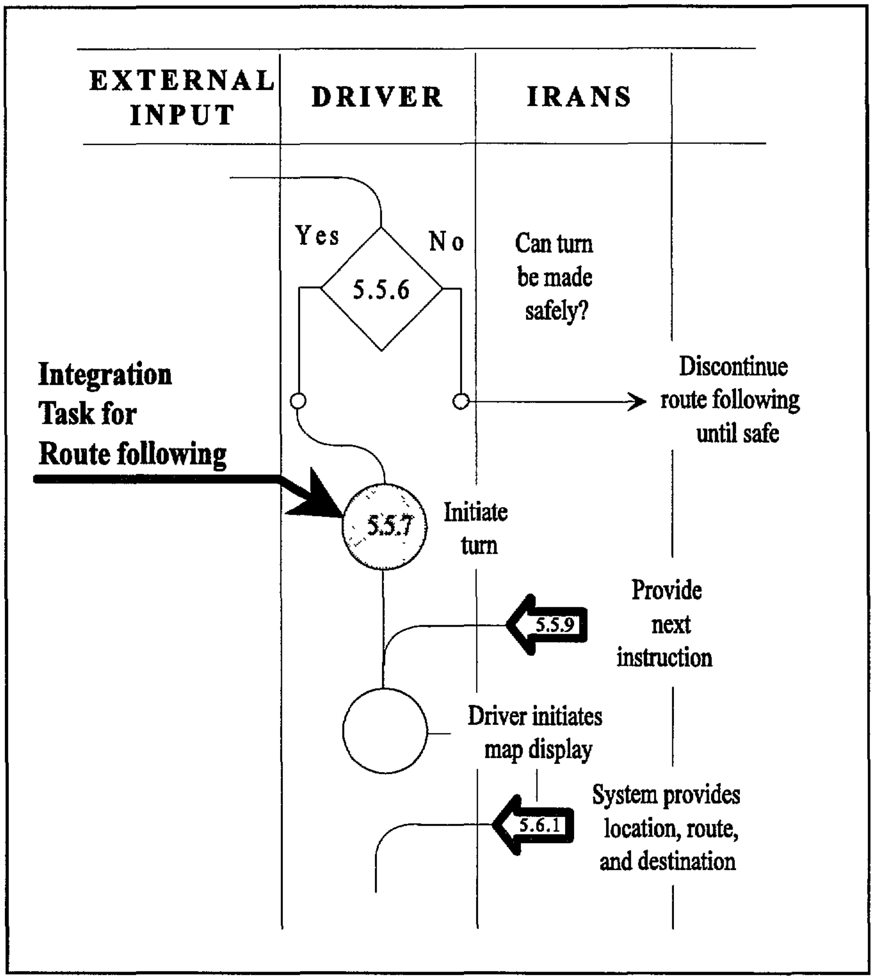



**Figure 23. Integration task for route following.**

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.

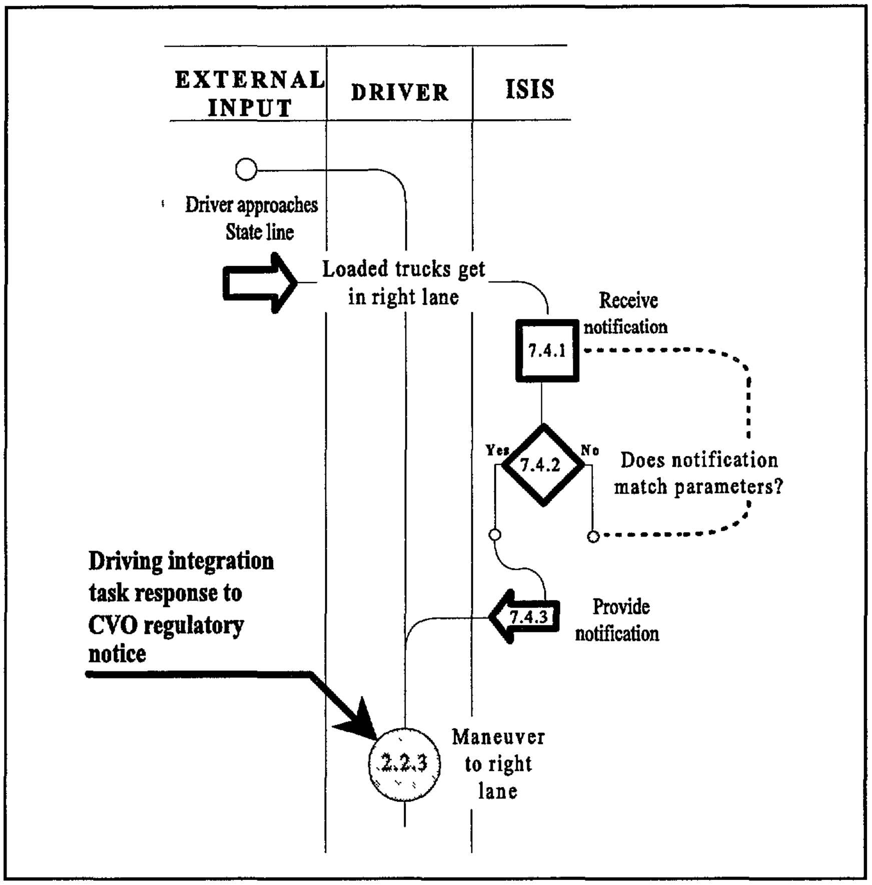



**Figure 24. Driving integration task response to CVO regulatory notice.**

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.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>- 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.<br>• 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.

## APPENDIX A. LITERATURE REVIEW

**Allen, R.W., Stein, A.C., Rosenthal, T.J., Ziedman, D., Torres, J.F., & Halati, A. (1991). A human factors simulation investigation of driver route diversion and alternate route selection using in-vehicle navigation systems. In *Vehicle Navigation and Information Systems Conference Proceedings* (pp. 9-26). Dearborn, MI.**

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TOPIC: Decision making in diverting
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers, ages 18-29, 30-55, and >55

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**ABSTRACT**

This paper describes a human factors simulation study of the decision-making behavior of drivers attempting to avoid nonrecurring congestion by diverting to alternate routes with the aid, of in-vehicle navigation systems. The object of the driver behavior experiment was to compare the effect of various experimental navigation systems on driver route diversion and alternate route selection. The experimental navigation system configurations included three map-based systems with varying amounts of situation information and a non-map-based route guidance system.

The overall study results indicated that navigation system characteristics can have a significant effect on driver diversion behavior, with better systems allowing more anticipation of traffic congestion. Subject route familiarity, commercial driving experience, and gender did not significantly affect the results. Alternate route analysis tended to confirm the main route diversion results and also showed that a majority of drivers were willing to accept alternate routes suggested by advanced navigation systems. Older drivers were more reluctant to divert from the main freeway route.

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**METHODOLOGY**

1. Independent variables

   a. Four different in-vehicle navigation systems (static map, dynamic map, advanced experimental, and route guidance).

   b. Three congestion conditions (moderate, heavy, and jammed).

   c. Three age groups (18-29, 30-55, and >55 years).

2. Dependent variables. Subject's willingness to choose alternate routes to avoid congestion.

3. Actual percentage of subjects who choose alternate routes.

4. Control conditions. Divided between commercial and non-commercial drivers, gender, and route familiarity.

5. Data analysis techniques. X2.

6. Methodology. Simulation on a personal computer that controlled visual and auditory displays simulating travel along a freeway. Rewards and penalties.

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REVIEW OF ARTICLE

Somewhat useful. Data were obtained using a simulation rather than a real setting. Generally, the results suggest that subjects are influenced by in-vehicle navigation systems. However, these results could have been biased because of subjects' expectations. Experimenters failed to consider the fact that the alternate routes could become congested.

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**CRITICAL FINDINGS**

1. Various classes of navigation systems: Class 0 (open-loop systems) to Class 4 (dynamic closed-loop systems). Class 0 includes simple directional aids, map display systems, route guidance aids (e.g., ETAK); Class 4 contains two-way communication between vehicle and control center, centralized vehicle tracking, optimal routing, and information transfer (e.g., Ali-Scout and Autoguide).

2. Driver's ability to navigate through a complex environment depends on knowledge of the surroundings and available navigational aids; driver's performance depends on trip purpose and driver's goals.

3. Older subjects took longer to divert in response to congestion.

4. A lower percentage of the older age group diverted as compared to the younger and middle-age groups.

5. Route familiarity and commercial driving experience did not influence diversion decisions.

6. The advanced experimental and route guidance systems encouraged subjects to divert sooner in anticipation of congestion.

7. Of the route guidance and advanced experimental groups, 70 to 85 percent followed the alternate route recommendation.

8. There was some tendency for drivers to select the shortest possible alternate route regardless of In-Vehicle Navigation System (IVNS) recommendations.

**Allen, T.M., Lunenfeld, H., & Alexander, G.J. (1971). Driver information needs.** ***Highway Research Record, 366,*** **pp. 102-115.**

TOPIC: Driver information needs
TYPE OF ARTICLE: Empirical study/position paper
SUBJECT POPULATION: Not applicable


**ABSTRACT**

The driving task was analyzed to determine the nature and interrelationship of the subtasks the driver performs and the information needed to perform them safely and efficiently. Data were developed using a modified information-decision-action task analysis method applied to several long driving trips. The task analysis provided the basis for categorizing the various component driving subtasks, identifying information needs associated with the subtasks and their present methods of satisfaction, and providing a structure to the driving task. Driving subtasks were categorized in accordance with information-decision-action complexity and ordered along a continuum. The subtasks were found to fall along a hierarchical scale. Vehicle control subtasks, such as steering and speed control, were ordered at the lowest level and identified as micro-performance (control). At an intermediate level, subtasks associated with response to road and traffic situations were identified as situational performance (guidance). The highest level subtasks, encompassing trip planning and preparation and route finding, were identified as macro-performance (navigation). Performance of subtasks at the highest level of the hierarchy involves component performance at a lower level. Drivers search the environment for information needed to perform the various subtasks and shift attention from one information source to another by a process of load-shedding. When load-shedding is required due to the demands of the driving situation encountered, information associated with subtasks relative to the subjective needs of the driver is attended to, and other information sources are shed.


**REVIEW**

Somewhat useful even though the article is dated. The article provides a model to identify the interrelationships between the various levels of performance activities that a driver must accomplish.

**CRITICAL FINDINGS**

1. Driving task analysis procedure: Data were collected: (a) for each situation encountered in transit; (b) for each piece of information displayed; (c) on driver observations and expectancies relative to information needed; (d) to reflect road and traffic conditions; (e) on driver perception; (f) on driver cognition (evaluations, predictions, and decisions); (g) to show driver control responses; and (h) on feedback information.

2. Levels of performance

a. *Micro-performance (control):* vehicle-control subtasks low in the hierarchy. Two subtasks: steering control and speed control.

b. *Situational performance (guidance):* responding to roadway and traffic situation. Numerous subtasks: car following, overtaking and passing, avoidance of pedestrians, response to traffic signals and advisory signs, etc.

c. *Macro-performance (navigation):* large behavioral subtasks at the high end of the hierarchy. Two phases: trip preparation and planning (pre-trip) as well as direction finding (in transit).

d. Performance of a subtask at any level in the hierarchical scale affects each subtask lower in the hierarchy.

3. Attention: The hierarchy describes the load-shedding behavior of the driver. When the driver becomes overloaded by a subtask at one level of performance, he or she sheds all tasks higher, but not those lower. One way to avoid overloading is to apply the principle of spreading the tasks.

4. Primacy

a. It is possible to establish a priority of subtasks and their associated information needs.

b. Information needs lower in the hierarchy have priority over needs higher in the hierarchy.

c. Because control (micro-performance) information is highest on the primacy scale, it must be presented before guidance (situational) and navigation (macro-performance).

5. Expectancy: It is necessary to respect driver's expectancy to maintain safe driving. This need is the greatest at the situational level as well as at the macro-performance level.

6. Information needs

a. Vehicle micro-performance.

b. ARI micro-performance (ARI refers to advisory, restrictive, or inhibitory factors that cannot be specifically categorized under vehicle, road, traffic, service, or directional).

c. Road micro-situational performance.

d. Traffic situational.

e. ARI situational.

f. Service macro-performance.

g. Directional macro-performance.

h. ARI macro-performance.

**Barrow, K. (1991). Human factors issues surrounding the implementation of in-vehicle navigation and information systems. *SAE Technical Paper Series* (SAE No. 910870, pp. l-15). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: Human factors in In-Vehicle Navigation Systems (IVNS)
TYPE OF ARTICLE: Literature review
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

Many questions surround the possible implementation of an advanced driver information system into passenger vehicles. The technology to relieve increasing traffic congestion problems exists today, but the methods to safely use this technology do not. There are many concerns in the government, industry, and academic communities surrounding the implementation of graphic display monitors inside passenger vehicles. This concern stems from recent studies on the effect of cellular phones, touch panels, and electronic navigational systems on driver attention demands.

These studies show that driver attention is taken from the roadway to operate these systems. However, more research into basic human/vehicle ergonomics needs to be conducted in order to determine how the demands of in-vehicle electronics affect highway safety. Recommendations include maintaining and broadening the scope of human factors research, continued use of field testing, the implementation of pre-production standards and regulations, increased driver education and training, and continuation of realistically engineered systems.


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**REVIEW**

This paper consists of an extensive review of the: (1) various Intelligent Vehicle-Highway Systems (IVHS), and (2) current human factors literature regarding the Advanced Traveler Information System (ATIS).

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**CRITICAL FINDINGS**

1. Various functions of IVHS

   a. ATMS: Advanced Traffic Management Systems (ATMS) uses traffic sensors to make real-time adjustments in ramp metering, traffic signals, and roadside message boards.

b. ADIS: Advanced Driver Information Systems (ADIS) uses monitors to inform drivers of current traffic situations. May contain some route guidance capabilities.

c. CVO: Uses automatic vehicle tracking, two-way communications, in-vehicle text, and map displays.

d. AVCS: Advanced Vehicle Control Systems (AVCS) will warn drivers of approaching objects and to apply brakes to avoid collisions.

e. ERGS: Electronic Route Guidance Systems (ERGS) technology of the 1960s. Project scrapped.

f. PATHFINDER: Field evaluation of ETAK system, map-based driver information system. Little human factors involved so far, but there will be an extensive evaluation process to consider the driver task load.

g. TRAVTEK: A lot of human factors considerations.

2. <u>Two types of driver information systems</u>

a. Basic congestion information system; map is overlaid with the current congestion.

b. Route guidance system.

3. <u>Results from various studies</u>

a. *Dingus & Wierwille:* Little difference between time to reach a destination using conventional or electronic map: conventional-looked before onset of trip; electronic-looked during driving.

b. *Greeter, Vitello, & Wonsiewicz:* Drivers with audio-only drove to their destinations more quickly, with fewer miles driven and with fewer errors, than groups with maps and groups with maps and audio instructions.

c. *Department of California Highway Patrol/Zwahlen:* Largest deterioration of safety occurred when people dialed a long string of numbers on car phones. Dialing pre-set numbers were no worse than tuning the radio.

d. *Zwahlen:* Probabilities of “lane exceedance” during the operation of a CRT are 15 percent for a l0-ft-wide (3.0-m-wide) lane, which is unacceptable.

e. *Labial:* A map with written communication is the easiest for drivers to recall, with map and audio being the next easiest, and map alone being the hardest to recall. Amount of information that could be handled depended on amount of attention that could be given to navigational systems. Lateral commands were used with fewer errors than when street names were used. Audio was preferred by 3 to 1 over the text; plain maps were preferred by 2 to 1 over maps with text. The navigator task required the most assistance, but tuning the radio, adjusting power mirror, and inserting a tape caused the largest "lane exceedance."

4. Design philosophy. Instead of controlling the amount of information, it is more desirable to control the characteristics of the display. It is better to specify a standard or regulation that indicates how much workload a display can place on a driver rather than a design standard that attempts to predict what that workload would be (e.g., number of items, size, shape, etc.).

**Coury, B.G., Weiland, M.Z., & Cuqlock-Knopp, V.G. (1992). Probing the mental models of system state categories with multidimensional scaling. *International Journal* of *Man-Machine Studies, 36,* pp. 673-696.**

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TOPIC: Mental models/multidimensional scaling
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Students (20 subjects)

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**ABSTRACT**

Identifying the underlying decision criteria used by people to classify system state is one of the major challenges facing designers of decision aids for complex systems. This research describes the use of multidimensional scaling (MDS) to probe the structure and composition of the mental models employed by users to identify system state and to evaluate the impact of different display formats on those models. Twenty people were trained to classify instances of system data. Pairwise similarity ratings of instances of system data were analyzed by MDS to reveal the dominant dimensions used in the task. Results showed that significant individual differences emerged and that the dimensions used by people were also a function of the type of display format.

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**METHODOLOGY**

1. Independent variables

   a. Four system-state categories.

   b. Two types of displays (digital and configural).

   c. Uncertainty.

2. Dependent variables

   a. Similarity of a subset of instances of system data.

   b. Performance measures (e.g., accuracy and response time).

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**REVIEW**

Somewhat useful, with the exception of some of the conclusions the authors reached regarding display designs. The methodology and system studied are too different from Task

E's purpose and interest; however, some of the general conclusions they reached should possibly be considered in working on Task E.

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**CRITICAL FINDINGS**

1. Conclusions

   a. The information used by the two display groups to identify system state was qualitatively different.

   b. Despite differences in the composition of the mental model, the structure of those models appeared to be relatively stable across people.

   c. The format of the display has a major impact on the user's knowledge about state category membership and will significantly influence the composition of that person's mental model of the decision problem.

   d. It is important to separate the issues related to uncertainty in a decision task and the selection of the appropriate display format of system data. The degree of uncertainty determines the mapping of system data to state categories, while the display format affects a person's ability to process and use system data to identify the state of the system.

   e. There were differences between individuals, which suggests that focusing on an aggregate analysis and ignoring the unique way in which individuals internally represent decision criteria can be dangerous; MDS provides the data necessary for assessing the disparity between the group analysis and individual dimensional configurations.

2. Design concepts

   a. Choice of a display is dependent upon:

      (1) Underlying statistical properties of the task.

      (2) Type of task.

      (3) Degree of uncertainty involved in identifying the state of the system.

   b. Display format can significantly affect performance in decision-making tasks, especially when the status of the decision problem is uncertain or the task incorporates severe time constraints.

c. Uncertainty is the primary factor that significantly affects the way people process information in a display and determines the utility of a particular type of display format.

d. When display elements were mapped directly to a particular system-state category, displays that possessed object-like properties (emergent features) were found to enhance the operator's ability to quickly process system data and accurately identify the state of a system. Once uncertainty reached a given point, a precise representation of system data provided by a separable display was necessary and allowed the operator to focus on specific, critical display elements.

3. General concepts

a. *User interaction with a system.* Movement through a state space that begins with the user's problem in some initial state and progresses through a series of intermediate states towards one or more goal states.

b. *Decision making.* A cognitive process employed by the user to guide movement from one state to the next, with feedback providing the necessary information to determine the success or failure of manipulations of the state space.

c. *Decision problem.* Defined by an initial state, one or more goal states, and a set of actions that can transform one state to another state. Once the state of the decision problem has been identified, the decision maker develops a plan of action to change the current state to some future state.

d. *User's mental model.* Must contain knowledge of the attributes that define a decision state, the relative importance of those attributes in identifying a specific state, the operations and actions to change the current state to a future state, the decision rules used to evaluate and select a course of action, and knowledge of the costs and benefits of specific actions.

e. *User's performance.* Is dependent upon the ability to match the data from each information source to an internal model, accurately classifying the state of the decision problem, and then constructing and executing a plan of action.

**Denning, S., Hoiem, D., Simpson, M., & Sullivan, K. (1990). The value of thinking-aloud protocols in industry: A case study at Microsoft Corporation. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 12851289). Santa Monica, CA: Human Factors Society.**

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TOPIC: Verbal protocol
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Computer users

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**ABSTRACT**

Thinking-aloud protocols traditionally have been used by academic researchers as a qualitative data collection method. This method is currently gaining acceptance in industry usability testing. The Usability Group at Microsoft has adopted the thinking-aloud protocol as a primary method for obtaining data from users. The authors found the method valuable, not only because it is valid for gathering qualitative data, but also because it is responsive to the constraints faced and the organizational culture in the workplace. The issue of validity has been discussed in detail by researchers, such as Deffner and Rhenius, and Ericcson and Simon. The case study further pursues the validity of thinking-aloud protocols and also discusses how this method allows the researcher to work within industry constraints and incorporate changes into the product within a small timeframe. Finally, the case study demonstrates how thinking-aloud protocols fit in well with Microsoft's corporate culture, where understandable and persuasive results are needed. This case study will have particular relevance for usability practitioners in industry.

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**REVIEW**

Although this article is directed towards the usability testing of products at Microsoft, it is <u>very useful</u>. It describes a time-saving method that is very useful in analyzing verbal protocols. In addition, it emphasizes the value of thinking-aloud protocols when evaluating incomplete products or products at the conceptual stage.

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**CRITICAL FINDINGS**

1. <u>General</u>

   a. Results are especially convincing when product designers are presented with a video of the subject actually using the system. Subjects' verbatim comments are also effective in written reports.

b. Aside from thinking-aloud protocols, triangulation is used across various methods: direct observations of users, questionnaires, interviews, and performance data (error rates, frequency of occurrences, and time intervals).

2. Time-saving methods

a. Engage the designer to observe test sessions to get an immediate auditory and visual picture of the usability of the system.

b. Analyze data while testing. Developed a categorizing scheme specific to the product, with categories based on particular parts of the interface that were tested. Any episode or discussion that fell under a pre-defined category was immediately marked with the time, the category, and a summary of the discussion. These entries were not used as data per se, but rather as an index to data on the videotapes of each test session. After all of the test sessions were recorded, the word processor files were imported into a spreadsheet and then sorted by category. Subcodes for second-level sorting were added according to patterns when they occurred. This two-level sorting served as a look-up table for relevant parts of the videotape where the verbatim protocol data resided. Thus, only the episodes of verbalization that were directly relevant to the pieces of the interface being tested were examined and transcribed. When it was necessary to look in closer detail at data collected on use of a particular component, relevant episodes on the videotapes were found quickly and easily.

c. The index described above was used to quickly make a highlights videotape containing thinking-aloud data of interest.

3. Incomplete products

Thinking-aloud protocols can encourage discussion about a product even when it is in an unfinished state, especially when used in a co-discovery setting (teams of subjects read the introductory guide and worked together in a co-discovery situation to explore the system's interface and the concept introduced in the training). Microsoft had a prototype of the application that was not fully functional. Tasks were designed to allow subjects to use the pieces of the interface that were functional and to come into contact with the pieces that were still to be implemented. Subjects were instructed to verbalize all their thoughts while they used functional parts of the product and to verbalize their expectations when they tried to use something that obviously was not implemented.

**Drury, C.G., Paramore, B., Van Cott, H.P., Grey, S.M., & Corlett, E.N. (1987). Task analysis. In G. Salvendy (Ed.), *Handbook of Human Factors* (pp. 370-401). New York: Wiley & Sons.**

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TOPIC: Task analysis
TYPE OF ARTICLE: Literature review/summary paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

Task analysis is a formal methodology, derived from systems analysis, which describes and analyzes the performance demands made on the human elements of a system. By concentrating on the human element in systems analysis, it can compare these task demands with known human capabilities. The goal of task analysis is to provide the basis for integrating humans and machines into a total human-machine system. A task analysis defines the performance required of humans, just as an engineering analysis defines the performance required of hardware and a program flowchart defines the performance of software. All three are necessary. In this chapter, the origins and antecedents of task analysis are explored for the understanding they can provide of modern developments in both military and industrial systems. These modern developments are described in some detail to show that there is no single method of task analysis applicable to all jobs. Finally, an example of a large, complex system is presented in detail to illustrate both the techniques of task analysis and the methods of collecting the information required.

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**REVIEW**

Useful to identify some of the numerous approaches that have been used in task analysis. Not detailed enough to follow any one specific method. Some examples could help in the understanding. Good theoretical reference material if a justification or an introductory paragraph needs to be written on the subject.

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**CRITICAL FINDINGS**

1. Human performance in technological systems

   a. System functions are activities that control the variables that influence the goal output of a system.

   b. The human constituents of a system bear the responsibility for recognizing, interpreting, compensating for, and correcting or mitigating the consequences of deficiencies, failures, and malfunctions in the hardware and software and in their own performance.

c. Task analysis should describe, evaluate, and facilitate the human performance required by the system.

2. Nature of tasks in technological systems

a. *Task:* A set of human actions that contributes to a specific functional objective and ultimately to the output goal of a system.

b. *Task characteristics:*

(1) Task actions are related to each other not only by their objective, but also by their occurrence in time.

(2) Task actions include perceptions, discriminations, decisions, control actions, and communications.

(3) Each task has a starting point and a stopping point.

(4) Task cues and feedback are important.

(5) A task is usually defined as a unit of action performed by one individual.

c. *Three types of tasks:*

(1) Discrete or procedural tasks require an individual to execute a series of separate action elements in response to specific stimuli and/or instructions given in a procedure document.

(2) Continuous or tracking tasks require an operator to work a control continuously and to maintain an output within given limits while sampling deviations from those limits that are viewed directly or displayed. Extends over a relatively long period of time. While a continuous task is being sustained, various discrete tasks may have to be executed.

(3) Branching tasks are variants of a discrete task where the task sequence is determined largely by the outcome of particular choice tasks in the operation. A typical task description for branching operation is done at a cruder level than for sequential operations.

3. Definitions in task analysis

a. Distinction between task and job analysis.

b. Distinction between task description and task analysis.

c. *Three different kinds of activity for task analysis:*

(1) System description and analysis.

(2) Specification of the human task requirements of the system *(task description).*

(3) Analysis, synthesis, interpretation, evaluation, and transformation of the task requirements in light of knowledge and theory about human characteristics *(task analysis).*

4. Recent developments in task analysis

a. *Drury's approach:* Uses the following categories-task number, purpose, action, check, control problems, display problems, and postural problems.

b. *Hierarchical task analysis:* Starts with the overall objectives of the system and describes an operation that fulfills these objectives. The operation is then redefined as a series of sub-operations plus a plan that defines how these sub-operations are linked. When to stop: apply the PxC rule >>; further re-description is unnecessary where the product of Probability of inadequate performance and the Cost of inadequate performance is acceptable.

c. *Signal-flow graph analysis:* Links the variables in the system together so that a diagram is formed to indicate the control complexity of the system. The variables are drawn as nodes and are linked together by branches that represent the system functions, or the causal dependency relating two variables. It is a way of presenting the system information so it is simple to analyze and it can aid in task analysis by making explicit the decisions involved. Information needed to perform a signal-flow graph: aims of the system, how the system works, and the part the operators play in the system.

d. *Position analysis questionnaire:* Consists of 187 job elements (organized in 6 divisions) that characterize or imply various types of basic human behaviors involved in jobs in general. Different from other instruments in that it provides for the analysis of jobs in terms of basic human behaviors that cut across various types of jobs.

e. *Ergonomic job analysis:* First it describes the work system and the task. Then it analyzes this task in terms of job demands for perception, decision, and response. The integration of the task with equipment and environment in the same analysis procedure gives a unique tool for detecting potential mismatches between job demands and human capabilities.

f. *Postural tusk analysis:* Concentrates on a detailed recording of the angles of each limb at each step in the task. Sequential task description format. The task analysis compared angles and forces recorded with human abilities to produce these angles and forces without injury.

5. Planning for task analysis

   a. Establish the objectives and scope of the task analysis.

   b. Establish a task data collection model that reflects the needs of the task analysis.

   c. Identify the personnel requirements of individuals on the task analysis team.

   d. Prepare a schedule for the task analysis effort.

   e. Obtain management support.

   f. Develop a task analysis program plan and uniform procedures for the team to follow.

   g. Set up a quality control method for reviewing the task descriptive data for completeness and technical accuracy.

6. Phases of task analysis

   a. *System description and analysis:*

      (1) System functional analysis: Review the organizational context and specify the goal outputs of the systems and any specific constraints and criteria. Define system functions based on modes of operation or major system states. Examine the equipment configuration. Describe the general process of function execution.

      (2) Operational sequence analysis: Describe the operational flow and the relationships of functions and human and equipment actions in time. Develop an operating sequence profile, a narrative description of the sequence, and functional flow diagrams. Develop an action-decision diagram and an operational sequence diagram.

   b. *Task description task list:* First step in task description is to prepare a list for each mission or operating sequence from the results of the system description/analysis. The task list indicates the scope and sequencing of the total array of human performance requirements in the sequence.

   c. *Descriptive data collection:* Four different techniques are available for data collection: documentation review, questionnaire survey, interviewing, and observations.

d. *Applications analyses:* Author describes several other analyses that could be based on the task analysis in domains such as human engineering, performance prediction, personnel selection, training, human/system reliability, and modeling of mental activity.

**Erlichman, J. (1992). A pilot study of the in-vehicle safety advisory and warning system (IVSAWS) driver-alert warning system design. In Proceedings *of the Human Factors Society 36th Annual* Meeting (pp. 480-484). Santa Monica, CA: Human Factors Society.**

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TOPIC: Warning systems
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers (13 subjects)

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**ABSTRACT**

This pilot study was conducted to obtain preliminary information regarding alternative signaling presentations and symbologies for the Driver-Alert Warning System (DAWS) design within the In-Vehicle Safety Advisory and Warning System (IVSAWS) program sponsored by the Federal Highway Administration. Preliminary analysis had been conducted by both Hughes Aircraft Company and the University of Michigan Transportation Research Institute. The pilot study concentrated on the driver attributes of understanding, relative effectiveness, and signaling format. Thirteen subjects were exposed to the new pictograms prototyped on a Macintosh computer and were requested to verbalize their understanding and preferences with regard to varying signaling characteristics. These characteristics included: (a) monochrome, (b) color, (c) blink, (d) tone, (e) text message, and (f) voice message. The results indicated that as a group, the combination of color, audio tone, text, and voice message was the preferred signaling presentation. Gender differences were noted with the female subjects indicating a preference for the combination that included color and blink. All pictograms were recognizable by the subjects, and all subjects agreed that IVSAWS would be a substantial aid to the driver.

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**METHODOLOGY**

1. Independent variables

   a. Eight pictograms of emergency hazards.

   b. Six different formats: monochrome, color, flash, audio tone, long voice and text messages, and short voice and text messages.

   c. Age, sex, group, and height.

2. Dependent variables: Rank order judgments (ordinal), commentaries, and opinions (nominal).

**REVIEW**

Somewhat useful if interested in drivers' preferences for the design of DAWS. This study was a pilot study evaluating alternative signaling presentations, codes, and symbologies.

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**CRITICAL FINDINGS**

1. Subjects preferred a signaling presentation (pictogram) that added each of the following characteristics: color, audio tone, text, and visual message (with both long and short messages).

2. Females subjects (4 out of 13 subjects) preferred the color + blink option. They interpreted the blink as a more immediate danger.

3. Long message and short message text and voice options rank higher than other options. Preferred by the 16- to 30-year-old group, followed by the age 5 l+ group.

4. Monochrome pictograph was ranked the lowest.

5. In general, data showed a preference for associating the pictogram to a voice and a text message that provided meaningful hazard/traffic recommendations.

6. Disparity between females and males for these categories only.

7. The audio tone would be more meaningful if they represented the sounds associated with the expected emergency. In general, audio tones were associated with a need to attend to a function and, therefore, should not be eliminated.

**Fath, J.L., & Bias, R.G. (1992). Taking the task out of task analysis. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 379-383). Santa Monica, CA: Human Factors Society.**

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TOPIC: Cognitive task analysis
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

Task analysis is a well-accepted component of user-centered design. It is often left out of the design process, however, due to a lack of practical methods, the difficulty in predicting the amount of resources required to perform it, and a short supply of people with the appropriate skills. A solution to these problems is a structured set of activities that make up a task analysis and relate to the overall design process.

The general framework into which these activities fit has three phases: data collection, data analysis, and design. During the data collection phase, user and task data are collected and validated. The data analysis phase requires analysis of user and task data in a way that results in suggestions for information representation, navigation, terminology, and consistency. Finally, the design phase requires translating the suggestions from the data analysis phase into a viable product.

A prototype task analysis workbook was developed to assess the feasibility of the structured approach to task analysis. The workbook includes tools for data collection, data analysis, and design, as well as instructions on how to use the tools. Over a period of 2 years, the workbook was used in five different development projects. A representative from each group was interviewed to determine how the workbook was used and which parts were most useful. Results of the interviews indicate that the workbook approach has merit.

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**REVIEW**

Very useful in providing a structured approach and method to conduct a task analysis. Easy to follow and well organized. For each set of activities, the authors provide a set of tools that help perform these activities. It might be interesting to ask for a copy of their workbook (1992). Even though it is directed to the development of computers (IBM), it still might prove useful, especially for what is called "Phases 1 and 2."

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**CRITICAL FINDINGS**

1. Structured activity set for Task Analysis (TA)

   a. *Phase 1: Data Collection*

      (1) Define user group.
      (2) Define tasks.
      (3) Validate user and task data.

   b. *Phase 2: Data Analysis*

      (1) Determine relationships between groups of objects.
      (2) Determine all actions performed on each object.
      (3) Determine product-specific terminology.
      (4) Analyze and classify likely errors for each task.
      (5) Validate analysis (map tasks to objects and actions).

   c. *Phase 3: Design*

      (1) Design individual screens.
      (2) Design the way to navigate between screens.
      (3) Determine which terminology to use.
      (4) Determine appropriate areas for consistency.
      (5) Prototype the design.
      (6) Evaluate the design.

2. Useful tools

   a. *Phase I: Data Collection*

      (1) User description tables that map the user groups to attributes related to users' backgrounds, jobs, and environments.

      (2) User-task matrix that indicates the frequency with which each user group performs each task, including critical tasks.

      (3) Task worksheets that document task assumptions, triggering events, inputs to the task, action sequences, outputs, common errors, and notes.

      (4) Measurable usability objective tables that document the objectives for each task.

b. *Phase 2: Data Analysis*

(1) Object-object matrix in which frequencies of object pairs are tabulated and cluster analyzed.

(2) Obiect-action matrix is a frequency matrix that matches objects with the actions that are performed on them.

(3) Terminology analvsis and error analysis.

c. *Phase 3: Design*

(1) User interface style guidelines.

(2) Prototyping tools.

3. Usefulness of workbook. Provides users with a starting point; it helps to organize task information and to identify gaps in that information, as well as to allocate design resources.

**Haselkorn, M.P. (1992). Making sense of advanced traveler information systems by understanding travelers. *ZTE Compendium of Technical Papers,* pp. 52-56.**

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TOPIC: ATIS - users' behavior
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Seattle users

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**ABSTRACT**

This paper has three parts. The first part examines the informational approach to dealing with traffic congestion, placing this approach in the context of other approaches to transportation problems. The second part looks at the complexities of ATIS design and technology. The third part looks at traveler behavior as a way to deal with these complexities.


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**REVIEW**

<u>Very useful</u>. Describes some of the functions that ATIS should have. Describes drivers' behavior (four groups of drivers) and how they will react to ATIS based on a study done in Seattle.

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**CRITICAL FINDINGS**

1. <u>Goals of IVHS and ATIS.</u> Give people more choices, make those choices easier to access, and give accurate information on the consequences of those choices.

2. <u>Control system</u>

   a. ATIS is a type of control system. A control system is simply a system that gathers data from its operating environment, does something with that data, and produces a response intended to improve the functioning of that environment. Response time requirements depend on the specific control system. Like response time requirements, there is a range of human response requirements that depend on the specific control system's goals and environment.

   b. The message produced by an ATIS cannot be viewed as the system response. That is because messages cannot improve the operating environment. Only people's reactions to those messages-changes in travel behavior-can improve the environment.

3. Functions

a. Post-trip information can provide essential feedback for long-term behavior modification (traveling habits).

b. Designers must not only consider where and when the information will be delivered, but also the trip being addressed. Information on special trips has its own requirements; for example, including a focus on route navigation information for trips in a rental car.

c. Each trip and information type has its own requirements for data gathering and delivery.

d. Different information types lead to the issue of different information purposes.

4. Users' behavior

a. Marketing techniques (cluster analysis) were applied to identify types of commuters in terms of their need for and response to traveler information.

b. Types of commuters in Seattle:

(1) Twenty-three percent of the people who are unlikely to change anything about their trip are male and are highest on the socio-economic scale.

(2) Twenty-one percent of the route changers who are willing to change route both before and especially during the commute respond more to visual congestion than information; are unlikely to change departure time; never get out of their cars (e.g., transit system); and are predominantly male.

(3) Forty percent of the people who change both route and time are inflexible about transportation modes and show no willingness to get out of their cars. Slightly more are females.

(4) Sixteen percent of the pre-trip changers who are very flexible prior to traveling-even showing a willingness to change transportation mode-are not flexible en route (more committed to their choices). They access traveler information an average of 3+ times before leaving in the morning, have the highest female ratio, and are lowest on the socioeconomic scale. In addition, they tend to live farther from work; have the longest commute; and care the most about saving time, making the trip more pleasurable, increasing safety, and decreasing travel distance. They also have jobs where there is high stress related to being on time.

**King, G.F. (1986). Driver attitudes concerning aspects of highway navigation.** ***Transportation Research Record, 1093,*** **pp. 11-21.**

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TOPIC: Driver attitudes
TYPE OF ARTICLE: Survey
SUBJECT POPULATION: Automobile drivers

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**ABSTRACT**

A comprehensive questionnaire dealing with various aspects of highway navigation was developed, pretested, and administered to a demographically representative sample of the United States driving population. The sample was drawn from a group of paid subjects engaged in highway navigation experiments. The analysis of 125 completed and usable questionnaires is presented. In addition to background information on demographics and driving experience, topics addressed included route selection, behavior under directional uncertainty, distance-time-cost trade-offs, and attitudes toward proposed remedial measures. The data obtained indicate that drivers are, generally, fairly satisfied with their ability to perform route-planning or route-following tasks effectively and believe that the major constraints on their effectiveness arise from the unavailability of adequate and accurate route and traffic information. This satisfaction, however, is not supported by data on the extent of excess travel due to navigational waste. Furthermore, answers to a number of questions indicated an insufficient appreciation of the complexities of determining optimum routes and of the extent and seriousness of the problem of navigational waste.

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**REVIEW**

Somewhat useful for obtaining an idea of how drivers view their own navigation and map-reading skills, what they feel are their weaknesses, as well as their willingness to have an automated system doing some of the work for them.

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**CRITICAL FINDINGS**

1. Efficiency of route selection and route following may be affected by driver age, sex, education, and driving experience. The degree of trip optimization may be affected by driver attitudes; beliefs; and behavior patterns, such as selection of route choice criteria, perceived driving costs, and distance-time trade-off patterns.

2. Perceived driving costs. Subjects' estimated costs were of the correct order; however, female estimations were higher and more variable.

3. Distance-time trade-offs. Less than one-fourth of all respondents were willing to make any trade-offs for savings of 1 min.

4. Trip planning behavior and skills. Subjects had a fairly high opinion of their route-planning and route-following skills. Male subjects were more likely to resort to maps and female subjects were more likely to ask for directions. Most subjects tried two or three alternate routes, and evaluation of four or more routes was infrequent.

5. Evaluation of candidate remedial measures. Improvements in signing, in map availability and accuracy, and in real-time traffic information were rated as being of greater importance by the subjects. Improving skills was considered less important than improving performance aids. Assistance in, or delegation of, the trip-planning and route-following tasks was ranked rather low.

6. The low rating of navigation and guidance systems might have been due to the relative unfamiliarity of the concepts involved, which would also be explained by the highest variability in the data.

7. Willingness to pay for improvements. Subjects' willingness to pay was considerably less than the anticipated probable costs for the various measures suggested.

8. These results suggest that subjects appear to have an insufficient appreciation of the complexities of determining and following optimum routes.

**Labiaie, G. (1989). Influence of in-car navigation map displays on drivers' performance. *SAE Technical Paper* Series (SAE No. 891683, pp. 11-18). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: Map displays
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers

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**ABSTRACT**

Different in-car navigation map displays have been tested with 60 drivers in real driving situations. The independent variable took into account three variables of guidance information (map alone, map associated with auditory guidance information, and map associated with written guidance information); two variables of itinerary complexity (number of turns); and two variables of information complexity (number of symbols). The dependent variables were composed of visual explorations, the memory recalling performance, the preference of map designs, the steering-wheel movements, and the speed variations of driving. The results have shown that map presentation associated with written directions resulted in a majority of the drivers being able to recall the route to follow. The complexity of map display designs had significant effects on the number and the duration of visual explorations and memorization performances. In the case of subjective preferences, most drivers preferred the simple map display design. Moreover, it was found that drivers reduced the speed of their vehicles while consulting the map displays. In conclusion, it was possible to propose some recommendations concerning the designs of navigational maps on board vehicles.


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**METHODOLOGY**

1. Independent variables

   a. Map alone, map with auditory information, and map with written information.

   b. Route complexity.

   c. Map viewed at stops versus during driving.

2. Dependent variables. Time spent looking at display, memory recall of route, preference of map display, steering-wheel movements, and speed variation of driving.

3. Data analysis techniques. ANOVA, X2.

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**REVIEW**

Useful only if we are interested in driver's preference and performance using various map displays. No task analysis or task descriptions.

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**CRITICAL FINDINGS**

1. Less time is spent glancing at a visual display when it is combined with auditory information than compared to a map alone or a map combined with written information.

2. Complexity of the routes has a negative influence on drivers' ability to recall an itinerary, especially when driving.

3. Average glances at the display are 1.28 s; 92.3 percent of all glances were 2 s or less (some could be as long as 4.8 s).

4. This effect was independent of the type of maps. Many more errors and omissions were noted for road names than for the drivers' ability to find their way.

5. Drivers preferred maps with auditory information (48 percent) over maps alone (34 percent) and maps with written information (17 percent), even though maps with written information led to the best recall (69 percent).

6. Author recommended:

    a. Maps should be supplemented with voice messages when used while driving or with written information to be viewed when stopped.

    b. Maps should be simplified for use while driving and have more detailed information for use when stopped.

**Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentations. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors Society.**

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TOPIC: Map displays
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers

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**ABSTRACT**

Two studies investigate the effects of presentation modalities (visual/auditory/repeated auditory) and complexity levels of different in-car road information on subjective preferences and on perceptual and cognitive performances of drivers. In real driving situations, each driver was alerted by a ringing signal prior to the presentation of a road information message or a map display associated with a road guidance message; the experimenter asked each driver 30 s later to recall the message or the itinerary. Results suggest that in real driving situations, short auditory road information messages or those associated with map displays optimize perceptual and cognitive performances and driving safety; written messages are of greater interest if screened when the vehicle is at rest.


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**METHODOLOGY**

1. Independent variables

   a. Visual or auditory information.

   b. Four levels of road information: 4 units; 7 to 9 units; 10 to 12 units; and 14 to 18 units.

   c. Two experiments that are similar, except that this time, maps were presented along with this visual or auditory information. The number of route changes was also manipulated.

2. Dependent variables. Recall performance, subjective preferences of modalities, visual exploration, vehicle course, and speed control.

3. Data analysis techniques. ANOVA, $X2$.

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REVIEW

Somewhat useful. The findings are similar to the ones found in another study by Labiale. It is useful to identify the amount of information that a driver can handle, both visual and auditory.

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CRITICAL FINDINGS

1. Drivers feel that auditory information is safer than visual information and it is preferred for messages of Levels 3 and 4. Drivers prefer maps associated with auditory guidance (71.8 percent) to the ones with visual guidance (28.1 percent).

2. Visual stimulus disturbed the driving task at higher levels of display complexity, both in course deviation and slowing of speed.

3. The optimal perceptual and cognitive solution seems to be an auditory message using a maximum of 7 to 9 informational units for road information, or if used visually, as a prompt to a very simple visual map or guidance presentation.

4. Recall at Level 1 is 100 percent and 48.4 percent at Level 4.

5. Increasing the message length increases the number of visual fixations and the overall duration of visual explorations, but not necessarily the average duration of each visual fixation.

**Lunenfeld, H. (1990). Human factor considerations of motorist navigation and information systems. In *Proceedings of First Annual Vehicle Navigation and Information Systems Conference* (pp. 3542). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: Human factors - IVNS
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

In-Vehicle systems have the potential for ameliorating problems associated with navigation and operations, including delay, excess fuel consumption, congestion, and increased safety risk. A proliferation of vehicle-based systems, however, has resulted in a lack of standardization and a diversity of functions. User interfaces are crucial to system effectiveness. Therefore, while display and control configurations will ultimately be determined by the marketplace, it is important that human factors be addressed and guidelines be developed. This will ensure standardization and display and control optimization. Human factors have been considered in terms of seven questions: Why? What? When? Where? How? Who? and Can?


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**REVIEW**

Very useful with respect to describing the individual task of driving, as well as in terms of the nature of the information required, display characteristics, users' limitations, and characteristics to enhance the efficiency of these systems.

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**CRITICAL FINDINGS**

1. Driving task

   a. Characterized as an Information Decision Action (IDA) activity, where information received in-transit is used with information and knowledge in-storage to make decisions and perform actions in a continuous feedback process.

   b. Driving consists of a number of discrete, interrelated subtasks. These subtasks can be arranged into three levels of performance:

      (1) Control: Vehicle control.
      (2) Guidance: Road following; safe path maintenance.
      (3) Navigation: Two phases-pre-trip and in-transit.

2. Navigational information

a. *Trip purpose:* commuting, family/personal, and social/recreational.

b. *Drivers:* locals, strangers, and local-strangers.

3. Navigational error

a. *Control and guidance errors's:* near misses, traffic conflicts, and accidents (due to improper speed, wrong path, and hazards).

b. *Navigation errors:* slow driving, erratic maneuvers, delay, and lost or confused drivers (due to stranger's planning and poor direction-finding).

c. *Pre-trip errors:* due to trip planning deficiencies.

d. *In-trip errors:* due to lack of trip planning; erroneous plan; deficient information display; unforeseen events; and/or task demands that lead to overload, missed choice points, and confusion. Deficiencies in navigational display can result in errors due to missing information carriers; illegible carriers; obscured signs; signs blocked by trucks or foliage; and information that is ambiguous, confusing, or with too high an information challenge.

e. *Manifestations:* slow, stop, or directional uncertainties (last-minute lane changes, stopping and backing on exit ramps, and illegal U-turns).

4. Purpose

a. Could develop a trip plan; optimize a route in real time; ensure error-free route following; aid in recovery if errors occur; and provide information regarding services, attractions, weather, sources of delay, congestion, road conditions, and road hazards.

b. Could provide collision avoidance information, vehicle status information, inter-vehicle communications, and communications with a central authority. Could aid in congestion relief by enabling users to report incidents and road/traffic conditions by inputing delay and travel time data to a central traffic management authority.

c. *Types of communications:* none, area broadcasting and/or local roadside transmission (one-way), or mobile radio systems and/or local roadside transponders (two-way).

5. Display considerations

a. *Allocation of functions on displays:* a display dedicated to a particular function or whether there will be shared functions.

b. *Three display modes:* visual, auditory, or combined visual/auditory. Cross-modal redundancy (e.g., continuous visual information versus repeated auditory).

c. Focus on integrating navigational and vehicle status displays whenever possible.

d. *Visual displays:* analog, digital, verbal, symbolic, and/or maps, or combinations. Size and location, conspicuity. Stimulus characteristics: color, brightness, contrast, and legibility.

e. *Auditory displays:* non-verbal warning signals, tones, verbal speech synthesis. Loudness and location. Stimulus characteristics: tone, fidelity, repetition rate, and message understandability.

f. *Display grouping:* level of interpretation, reading errors, and ambiguity.

g. *Control design and panel layout:* several factors to consider.

6. User characteristics. Anthropometrics, vision, hearing, time and task sharing, and memory.

7. Decrements

a. *Transitory states:* alcohol, drugs, fatigue, distress, attitudinal problems, and lawbreaking.

b. *Long-term states:* illiteracy, inexperience, lack of knowledge (overcome by experience, training, and a user-friendly system), color weaknesses, visual acuity and accommodation, hearing loss, and inattention.

c. *Older drivers.*

**Noy, Y.I. (1989). Intelligent route guidance: Will the new horse be as good as the old? In *Vehicle Navigation and Information Systems Conference Proceedings* (pp. 49-55). Toronto, Ontario, Canada: International Ergonomics Association.**

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TOPIC: Intelligent route guidance systems
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers (20 subjects)

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**ABSTRACT**

Automobile navigation systems are undergoing rapid technological evolution following advances in microprocessors and artificial intelligence. The present study was initiated to investigate the human factors of intelligent automobile displays with a view towards determining the need for design guidelines. The experiment was designed to examine the relationship between drivers' visual attention and performance under concurrent multi-task conditions. Twenty young male and female students with normal vision and a minimum of 3 years of driving experience were randomly assigned to two groups in a mixed, three-factor experiment. Subjects drove in a moving-base simulator and performed cognitive tasks on a CRT display that was located on the instrument panel to the right of the driver. The two display tasks-a spatial perception task and a verbal memory task-were designed to place differential demands on cognitive resources. Subjects were instructed to perform their best on the display and driving tasks, giving priority to the driving. Display task difficulty and driving difficulty were manipulated within subjects. Task type (memory and perception) was the between-groups factor. Eleven dependent variables provided measures of driving performance, attentional behavior, display task performance, and workload. In addition, on-line eye movement sampling indicated whether the subject looked at the roadway or at the computer display. Results are discussed in relation to the need for ergonomics guidelines for the design of navigation displays.


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**METHODOLOGY**

1. Independent variables. Simulated driving task.

   a. *Two auxiliary tasks:*

      (1) Memory task based on Sternberg paradigm (four levels of difficulty).

      (2) Perceptual task: line length distinction (four levels of difficulty).

   b. *Driving difficulty:* four levels of curve type.

2. Dependent variables

a. *Auxiliary task performance:* reaction time.

b. *Driving performance* lane position, lane exceedance ratio, time-to-lane crossing, headway, and velocity.

c. *Attention behavior:* dwell time, look frequency, and viewing ratio.

d. *Mental workload* time load index, mental demand, physical demand, temporal demand, effort, performance, and frustration.

3. Controls. Measures were taken for driving alone, auxiliary task alone, and auxiliary tasks with simulated movement to reduce confounds.

4. Purpose of research

a. Investigate the effects of auxiliary task load, resource structure, and driving load on driving performance in order to assess the need for ergonomics guidelines for the design and use of such displays.

b. Test/demonstrate a methodology that could be used to evaluate the intrusiveness of an intelligent display on driving.

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REVIEW

Very useful. Provides interesting findings regarding driver behavior when working on an auxiliary task, which could be compared to using an intelligent route guidance system.

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CRITICAL FINDINGS

1. Effects of auxiliary task load on driving

a. The presence and nature of the auxiliary task affected the quality of driving observed as measured by time-to-lane crossing, standard deviations of lane position, headway, and standard deviations of velocity.

b. However, there was no strong evidence that auxiliary task load (difficulty) affected driving.

c. The increased variance of speed and lane position are particularly important to traffic safety since these measures have been shown to correlate well with accident experience.

2. Effects of driving load on driving performance

   a. The more difficult the driving, the shorter the time margin for initiating correcting responses (time-to-lane crossing increased monotonically with road curvature).

   b. Higher road curvatures yielded larger decrements in time-to-lane crossing.

3. Effects of task load on attention

   a. Attentional response did not appear to be mediated by task difficulty, suggesting that attention is allocated primarily on the basis of driving load.

   b. In many respects, attentional response is a more useful indicator of task intrusion than driving performance, reflecting the drivers' perceptions of road performance requirements and experiences of workload.

4. Effects of driving load on attention

   a. Look frequency was highly dependant on driving load as well as the type of auxiliary task.

   b. Increased driving difficulty caused subjects to pay less attention to the auxiliary display.

   c. Look frequency more than doubled over the range of curve type, whereas dwell time increased by about 30 percent.

   d. The marginal increase in spare visual capacity associated with decreasing driving load was directed towards the auxiliary task primarily through increased sampling frequency.

   e. Glance duration also increased, although to a lesser extent.

   f. Viewing ratio increased from 20 percent for high driving load conditions to 50 percent for relatively low driving load conditions.

5. Effects of gaze direction on driving

   a. Driving variability was larger in magnitude while looking outside the vehicle than while looking inside; hence, drivers tended to look at the auxiliary display when they considered that it was relatively safe to do so.

   b. A major factor underlying subjects' scanning strategy was their estimation of their driving performance. They adopted switching strategies that were designed to maintain driving quality within individually set limits.

**Nystuen, J.D. (1990). A framework for assessing travel behavior response to Intelligent Vehicle-Highway Systems. *SAE Technical Paper Series* (SAE No. 901509, pp. 103-111). Warrendale, PA: Society of Automotive Engineers.**

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TOPIC: IVHS - Transportation System Model
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Automobile drivers

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**ABSTRACT**

Identification of a framework for assessing the consequences of adopting IVHS applications is presented. IVHS applications modify vehicle-highway capacities by enhanced information processing. Mobility opportunities change and, if acted upon, change individual travel behavior. Changes in individual travel behavior affect aggregate travel behavior and transportation network loadings. Decisions to change the transportation system cycle through a three-step social action process involving goals and aspirations, knowledge and technology, and financial and legal capacity to act. Action is then constrained by opportunities available in the environment. The transportation system model presents a framework for designing research to estimate the requirements and consequences of adopting the new technology.

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**REVIEW**

Limited use except maybe for the Transportation System Model. The model possibly could be used to identify the chain of consequences that flow from adoption of physical devices or systems to travel behavior responses to secondary responses, and to the distribution of benefits between users and non-users.

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**CRITICAL FINDINGS**

1. The Transportation System Model shows the relationship between evaluation of mobility opportunities, individual and aggregate travel behavior, and spacial choice over a range of time frames. In summary, the models seems to indicate:

   a. All innovations that change system parameters will cycle through a three-step social action process that, subsequently, is constrained by what the environment offers. The social actions are factors such as goals and aspirations, knowledge and technology, and power of money and legal issues.

   b. At the environmental level, there are the transportation facilities (mobility opportunity) and the land-use pattern (mobility needs).

c. The transportation facilities supply the means for mobility (traffic flow and aggregate trips at three different levels-modal split, route assignment, and traffic load by network links). The land-use pattern creates the demand for mobility in the form of individual trip generation.

2. There is an implicit assumption that the IVHS research and development community holds, that as a society, we want to keep out individual, high-speed mobility.

3. The main thrust for policy planning is that IVHS is evolving in a distributed system where no one is in charge (may have been true in 1990; is it nowadays?).

4. New travel behavior may call for new rules for governing transport as risk and responsibility shift.

**Petchenik, B.B. (1989). The nature of navigation: Some difficult cognitive issues in automatic vehicle navigation. In *Vehicle Navigation and Information Systems Conference Proceedings* (No. CH2789-6/89/0000-0043). Toronto, Ontario, Canada.**

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TOPIC: Automatic vehicle navigation system
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

If one believes everything one reads in the newspapers, a technology for providing automatic car navigation is virtually in place. But, in fact, this is far from true. It is the purpose of this paper to demonstrate that finding one's way from place to place while driving a car is a complex cognitive task, and that if there is to be authentic computer-based assistance to drivers, it must come from devices and systems significantly different from the digital dashboard maps that have been offered to date.


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**REVIEW**

Not very useful. Very general and broad approach. Does not add much to what we already know. Actually, in some cases, the article makes wrong assumptions.

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**CRITICAL FINDINGS**

1. Navigation environment falls into four categories:

   a. *Static macro-environment:* landscape (e.g., roads, buildings, cities, rivers, etc.).

   b. *Static micro-environment:* physical landscape attended to by the driver (e.g., road, lanes, exits, ramps, overpass, curbs, signs, etc.).

   c. *Dynamic macro-environment:* overall driving conditions that change with time (e.g., traffic flow, congestion, weather, etc.).

   d. *Dynamic micro-environment:* constantly shifting milieu that is unique to each driver (e.g., proximate vehicles and objects, ice, water on the road, etc.).

2. In addition to these visible environments, the driver must be aware of and integrate information from at least five additional domains:

a. Place identifiers (e.g., names and numbers that identify places, areas, roads, highways, etc.).

b. Regulatory environment (e.g., signs or signals).

c. Tool environment (e.g., maps, directions, telephones, radios, etc.).

d. Driver's knowledge.

e. Driver's affective/sensory makeup (e.g., motivation, sensations, fatigue, etc.).

**Redding, R.E. (1990). Taking cognitive analysis into the field: Bridging the gap from research to application. In *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 1304-1308). Santa Monica, CA: Human Factors Society.**

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TOPIC: Cognitive Task Analysis (CTA)
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

Cognitive methods of task analysis have been used for training development. Although quite promising, these methods are generally time consuming, labor intensive, and require considerable expertise. This has precluded their full use in field training situations. Economical, practical, and user-friendly methods are needed that can be integrated easily with current approaches. This symposium paper discusses the potential of cognitive task analysis as well as the practicality problem. Of particular concern is how cognitive methods can receive widespread application among training practitioners-how to transition theory and research in cognitive task analysis into mainstream training development programs.


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**REVIEW**

Somewhat useful in terms of the elements to be considered when performing a cognitive task analysis. Aside from these points, the article is quite basic and general in its content.

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**CRITICAL FINDINGS**

1. Goals of CTA

   a. Identification of task components.

   b. Identification of the conceptual and procedural knowledge required for performance of similar components.

   c. Identification of differences between novices and experts as well as intermediate knowledge states.

   d. Specification of learning conditions that best facilitate progress from one knowledge state to the next.

2. Difference between traditional and cognitive task analysis

   a. Traditional task analysis identifies the skills and knowledge for each subtask or activity, but does not address overall knowledge organization. Segments the components into behaviorally distinct tasks.

   b. Cognitive task analysis analyzes knowledge base organization for the job as a whole, examining the interrelationship between salient concepts. Emphasis is on mental models used in task performance and the identification of components that can be trained to automaticity. The tasks are segmented according to the types of underlying skills involved and consistent task components that can be trained to automaticity.

3. Methods used in CTA

   a. Scaling techniques and protocol analysis.

   b. Interviews and observations must be structured to determine mental models, information-processing steps and strategies, task components that can be trained to automaticity, differences between novices and experts, and potential conceptual errors.

4. Tasks that should be analvzed. Tasks that require a high degree of problem solving and decision making place high workload requirements on the individual, require a well-developed conceptual knowledge base, and represent bottlenecks or problems in job performance or in which there are frequent errors.

**Roth, E., Bennett, K., & Woods, D.D. (1988). Human interaction with an "intelligent" machine. In E. Hollnagel, G. Mancini, & D.D. Woods (Eds.), *Cognitive Engineering in Complex Dynamic Worlds. New* York: Academic Press.**

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TOPIC: Problem solving/expert systems
TYPE OF ARTICLE: Position paper/empirical study
SUBJECT POPULATION: Technicians

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**ABSTRACT**

This paper reports the results of a study of technicians diagnosing faults in electro-mechanical equipment with the aid of an expert system. Technicians varying in level of experience and interactive style (active or passive) diagnosed faults varying in level of difficulty. The results indicate that the standard approach to expert system design, in which the user is assigned the role of data gatherer for the machine, is inadequate. Problem solving was marked by novel situations outside the machine's competence, special conditions, underspecified instructions, and error recovery, all of which required substantial knowledge and active participation on the part of technicians. It is argued that the design of intelligent systems should be based on the notion of a joint cognitive system architecture: computational technology should be used to aid the user in the process of solving his or her problem. The human's role is to achieve total system performance as a manager of knowledge resources that can vary in kind and amount of intelligence or power.


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**REVIEW**

Useful for its innovative approach on how support systems should be designed. The authors divert from the traditional approach to design support systems as *prostheses* (replacement or remedies for deficiencies) to a more innovative approach that considers support systems as a *cognitive instrument* (deploy machine power to assist human performance).

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**CRITICAL FINDINGS**

1. Two fundamental approaches to system design

   a. *Prosthesis paradigm:* The primary design focus is to apply computational technology to develop a stand-alone machine expert that offers some form of problem solution. The machine expert guides all problem-solving activities, dictating what observations and actions the user is to take to solve the problem. The user is assigned the role of data gatherer and action implementer.

   b. *Cognitive instrument paradigm:* The focus is to design a support system that uses computational technology to aid the user in the process of solving his or her problem.

Thus, the human's role is to achieve total system performance objectives as a manager of knowledge resources that can vary in intelligence or power.

2. Analysis of protocols. Problem-solving episodes were analyzed by charting the flow of judgments and actions that were made either by the machine or by the operator, and comparing the actual path of each episode to the canonical path.

3. Performance analysis

   a. Differences in performance were reflected in the amount of time required to solve a problem and in the number and substance of user-initiated activity and experimenter's interventions.

   b. Technician experience level and level of initiative turned out to be critical factors in determining the accuracy and speed of person-machine performance.

   c. Contrary to the assumption of the machine-as-prosthesis paradigm, the technicians did not and could not function solely as passive data gatherers.

   d. Successful performance depended on the ability of the technician to apply knowledge of the structure and function of the device and sensible troubleshooting approaches.

   e. Once the machine expert was off track, it could not recover by itself. The burden to detect and recover from deviations fell on the human.

4. Reasons for deviations from the canonical path

   a. Mismatches between the technician's state of knowledge and the one assumed by the machine expert.

   b. Technician entry errors due to slips, mismeasurements, n&observations, or misinterpretations.

   C. Technician installation errors.

   d. Technician errors due to inability to assess the intentions of the machine expert.

   e. Inherent variability of actual devices.

   f. Existence of multiple simultaneous faults.

   g. Unavailability of test equipment.

   h. Bugs in the machine expert's knowledge system.

5. <u>How to convert to a cognitive instrument machine</u>

   a. Build displays that provide a shared frame of reference.

   b. Provide more capabilities for a human to direct the machine's reasoning.

**Senders, J.W., Kristofferson, A.B., Levison, W.H., Dietrich, C.W., & Ward, J.L. (1967). The attentional demand of automobile driving.** ***Highway Research Record, 195,*** **pp. 15-33.**

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TOPIC: Attentional demands
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers (five subjects, including two of the authors)

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**ABSTRACT**

A theoretical analysis and an experimental investigation of certain aspects of automobile driver information processing were undertaken. The theoretical analysis was the result of an effort to avoid difficulties associated with a servomechanistic approach to the automobile driving problem. The analysis is predicated on the assumption that a driver's attention is, in general, not continuously, but only intermittently, directed to the road. Between observations, uncertainty about both the position of his own vehicle on the road and the possible presence of other vehicles or obstacles increases until it exceeds a threshold. At that moment in time, the driver looks again at the road. This simple model appears to be a useful analog of the driving process. The analysis makes specific predictions about the form of the functional relationship between intervals and between observations and vehicle speed. The experimental program had two goals. One was the empirical investigation of the relation between amount of interruption of vision and driving speed. The other was the determination for various drivers and various roads of the values of some of the parameters in the mathematical model. This report presents the results of the theoretical and experimental investigation. In general, the model is a fair approximation of actual behavior and it remains for future work to determine whether this approximation is good enough to be useful for the specification of vehicle, highway, and user characteristics.

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**METHODOLOGY**

1. Independent variables. Four experiments using two kinds of roads (easy and difficult) and two procedures (fixed occlusion and viewing time, fixed velocity and viewing time).

   a. *Fixed occlusion and viewing time:* used a constant period of occlusion and a constant observation time, with driver controlling speed to his or her maximum.

   b. *Fixed velocity and viewing time:* used a constant speed and permitted the driver to look when he or she wished.

      (1) Experiment 1: Easy road, fixed occlusion and viewing time.
      (2) Experiment 2: Easy road, fixed velocity and viewing time (voluntary control of occlusion).

(3) Experiment 3: Difficult road, fixed velocity and viewing time.
(4) Experiment 4: Difficult road, fixed occlusion and viewing time.

2. Dependent variables. Speed (Mi/h), viewing time (s), and occlusion time (s).

3. Control conditions. Not applicable.

4. Data analvsis techniques. Not applicable.

5. Methodology. Test track road.

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**REVIEW**

Not useful for this task. It is useful in determining how much attention may be demanded of a driver for varying road types and speeds and to compare these results using a mathematical approach.

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**CRITICAL FINDINGS**

1. The higher the speed, the shorter the interval needed between observations.

2. The less frequent the observations or the shorter the period of observations, the slower the speed the driver can maintain.

3. Authors suggest that drivers tend to drive to a limit and that limit is determined by the point when the driver's information-processing capacity, either real or imagined, is matched by the information generation rate of the road, either real or estimated.

**Smiley, A. (1989). Mental workload and information management. In *Vehicle, Navigation, and Information Systems Conference Proceedings* (pp. 435-438). Toronto, Ontario, Canada.**

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TOPIC: Subjective workload
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

The use of high technology in vehicles has the potential of greatly increasing the amount of information presented to a driver. The need for the new support systems to be sensitive to the mental workload experienced by the driver is discussed. Primary task, secondary task, and physiological and subjective measures of mental workload are described. The contribution of task difficulty, effort, and arousal to the driver's subjective mental workload is discussed. The manner in which each of these factors might be measured on-line is described. Finally, system adaptations that might be made at high levels of mental workload are suggested.

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**METHODOLOGY**

Not applicable.

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**REVIEW OF ARTICLE**

<u>Somewhat useful</u> for its theoretical approaches to workload measures and their usefulness in in-vehicle support systems. Does not add much that is not already known.

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**CRITICAL FINDINGS**

1. Important not to overload drivers at critical times during the driving task (e.g., intersections, curves, and heavy traffic). Have to consider more than just task difficulty because the same task can be perceived differently by different drivers.

2. The high technology support systems will have to be:

   a. Evaluated according to the level of mental workload they create.

   b. Designed to measure and respond to a driver's mental workload as it changes during the trip.

3. Two major uses of the four mental workload measures are:

   a. Designing and evaluating support systems to ensure that they present information in a way that does not overload the driver.

   b. Determining subjective mental workload while the car is in operation so that the support system can reduce any load it is placing on the driver when he or she is busy.

4. Visual capacity: a driver of a 1.8-m car traveling in a lane 3.7 m wide, at 50 km/h, and reading text in a vehicle for 2, 4, and 6 s would have probabilities of laterally deviating out of the lane of 0.05 percent, 1.1 percent, and 8.7 percent. Reducing the lane width increases these probabilities. *Mental workload can be reduced if visual material is presented in small chunks and at a slow rate.*

5. Contributing factor to subjective mental workload: task difficulty, driver effort, and driver arousal.

**Thordsen, M.L. (1991). A comparison of two tools for cognitive task analysis: Concept mapping and the critical decision method. In *Proceedings of the Human Factors Society 35th Annual Meeting* (pp. 283-285). Santa Monica, CA: Human Factors Society.**

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TOPIC: Cognitive task analysis
TYPE OF ARTICLE: Position paper
SUBJECT POPULATION: Not applicable

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**ABSTRACT**

Two knowledge elicitation tools for cognitive task analysis are described and compared: Concept Mapping (CM) and the Critical Decision Method (CDM). CM is a procedure that can be used to represent the interviewee's conception of a task by developing a graphical schematic of the perceptions of the task's components. It is appropriate when one needs to capture the interviewee's cognitive organization of the task's routine elements and how these elements fit together. CDM is highly effective at eliciting tacit knowledge about perceptions, expertise, and aspects of a domain that are often difficult for experts to articulate. It has proven to be an effective tool for capturing the deeper, difficult-to-articulate knowledge that separates experts from novices. Used together, these techniques can be very complementary and effective. CM provides an overview of the user's image of the task, including information about the clustering of and flow between concepts. CDM is an effective tool for identifying decision strategies, critical cues, situation assessment, goals and intent, expectancies, mental simulation strategies, and improvisation. Used in combination, the techniques can effectively generate recommendations for training and display design.

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**REVIEW**

Useful. Some aspects of these two task analyses could be useful to Task E. The Critical Decision Method is an interview process that has been developed for the analysis of critical incidents. As a consequence, it might be difficult to transfer to the type of usage required for Task E, but it is recommended as a method for providing display design recommendations. Concept Mapping is also an interview process that produces a schematic representation of the relationships among a task's components. It might be applicable to this project.

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**CRITICAL FINDINGS**

1. Concept Mapping (CM)

   a. Interview process that results in a schematic representation of the relationships among a task's components.

b. Specific concepts are represented by notes that are linked with directional arrows that are labeled, thus giving information about the nature of the link.

c. Can be used to examine the commonalities and idiosyncracies that exist in a knowledge base. Also can be used to generate a comprehensive knowledge representation of domain expertise.

2. <u>Critical Decision Method (CDM)</u>

a. Uses recollection of a specific incident as its starting point and is a method of eliciting the tacit knowledge about perceptions, expertise, and aspects that differentiate experts from novices.

b. Interviewees are asked to identify a non-routine event where their expertise made a difference and then a timeline of the event is constructed. From that timeline, questions are asked regarding goals; options that were generated, evaluated, and chosen; cue utilization; contextual elements; situation assessment factors; and decision strategies.

c. Useful to identify cognitive elements that are central to its proficient performance.

3. <u>Steps to the approach (CM + CDM together)</u>

a. Construct a concept map of the task, beginning with higher concepts and descending to more specific ones.

b. During the CDM interview, generate examples of incidents that underlie these concepts.

c. Determine, in advance, the type of information that is needed.

d. During the CDM interview, work from specific examples and work back towards more general concepts.

e. Go back to the concept map and identify and circle the larger conceptual clusters that are present.

4. <u>Four types of knowledge elicited</u>

a. Concepts and relationships among them.

b. Higher level clusters of groups of concepts.

c. Detailed enhancements of the critical concepts derived from the CDM.

d. Incidents identified as being representative of the critical concepts.

**Wierwille, W., Hulse, M., Fisher, T., & Dingus, T. (1988).** ***Effects of variations in driving task attentional demand on in-car navigation system usage.*** **General Motors Research Laboratories Contract Report No. CR-SS/02/05. Warren, MI.**

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TOPIC: Attentional demands
TYPE OF ARTICLE: Empirical study
SUBJECT POPULATION: Automobile drivers (24 subjects)

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**ABSTRACT**

Earlier studies have shown that drivers' visual scan patterns and dwell times are changed when using an in-car navigation display system. The fact that these changes occur raises questions about a driver's ability to adapt appropriately to high-demand driving situations. Thus, additional experiments were conducted to determine whether or not drivers adapt appropriately to high driving task demands while simultaneously navigating. One experiment was designed to investigate adaptation to high anticipated driving task demands, and a second was designed to investigate adaptation to high unanticipated driving task demands. The results of the two experiments demonstrate clearly that as driving task demands increase, drivers do indeed shift their visual sampling strategy appropriately. However, variability in the data suggests that good human factors design and appropriate placement of the display remain important issues.

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**METHODOLOGY**

1. Independent variables. Two experiments:

   a. *Anticipated attentional demand:* low, medium, and high.

   b. *Unanticipated attentional demand.*

2. Dependent variables

   a. *Attentional demands* rated both subjectively and objectively.

      (1) Objectives: sight distance, curvature, road width, and lane restriction.

      (2) Subjectives: ratings of road segments by human factors graduate students.

   b. *Eye movements:* eye scanning measures of roadway center, roadway off-center, signs, displays/controls, mirror, navigator, etc.

3. Data analysis. ANOVA, MANOVA.

4. Controls. Subjects were trained. They drove to unknown destinations all the time. They were used for both experiments (two runs in the first, three in the second).

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**REVIEW**

Somewhat useful if the reader's interest is in finding out how a navigation system affects drivers' attention, as measured by eye movements. The article has implications for the positioning of these instrumentations and their impact on the driving task.

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**CRITICAL FINDINGS**

1. For increases in both anticipated and unanticipated driving demands, drivers *increased* the proportion of time spent on the forward central view and *decreased* the proportion of time spent observing the navigator.

2. Increased anticipated demands resulted in *an increased* visual sampling rate by the drivers. The length of the sampling rate was shorter for anticipated driving demands and longer for unanticipated driving demands.

3. For increased unanticipated demands, the visual sampling rate *decreased* and drivers concentrated on the forward view with longer glances.

## ADDITIONAL RELEVANT LITERATURE


Alm, H., & Nilsson, L. (1991). *Changes in driver behaviour as a function of hands-free mobile telephones: A simulator study.* Linkoeping, Sweden: National Swedish Road and Traffic Research Institute.

Bhaskar, R., & Simon, H.A. (1977). Problem solving in semantically rich domains: An example from engineering thermodynamics. *Cognitive Science, I,* pp. 193-215.

Biggs, S.F., Rosman, A.J., & Sergenian, G.K. (1993). Methodological issues in judgment and decision-making research: Concurrent verbal protocol validity and simultaneous traces of process. *Journal of Behavioral Decision Making, 6,* pp. 187-206.

Bowers, V.A., & Snyder, H.L. (1990). Concurrent versus retrospective verbal protocol for comparing window usability. *Proceedings of the Human Factors Society 36th Annual Meeting* (pp. 1270-1274). Santa Monica, CA: Human Factors Society.

Carey, M., & Walley, S. (1990). Cognitive task analysis techniques in the design and evaluation of complex technological systems. *11 th Advances in Reliability Technology Symposium* (pp. 1 l-26). London, England: Elsevier.

Chubb, G. (May 1991). Some system analysis techniques. *System Development Technical Group Newsletter.* Santa Monica, CA: Human Factors Society.

Dingus, T.A., Antin, J.F., Hulse, M.C., & Wierwille, W.W. (1989). Attentional demand requirements of an automobile moving-map navigation system. *Transportation Research, 23A(4),* pp. 301-3 15.

Ericsson, K.A., & Simon, H.A. (1984). *Protocol analysis: Verbal reports as data.* Cambridge, MA: The MIT Press.

McKnight, A.J., & Adams, B.B. *(1970). Driver education task analysis. Volume I: Task descriptions.* (Report No. DOT-HS-800-367, HUMPRO-TR-70-103). Washington, DC: National Highway Traffic Safety Administration.

McKnight, A.J.,& Adams, B.B. (1970). *Driver education task analysis. Volume 2: Task analysis methods.* (Report No. DOT-HS-800-368, HUMPRO-IR-DI-70-l). Washington, DC: National Highway Traffic Safety Administration.

Miller, R.B. (1953). *A method for man-machine task analysis.* Wright-Patterson Air Force Base, OH: Wright Air Development Center, Air Research and Development Command.

Moe, G.L., Kelley, G.R., & Farlow, D.E. (1973). *Truck and bus driver task analysis* (Report No. DOT-HS-800-835). Goleta, CA: Human Factors Research Inc.

Redding, R.E. (1989). Perspective on cognitive task analysis: The state of the art. *Proceedings of the Human Factors Society 33rd Annual Meeting* (pp. 1348-1352). Santa Monica, CA: Human Factors Society.

Road Transport Research. (1988). *Route guidance and in-car communication systems. Chapter VIII: Conclusions and recommendations for future research* (pp. 85-104). Paris, France: OECD Scientific Experts Group.

Sanderson, P.M., James, J.M., & Seidler, K.S. (1989). SHAPA: An interactive software environment for protocol analysis. *Ergonomics,* II, pp. 1271-1302.

Triggs, T.J., Kantowitz, B.H., Terrill, B.S., Bittner Jr., A.C., & Fleming, T.F. (1990). The playback method of protocol analysis applied to rapid aiming task. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 1275-1279). Santa Monica, CA: Human Factors Society.

Woods, D.D., & Hollnagel, E. (1987). Mapping cognitive demands in complex problem-solving worlds. *International Journal of Man-Machine Studies, 26,* pp. 257-275.

# APPENDIX B. FUNCTION AND SCENARIO SELECTION

## FUNCTION SELECTION

The following paragraphs summarize the procedure and results of each analysis used for function selection, initially for the private vehicle operations and then for the commercial vehicle operations.

### Functional Characteristics Included in the Private Vehicle Task Analysis

A casual examination of the functional characteristics suggest that some may be more critical than others for overall system operation. In addition, it is obvious that certain combinations of ATIS functional characteristics may interact more strongly than others. A detailed examination of the information flows ensures that the scenarios used for the task analysis include important functional characteristics and meaningful groups of functional characteristics. This detailed examination shows which functions are most central to ATIS/CVO and which functional characteristics form highly coupled groups, based on the information flows that link them.

This analysis depends on identifying the information flows to and from each functional characteristic. The functional characteristics and information flows can be considered as a network, with functional characteristics representing the nodes of the network and information flows representing the links between nodes (see figure 3). This network can also be considered as a matrix of input/output relations. Such a matrix of input/output relations (see table 24) was created to summarize the information flows between functions.

To better understand what is meant by input/output relations, it is necessary to define a frame of reference for these inputs/outputs. In this particular analysis, the frame of reference used is the ATIS itself. In other words, an "input" is defined as information and data coming *to* the function, while an "output" is defined as information and data coming *from,* or produced by, the function. Thus, the ATIS function acts as a transfer function, transforming information and data from inputs to outputs.

In this matrix, an entry was made each time a given function served as either an input or output to another function. In other words, each time there is a "1" in the matrix, it indicates a link between the two functions. The first row and the first column of numbers represent each one of the functions, and the matrix reads as follows: Function 5.1 provides information to functions 5.2, 5.3, 5.6, 6.1, 6.3, 7.1, 7.2, and 8.2. Similarly, the first column reads as follows: Functions 5.7, 6.2, and 8.2 provide information to function 5.1. In other words, functional characteristics listed horizontally receive input from the functional characteristics listed vertically. To make it easier to understand, figure 25 provides a graphical representation of this first row and column, illustrating the functions that are considered inputs and the ones that are considered outputs.

**Table 24. Information flows between functions for private vehicle operations.**

| INPUTS | Function | IRANS 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 | IMSIS 6.1 | 6.2 | 6.3 | 6.4 | ISIS 7.1 | 7.2 | 7.3 | IVSAWS 8.1 | 8.2 | 8.3 | 8.4 | 8.5 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **OUTPUTS** | | | | | | | | | | | | | | | | | | | |
| IRANS | 5.1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 8 |
| IRANS | 5.2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| IRANS | 5.3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 7 |
| IRANS | 5.4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 5 |
| IRANS | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IRANS | 5.6 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| IRANS | 5.7 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| IMSIS | 6.1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| IMSIS | 6.2 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| IMSIS | 6.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| IMSIS | 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ISIS | 7.1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| ISIS | 7.2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| ISIS | 7.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| IVSAWS | 8.1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 |
| IVSAWS | 8.2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 9 |
| IVSAWS | 8.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| IVSAWS | 8.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| IVSAWS | 8.5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 5 |
| | TOTAL | 3 | 5 | 5 | 6 | 3 | 8 | 0 | 3 | 2 | 8 | 3 | 5 | 3 | 0 | 2 | 3 | 1 | 3 | 0 | |
| | INTERACTION TOTAL | 11 | 8 | 12 | 6 | 3 | 10 | 3 | 6 | 6 | 9 | 3 | 7 | 4 | 0 | 6 | 12 | 3 | 7 | 5 | |
| | RANK | 3 | 6 | 1.5 | 10.5 | 16.5 | 4 | 16.5 | 10.5 | 10.5 | 5 | 16.5 | 7.5 | 14 | 19 | 10.5 | 1.5 | 16.5 | 7.5 | 13 | |

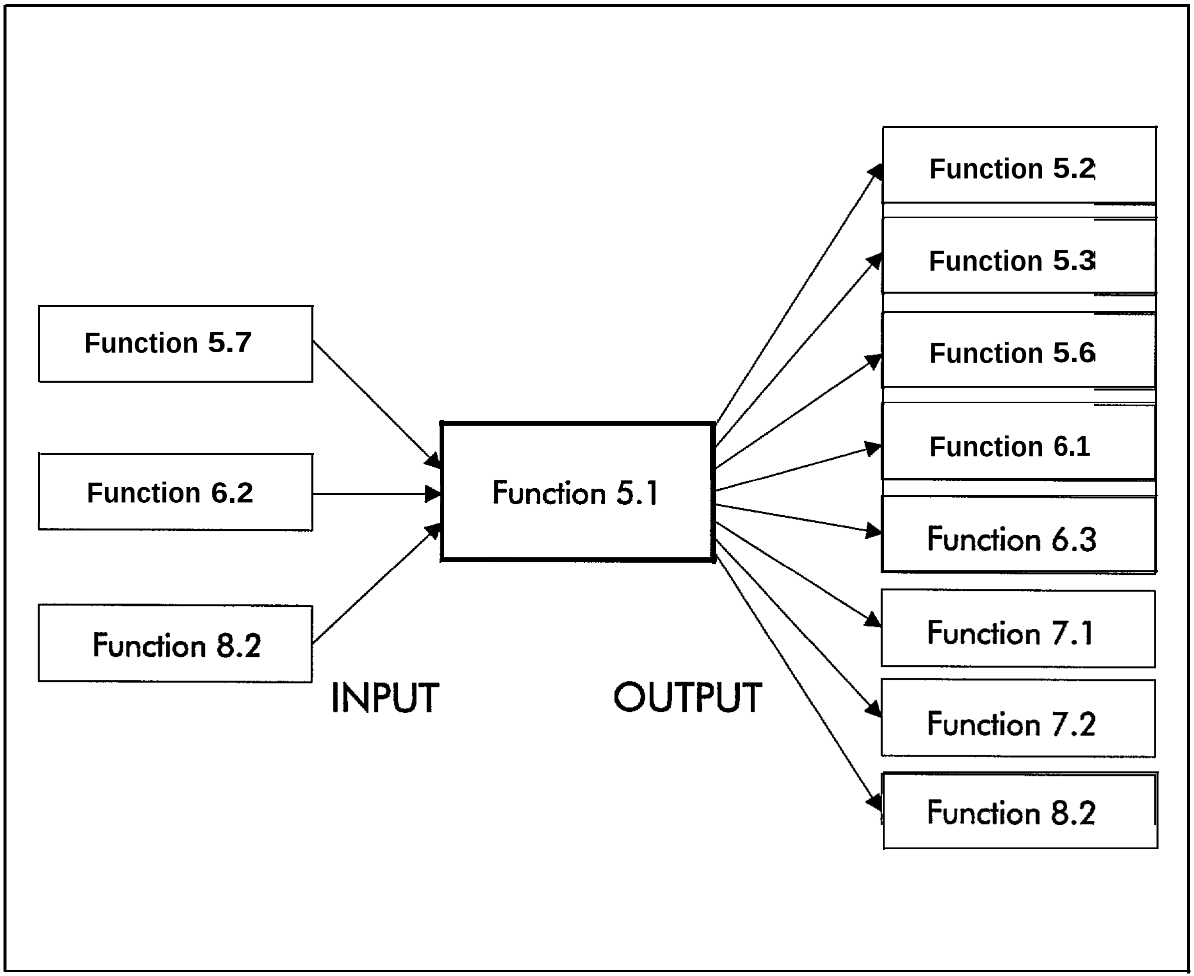



**Figure 25. Graphical representation of the first row and column of the matrix (table 24).**

Using this matrix of input/output relations, it is possible to calculate several measures of the importance of a functional characteristic and, as a consequence, determine its level of centrality in the system. Some of the measures calculated include a simple frequency count of the number of interactions between functions, while other measures of centrality are derived from network analysis techniques. The following paragraphs summarize the findings for each one of these analyses.

Frequency Count

A simple measure of the importance of a functional characteristic is the number of times it either receives from or provides information to other functions. The matrix depicted in table 24 offers the information necessary to calculate this frequency count. The bottom shaded row of table 24 indicates the total number of times a function receives information from other functions. This row shows that destination coordination (6.3) and route navigation (5.6) receive input from more functional characteristics than any other (eight times). Similarly, the right-most column shows the total number of inputs sent to other functional characteristics; for example, road condition information (8.2) provides information to more functional characteristics than any other (nine times).

By adding the row and column totals, it is possible to obtain a crude estimate of functional characteristic centrality. Those functional characteristics requiring the most inputs from other functions and providing the most outputs to other functional characteristics represent important nodes in the network of information flows that make up the ATIS. This analysis identifies pre-drive route and destination selection (5.3) and road condition information (8.2) as the two most central functions to an ATIS. The last row of table 24 shows the rank of each functional characteristic. Table 25 summarizes these results, showing the relative centrality of each functional characteristic.

**Table 25. Rank ordering of the private functional characteristics.**

| RANK | FUNCTION | | SYSTEM |
|---|---|---|---|
| 1.5 | 5.3 | Pre-drive and destination selection | IRANS |
| | 8.2 | Road condition information | IVSAWS |
| 3 | 5.1 | Trip planning | IRANS |
| 4 | 5.6 | Route navigation | IRANS |
| 5 | 6.3 | Destination coordination | IMSIS |
| 6 | 5.2 | Multi-mode travel coordination and planning | IRANS |
| 7.5 | 7.1 | Guidance information | ISIS |
| | 8.4 | Manual aid reauest | IVSAWS |
| 10.5 | 5.4 | Dynamic route selection | IRANS |
| | 6.1 | Broadcast services/attractions | IMSIS |
| | 6.2 | Services/attractions directory | IMSIS |
| | 8.1 | Immediate hazard warning | IVSAWS |
| 13 | 8.5 | Vehicle condition monitoring | IVSAWS |
| 14 | 7.2 | Notification information | ISIS |
| 16.5 | 5.5 | Route guidance | IRANS |
| | 5.7 | Automated toll collection | IRANS |
| | 6.4 | Message transfer | IMSIS |
| | 8.3 | Automatic aid request | IVSAWS |
| 19 | 7.3 | Regulatory information | ISIS |

Network Analyses

In addition to the simple frequency count, other methods exist to determine the relative centrality of functional characteristics. These measures provide an added level of sophistication that may generate a more accurate estimate of centrality. The frequency count estimates centrality by independently considering the input and output of each functional characteristic. In many cases, this may not be an appropriate approach because a functional characteristic might be more central than another one. For instance, a functional characteristic that has several inputs coming into it has a heavier weight and should be considered more central than a functional characteristic that has only one input. For example, figure 26 shows that the function characteristic "A" has three inputs coming to it, while function characteristic "B" has only one input. In this instance, the output coming from "A" has a heavier weight than the one coming from "B" and should be given more importance when considering its implication in regard to function characteristic "C." To overcome the limits of the frequency count, a network analysis was conducted using the same matrix that generated the frequency counts.

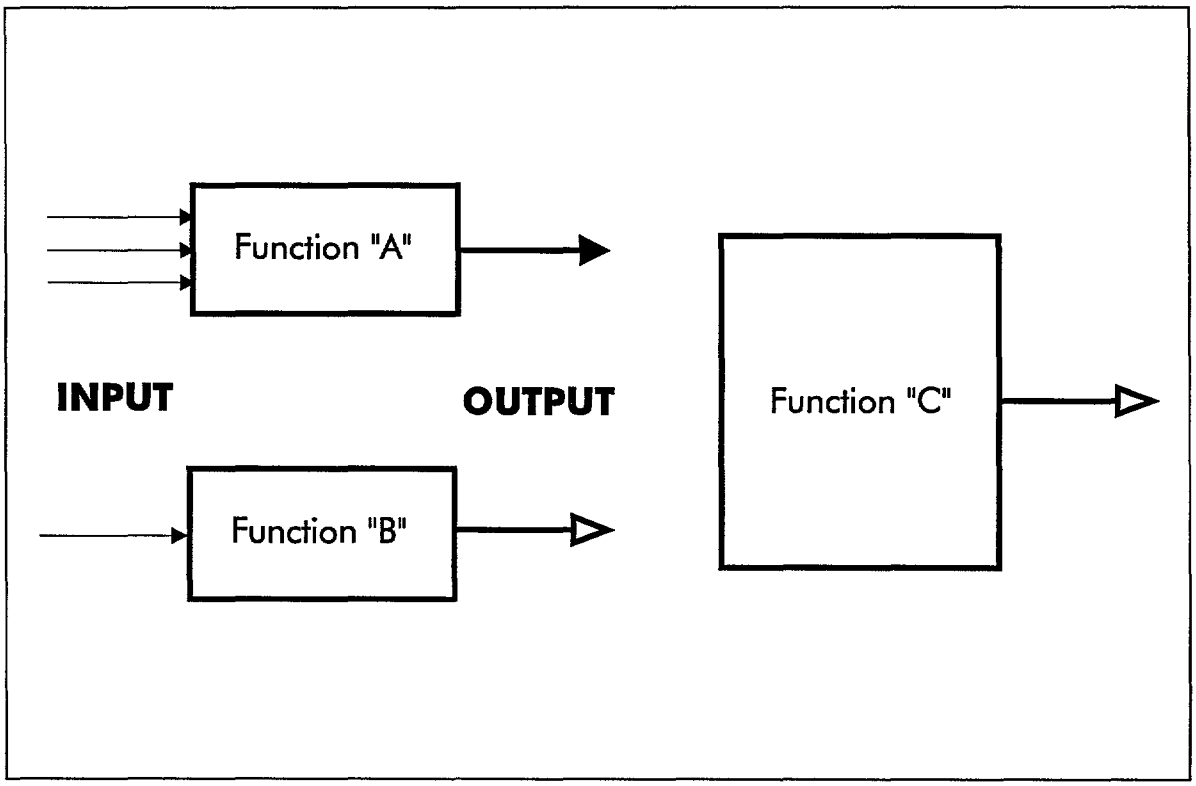



**Figure 26. Example of a differential weight applied to a functional characteristic.**

Measure of centrality. A variety of network analysis measures is available to estimate centrality of ATIS functional characteristics. Many of these measures make no distinction between inputs and outputs of a network. Because the network represented in table 24 does make this distinction (i.e., it is asymmetrical), a measure was chosen that accommodates the asymmetry of the matrix. As a consequence, this measure reflects the importance of functions based on information flows in and out of each function. Thus, each function has two measures of centrality, one as an input and one as an output. The input and output measures of centrality can be used to anticipate how people might need to interact with the system.

Functions with high levels of centrality, based on their output, represent functions that provide information to other functions. With these functions, the task analysis should focus on how the transfer of information from function to function may be facilitated by minimizing the amount of recoding and memory required of the driver. Conversely, functions that are highly central, based on the number of functions providing input, represent functions that tend to combine information from a variety of sources and then relay it to the driver. Passing information between functions will involve the driver in an entirely different set of tasks, compared to the tasks involved in acting on information provided by the system. Thus, a task analysis of these functions should focus on how the system conveys information to the driver, rather than on how information is passed between functions. In general, functions that are highly connected with other functions may merit special attention in the task analysis, because many aspects of the system may depend on them.

Freeman's measure of centrality (1979) estimates the centrality of the functional characteristics based on their output and input information flows. This estimate of centrality reflects the number of adjacent vertices to a given vertex, divided by the maximum possible vertices, and expressed as a percentage (Borgatti, Everett, & Freeman, 1992). For ease of understanding, a numerical example is provided.

As an example, five ATIS/CVO functions are considered. As table 24 shows, these functions are linked to other functions, but for simplicity, these links will be ignored for this example. The links between these five functions can be shown graphically, as in figure 27.

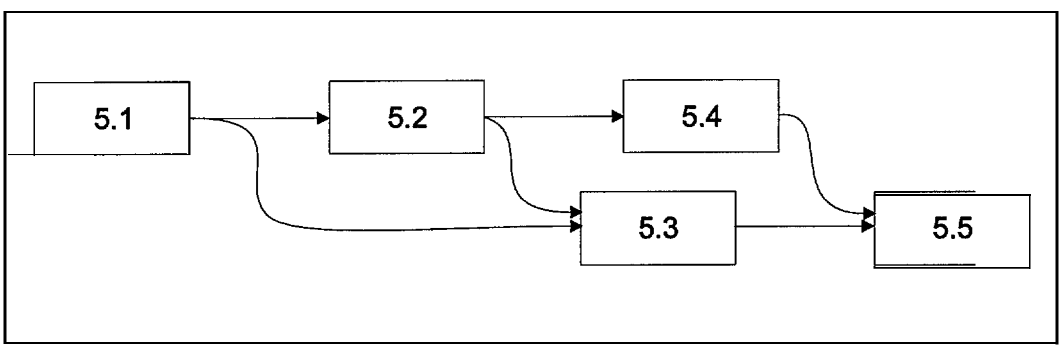



**Figure 27. Graphical depiction of the information flows linking a subset of ATIS/CVO functions.**

The links can also be shown as a matrix, as in table 26.

**Table 26. Matrix of input/output (centrality/links).**

| | Function | OUTPUTS | | | | |
|---|---|---|---|---|---|---|
| | | 5.1 | 5.2 | 5.3 | 5.4 | 5.5 |
| INPUTS | 5.1 | 0 | 1 | 1 | 0 | 0 |
| | 5.2 | 0 | 0 | 1 | 1 | 0 |
| | 5.3 | 0 | 0 | 0 | 0 | 1 |
| | 5.4 | 0 | 0 | 0 | 0 | 1 |
| | 5.5 | 0 | 0 | 0 | 0 | 0 |

Using the data in this table, the input and output centrality of each function can be calculated. To determine the input centrality, the number of inputs to a function are added (adjacent vertices). This number is divided by the total possible inputs (total vertices). For function 5.1, the input centrality is the number of inputs divided by the total possible inputs (0/4 = 0 percent). This results because function 5.1 has no inputs and a possible total of four inputs. For function 5.2, the input centrality is 1/4 = 25 percent, because table 27 shows one input to function 5.2 out of a possible four inputs.

Output centrality is calculated in the same manner. For example, function 5.1 has outputs to functions 5.2 and 5.3. Since the output centrality is the total number of outputs divided by the total possible inputs, the output centrality for function 5.1 is 2/4 = 50 percent. The input and output centrality for each function in this example is summarized below.

**Table 27. Calculating input and output centrality.**

| Function | Input Centrality | Output Centrality |
|---|---|---|
| 5.1 | 0 | 50 |
| 5.2 | 25 | 50 |
| 5.3 | 50 | 25 |
| 5.4 | 25 | 25 |
| 5.5 | 50 | 0 |

Table 28 summarizes this measure of centrality. Input centrality is proportional to the number of functions that a given function receives, while output centrality is proportional to the number of functions to which a given function provides information. In other words, a function that has a large number of outputs has a greater output centrality than a function that has fewer outputs. For example, table 28 shows that destination coordination (6.3) and route navigation (5.6) are very central in terms of the inputs they receive from other functional characteristics. Table 28 also shows road condition information (8.2) to be central based on the input it provides to other functional characteristics. These two facts are illustrated in figure 28. To ensure that the scenarios accurately represent the ATIS, several scenarios should include functional characteristics that are highly central; otherwise, scenarios may fail to capture a representative set of tasks associated with the functional characteristics critical to system success.

**Table 28. Centrality measures for private driver functional characteristics.**

| FUNCTION | | INPUT CENTRALITY | OUTPUT CENTRALITY |
|---|---|---|---|
| IRANS | 5.1 | 16 | 44 |
| | 5.2 | 27 | 16 |
| | 5.3 | 27 | 38 |
| | 5.4 | 33 | 28 |
| | 5.5 | 17 | 0 |
| | 5.6 | 44 | 11 |
| | 5.7 | 0 | 17 |
| IMSIS | 6.1 | 17 | 17 |
| | 6.2 | 11 | 22 |
| | 6.3 | 44 | 6 |
| | 6.4 | 17 | 0 |
| ISIS | 7.1 | 28 | 11 |
| | 7.2 | 17 | 6 |
| | 7.3 | 0 | 0 |
| IVSAWS | 8.1 | 11 | 22 |
| | 8.2 | 17 | 50 |
| | 8.3 | 6 | 11 |
| | 8.4 | 17 | 22 |
| | 8.5 | 0 | 28 |
| MEAN | | 18.42 | 18.42 |
| STANDARD DEVIATION | | 12.88 | 14.20 |

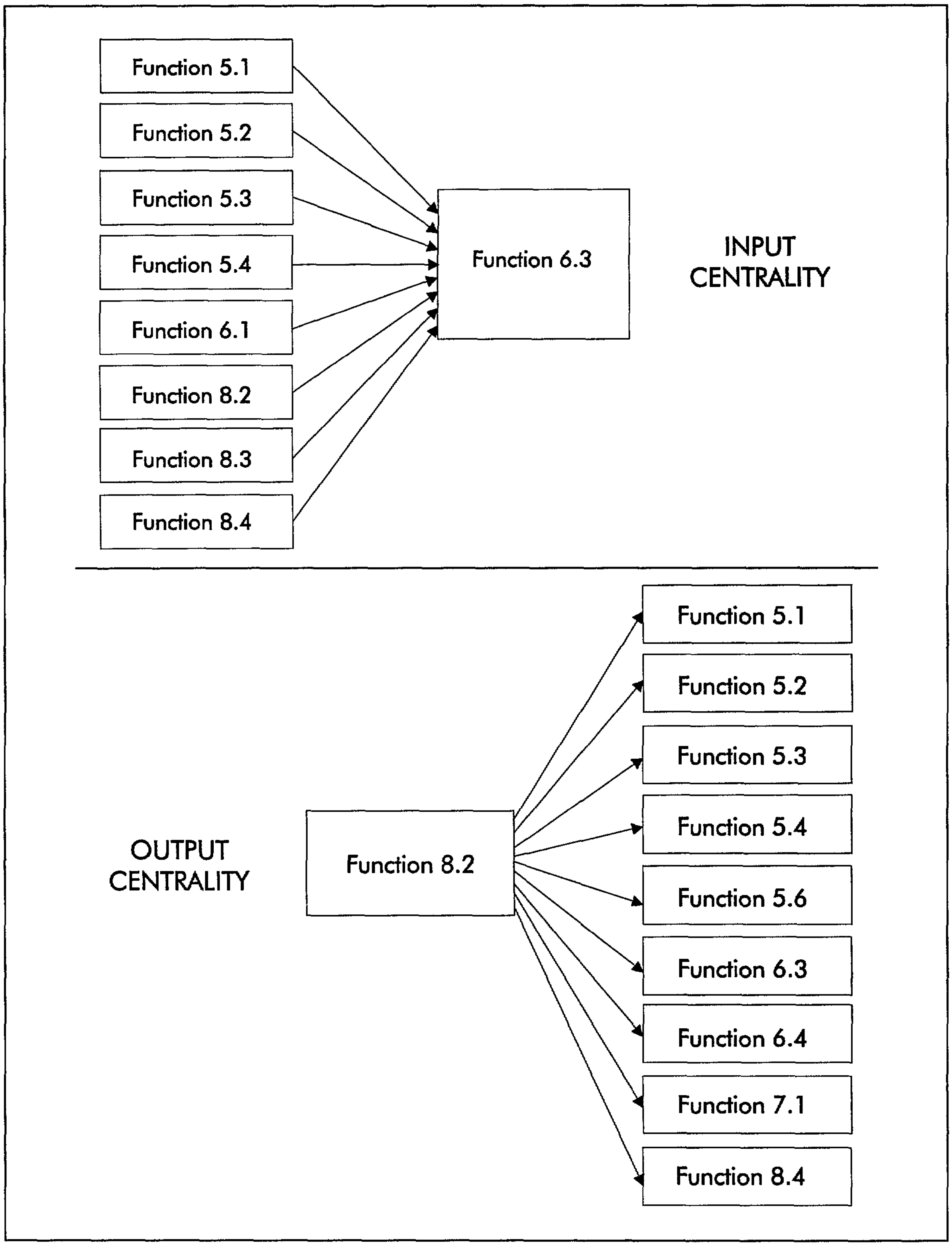



**Figure 28. Examples of input and output centrality.**

In conclusion, based on the network analyses for the private group, the centrality measures indicate that seven measures were found to be highly central. They are:

- 5.1 Trip planning.
- 5.2 Multi-mode travel coordination and planning.
- 5.3 Pre-drive route and destination selection.
- 5.4 Dynamic route selection.
- 5.6 Route navigation.
- 6.3 Destination coordination.
- 8.2 Road condition information.

Cliques

In addition to estimates of the centrality of each functional characteristic, an estimate of how information flows link functional characteristics into groups is an important element in identifying representative scenarios. If scenarios contain arbitrary sets of functions, they are unlikely to reveal representative information transfers between functional characteristics. Two network analyses were performed to explain how information flows link groups of functional characteristics. One analysis identified cliques and one identified clusters or "factions." Each uses a different criteria to group functional characteristics, but provides converging measures of groups of functional characteristics linked by information flows.

A clique is a formal description of the density of links between nodes of a network. The density of links is equal to the total number of links divided by the number of nodes present. For example, if the number of links between two groups of functions is equal, the group that has the smallest number of functions (nodes) would have the greatest density of links. A clique also represents a maximally complete subgraph, which is defined as a coherent grouping of nodes connected by links or information flows. In other words, a clique is defined as a set of nodes that are directly linked to each other. Each member of a clique must have at least as many connections to other functional characteristics as there are members in the clique. Specifically, in a clique of three nodes, each node must have links to each of the other nodes in the clique (three) plus any other links to other nodes in the network that are not part of the clique. Thus, a clique shows a group of functions that share information directly between each other. For the private application of ATIS, the network analysis (see table 29) identifies 20 cliques of three functions or more (a clique of two is trivial, simply a pair of linked nodes). These results suggest that the selection of scenarios should include those that consist of groups of functional characteristics from the 20 combinations.

Clusters

A cluster or faction (Borgatti, Everett, & Freeman, 1992) analysis represents another network analysis method that can identify groups of functional characteristics linked by their information flows. The cluster analysis extracts "factions" and does not impose the same strict, formal definition on the members of a group that a clique does. This analysis

**Table 29. Cliques for private functions.**

| CLIQUE | FUNCTIONS | | | | |
|---|---|---|---|---|---|
| **1** | 5.1 | 5.2 | 5.3 | 5.6 | 6.2 |
| **2** | 5.1 | 5.2 | 5.3 | 5.6 | 8.2 |
| **3** | 5.1 | 5.3 | 5.6 | 6.1 | |
| **4** | 5.1 | 5.3 | 5.6 | 7.1 | 8.2 |
| **5** | 5.1 | 5.3 | 5.6 | 7.2 | |
| **6** | 5.1 | 5.2 | 5.3 | 5.7 | |
| **7** | 5.1 | 5.2 | 5.3 | 6.3 | 8.2 |
| **8** | 5.1 | 5.3 | 6.1 | 6.3 | |
| **9** | 5.3 | 5.5 | 7.1 | | |
| **10** | 5.4 | 5.6 | 7.1 | 8.1 | |
| **11** | 5.4 | 5.6 | 7.1 | 8.2 | |
| **12** | 5.4 | 5.6 | 6.1 | | |
| **13** | 5.2 | 5.4 | 5.6 | 8.2 | |
| **14** | 5.4 | 5.6 | 7.2 | | |
| **15** | 5.4 | 5.5 | 7.1 | | |
| **16** | 5.2 | 5.4 | 6.3 | 8.2 | |
| **17** | 5.4 | 6.1 | 6.3 | | |
| **18** | 5.4 | 6.1 | 8.5 | | |
| **19** | 6.3 | 6.4 | 8.2 | 8.4 | |
| **20** | 6.2 | 8.4 | 8.5 | | |

optimizes a cost function that is based on the extent that a group of functional characteristics consists of linked clique-like structures (Borgatti, Everett, & Freeman, 1992). Thus, the cluster analysis identifies groups of functional characteristics in a manner vaguely analogous to factor analyses in traditional statistics. Table 30 summarizes the results of the analysis when five clusters were specified. Two of the five clusters were not considered meaningful as they contained functions that interacted only with themselves. The five clusters for the private operations consist of the functions listed in table 31.

**Table 30. Clusters for private functions.**

| FUNCTION | 5.1 | 5.2 | 5.3 | 5.4 | 8.2 | 5.6 | 7.1 | 7.2 | 5.7 | 6.2 | 8.1 | 8.5 | 8.4 | 8.3 | 6.1 | 6.4 | 6.3 | 7.3 | 5.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.1 | 1 | | | | 1 | | | | 1 | 1 | | | | | | | | | |
| 5.2 | 1 | 1 | | | 1 | 1 | | | 1 | 1 | | | | | | | | | |
| 5.3 | 1 | 1 | 1 | | 1 | | | | 1 | 1 | | | | | | | | | |
| 5.4 | | 1 | | 1 | 1 | 1 | | | | | 1 | 1 | | | 1 | | | | |
| 8.2 | 1 | | 1 | 1 | 1 | | | | | | | | | | | | | | |
| 5.6 | 1 | | 1 | | 1 | 1 | 1 | 1 | | 1 | 1 | | | | 1 | | | | |
| 7.1 | 1 | | 1 | 1 | 1 | | 1 | | | | 1 | | | | | | | | |
| 7.2 | 1 | | 1 | 1 | | | | 1 | | | | | | | | | | | |
| 5.7 | | | | | | | | | 1 | | | | | | | | | | |
| 6.2 | | | | | | | | | | 1 | | 1 | 1 | | | | | | |
| 8.1 | | | | | | | | | | | 1 | | 1 | 1 | | | | | |
| 8.5 | | | | | | | | | | | | 1 | | | | | | | |
| 8.4 | | | | | 1 | | | | | | 1 | 1 | 1 | | | | | | |
| 8.3 | | | | | | | | | | | | 1 | | 1 | | | | | |
| 6.1 | 1 | | 1 | | | | | | | | | 1 | | | 1 | | | | |
| 6.4 | | | | | 1 | | | | | | | | 1 | | | 1 | 1 | | |
| 6.3 | 1 | 1 | 1 | 1 | 1 | | | | | | | | 1 | 1 | 1 | | 1 | | |
| 7.3 | | | | | | | | | | | | | | | | | | 1 | |
| 5.5 | | | 1 | 1 | | | 1 | | | | | | | | | | | | 1 |

**Table 31. Private vehicle cluster analysis.**

| | |
|---|---|
| **CLUSTER 1: PLANNING AND NAVIGATION** | |
| 5.1 Trip planning | IRANS |
| 5.2 Multi-mode travel coordination and planning | IRANS |
| 5.3 Pre-drive route and destination selection | IRANS |
| 5.4 Dynamic route selection | IRANS |
| 5.6 Route navigation | IRANS |
| 7.1 Guidance sign information | ISIS |
| 8.2 Road condition information | IVSAWS |
| **CLUSTER 2: MISCELLANEOUS FUNCTIONS** | |
| This cluster is not meaningful. It is composed of two functions and each interacts only with itself. | |
| CLUSTER 3: AID AND EMERGENCY SERVICES | |
| 6.2 Services/attractions directory | IMSIS |
| 8.1 Immediate hazard notification | IVSAWS |
| 8.3 Automatic aid request | IVSAWS |
| 8.4 Manual aid request | IVSAWS |
| 8.5 Vehicle condition monitoring | IVSAWS |
| **CLUSTER 4: TRAVEL COORDINATION** | |
| 6.1 Broadcast services/attractions | IMSIS |
| 6.3 Destination coordination | IMSIS |
| 6.4 Message transfer | IMSIS |
| **CLUSTER 5: MISCELLANEOUS FUNCTIONS** | |
| This cluster is not meaningful. It is composed of two functions and each interacts only with itself. | |

These clusters of functions can help guide the task analysis by identifying scenarios that consist of functions within a single cluster and scenarios that require functions from several clusters. A task analysis of a scenario that consists of functions from a single cluster can reveal the requirements of supporting a driver with what should be an integrated set of functions (from the perspective of the information flows that generated the clusters). One interesting result of the cluster analysis is that the resulting clusters do not correspond only to the ATIS subsystems (IRANS, IMSIS, ISIS, IVSAWS). Nevertheless, these distinctions do indeed capture an essential feature: IRANS-Cluster 1, IVSAWS-Cluster 3, and IMSIS-Cluster 4.

**Functional Characteristics Included in the Commercial Vehicle Task Analysis**

Frequency Count

A similar analysis using the matrix of information flows between functions (see table 32) was performed for the ATIS/CVO functional characteristics appropriate for commercial drivers. The results of the rank ordering of each function according to interactions with other functions are listed in table 33. Once more, the functions are ranked from those with the

## Table 32. Information flows between functions for commercial vehicle operations.

| INPUTS | | OUTPUTS: IRANS 5.1 | 5.2 | 5.3 | 5.4 | 5.5 | 5.6 | 5.7 | 5.8 | IMSIS 6.1 | 6.2 | 6.3 | 6.4 | ISIS 7.1 | 7.2 | 7.3 | 7.4 | IVSAWS 8.1 | 8.2 | 8.3 | 8.4 | 8.5 | 8.6 | CVO 9.1 | 9.2 | 9.3 | 9.4 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IRANS | 5.1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 12 |
| | 5.2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 8 |
| | 5.3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 12 |
| | 5.4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 7 |
| | 5.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5.6 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | 5.7 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 6 |
| | 5.8 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 11 |
| IMSIS | 6.1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | 6.2 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| | 6.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| | 6.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 3 |
| ISIS | 7.1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | 7.2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 7.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7.4 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 6 |
| IVSAWS | 8.1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| | 8.2 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 12 |
| | 8.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 5 |
| | 8.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 6 |
| | 8.5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 10 |
| | 8.6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 10 |
| CVO | 9.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| | 9.2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 5 |
| | 9.3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 4 |
| | 9.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 3 |
| TOTAL | | 5 | 5 | 8 | 11 | 3 | 10 | 0 | 8 | 5 | 3 | 9 | 6 | 5 | 3 | 0 | 2 | 1 | 4 | 2 | 4 | 0 | 1 | 13 | 16 | 10 | 7 | |
| | | 17 | 13 | 20 | 18 | 3 | 12 | 6 | 19 | 8 | 8 | 11 | 9 | 7 | 4 | 0 | 8 | 5 | 16 | 7 | 10 | 10 | 11 | 15 | 21 | 14 | 10 | INTERACTION TOTAL |
| | | 5 | 9 | 2 | 4 | 25 | 10 | 22 | 3 | 18 | 18 | 11.5 | 16 | 20.5 | 24 | 26 | 18 | 23 | 6 | 20.5 | 14 | 14 | 11.5 | 7 | 1 | 8 | 14 | RANK |

**Table 33. Rank ordering of the commercial functional characteristics.**

| RANK | FUNCTION | SYSTEM |
|---|---|---|
| 1 | 9.2 Dispatch | CVO-specific |
| 2 | 5.3 Pre-drive route and destination selection | IRANS |
| 3 | 5.8 Route scheduling | CVO-specific |
| 4 | 5.4 Dynamic route selection | IRANS |
| 5 | 5.1 Trip planning | IRANS |
| 6 | 8.2 Road condition information | IVSAWS |
| 7 | 9.1 Fleet resource management | CVO-specific |
| 8 | 9.3 Regulatory administration | CVO-specific |
| 9 | 5.2 Multi-mode travel coordination | IRANS |
| 10 | 5.6 Route navigation | IRANS |
| 11.5 | 6.3 Destination coordination<br>8.6 Cargo and vehicle monitoring | IMSIS<br>IVSAWS |
| 14 | 8.4 Manual aid request<br>8.5 Vehicle condition monitoring<br>9.4 Regulatory enforcement | IVSAWS<br>IVSAWS<br>CVO-specific |
| 16 | 6.4 Message transfer | IMSIS |
| 18 | 6.1 Broadcast services/attractions<br>6.2 Services/attractions directory<br>7.4 Road restriction information | IMSIS<br>IMSIS<br>CVO-specific |
| 20.5 | 7.1 Guidance information<br>8.3 Automatic aid request | ISIS<br>IVSAWS |
| 22 | 5.7 Automated toll collection | IRANS |
| 23 | 8.1 Immediate hazard warning | IVSAWS |
| 24 | 7.2 Notification information | ISIS |
| 25 | 5.5 Route guidance | IRANS |
| 26 | 7.3 Regulatory information | ISIS |

most interactions to those with the least. This table indicates that dispatch is the most frequent interacting function, closely followed by the pre-drive route and destination selection, which also happened to be the most frequent interacting function for the private vehicle operations.

Network Analyses

An analysis was performed of the network formed by the ATIS and the CVO-specific functional characteristics and the information flows that connect them. This analysis parallels that done for the private drivers.

Measure of centrality. Freeman's measures of centrality for functional characteristics of commercial drivers show differences in comparison to the analysis of the private drivers. For the commercial drivers, dispatch (9.2) appeared to be most central in terms of information received from other functional characteristics. Three functional characteristics all had the same measure of centrality, based on the information they provided to other functional characteristics; i.e., trip planning (5.1), pre-driver route and destination selection (5.3), and road condition information (8.2). Table 34 summarizes these results.

**Table 34, Centrality measures for commercial driver functional characteristics.**

| FUNCTION | | INPUT CENTRALITY | OUTPUT CENTRALITY |
|---|---|---|---|
| TRANS | 5.1 | 20 | 48 |
| | 5.2 | 20 | 32 |
| | 5.3 | 32 | **48** |
| | 5.4 | 44 | 28 |
| | 5.5 | 12 | 0 |
| | 5.6 | 40 | 8 |
| | 5.7 | 0 | 24 |
| | 5.8 | 32 | 44 |
| IMSIS | 6.1 | 20 | 12 |
| | 6.2 | 12 | 20 |
| | 6.3 | 36 | 8 |
| | 6.4 | 24 | 12 |
| ISIS | 7.1 | 20 | 8 |
| | 7.2 | 12 | 4 |
| | 7.3 | 0 | 0 |
| | 7.4 | 4 | 24 |
| IVSAWS | 8.1 | 8 | 16 |
| | 8.2 | 16 | **48** |
| | 8.3 | 8 | 20 |
| | 8.4 | 16 | 24 |
| | 8.5 | 0 | 40 |
| | 8.6 | 0 | 40 |
| CVO | 9.1 | 52 | 8 |
| | 9.2 | 68 | 20 |
| | 9.3 | 40 | 16 |
| | 9.4 | 28 | 12 |
| MEAN | | 21.69 | 21.69 |
| STANDARD DEVIATION | | 17.12 | 14.89 |

Cliques

Using the CVO functions, there was a possibility of 57 cliques containing 3 or more functions. Considering that a clique indicates that each function is immediately linked to the others in the clique, this measure becomes a very constrained way for functions to interact. Table 35 indicates the first 29 cliques in the analysis. Considering that quite a large number of cliques exist for the CVO, it is easy to select scenarios that would reflect some of these groups of functional characteristics.

**Table 35. Cliques for commercial functions.**

| CLIQUE | FUNCTIONS | | | | | |
|---|---|---|---|---|---|---|
| 1 | 5.1 | 5.2 | 5.3 | 6.3 | 8.2 | 9.2 |
| 2 | 5.1 | 5.2 | 5.3 | 8.2 | 8.6 | 9.2 |
| 3 | 5.1 | 5.2 | 5.3 | 5.7 | 9.1 | 9.3 |
| 4 | 5.1 | 5.2 | 5.3 | 9.1 | 9.2 | 9.3 |
| 5 | 5.1 | 5.2 | 5.3 | 5.6 | 6.1 | |
| 6 | 5.1 | 5.2 | 5.3 | 5.6 | 8.2 | |
| 7 | 5.1 | 5.3 | 5.6 | 7.1 | 8.2 | |
| 8 | 5.1 | 5.3 | 7.4 | 9.1 | 9.2 | |
| 9 | 5.1 | 5.3 | 7.4 | 9.2 | 9.4 | |
| 10 | 5.2 | 5.3 | 5.8 | 6.3 | 8.2 | 9.1 |
| 11 | 5.2 | 5.3 | 5.8 | 8.2 | 9.1 | 9.2 |
| 12 | 5.2 | 5.3 | 5.7 | 5.8 | 9.2 | 9.3 |
| 13 | 5.2 | 5.3 | 5.8 | 9.2 | 9.3 | 9.4 |
| 14 | 5.2 | 5.3 | 5.6 | 5.8 | 6.2 | |
| 15 | 5.2 | 5.3 | 5.6 | 5.8 | 8.1 | |
| 16 | 5.2 | 5.4 | 5.8 | 6.3 | 8.2 | 9.1 |
| 17 | 5.2 | 5.4 | 5.8 | 8.2 | 9.1 | 9.2 |
| 18 | 5.2 | 5.4 | 5.8 | 9.2 | 9.3 | |
| 19 | 5.4 | 5.8 | 8.5 | 9.1 | 9.2 | |
| 20 | 5.4 | 5.8 | 8.5 | 9.2 | 9.3 | |
| 21 | 5.4 | 5.8 | 8.6 | 9.1 | 9.2 | |
| 22 | 5.4 | 5.8 | 8.6 | 9.2 | 9.3 | |
| 23 | 5.2 | 5.4 | 5.6 | 5.8 | 8.2 | |
| 24 | 5.8 | 6.4 | 8.2 | 9.1 | 9.2 | |
| 25 | 5.8 | 6.3 | 6.4 | 8.2 | 9.2 | |
| 26 | 6.4 | 8.2 | 8.4 | 9.1 | 9.2 | |
| 27 | 6.3 | 6.4 | 8.2 | 8.4 | 9.2 | |
| 28 | 5.8 | 8.5 | 9.2 | 9.3 | 9.4 | |
| 29 | 5.8 | 8.6 | 9.2 | 9.3 | 9.4 | |

## Clusters

The cluster analysis grouped the functions into five distinct clusters (see table 36). The five clusters for the commercial vehicle analysis are listed in table 37. The cluster analysis generated interesting results in the sense that except for one, each cluster organized functional characteristics into meaningful goals or sets of activities. These clusters did not correspond to the formal groupings of functional characteristics (IRANS, IMSIS, ISIS, IVSAWS, and CVO-specific) as closely as they did for the private-driver analysis. As a consequence, these findings suggest that it is important to attend closely to the CVO-specific functions as they tend to interact with the other functions in a way that alters the groupings found in the private applications.

**Table 36. Clusters for commercial functions.**

| FUNCTION | 9.1 | 5.8 | 5.3 | 8.2 | 6.4 | 6.3 | 9.2 | 7.2 | 7.1 | 5.4 | 8.1 | 5.6 | 5.7 | 5.2 | 9.3 | 5.1 | 9.4 | 7.3 | 5.5 | 7.4 | 8.3 | 6.1 | 6.2 | 8.5 | 8.6 | 8.4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.1 | 1 | 1 | 1 | 1 | 1 | | | | | 1 | | | | 1 | | 1 | | | | 1 | 1 | | | 1 | 1 | 1 |
| 5.8 | | 1 | 1 | 1 | 1 | | | | | | | | 1 | 1 | | | | | | | | | 1 | 1 | 1 | |
| 5.3 | | 1 | 1 | 1 | | | 1 | | | | | | 1 | 1 | | 1 | | | | 1 | | | 1 | | | |
| 8.2 | | 1 | 1 | 1 | | | | | | 1 | | | | | | 1 | | | | | | | | | | |
| 6.4 | 1 | 1 | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | 1 |
| 6.3 | | 1 | 1 | 1 | | 1 | | | | 1 | | | | 1 | | 1 | | | | | 1 | 1 | | | | 1 |
| 9.2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | | | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | | | 1 | 1 | 1 |
| 7.2 | | | 1 | | | | | 1 | | 1 | | | | | | 1 | | | | | | | | | | |
| 7.1 | | | 1 | 1 | | | | | 1 | 1 | 1 | | | | | 1 | | | | | | | | | | |
| 5.4 | | 1 | | 1 | | | 1 | | | 1 | 1 | 1 | | 1 | 1 | | | | | 1 | | 1 | | 1 | 1 | |
| 8.1 | | | | | | | | | | | 1 | | | | | | | | | | 1 | | | | | 1 |
| 5.6 | | 1 | 1 | 1 | | | | 1 | 1 | | 1 | 1 | | | | 1 | | | | 1 | | 1 | 1 | | | |
| 5.7 | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| 5.2 | | | | 1 | | | | | | | | 1 | 1 | 1 | | 1 | | | | | | | 1 | | | |
| 9.3 | | 1 | 1 | | | | 1 | | | | | | 1 | 1 | 1 | 1 | 1 | | | | 1 | | | 1 | 1 | |
| 5.1 | | | | 1 | | | | | | | | | 1 | | 1 | 1 | | | | 1 | | | 1 | | | |
| 9.4 | | 1 | 1 | | | | | | | | | | | 1 | 1 | 1 | 1 | | | | | | | 1 | 1 | |
| 7.3 | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| 5.5 | | | 1 | | | | | | 1 | 1 | | | | | | | | | 1 | | | | | | | |
| 7.4 | | | | | | | | | | | | | | | | | 1 | | | 1 | | | | | | |
| 8.3 | | | | | | | | | | | | | | | | | | | | | 1 | | | 1 | 1 | |
| 6.1 | | 1 | 1 | | | | | | | | | | | | | 1 | | | | | | 1 | | 1 | 1 | |
| 6.2 | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 |
| 8.5 | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| 8.6 | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| 8.4 | | | | 1 | | | | | | | 1 | | | | | | | | | | | | | 1 | 1 | 1 |

**Table 37. Commercial vehicle cluster analysis.**

| | |
|---|---|
| **CLUSTER 1: RESOURCE MANAGEMENT AND PLANNING** | |
| 5.3 Pre-drive route and destination selection | IRANS |
| 5.8 Route scheduling | IRANS |
| 6.3 Destination coordination | IMSIS |
| 6.4 Message transfer | IMSIS |
| 8.2 Road condition information | IVSAWS |
| 9.1 Fleet resource management | CVO-specific |
| 9.2 Dispatch | CVO-specific |
| CLUSTER 2: NAVIGATION AND ROUTE GUIDANCE | |
| 5.4 Dynamic route selection | IRANS |
| 5.6 Route navigation | IRANS |
| 7.1 Guidance sign information | ISIS |
| 7.2 Notification information | ISIS |
| 8.1 Immediate hazard notification | IVSAWS |
| CLUSTER 3: REGULATORY AND ADMINISTRATIVE COORDINATION | |
| 5.1 Trip planning | IRANS |
| 5.2 Multi-mode travel coordination | IRANS |
| 5.7 Automatic toll collection | IRANS |
| 9.3 Regulatory administration | CVO-specific |
| 9.4 Reaulatorv enforcement | CVO-specific |
| **CLUSTER 4: MISCELLANEOUS FUNCTIONS** | |
| This cluster was not meaningful. It was composed of four functions and each function was interacting only with itself; there were no interactions with any of the other functions. | |
| CLUSTRR 5: SERVICES REQUEST | |
| 6.1 Broadcast services/attractions | IMSIS |
| 6.2 Services/attractions directory | IMSIS |
| 8.4 Manual aid request | IVSAWS |
| 8.5 Vehicle condition monitoring | IVSAWS |
| 8.6 Cargo condition monitoring | IVSAWS |

## SCENARIO SELECTION

### Scenario Conceptualization

One of the main goals of the task analysis is that it be a systematic, top-down analysis of the tasks performed by users of ATIS/CVO systems in order to meet the required functions of each system. The task analysis should describe the set of tasks that a driver would have to perform in a realistic driving environment. These tasks include both driving-related tasks and ATIS/CVO-related tasks. To study the interactions between these two sets of tasks, it is necessary to have a fairly realistic setting. However, because these systems do not fully exist, it was useful to create fictional scenarios that would provide the context of a realistic environmental setting in order to explore how these two sets of tasks could interact.

Task B generated several scenarios, both for private and commercial operations. The purpose of these scenarios was to aid in the identification of ATIS features and functions, as well as to support the task analysis effort. The scenarios in Task B were not based on comprehensive analyses of ATIS features and functions, nor on a comprehensive analysis of the task of driving with the aid of an ATIS. In fact, they were created to represent a broad sample of the driving scenarios identified by the transportation community as part of the Task B effort. In general, they summarize the issues, capabilities, functions, and features specific to each one of the ATIS/CVO systems as identified during the course of Task B interviews.

Unfortunately, the conceptualization of these scenarios occurred before the completion of Task C, the purpose of which was to identify functional characteristics for each of the ATIS/CVO systems. In addition to identifying functional characteristics, Task C contributed to each of these scenarios by illustrating how each scenario draws upon a set of functional characteristics. Table 38 shows the functional characteristics used in the private vehicle scenarios, while table 39 shows the same breakdown for the commercial vehicle scenarios.

These two tables show two important facts. First, the scenarios developed in Task B do not span the entire range of functional characteristics. Some functional characteristics are not illustrated at all. For example, table 38 for private vehicle scenarios shows that as many as eight functional characteristics (5.2, 5.4, 5.7, 6.1, 6.3, 6.4, 7.1, and 8.3) were not considered in the conceptualization of these scenarios. Similarly, table 39 for the commercial vehicle scenarios shows that as many as nine functional characteristics (5.1, 6.1, 6.3, 7.1, 7.2, 7.3, 8.5, 8.6, and 9.4) failed to appear in any of the scenarios. Second, almost all scenarios showed an integration of more than one functional characteristic or ATIS subsystem into one situational context. As pointed out in Task C, this illustrates the importance of closely examining the interactions between functions to identify the coupling of various systems. By knowing how the functional characteristics interact within a subsystem or across systems, it will be possible to provide meaningful guidelines for the design of integrated ATIS/CVO systems rather than create a disconnected collection of independent functions and subsystems.

Considering that several functional characteristics failed to appear in the scenarios of Task B, it may be useful to enhance the scenarios in the context of the full list of functional characteristics developed in Task C. As a consequence, the initial set of scenarios was expanded, and the functional characteristic breakdown for each one of the new private vehicle scenarios is summarized in table 40, while the one for the commercial vehicle scenarios is reviewed in table 4 1.

## Table 38. Functional characteristics used in private vehicle scenarios as originally designed in Task B.

| FUNCTIONS | SCENARIOS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| **IRANS** | | | | | | | | | | | | | |
| 5.1 Trip planning | | 1 | | 1 | 1 | | | | | | | | 3 |
| 5.2 Multi-mode travel coordination and planning | | | | | | | | | | | | | 0 |
| 5.3 Pre-drive route and destination selection | 1 | | 1 | | 1 | 1 | | 1 | | | | | 5 |
| 5.4 Dynamic route selection | | | | | | 1 | | | | | | | 1 |
| 5.5 Route guidance | 1 | 1 | 1 | | | | | | 1 | | | | 4 |
| 5.6 Route navigation | 1 | 1 | | 1 | | | | | | | | | 3 |
| 5.7 Automated toll collection | | | | | | | | | | | | | 0 |
| **IMSIS** | | | | | | | | | | | | | |
| 6.1 Broadcast services/attractions information | | | | | | | | | | | | | 0 |
| 6.2 Services/attractions directory | | | | 1 | 1 | 1 | | | | | | | 3 |
| 6.3 Destination coordination | | | | | | 1 | | | | | | | 1 |
| 6.4 Message transfer | | | | | | | | | | | | | 0 |
| **ISIS** | | | | | | | | | | | | | |
| 7.1 Roadway guidance sign | | | | | | | | 1 | | | | | 1 |
| 7.2 Roadway notification sign information | | | | | | | | | 1 | | | | 1 |
| 7.3 Roadway regulatory sign information | | | | | | | 1 | 1 | 1 | | | | 3 |
| **IVSAWS** | | | | | | | | | | | | | |
| 8.1 Immediate hazard warning | | | | | | | | | | 1 | 1 | | 2 |
| 8.2 Road condition information | | | | | | | | | | | 1 | 1 | 2 |
| 8.3 Automatic aid request | | | | | | | | | | | | | 0 |
| 8.4 Manual aid request | | | | | | | | | | | | 1 | 1 |
| 8.5 Vehicle condition monitoring | | | | | | | | | | | | | 0 |
| **Total** | 3 | 3 | 2 | 3 | 3 | 4 | 1 | 3 | 3 | 1 | 2 | 2 | 30 |

**Table 39. Functional characteristics used in commercial vehicle scenarios as originally designed in Task B.**

| FUNCTIONS | SCENARIOS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| **IRANS** | | | | | | | | | | | | | | | |
| 5.1 Trip planning | | | | | | | | | | | | | | | 0 |
| 5.2 Multi-mode travel coordination and planning | | | | | | | | | | | | | 1 | | 1 |
| 5.3 Pre-drive route and destination selection | | 1 | 1 | | | | | | | | | | | | 2 |
| 5.4 Dynamic route selection | | | | 1 | 1 | 1 | 1 | | | | | | | | 4 |
| 5.5 Route guidance | 1 | 1 | 1 | | | 1 | | | | | | | | | 4 |
| 5.6 Route navigation | 1 | | 1 | | | | | | | | | | | | 2 |
| 5.7 Automated toll collection | | | | | | | | | | | 1 | | | | 1 |
| 5.8 Route scheduling | | | | | | | | | | | | 1 | 1 | 1 | 3 |
| **IMSIS** | | | | | | | | | | | | | | | |
| 6.1 Broadcast services/ attractions information | | | | | | | | | | | | | | | 0 |
| 6.2 Services/attractions directory | | | | 1 | | | | | | | | | | | 1 |
| 6.3 Destination coordination | | | | | | | | | | | | | | | 0 |
| 6.4 Message transfer | 1 | | | | | | | | | | | 1 | 1 | 1 | 4 |
| ISIS | | | | | | | | | | | | | | | |
| 7.1 Roadway guidance sign | | | | | | | | | | | | | | | 0 |
| 7.2 Roadway notification sign information | | | | | | | | | | | | | | | 0 |
| 7.3 Roadway regulatory sign information | | | | | | | | | | | | | | | 0 |
| 7.4 Road restriction information | | | 1 | | 1 | 1 | | | | | | | | | 3 |
| IVSAWS | | | | | | | | | | | | | | | |
| 8.1 Immediate hazard warning | | | | | | | | 1 | | | | | | | 1 |
| 8.2 Road condition information | | | | | | | 1 | | | 1 | | | | | 2 |
| 8.3 Automatic aid request | | | | | | | | | | 1 | | | | | 1 |
| 8.4 Manual aid request | | | | | | | | | 1 | | | | | | 1 |

**Table 39. Functional characteristics used in commercial vehicle scenarios as originally designed in Task B (continued).**

| FUNCTIONS | SCENARIOS | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| **IVSAWS (cont'd.)** | | | | | | | | | | | | | | | |
| 8.5 Vehiclecondition monitoring | | | | | | | | | | | | | | | 0 |
| 8.6 Cargo condition monitoring | | | | | | | | | | | | | | | 0 |
| CVO | | | | | | | | | | | | | | | |
| 9.1 Fleetresource management | | | | | | | | | | | | 1 | 1 | 1 | 3 |
| 9.2 Dispatch | | | | | | | | | | | | 1 | 1 | 1 | 3 |
| 9.3 Regulatory administration | | | | | | | | | | | 1 | | | | 1 |
| 9.4 Regulatory enforcement | | | | | | | | | | | | | | | 0 |
| Total | 3 | 2 | 4 | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 2 | 4 | 5 | 4 | 37 |

**Table 40. Functional characteristics used in the expanded private vehicle scenarios.**

| FUNCTIONS | SCENARIOS | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 22 | Total |
| **IRANS** | | | | | | | | | | | | | | | | | | |
| 5.1 Trip planning | | 1 | | 1 | 1 | | | | | | | | | | | | | 3 |
| 5.2 Multi-mode travel coordination and planning | | | | | | | | | | | | | | 1 | | | | 1 |
| 5.3 Pre-drive route and destination selection | 1 | 1 | 1 | | 1 | 1 | | 1 | | | | | | 1 | 1 | 1 | | 9 |
| 5.4 Dynamic route selection | | | | | | 1 | | | | | | | 1 | 1 | | 1 | | 4 |
| 5.5 Route guidance | 1 | 1 | 1 | | | | | | 1 | | | | | | | | | 4 |
| 5.6 Route navigation | 1 | 1 | | 1 | | | | | | | | | | | | | | 3 |
| 5.7 Automated toll collection | | | | | | | | | | | | | | 1 | | | | 1 |
| **IMSIS** | | | | | | | | | | | | | | | | | | |
| 6.1 Broadcast services/attractions information | | | | | | | | | | | | | | | 1 | | 1 | 2 |
| 6.2 Services/attractions directory | | | | 1 | 1 | 1 | | | | | | | | | | | | 3 |
| 6.3 Destination coordination | | | | | | 1 | | | | | | | | | 1 | | 1 | 3 |
| 6.4 Message transfer | | | | | | | | | | | | | | | | 1 | | 1 |
| **ISIS** | | | | | | | | | | | | | | | | | | |
| 7.1 Roadway guidance sign | | | | | | | | 1 | | | | | | | | | | 1 |
| 7.2 Roadway notification sign information | | | | | | | | | 1 | | | | | | | | | 1 |
| 7.3 Roadway regulatory sign information | | | | | | | 1 | 1 | 1 | | | | | | | | 1 | 4 |
| **IVSAWS** | | | | | | | | | | | | | | | | | | |
| 8.1 Immediate hazard warning | | | | | | | | | | 1 | 1 | | 1 | | | | 1 | 4 |
| 8.2 Road condition information | | | | | | | | | | | 1 | 1 | | 1 | | | | 3 |
| 8.3 Automatic aid request | | | | | | | | | | | | | | | | | 1 | 1 |
| 8.4 Manual aid request | | | | | | | | | | | | 1 | | | 1 | | | 2 |
| 8.5 Vehicle condition monitoring | | | | | | | | | | | | | | | 1 | | 1 | 2 |
| Total | 3 | 4 | 2 | 3 | 3 | 4 | 1 | 3 | 3 | 1 | 2 | 2 | 2 | 5 | 6 | 4 | 4 | 52 |

## Table 41. Functional characteristics used in the expanded commercial vehicle scenarios.

| FUNCTIONS | SCENARIOS | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **Total** |
| **IRANS** | | | | | | | | | | | | | | | | |
| 5.1 Trip planning | | | | | | | | | | | | | | | | 0 |
| 5.2 Multi-mode travel coordination and planning | | | | | | | | | | | | | 1 | | | 1 |
| 5.3 Pre-drive route and destination selection | | 1 | 1 | | | | | | | | | 1 | | | | 3 |
| 5.4 Dynamic route selection | | | | 1 | 1 | 1 | 1 | | | | | 1 | | | | 5 |
| 5.5 Route guidance | 1 | 1 | 1 | | | 1 | | | | | | | | | | 4 |
| 5.6 Route navigation | 1 | | 1 | | | | | | | | | | | | | 2 |
| 5.7 Automated toll collection | | | | | | | | | | | 1 | | | | | 1 |
| 5.8 Route scheduling | | | | | | | | | | | | | 1 | 1 | | 2 |
| **IMSIS** | | | | | | | | | | | | | | | | |
| 6.1 Broadcast services/attractions information | | | | | | | | | | | | | | | | 0 |
| 6.2 Services/attractions directory | | | | 1 | | | | | | | | | | | 1 | 2 |
| 6.3 Destination coordination | | | | | | | | | | | | | | | | 0 |
| 6.4 Message transfer | 1 | | | | | | | | | | | | 1 | 1 | | 3 |
| **ISIS** | | | | | | | | | | | | | | | | |
| 7.1 Roadway guidance sign | | | | 1 | | | | | | | | | | | | 1 |
| 7.2 Roadway notification sign information | | | | 1 | | | | | | | | | | | | 1 |
| 7.3 Roadway regulatory sign information | | | | 1 | | | | | | | | | | | | 1 |
| 7.4 Road restriction information | | | 1 | 1 | 1 | 1 | | | | | | | | | | 4 |
| **IVSAWS** | | | | | | | | | | | | | | | | |
| 8.1 Immediate hazard warning | | | | 1 | | | | 1 | | | | | | | | 2 |
| 8.2 Road condition information | | | | | | | 1 | | | 1 | | 1 | | | | 3 |
| 8.3 Automatic aid request | | | | | | | | | | 1 | | | | | | 1 |
| 8.4 Manual aid request | | | | | | | | | 1 | | | | | | 1 | 2 |

**Table 41. Functional characteristics used in the expanded commercial vehicle scenarios (continued).**

| FUNCTIONS | SCENARIOS | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | Total |
| **IVSAWS (cont'd.)** | | | | | | | | | | | | | | | | |
| 8.5 Vehicle condition monitoring | | | | | | | | | | | | | | | | 0 |
| 8.6 Cargo condition monitoring | | | | | | | | | | | | | | | 1 | 1 |
| **CVO** | | | | | | | | | | | | | | | | |
| 9.1 Fleet resource management | | | | | | | | | | | | | 1 | 1 | | 2 |
| 9.2 Dispatch | | | | | | | | | | | | 1 | 1 | 1 | | 3 |
| 9.3 Regulatory administration | | | | | | | | | | | 1 | | | | | 1 |
| 9.4 Regulatory enforcement | | | | | | | | | | | 1 | | | | | 1 |
| Total | 3 | 2 | 4 | 7 | 2 | 3 | 2 | 1 | 1 | 2 | 3 | 4 | 5 | 4 | 3 | 46 |

## Scenarios Selected for Analysis

Scenarios involving both private vehicle operations and commercial vehicle operations were selected to optimize the efficiency of the analysis. Scenarios were selected based on their representativeness in terms of the analysis that was done on the relative importance of functions as determined by information interactions and to represent several specific characteristics of the dynamic driving task that are likely to be of particular importance to an understanding of the way that drivers will interact with ATIS/CVO.

## Private Vehicle Scenarios

Private Driving Scenarios Based on Frequency Count and Centrality Measure

The frequency count analysis and the centrality measure analysis showed that pre-drive route and destination selection was the functional characteristic that had the greatest number of interactions with other functions and that was also considered the most central. Scenario P6 (see table 42) was chosen because it was one of the original scenarios developed in Task B and because it included pre-drive route and destination selection and other functional characteristics that were considered relatively central as well (e.g., destination coordination).

**Table 42. Description of Scenario P6.**

| | |
|---|---|
| PURPOSE | To show the centrality of pre-drive route and destination selection. |
| SUMMARY | 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 look interesting. Before proceeding toward his destination, he makes a reservation using ATIS. |

| SYSTEM | FUNCTIONAL CHARACTERISTICS |
|---|---|
| IRANS<br>IMSIS | 5.3 Pre-drive route and destination selection<br>5.4 Dynamic route selection<br>6.2 Services/attractions directory<br>6.3 Destination coordination |

Private Driving Scenarios Based on Functional Clusters

The cluster analysis organized the functional characteristics into a pre-selected number of groups, or clusters. Out of the five specified clusters, three formed meaningful groupings. Each cluster represents a grouping of functions that are related to more than one ATIS subsystem. Considering that each cluster grouped functional characteristics that were linked together according to the network analysis, they formed fairly homogeneous groups. The first cluster includes functional characteristics related to planning and navigation, the second cluster is associated with aid and emergency services, the third cluster has to do with travel coordination.

For each one of these clusters, a scenario was chosen that illustrates one particular situation in which these functional characteristics are interacting together. However, it is important to note that these scenarios illustrate one of several possible alternatives for combining these various functions into one situational context.

Alternatively, it is interesting to consider scenarios that illustrate interactions between different clusters in addition to interactions between functions within the same cluster. In this regard, Scenario P6 (above) is one such example that shows an interaction between the three different clusters. The interest in these cluster interactions stems from the fact that these particular scenarios not only show the requirements of supporting a task that requires the interactions with different subsystems, but also tasks that require a diverse set of functions.

Cluster 1. This cluster groups functional characteristics that span across three different ATIS subsystems, although the emphasis is mainly on IRANS. This cluster is also the largest of the three, grouping on the whole with seven different functional characteristics. Table 43 is a description of Scenario P14.

**Table 43. Description of Scenario P14.**

| | |
|---|---|
| **PURPOSE** | **To illustrate a grouping of functional characteristics from Cluster 1 (5.1, 5.2, 5.3, 5.4, 5.6, 7.1, and 8.2).** |
| **SUMMARY** | 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 her 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. |

| **SYSTEM** | **FUNCTIONAL CHARACTERISTICS** |
|---|---|
| IRANS | 5.2 Multi-mode coordination and planning<br>5.3 Pre-drive route and destination selection<br>5.4 Dynamic route selection<br>5.7 Automatic toll collection<br>8.2 Road condition information |

Cluster 2. This cluster of functional characteristics focuses mainly on aid requests as well as on emergency services needs. Most of the functions included in this cluster are related to IVSAWS, except for the services/attractions directory that is provided by IMSIS. As shown in table 44, this particular scenario uses three out of the five possible functional characteristics.

**Table 44. Description of Scenario P22.**

| | |
|---|---|
| **PURPOSE** | **To illustrate a grouping of the functional characteristics found in Cluster 2** (6.2, 8.1, 8.3 8.4, and 8,5), |
| **SUMMARY** | 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, 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. |

| **SYSTEM** | **FUNCTIONAL CHARACTERISTICS** |
|---|---|
| ISIS<br>IVSAWS | 7.3 Roadway regulatory sign information<br>8.1 Immediate hazard warning<br>8.3 Automatic aid request<br>8.5 Vehicle condition monitoring |

Cluster 3. This cluster facilitates the travel coordination required by a driver going to either a service facility or a tourist attraction. In addition, this cluster enables the coordination between parties if one of them needs to be informed of delays or other unusual circumstances. Scenario P16 refledts multiple interactions with the system and, at the same time, combines the three functional characteristics that make up Cluster 3 (see table 45).

**Table 45. Description of Scenario P16.**

| | |
|---|---|
| **PURPOSE** | **To illustrate a grouping of functional characteristics from Cluster 3 (6.1, 6.3, and 6.4).** |
| SUMMARY | A driver uses ATIS to travel from her hotel to a restaurant on the outskirts of town. While traveling, she receives notification that the engine's oil 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. |
| SYSTEM | FUNCTIONAL CHARACTERISTICS |
| IRANS<br>IVSAWS<br>IMSIS | 5.3 Pre-drive route and destination selection<br>6.2 Broadcast services/attraction<br>6.3 Destination coordination<br>6.4 Message transfer<br>8.3 Manual aid request<br>8.5 Vehicle condition monitoring |

Private Driving Scenarios Based on the Nature of Task Interactions

As illustrated in the scenarios above, functional characteristics, either ATIS-related and/or driving-related, have a tendency to operate in groups. In some instances, several functions originate from only one specific ATIS subsystem. In other circumstances, one or several functional characteristics from two subsystems or more are used in the same situational context. The nature of the interactions between these various functional characteristics varies and has some important implications for the task analysis breakdown. In fact, the interactions between various functional characteristics can be categorized into three different types: (1) sequential, (2) branching, and (3) recursive. Each of these types of interactions will be described in one of the following subsections. Although it is possible to be in an environmental context that could combine the three different types of interactions, for ease of clarity, the present task analysis will focus on scenarios that illustrate only one type of functional interaction at a time.

Private driving scenario based on sequential functions. This type of interaction is the simplest of all three types, as each functional characteristic occurs in sequence with the other. In other words, the driver has to complete a set of tasks associated with a particular function before he or she can proceed with the other functions.

Scenario Pl was chosen to illustrate the nature of sequential functions for four reasons: (1) it is a scenario that was designed as part of Task B and did not need to be modified; (2) it focuses on the pre-drive route and destination selection, which is the most central measure; (3) it is relatively simple, using only three functional characteristics that belong to the same subsystem, IRANS; and (4) it includes two functional characteristics that were not included in any of the scenarios chosen so far (see table 46).

**Table 46. Description of Scenario Pl.**

| | |
|---|---|
| **PURPOSE** | **To illustrate the sequencing type of interactions among various functional characteristics.** |
| 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 | 5.3 Pre-drive route and destination selection<br>5.5 Route guidance<br>5.6 Route navigation |

Private driving scenario based on branching functions. When a driver has completed a sequence of tasks from one particular functional characteristic and is at a way-point having to choose between two different functions, each with its particular set of tasks, the driver is, in fact, choosing between two different branches of the task descriptions (see table 47). When the driver chooses to accomplish function "A," for example, he or she will not accomplish function "B." By choosing "A" instead of "B," the driver defines the path taken. In some instances, the sequence of functions is the same whether the driver chooses "A" or "B"; in other circumstances, the path will remain different throughout the entire remainder of the sequence.

**Table 47. Description of Scenario P20.**

| SYSTEM | FUNCTIONAL CHARACTERISTICS |
|---|---|
| PURPOSE To illustrate the branching type of interactions among various functional characteristics | |
| SUMMARY It is Friday afternoon and a driver is following her 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 towards the winery. | |
| IRANS<br>IMSIS | 5.3 Pre-drive route and destination selection<br>5.4 Dynamic route change<br>6.2 Broadcast services/attractions<br>6.3 Destination coordination |

Private driving scenario based on recursive functions. In this instance, the functions are not following each other in a sequence, but rather require that the driver repeat a step that previously had been partially or entirely completed. In other words, this type of interaction implies that a driver can accomplish a given set of tasks associated with a given function, continue to another function, and come back to that first function later on. The rationale for such a set of interactions is that the outcome of one particular functional characteristic may require additional information or transformation before proceeding to the next one.

Scenario P2 (shown in table 48) was chosen for three different reasons. First, it illustrates a type of interacting functions that could be repeated more than once, if needed. Second, this scenario was also favored because it originated from Task B's initial set of scenarios. Finally, Scenario P2 adds one more function (trip planning) to the overall set of functional characteristics analyzed so far.

Private Driving Scenario Based on High Workload Demands

One of the main concerns of the implementation of these ATIS is that they interact with the existing driving tasks. In fact, it becomes essential to investigate to what degree ATIS demands will impair or facilitate the driving task. In some instances in which the driver is required to operate under high demands, such as traveling in an unknown city during bad weather, the ATIS might be more negative than beneficial. The purpose of this scenario is to provide an example of how various functions could interact during an already demanding driving task (see table 49).

## Table 48. Description of Scenario P2.

| | | |
|---|---|---|
| **PURPOSE** | To illustrate the interactions among various functional characteristics. | |
| **SUMMARY** | 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. | |
| **SYSTEM** | | **FUNCTIONAL CHARACTERISTICS** |
| IRANS | | 5.1 Trip planning<br>5.5 Route guidance<br>5.6 Route navigation |

## Table 49. Description of Scenario P8.

| | | |
|---|---|---|
| **PURPOSE** | To illustrate that the requirements generated by ATIS may impose high workload demands on the driver. | |
| **SUMMARY** | 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 the ATIS, from his hotel to his first destination that 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. | |
| **SYSTEM** | | **FUNCTIONAL CHARACTERISTICS** |
| IRANS<br>ISIS<br>IVSAWS | | 5.3 Pre-drive route and destination selection<br>7.1 Roadway guidance sign information<br>7.3 Roadway regulatory sign information<br>8.1 Immediate hazard warning<br>8.2 Road condition information |

the driver chooses to accomplish function "A," for example, he or she will not accomplish function "B." By choosing "A" instead of "B," the driver defines the path taken. In some instances, the sequence of functions is the same whether the driver chooses "A" or "B"; in other circumstances, the path will remain different throughout the entire remainder of the sequence.

## Commercial Vehicle Scenarios

Commercial Driving Scenarios Based on Frequency Count and Centrality Measure

The frequency count analysis and the centrality measure analysis showed that dynamic route selection was the functional characteristic that had the greatest number of interactions with other functions, while dispatch was considered the most central. In addition to these two measures, route scheduling and road condition information were also considered quite central as well.

Scenario C12 (shown in table 50) was chosen because it included three of the most central and most frequently interacting functional characteristics (5.3, 8.2, and 9.2). In addition, this scenario illustrates the interactions between two different subsystems, while accentuating CVO-specific characteristics.

### Table 50. Description of Scenario C12.

| | |
|---|---|
| **PURPOSE** | To illustrate the functional characteristic that had the greatest frequency count, dynamic route selection, and the one that was considered the most central, dispatch. |
| **SUMMARY** | 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 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 reception 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. |

| SYSTEM | FUNCTIONAL CHARACTERISTICS |
|---|---|
| IRANS<br>IVSAWS<br>CVO-SPECIFIC | 5.3 Pre-drive route and destination selection<br>5.4 Dynamic route selection<br>8.2 Road condition information<br>9.2 Dispatch |

## Commercial Driving Scenarios Based on Functional Clusters

As indicated in the private scenarios section, this cluster analysis organizes the functional characteristics into five pre-specified groups (clusters). In the case of the commercial scenarios, out of the five specified clusters, four of them had a meaningful relationship. The first cluster has been labeled Resource Management and Planning as it groups functions that related mostly to fleet resource management and dispatch. The second cluster is called Navigation and Route Guidance and includes both IRANS and ISIS functions, except for the immediate hazard warning from IVSAWS. The third cluster is concerned with Regulatory and Administration Coordination as three of its functions are related to the regulatory or administrative agencies. The fourth cluster was not included in this analysis, as it was indicated in the function selection section of this document. Finally, the fifth cluster is named Services Request because it includes the functional characteristics related to services and attractions as well as the manual aid request function. For each one of these clusters, a scenario has been chosen that illustrates one particular situation. As mentioned previously, these scenarios are only one example of the many mapping between functional characteristics.

Cluster 1. This cluster has functional characteristics that span across three different ATIS subsystems, in addition to some of these functions being specific to CVOs. This cluster of functions is the largest of the four, grouping on the overall seven functional characteristics. A description of Scenario Cl3 is shown in table 43.

**Table 51. Description of Scenario C13.**

| | |
|---|---|
| **PURPOSE** | **To illustrate a grouping of functional characteristics from Cluster 1 (5.3, 5.8, 6.3, 6.4, 8.2, 9.1, and 9.2).** |
| SUMMARY | 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 pick-up schedule of the day and transmits this information to the drivers. |
| SYSTEM | FUNCTIONAL CHARACTERISTICS |
| IRANS<br>IMSIS<br>IVSAWS | 5.8 Route scheduling<br>6.4 Message transfer<br>9.1 Fleet resource management<br>9.2 Dispatch |

Cluster 2. This cluster focuses mainly on navigation and route guidance. The functions, once more, originate from three different systems (IRANS, ISIS, and IVSAWS). Scenario C4 was chosen as it includes four out of the five functional characteristics that make up Cluster 2 (see table 52). It is also interesting to note that the functional characteristics that make up this cluster (5.4, 5.6, 7.1, 7.2, and 8.1) are not specifically related to CVO operations.

**Table 52. Description of Scenario C4.**

| | |
|---|---|
| **PURPOSE** | To illustrate a grouping of the functional characteristics found in Cluster 2 (5.4, 5.6, 7.1, 7.2, and 8.1). |
| SUMMARY | A young interstate truck operator is traveling at night on a narrow, two-way 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 ISIS to provide speed-limit transitions, street signs, and merge signs. |

| **SYSTEM** | **FUNCTIONAL CHARACTERISTICS** |
|---|---|
| IRANS<br>ISIS<br>IVSAWS | 5.4 Dynamic route change<br>6.2 Services/attractions directory<br>7.1 Roadway guidance sign information<br>7.2 Roadway notification sign information<br>7.3 Roadway regulatory sign information<br>7.4 CVO road restriction information<br>8.1 Immediate hazard warning |

Cluster 3. This cluster summarizes some of the activities conducted by the regulatory and administrative agencies regarding trip planning and toll collection. In some ways, this cluster illustrates how IRANS could be used specifically by CVOs. Scenario Cl 1 was chosen as it included three of the functional characteristics that are organized into Cluster 3. In addition, Scenario Cl 1 was slightly modified to include regulatory enforcement, a function that had not been considered during the conceptualization of the commercial scenarios in Task B (see table 53).

**Table 53. Description of Scenario C11.**

| | |
|---|---|
| **PURPOSE** | To illustrate a grouping of functiona l characteristics from Cluster 3 (5.1,52,5+7,9.3, and 9.41, |
| SUMMARY | An experienced interstate truck operator is passing between two States at nighttime. Prior to reaching the inspection point, her 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 credential 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. |

| **SYSTEM** | **FUNCTIONAL CHARACTERISTICS** |
|---|---|
| IRANS<br>CVO-SPECIFIC | 5.7 Automatic toll collection<br>9.3 Regulatory administration<br>9.4 Regulatory enforcement |

Cluster 5. Scenario C15 (see table 54) facilitates mainly the service directory and aid request. Most of the functions included in this cluster are related to IMSIS and IVSAWS. This cluster is important to consider as it represents two ATIS subsystems that support both the private and the commercial industries. Considering that the scenarios generated initially in Task B included, for the most part, a very limited number of functional characteristics, it was necessary to create a new scenario that would include more than one or two functions.

**Table 54. Description of Scenario C15.**

| | |
|---|---|
| **PURPOSE** | To illustrate a grouping of functional characteristics from Cluster 5 (6.1, 6.2, 8.4, 8.5, and 8.6). |
| **SUMMARY** | 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. |

| **SYSTEM** | **FUNCTIONAL CHARACTERISTICS** |
|---|---|
| IMSIS<br>IVSAWS | 6.2 Services/attractions directory<br>8.4 Manual aid request<br>8.6 Cargo/vehicle condition monitoring |

Commercial Driving Scenarios Based on the Nature of Task Interactions

The nature of task interactions remains the same whether or not the environment is private or commercial. In fact, regardless of whether the driver is operating in a private or a commercial vehicle, the order with which he or she will accomplish the various driving-related and ATIS-related tasks will not vary. In either case, some of the functions will interact in a sequential manner, while others will either branch out or be recursive. As a consequence, it seemed repetitive to create commercial driving scenarios that would illustrate each one of these interactions, especially considering that the above four scenarios summarized them. A similar conclusion was reached for the scenarios requiring high workload demands.

## APPENDIX C. HIERARCHICAL TASK DESCRIPTIONS

PRIVATE VEHICLE OPERATIONS

1 PRE-DRIVE
- 1.1 PRE-DRIVE INSPECTION
- 1.2 PRE-DRIVE STARTUP
- 1.3 PRE-DRIVE AUXILIARY SYSTEMS
- 1.4 PLANNING

2 DRIVE
- 2.1 NAVIGATION AND ROUTING
- 2.2 GUIDANCE AND MANEUVERS
- 2.3 CONTROL
- 2.4 VEHICLE SYSTEM OPERATION AND MONITORING
- 2.5 REACTING TO EMERGENCIES

5 IRANS
- 5.1 TRIP PLANNING
- 5.2 MULTI-MODE TRAVEL COORDINATION
- 5.3 PRE-DRIVE ROUTE AND DESTINATION SELECTION
- 5.4 DYNAMIC ROUTE SELECTION
- 5.5 ROUTE GUIDANCE
- 5.6 ROUTE NAVIGATION
- 5.7 AUTOMATED TOLL COLLECTION

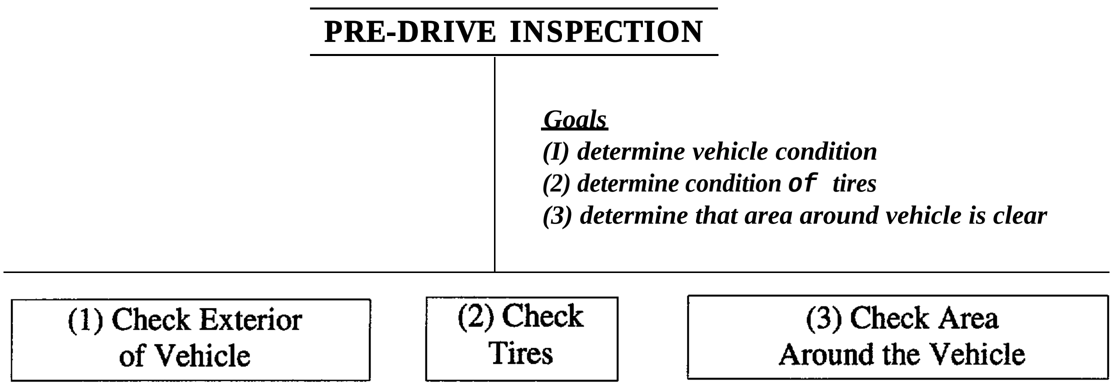
6 IMSIS
- 6.1 BROADCAST SERVICES/ATTRACTIONS
- 6.2 SERVICES/ATTRACTIONS DIRECTORY
- 6.3 DESTINATION COORDINATION
- 6.4 MESSAGE TRANSFER

7 ISIS
- 7.1 ROADWAY GUIDANCE SIGN INFORMATION
- 7.2 ROADWAY NOTIFICATION SIGN INFORMATION
- 7.3 ROADWAY REGULATORY SIGN INFORMATION

8 IVSAWS
- 8.1 IMMEDIATE HAZARD WARNING
- 8.2 ROAD CONDITION INFORMATION
- 8.3 AUTOMATIC AID REQUEST
- 8.4 MANUAL AID REQUEST
- 8.5 VEHICLE CONDITION MONITORING

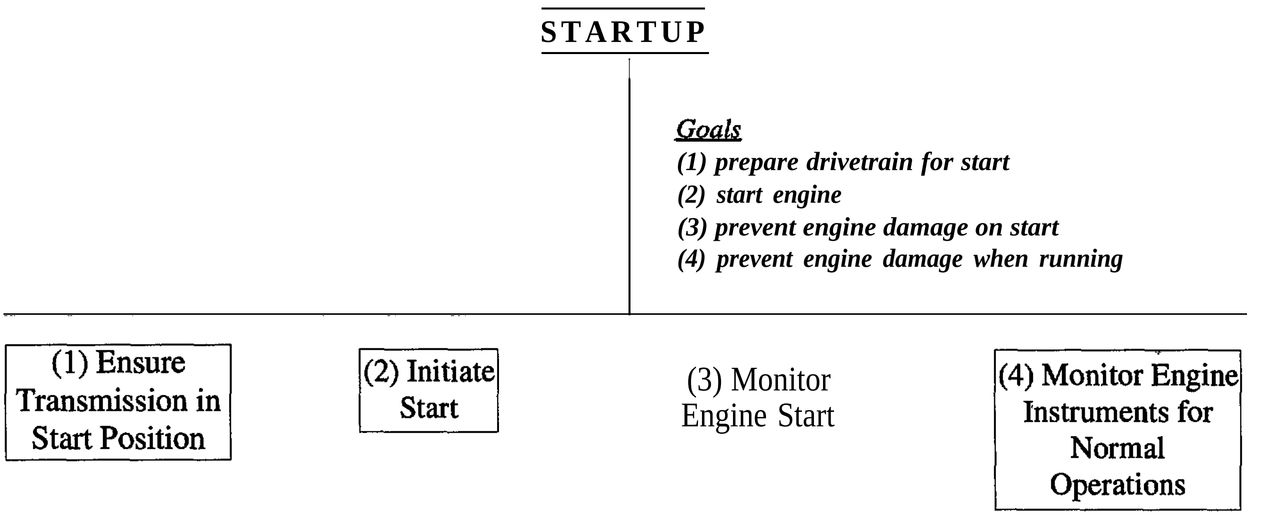
# Hierarchical Task Description of Private Driving and ATIS

1.1 **PRE-DRIVE INSPECTION**
- 1.1.1 Check Exterior of the Vehicle
- 1.1.2 Check Tires
- 1.1.3 Check Area Around the Vehicle



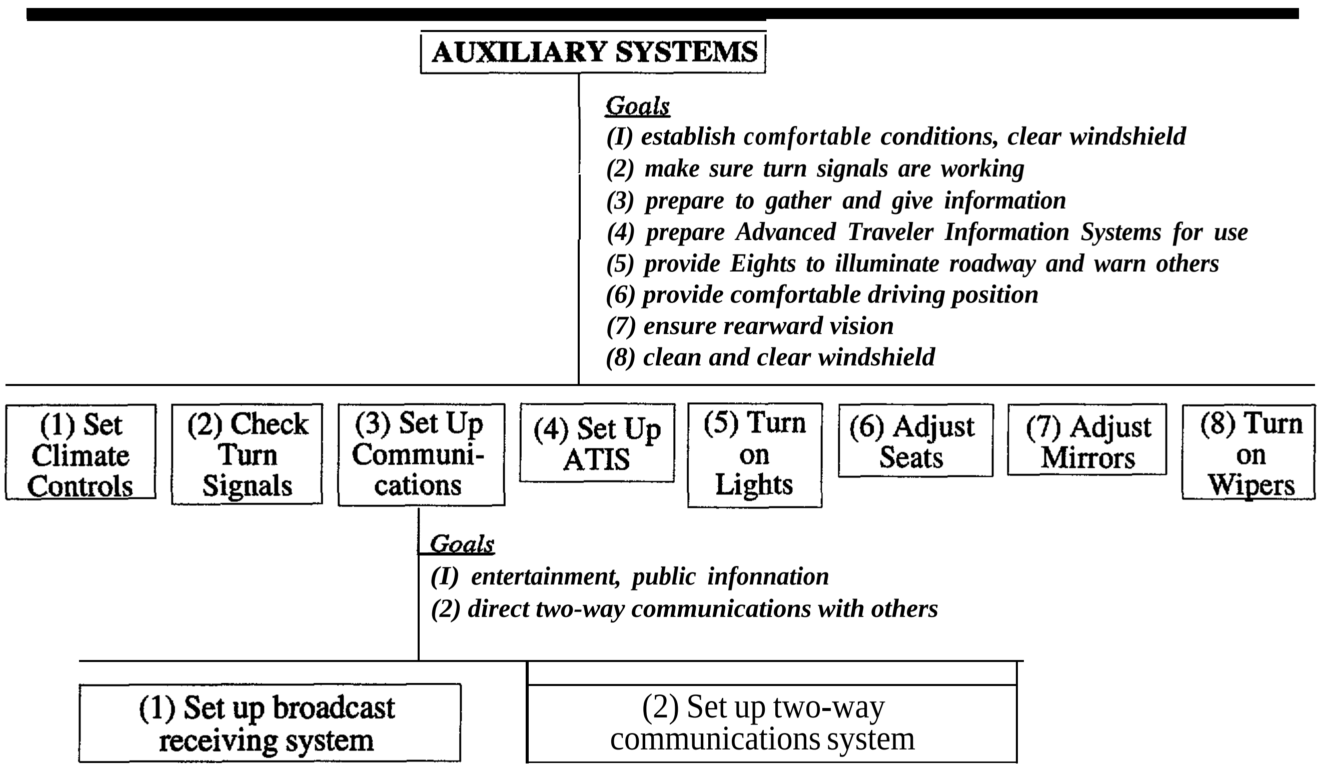
# Hierarchical Task Description of Private Driving and ATIS

1.2 **STARTUP**
- 1.2.1 Ensure Transmission in Start Position
- 1.2.2 Initiate Start
- 1.2.3 Monitor Engine Start
- 1.2.4 Monitor Engine Instruments for Normal Operations



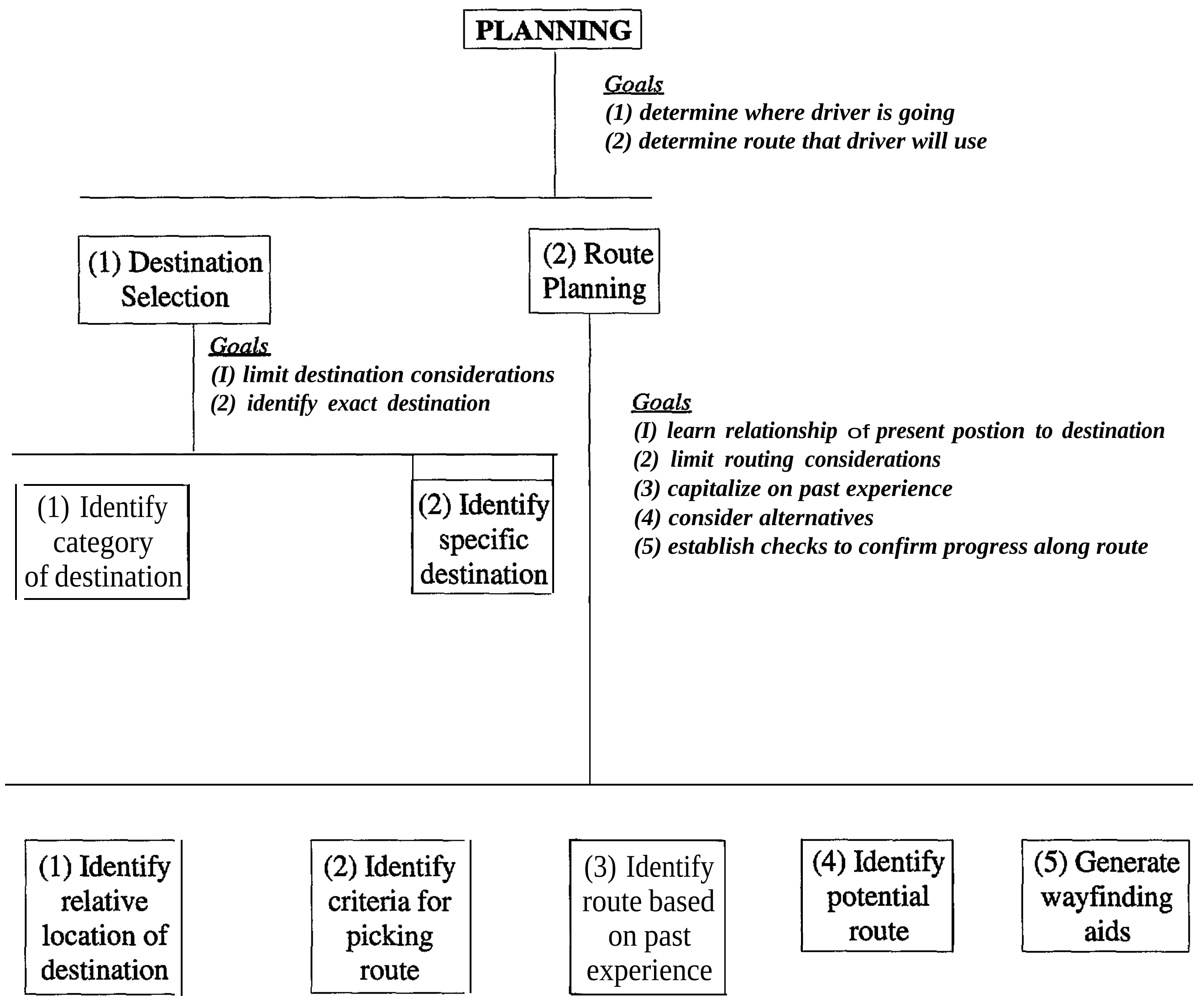
# Hierarchical Task Description of Private Driving and ATIS

1.3 **AUXILIARY SYSTEMS**
- 1.3.1 Climate Control
  - 1.3.1.1 Set climate controls as necessary
- 1.3.2 Turn Signals
  - 1.3.2.1 Check operations
- 1.3.3 Communications
  - 1.3.3.1 Broadcast radio/entertainment system
    - 1.3.3.1.1 Turn on
    - 1.3.3.1.2 "Select mode, station, program"
  - 1.3.3.2 Two-way communications
    - 1.3.3.2.1 Turn on
- 1.3.4 ATIS
  - 1.3.4.1 Turn on
  - 1.3.4.2 Verify system readiness
  - 1.3.4.3 Initiate system operation
    - 1.3.4.3.1 Input desired system parameters
    - 1.3.4.3.2 Verify system parameters correct
- 1.3.5 Lighting
  - 1.3.5.1 Turn on if necessary
- 1.3.6 Seats
  - 1.3.6.1 Adjust seat if necessary
- 1.3.7 Mirrors
  - 1.3.7.1 Adjust mirrors if necessary
- 1.3.8 Wipers/Windshield Washer
  - 1.3.8.1 Turn on wipers/windshield washer as necessary



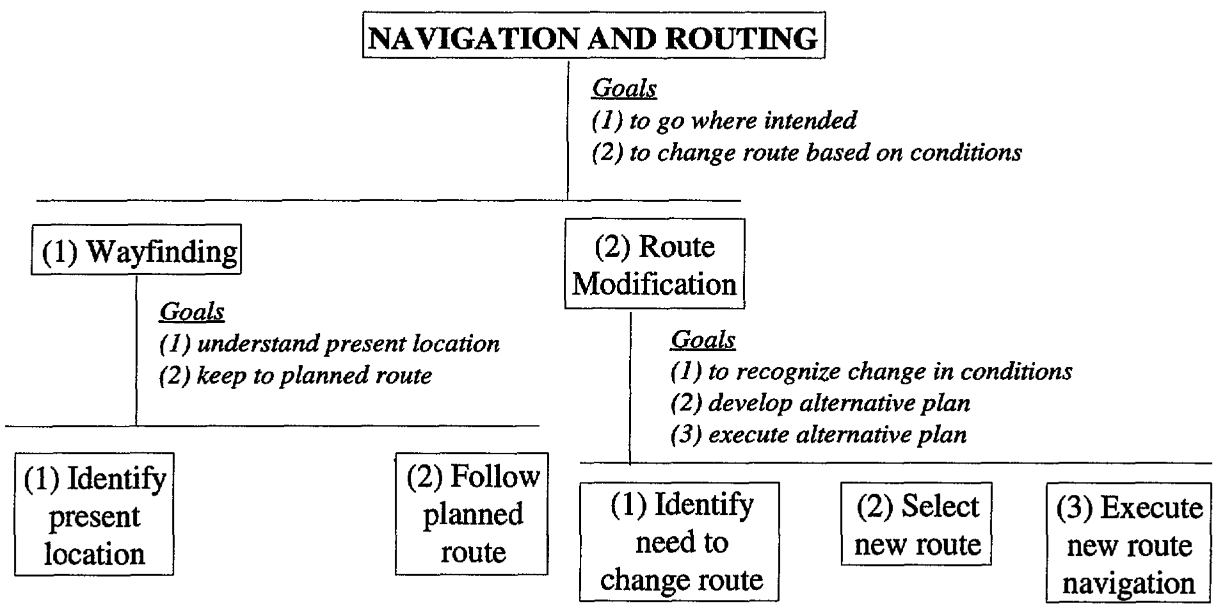
## Hierarchical Task Description of Private Driving and ATIS

1.4 **PLANNING**
1.4.1 Destination Selection
1.4.1.1 Identify category of destination
1.4.1.2 Identify specific destination
1.4.2 Route Planning
1.4.2.1 Identify relative location of destination
1.4.2.2 Identify criteria for picking route
1.4.2.3 Identify route based on past experience
1.4.2.4 Identify potential route
1.4.2.5 Generate wayfinding aids



# Hierarchical Task Description of Private Driving and ATIS

2.1 **NAVIGATION AND ROUTING**
- 2.1.1 Wayfinding
  - 2.1.1.1 Navigation
    - 2.1.1.1.1 Identify present location
    - 2.1.1.1.2 Determine relative direction and distance to destination
    - 2.1.1.1.3 Use landmarks to determine orientation and present location
    - 2.1.1.1.4 Compare expected location to map reference points and expectations
  - 2.1.1.2 Route following
    - 2.1.1.2.1 Identify next waypoint
    - 2.1.1.2.2 Identify present location relative to waypoint
    - 2.1.1.2.3 Identify required maneuver to proceed beyond the waypoint
    - 2.1.1.2.4 Execute maneuvers
    - 2.1.1.2.5 Verify present location and direction against expectation
- 2.1.2 Route Modification
  - 2.1.2.1 Identify need
    - 2.1.2.1.1 Identify traffic conditions and hazard on projected route
    - 2.1.2.1.2 Evaluate consequence of traffic condition and hazard
    - 2.1.2.1.3 Identify descrepancy between planned and actual route
  - 2.1.2.2 Select and change
    - 2.1.2.2.1 Determine position relative to traffic congestion or hazard
    - 2.1.2.2.2 Identify alternate routes
    - 2.1.2.2.3 Determine distance to waypoint
    - 2.1.2.2.4 Determine required maneuver
    - 2.1.2.2.5 Verify present location and direction against expectations



## Hierarchical Task Description of Private Driving and ATIS

2.2 GUIDANCE AND MANEUVERS

2.2.1 Traffic Coordination

2.2.1.1 Monitor distance between own vehicle and others

2.2.1.2 Execute speed and position control to maintain separation

2.2.1.3 Monitor position of vehicle relative to traffic condition and waypoint

2.2.1.4 Execute maneuvers to accommodate traffic conditions and vehicle dynamics

2.2.2 Rule Compliance

2.2.2.1 Monitor environment for regulatory signs

2.2.2.2 Recall from memory regulatory information

2.2.2.3 Evaluate planned route relative to regulatory requirements

2.2.2.4 Compare current driving status against regulatory requirements

2.2.2.5 Execute driving maneuvers to comply

2.2.2.6 Execute speed and position control to comply

2.2.3 Maneuvering

2.2.3.1 Identify present speed and position

2.2.3.2 Identity distance to waypoint

2.2.3.3 Identify traffic condition

2.2.3.4 Adjust speed and lane position

2.2.3.5 Signal intended maneuver

2.2.3.6 Execute desired maneuver

2.2.4 Hazard Observation

2.2.4.1 Estimate hazard potential on planned route

2.2.4.2 Make adjustment to planned route to accommodate hazard

2.2.4.3 Monitor roadway surface and surroundings

2.2.4.4 Monitor traffic conditions for hazardous situations

2.2.4.5 Estimate hazard potential to vehicle

2.2.4.6 Execute speed and position control to compensate for hazard

2.2.4.7 Execute driving maneuver to compensate for hazard

---

**GUIDANCE AND Maneuvers**

Goals

***(I) keep vehicle at safe distance from other vehicles***

***(2) keep vehicle within regulated safety limits***

***(3) cause vehicle to go where intended***

***(4) avoid hazardous conditions***

(1) Coordinate Vehicle Movements With Other Traffic

(2) Keep Speed and Other Activities Within What Regulations Require

(3) Control Car Direction and Speed to Reach Intended Destination

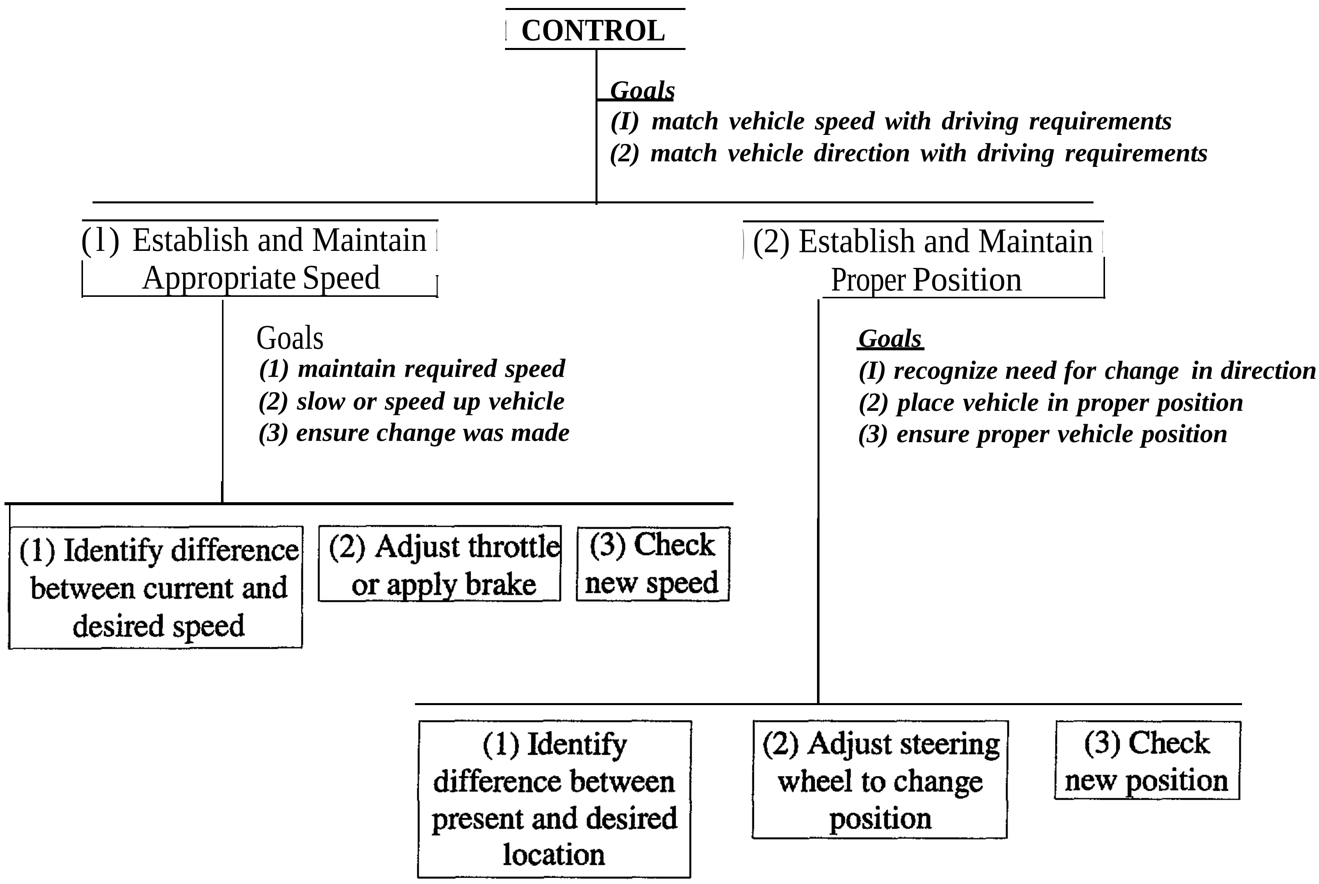
(4) Observe and Take Necessary Actions to Avoid Hazardous Conditions

# Hierarchical Task Description of Private Driving and ATIS

**2.3 CONTROL**

2.3.1 Speed Control
- 2.3.1.1 Identify discrepancy between current and desired speed
- 2.3.1.2 Adjust throttle or brake to control speed
- 2.3.1.3 Verify adjustment of speed

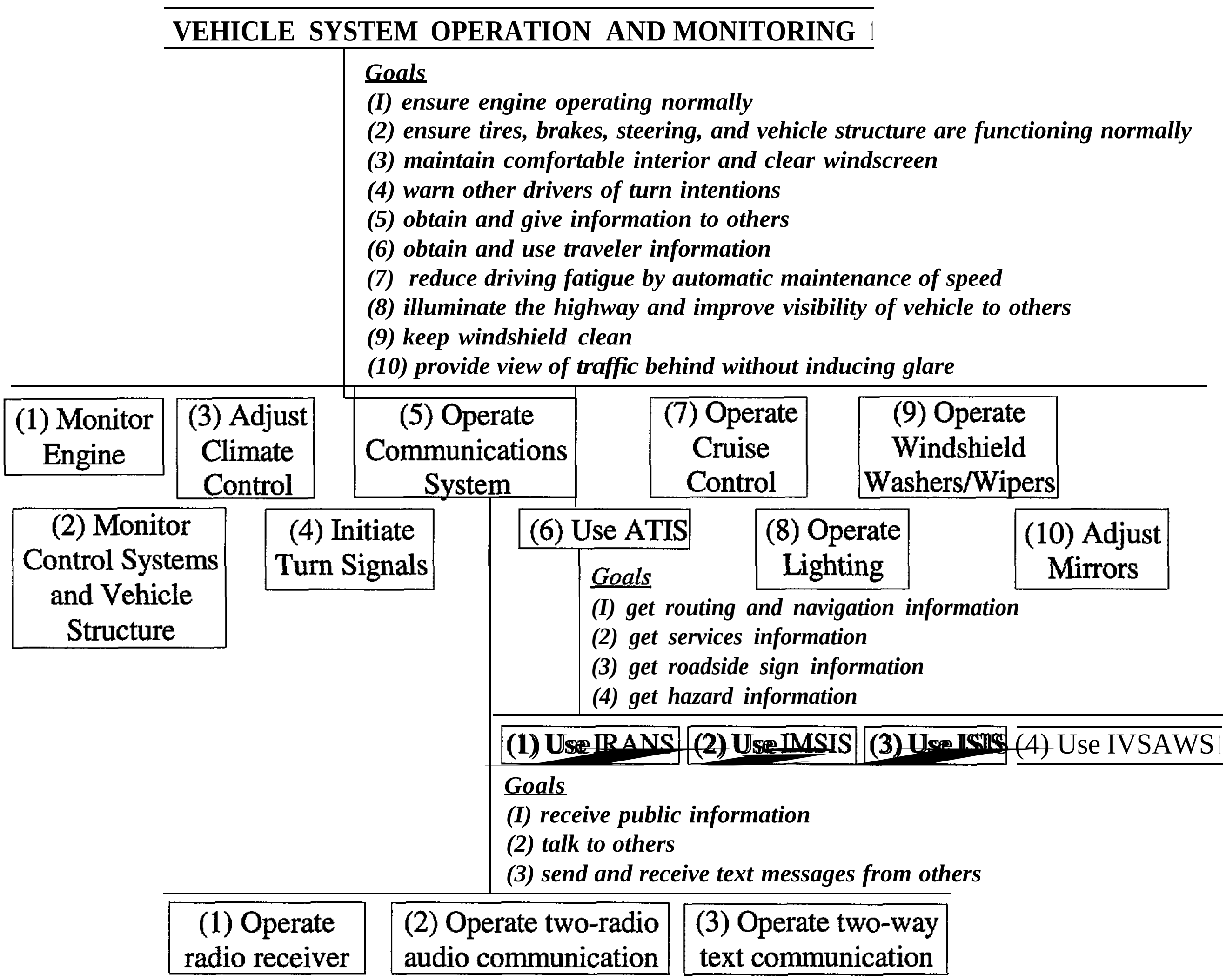
2.3.2 Position Control
- 2.3.2.1 Identify discrepancy between current and desired lane positions
- 2.3.2.2 Adjust steering wheel to compensate
- 2.3.2.3 Verify adjustment of lane position



## Hierarchical Task Description of Private Driving and ATIS

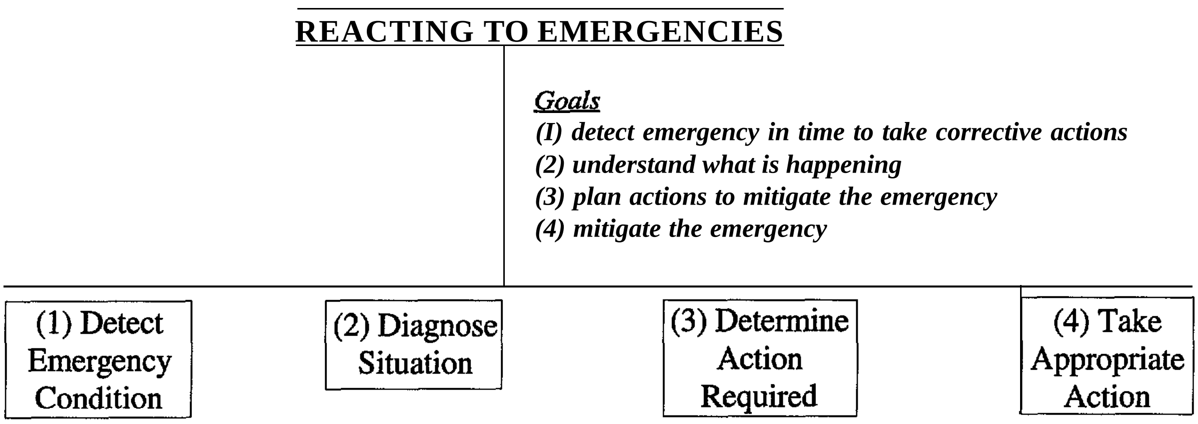
### 2.4 VEHICLE SYSTEM OPERATION AND MONITORING

- 2.4.1 Monitor Engine Operation
- 2.4.2 Monitor Control Systems and Vehicle Structure
- 2.4.3 Adjust Climate Control
- 2.4.4 Initiate Turn Signals
- 2.4.5 Operate Communications Systems
  - 2.4.5.1 Operate broadcast radio/entertainment system
  - 2.4.5.2 Operate two-way communications (audio)
  - 2.4.5.3 Operate two-way communications (text)
- 2.4.6 Use Advanced Traveler Information Systems (ATIS)
  - 2.4.6.1 Use In-Vehicle Routing and Navigation System (lRANS)
  - 2.4.6.2 Use In-Vehicle Motorist Services Information System (IMSIS)
  - 2.4.6.3 Use In-Vehicle Sign Information System (ISIS)
  - 2.4.6.4 Use In-Vehicle Safety Advisory and Warning System (IVSAWS)
- 2.4.7 Operate Cruise Control
- 2.4.8 Operate Lighting Systems
- 2.4.9 Operate Windshield Washers/Wipers
- 2.4.10 Adjust Rearview Mirrors



**2.5 REACTING TO EMERGENCIES**

2.5.1 Detect Emergency Condition
2.5.2 Diagnose Situation
2.5.3 Determine Action Required
2.5.4 Take Appropriate Action



# Hierarchical Task Description of Private Driving and ATIS

5.1 **TRIP PLANNING**
- 5.1.1 Gather Information
  - 5.1.1.1 Destination and stopping points
  - 5.1.1.2 Desired route parameters
- 5.1.2 Input Information
  - 5.1.2.1 Destination(s)
    - 5.1.2.1.1 Enter destination(s)
    - 5.1.2.1.2 Verify destination(s) entry correct
  - 5.1.2.2 Route parameters
    - 5.1.2.2.1 Enter route parameters
    - 5.1.2.2.2 Verify route parameters correct
- 5.1.3 Review Recommended Route
- 5.1.4 Decide if Route Is Acceptable
- 5.1.5 Initiate System Approval

---

**TRIP PLANNING**

*Goals*
*(1) develop pre-planning information*
*(2) provide system with needed information and limitations*
*(3) understand route recommended by the system*
*(4) determine if route meets requirements*
*(5) accept planning and initiate system guidance*

(1) Gather Information | (2) Input Information | (3) Review Recommended Route | (4) Decide if Route Is Acceptable | (5) Initiate System Approval

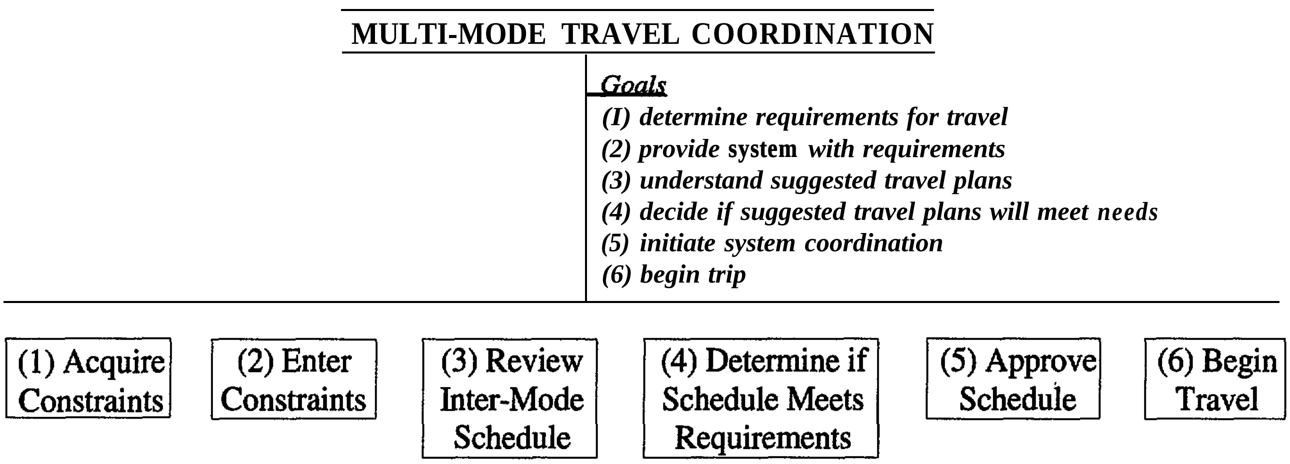
*Goals*
*(1) give system required planning destination*
*(2) give system constraints on planning route*

(1) Input destination(s) | (2) Input route parameters

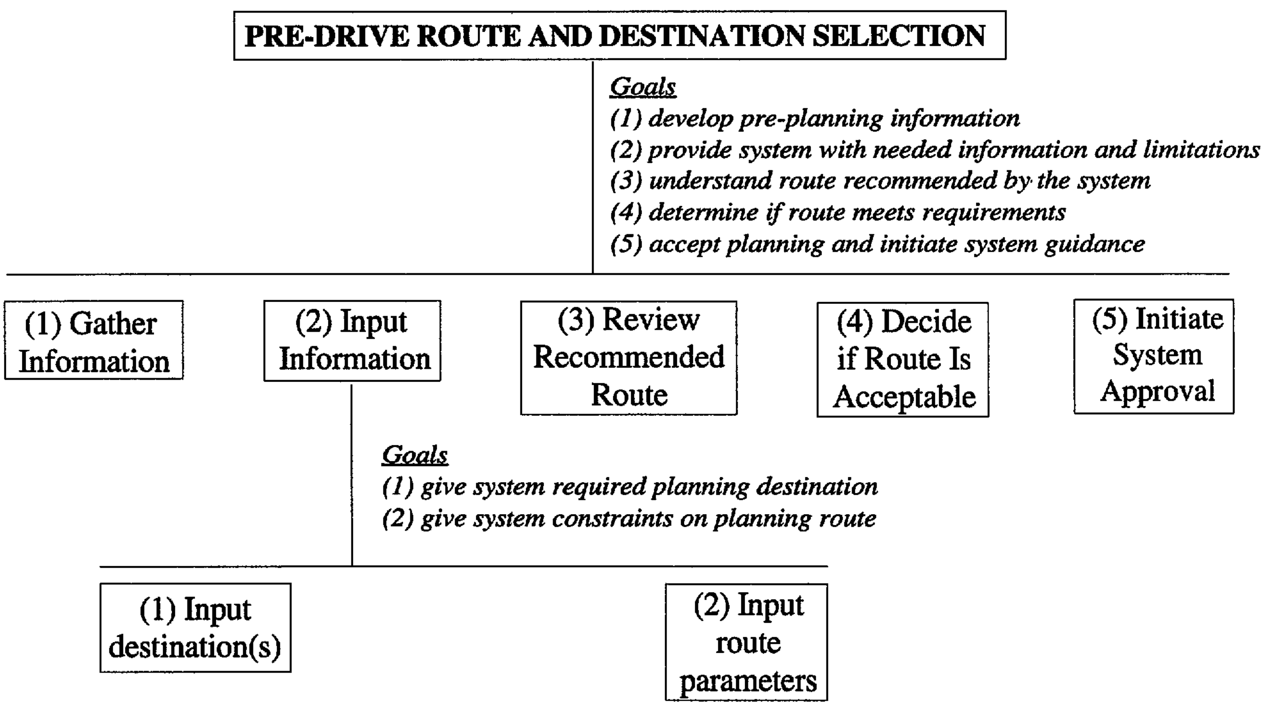
## Hierarchical Task Description of Private Driving and ATIS

**5.2 MULTI-MODE TRAVEL COORDINATION**

5.2.1 Acquire Constraints
5.2.2 Enter Constraints
5.2.3 Review Inter-Mode Schedule
5.2.4 Determine if Inter-Mode Schedule Will Meet Requirements
52.5 Approve Inter-Mode Schedule
5.2.6 Begin First Mode Travel
- 5.2.6.1 System update of arrival times
  - 5.2.6.1.1 Arrival time for current mode
  - 5.2.6.1.2 Arrival time for next mode
- 5.2.6.2 System alerts of change in arrival time for next mode
- 5.2.6.3 System computes change in destination arrival time
- 5.2.6.4 System proposes new inter-mode schedule
- 5.2.6.5 Determine new inter-mode schedule will meet requirements
  - 5.2.6.5.1 If will meet requirements, accept schedule
  - 5.2.6.5.2 If will not meet requirements, request different routing



**5.3 PRE-DRIVE ROUTE AND DESTINATION SELECTION**
- 5.3.1 Gather Information
  - 5.3.1.1 Destination and stopping points
  - 5.3.1.2 Desired route parameters
- 5.3.2 Input Information
  - 5.3.2.1 Destination
    - 5.3.2.1.1 Enter destination
    - 5.3.2.1.2 Verify destination entry correct
  - 5.3.2.2 Route parameters
    - 5.3.2.2.1 Enter route parameters
    - 5.3.2.2.2 Verify route parameters correct
- 5.3.3 Review Recommended Route
- 5.3.4 Decide if Route Is Acceptable
- 5.3.5 Initiate System Approval



## Hierarchical Task Description of Private Driving and ATIS

**5.4 DYNAMIC ROUTE SELECTION**

5.4.1 Driver-Initiated Dynamic Route Selection
- 5.4.1.1 Driver recognizes need for revised.route
- 5.4.1.2 Initiate new route request of IRANS
- 5.4.1.3 System computes new route
- 5.4.1.4 System presents revised route
- 5.4.1.5 Driver reviews recommended route
- 5.4.1.6 Decide if recommended route is satisfactory
- 5.4.1.7 Initiate route approval

5.4.2 System-Initiated Dynamic Route Selection
- 5.4.2.1 System recognizes need for new route
- 5.4.2.2 System alerts driver of change in route conditions
- 5.4.2.3 System computes revised route recommendation
- 5.4.2.4 System presents revised route
- 5.4.2.5 Driver reviews recommended route
- 5.4.2.6 Decide if recommended route is satisfactory
- 5.4.2.7 Initiate route approval

---

**DYNAMIC ROUTE SELECTION**

Driver-Initiated Dynamic Route Selection/

*Goals*
- *(I)* **detect** *change in conditions* **in time** *to affect outcome*
- *(2) plan new route*
- *(3) understand proposed new route*
- *(4) determine if new route will meet requirements*
- *(5) have system provide directions based on new route*

| (1) Driver recognizes need for revised route | (2) Initiate request for new route | (3) Review recommended route | (4) Decide if route is satisfactory | (5) Initiate route approval |
|---|---|---|---|---|

---

**DYNAMIC ROUTE SELECTION**

System-Initiated Dynamic Route Selection

*Goals*
- *(I) automatic update of route based on conditions*
- *(2) provide most efficient route given conditions*
- *(3) understand recommendations*
- *(4) determine if recommendations are acceptable*
- *(5) initiate route guidance along new route*

| (1) System recognizes need for revised route | (2) Initiate request for new route | (3) Review recommended route | (4) Decide if new route is satisfactory | (5) Initiate route approval |
|---|---|---|---|---|

**5.5 ROUTE GUIDANCE**

5.5.1 System Generates Instruction
5.5.2 Driver Observes Instruction for Next Action
5.5.3 Driver Plans for Next Route Action
5.5.4 System Alerts Driver of Approaching Action Point
5.5.5 Driver Confirms Action Is Appropriate
5.5.6 Driver Confirms That Action Is Safe
5.5.7 Driver Initiates Necessary Action
5.5.8 Driver Completes Necessary Action
5.5.9 System Generates Next Instruction

---

**ROUTE GUIDANCE)**

***Goals***

***(I) provide driver with guidance along route***
***(2) get instructions from system***
***(3) understand instructions and prepare response in advance***
***(4) provide warning of impending action in time to initiate***
***(5) ensure system guidance is correct***
***(6) ensure maneuver can be safely completed***
***(7) guide vehicle along suggested route***
***(8) prepare for next instruction***
***(9) provide next instruction***

(1) System Generates Instruction

(2) Driver Observes Instruction

(3) Driver Plans Next Action

(4) System Alerts Driver of Approaching Action Point

(5) Driver Confirms Action Is Appropriate

(6) Driver Confirms Action Is Safe

(7) Driver Initiates Action

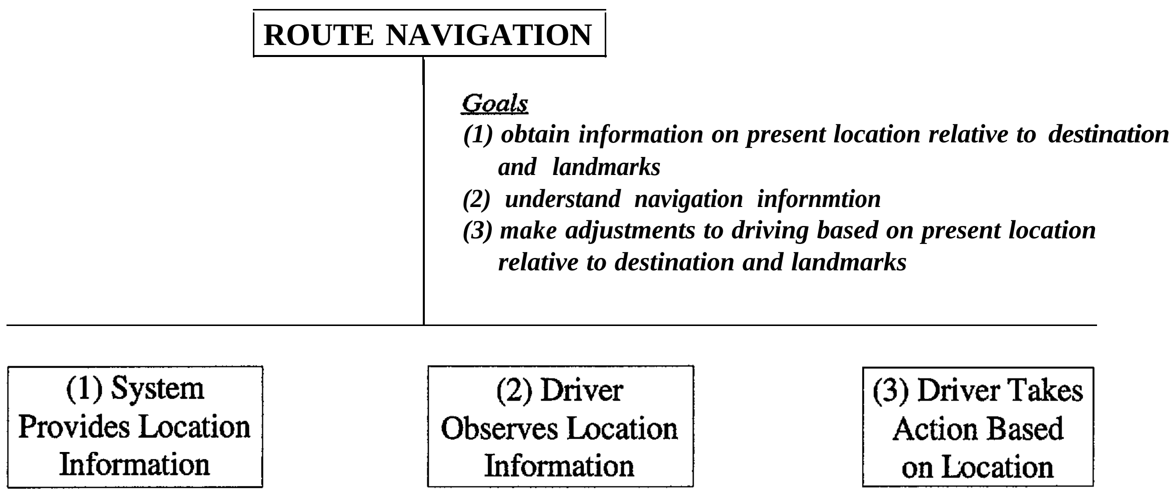
(8) Driver Completes Action

(9) System Generates Next Instruction

## Hierarchical Task Description of Private Driving and ATIS

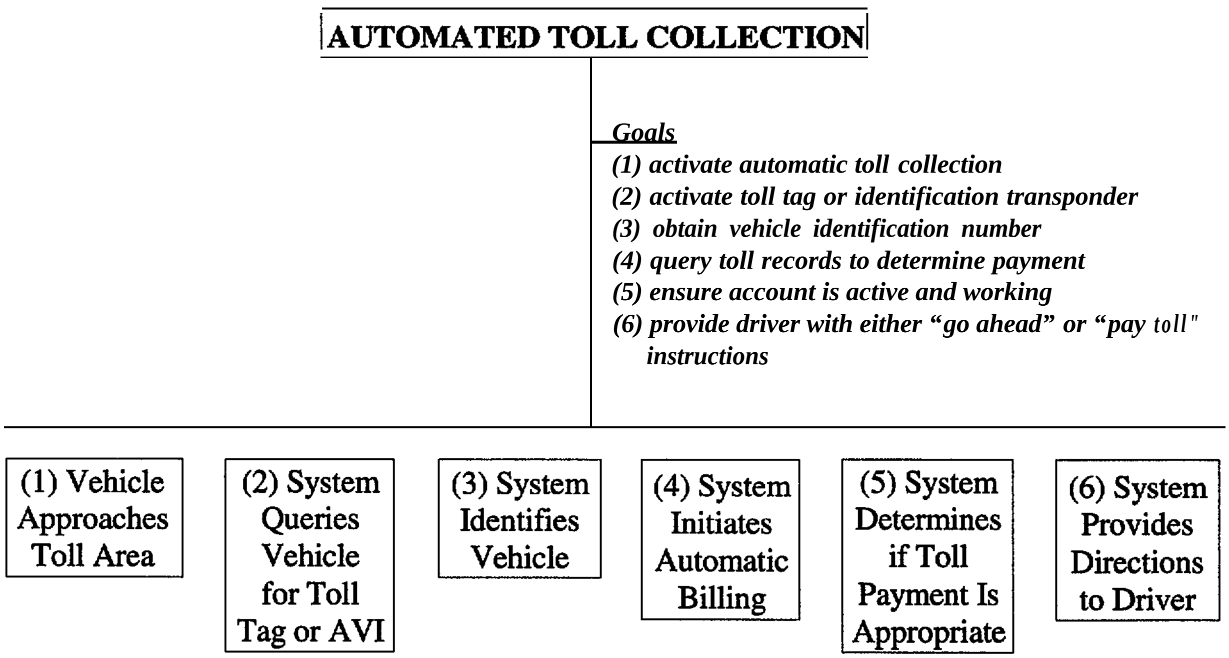
5.6 **ROUTE NAVIGATION**

- 5.6.1 System Provides Navigation Information
- 5.6.2 Driver Observes Navigation Information
- 5.6.3 Driver Takes Action Based on Navigation Information



**5.7 AUTOMATED TOLL COLLECTION**

5.7.1 Vehicle Approaches Toll Area
5.7.2 System Queries Vehicle for Toll Tag or Automatic Vehicle Identification (AVI)
5.7.3 System Identifies Vehicle
5.7.4 System Initiates Automatic Billing or Deducts Toll
5.7.5 System Determines if Toll Payment Is Appropriate
5.7.5.1 If yes, indicate to driver that he or she is free to continue
5.7.5.2 If no, indicate driver must stop at toll booth



# Hierarchical Task Description of Private Driving and ATIS

6.1 **BROADCAST SERVICES/ATTRACTIONS**
- 6.1.1 Driver Initiates Broadcast Services Receiving Equipment
- 6.1.2 Driver Enters Screening Parameters
  - 6.1.2.1 Services of interest
  - 6.1.2.2 Proximity to route or area of interest
- 6.1.3 System Provides Announcement of Services as Approached
- 6.1.4 Driver Takes Desired Action Regarding Services

---

**BROADCAST SERVICES/ATTRACTIONS**

<u>*Goals*</u>
*(1) prepare equipment to receive broadcast services*
*(2) limit alert messages by type and proximity*
*(3) provide information desired*
*(4) use information*

(1) Initiate Broadcast Services Receiving Equipment

(2) Enter Screening Parameters

(3) Receive Announcement of Services

(4) Take Desired Action

## *6.2* SERVICES/ATTRACTIONS DIRECTORY

- 6.2.1 Driver Initiates Services/Attractions Directory
- 6.2.2 Select Class of Services Desired
- 6.2.3 Select Parameters for Class of Services
- 6.2.4 Review Listing
- 6.2.5 Select Item From Listing
- 6.2.6 Initiate Route Guidance to Selected Item

---

**SERVICES/ATTRACTIONS DIRECTORY**

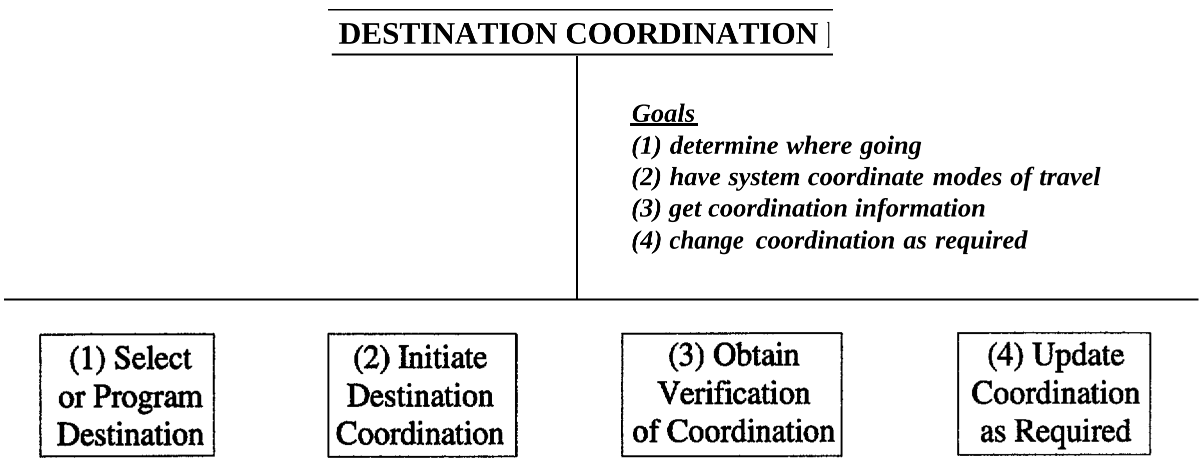
***Goals***

***(1) prepare system to provide services/attractions listing***
***(2) reduce search to specific type of services/attractions wanted***
***(3) limit search to specific area, distance, or other characteristic***
***(4) review possible selections***
***(5) determine specific location of desired services/attractions***
***(6) obtain directions to services/attractions***

| | | | | | |
|---|---|---|---|---|---|
| (1) Initiate Services/ Attractions Directory | (2) Select Class of Services Desired | (3) Select Parameters for Class of Services | (4) Review Listing | (5) Select Item From Listing | (6) Initiate Route Guidance |

## Hierarchical Task Description of Private Driving and ATIS

6.3 **DESTINATION COORDINATION**
- 6.3.1 Select or Program Destination
- 6.3.2 Initiate Destination Coordination
- 6.3.3 Obtain Verification of Coordination
- 6.3.4 Update Coordination as Required
  - 6.3.4.1 System update of arrival time
  - 6.3.4.2 Driver updates changes in services required



# Hierarchical Task Description of Private Driving and ATIS

**6.4 MESSAGE TRANSFER**

6.4.1 Message Sent From Vehide

6.4.1.1 Driver generates message

6.4.1.1.1 Preset message using menu or programmed keys

6.4.1.1.2 Text message generated by keyboard or other device

6.4.1.2 Driver initiates message transfer

6.4.1.3 System indicates message delivery and receipt

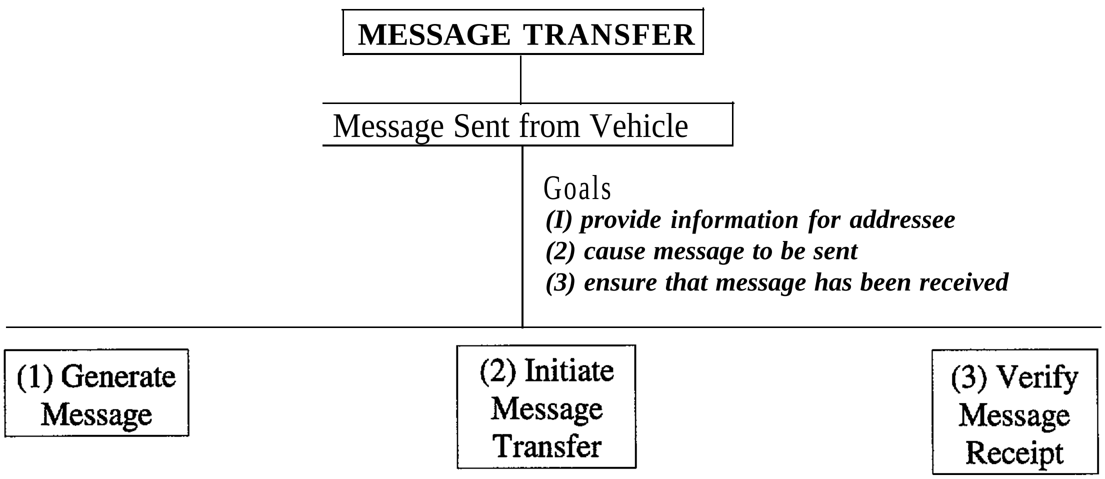
6.4.2 Message Received by Vehicle

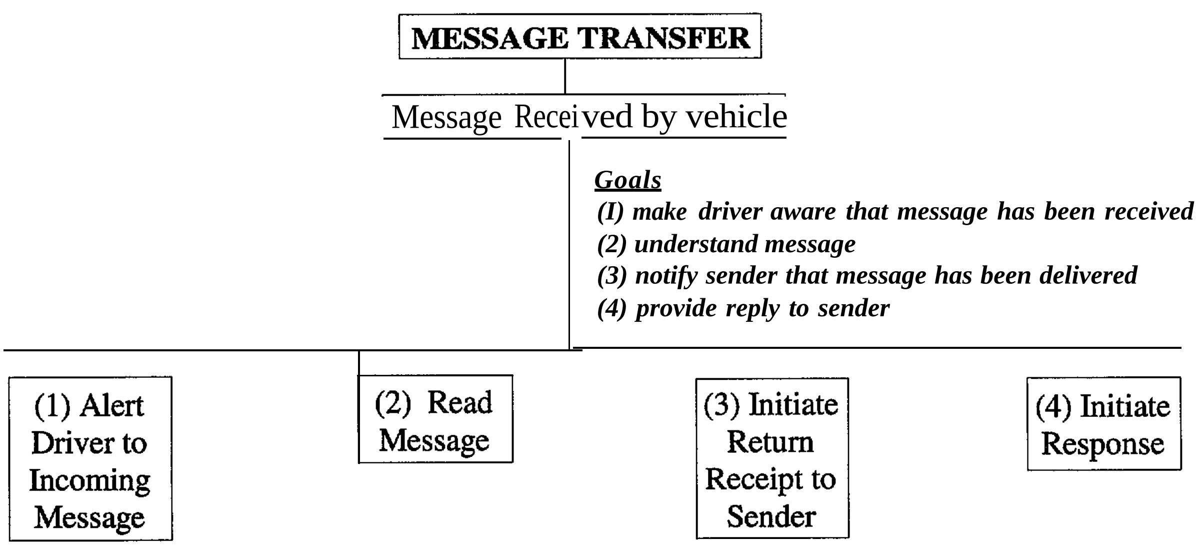
6.4.2.1 System alerts driver to receipt of message

**6.4.2.2** Driver reads message

6.4.2.3 System notifies sender that message has been received

6.4.2.4 Driver initiates response if necessary



## Hierarchical Task Description of Private Driving and ATIS

**7.1 ROADWAY GUIDANCE SIGN INFORMATION**

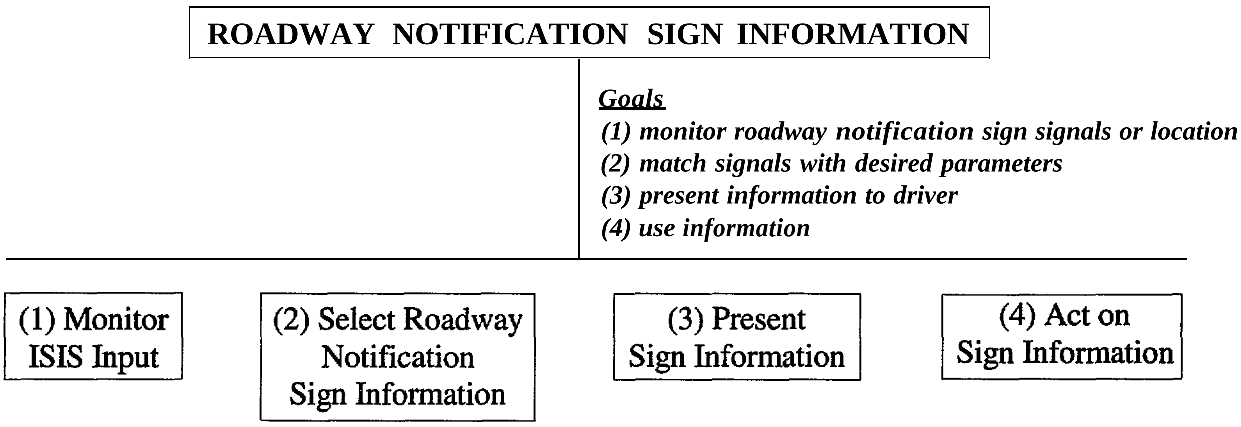
7.1.1 System Monitors ISIS Input
7.1.2 Select Roadway Guidance Sign Information
7.1.3 System Presents Selected Sign Information
7.1.4 Driver Acts on Sign Information as Desired

**ROADWAY GUIDANCE SIGN INFORMATION**

*Goals*
***(I) monitor roadway guidance sign signals or location***
***(2) match signals with desired parameters***
***(3) present infomuztion to driver***
***(4) use information***

| (1) Monitor ISIS Input | (2) Select Roadway Guidance Sign Information | (3) Present Sign Information | (4) Act on Sign Information |
|---|---|---|---|

7.2 **ROADWAY NOTIFICATION SIGN INFORMATION**
- 7.2.1 System Monitors ISIS Input
- 7.2.2 Select Roadway Notification Sign Information
- 7.2.3 System Presents Selected Sign Information
- 7.2.4 Driver Acts on Sign Information as Desired



**7.3 ROADWAY REGULATORY SIGN INFORMATION**

7.3.1 System Monitors ISIS Input
7.3.2 Select Roadway Regulatory Sign Information
7.3.3 System Presents Selected Sign Information
**7.3.4** Driver Acts on Sign Information as Desired

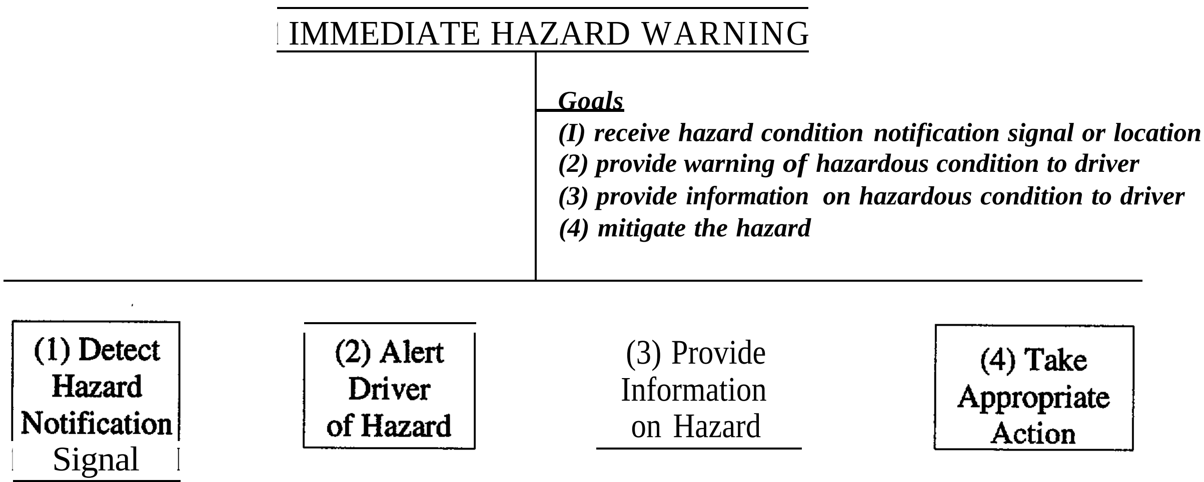
**ROADWAY REGULATORY SIGN INFORMATION**

*Goals*
*(I) monitor roadway regulatory sign signals or location*
*(2) match signals with desired parameters*
*(3) present information to driver*
*(4) use information*

| (1) Monitor ISIS Input | (2) Select Roadway Regulatory Sign Information | (3) Present Sign Information | (4) Act on Sign Information |
|---|---|---|---|

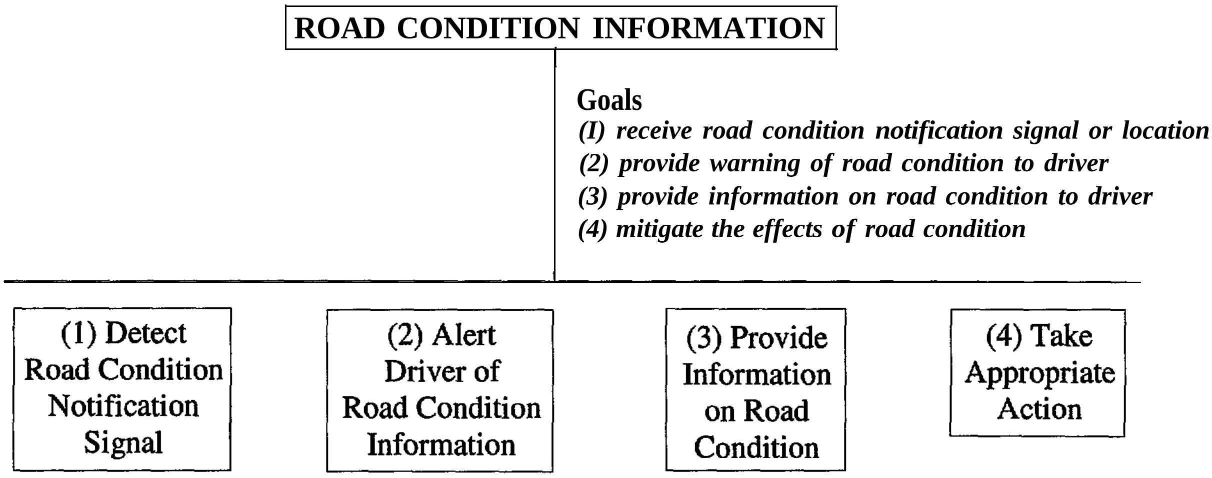
## Hierarchical Task Description of Private Driving andATIS

8.1 IMMEDIATE HAZARD **WARNING**
- 8.1.1 System Detects Hazard Notification
- 8.1. System Alerts Driver of Hazard
- 8.1.3 System Provides Information on Hazard Type
- 8.1.4 Driver Takes Appropriate Action in Response to Hazard



***8.2*** **ROAD CONDITION INFORMATION**

8.2.1 System Detects Road Condition Notification
8.2.2 System Alerts Driver of Road Condition Notification
8.2.3 System Provides Information on Road Condition
8.2.4 Driver Takes Appropriate Action in Response to Road Condition



**8.3 AUTOMATIC AID REQUEST**
8.3.1 System Detects Emergency Condition
8.3.2 System Broadcasts Emergency Request

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**[AUTOMATIC AID REQUEST]**

***Goals***
***(1) detect when crash or other emergency has occurred***
***(2) summon help***

(1) Detect Emergency Condition

(2) Broadcast Emergency Request

**8.4 MANUAL AID REQUEST**

8.4.1 Driver Activates Manual Aid Request
8.4.1.1 Aid required
8.4.1.2 Urgency
8.4.2 System Sends Request as Well as Vehicle Location
8.4.3 System Acknowledges Request Received
8.4.4 System Gets Update of Arrival Time for Aid
8.4.5 Notifies Driver of Arrival Time for Aid

---

**MANUAL AID REQUEST**

***Goals***
***(I) activate system to request aid***
***(2) provide vehicle location***
***(3) provide feedback to driver that message has been received***
***(4) obtain information on arrival time for aid***
***(5) provide driver with information on arrival time***

| (1) Initiate Manual Aid Request | (2) Send Request and Vehicle Location | (3) Acknowledge Request Received | (4) Receive Update of Arrival Time for Aid | (5) Notifies Driver of Arrival Time for Aid |
|---|---|---|---|---|

# Hierarchical Task Description of Private Driving and ATIS

**8.5 VEHICLE CONDITION MQNITORING**

8.5.1 System Monitors Vehicle Parameters
8.5.2 System Detects Abnormal Condition
8.5.3 System Alerts Driver
8.5.4 System Provides Description of Problem
8.5.5 Driver Takes Appropriate Action

**VEHICLE CONDITION MONITORING**

***Goals***
***(I) early detection of mechanical and electrical problems***
***(2) initiate alert sequence when condition exceeds threshold***
***(3) provide driver with warning of problem***
***(4) provide driver with information on the problem***
***(5) mitigate*** the ***possible consequences of the problem***

(1) Monitor Vehicle Parameters

(2) Detect Abnormal Condition

(3) Alert Driver

(4) Provide Description of Problem

(5) Take Appropriate Action

COMMERCIAL VEHICLE OPERATIONS

1 PRE-DRIVE
  1.1 PRE-DRIVE INSPECTION
  1.2 STARTUP
  1.3 AUXILIARY SYSTEMS
  1.4 PLANNING
2 DRIVE
  2.1 NAVIGATION AND ROUTING
  2.2 GUIDANCE AND MANEUVERS
  2.3 CONTROL
  2.4 VEHICLE SYSTEM OPERATION AND MONITORING
  2.5 REACTING TO EMERGENCIES
51RANs
  5.1 TRIP PLANNING
  5.2 MULTI-MODE TRAVEL COORDINATION
  5.3 PRE-DRIVE ROUTE AND DESTINATION SELECTION
  5.4 DYNAMIC ROUTE SELECTION
  5.5 ROUTE GUIDANCE
  5.6 ROUTE NAVIGATION
  5.7 AUTOMATED TOLL COLLECTION
6 IMSIS
  6.1BROADCASTSERVICES/ATTRACTIONS
  6.2SERVICES/ATTRACTIONSDIRECTORY
  6.3 DESTINATION COORDINATION
  6.4 MESSAGE TRANSFER
7 ISIS
  7.1 ROADWAY GUIDANCE SIGN INFORMATION
  7.2 ROADWAY NOTIFICATION SIGN INFORMATION
  7.3 ROADWAY REGULATORY SIGN INFORMATION
  7.4 ROAD RESTRICTION INFORMATION
8 IVSAWS
  8.1 IMMEDIATE HAZARD WARNING
  8.2 ROAD CONDITION INFORMATION
  8.3 AUTOMATIC AID REQUEST
  8.4 MANUAL AID REQUEST
  8.5 VEHICLE CONDITION MONITORING
9 CVO FUNCTIONS
  9.1 FLEET RESOURCE MANAGEMENT
  9.2 DISPATCH
  9.3 REGULATORY ENFORCEMENT

# Hierarchical Task Description of Commercial Vehicles'

1.1 **PRE-DRIVE INSPECTION**
- 1.1.1 Check Exterior of the Vehicle
  - 1.1.1.1 Inspect wheels
  - 1.1.1.2 Inspect tires
  - 1.1.1.3 Inspect brakes
  - 1.1.1.4 Inspect suspension
- 1.1.2 Check Tires
  - 1.1.2.1 Inspect steering wheel
  - 1.1.2.2 Inspect brake pedal
  - 1.1.2.3 Inspect clutch pedal
  - 1.1.2.4 Inspect accelerator pedal
- 1.1.3 Check Area Around the Vehicle
  - 1.1.3.1 Check hydraulic brakes
  - 1.1.3.2 Check parking brake
  - 1.1.3.3 Check service brake
  - 1.1.3.4 Check trailer brake
- 1.1.4 Inspect Air Brakes
  - 1.1.4.1 Check low-pressure warning system
  - 1.1.4.2 Check tractor protection valve
  - 1.1.4.3 Check air pressure buildup
  - 1.1.4.4 Check air pressure level
- 1.1.5 Inspect Load
  - 1.1.5.1 Check cargo securing devices
  - 1.1.5.2 Check cargo protection
  - 1.1.5.3 Check vehicle overload
  - 1.1.5.4 Check vehicle balance of weight

---

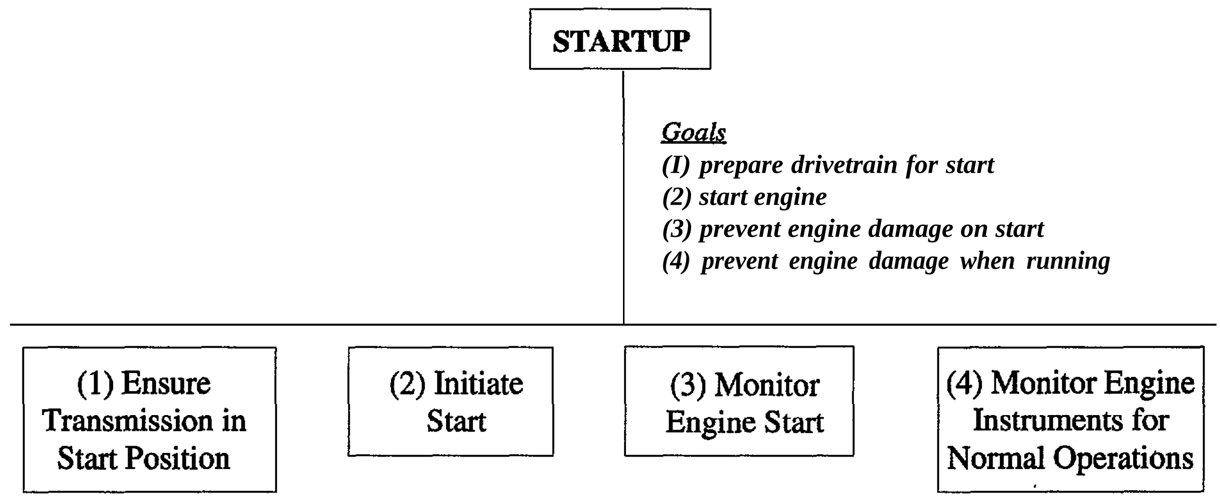
**PRE-DRIVE INSPECTION**

*Goals*
*(1) determine vehicle condition*
*(2) determine condition of tires*
*(3) determine that area around vehicle is clear*

| (1) Check Exterior of Vehicle | (2) Check Tires | (3) Check Exterior of Vehicle | (4) Inspect Air Brakes | (5) Inspect Load and Protection |
|---|---|---|---|---|

# Hierarchical Task Description of Commercial Vehicles

1.2 STARTUP
- 1.2.1 Ensure Transmission in Start Position
- 1.2.2 Initiate Start
- 1.2.3 Monitor Engine Start
- 1.2.4 Monitor Engine Instruments for Normal Operations



## Hierarchical Task Description of Commercial Vehicles

**1.3 AUXILIARY SYSTEMS**

1.3.1 Climate Control
- 1.3.1.1 Set climate controls as necessary

1.3.2 Turn Signals
- 1.3.2.1 Check operations

1.3.3 Communications
- 1.3.3.1 Broadcast radio/entertainment system
  - 1.3.3.1.1 Turn on
  - 1.3.3.1.2 “Select mode, station, program”
- 1.3.3.2 Two-way communications
  - 1.3.3.2.1 Turn on

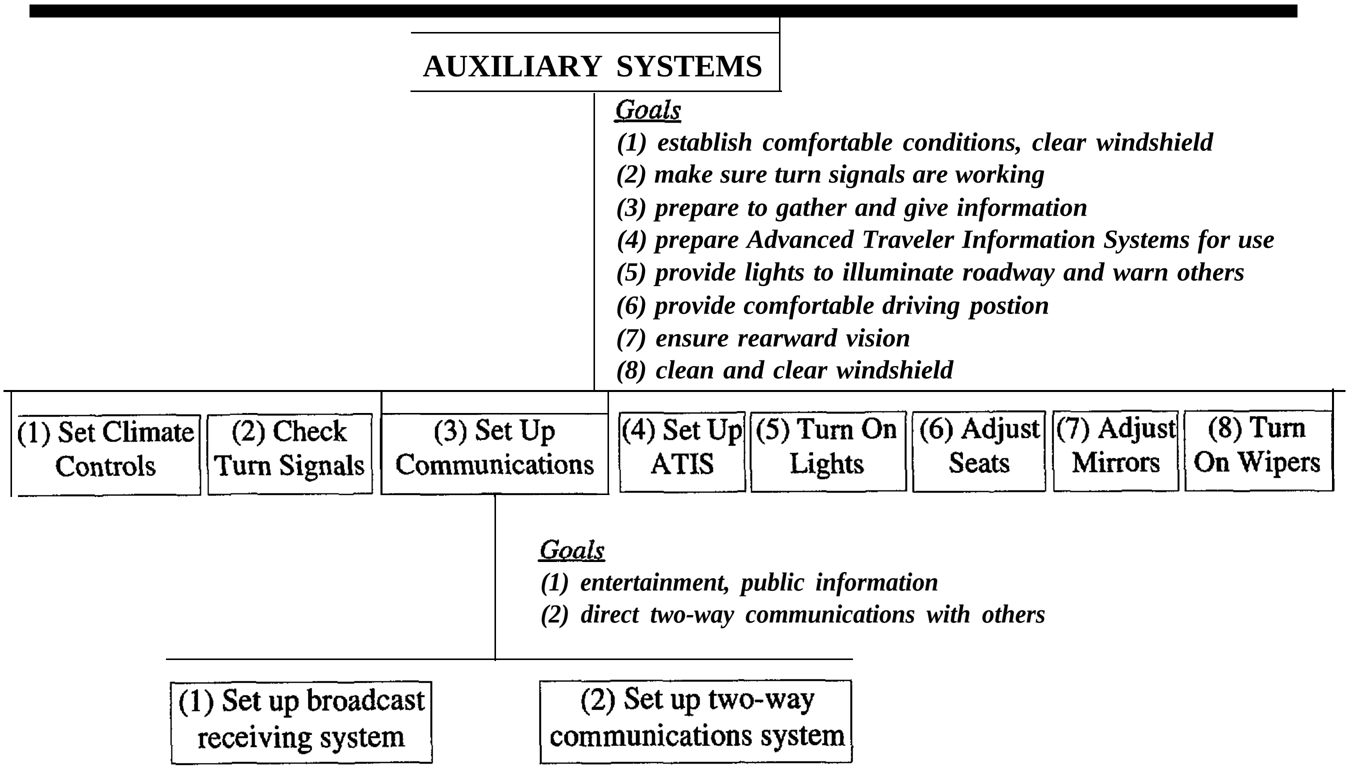
1.3.4 ATIS Systems
- 1.3.4.1 Turn on
- 1.3.4.2 Verify system readiness
- 1.3.4.3 Initiate system operation
  - 1.3.4.3.1 Input desired system parameters
  - 1.3.4.3.2 Verify system parameters correct

1.3.5 Lighting
- 1.3.5.1 Turn on if necessary

1.3.6 Seats
- 1.3.6.1 Adjust seat if necessary

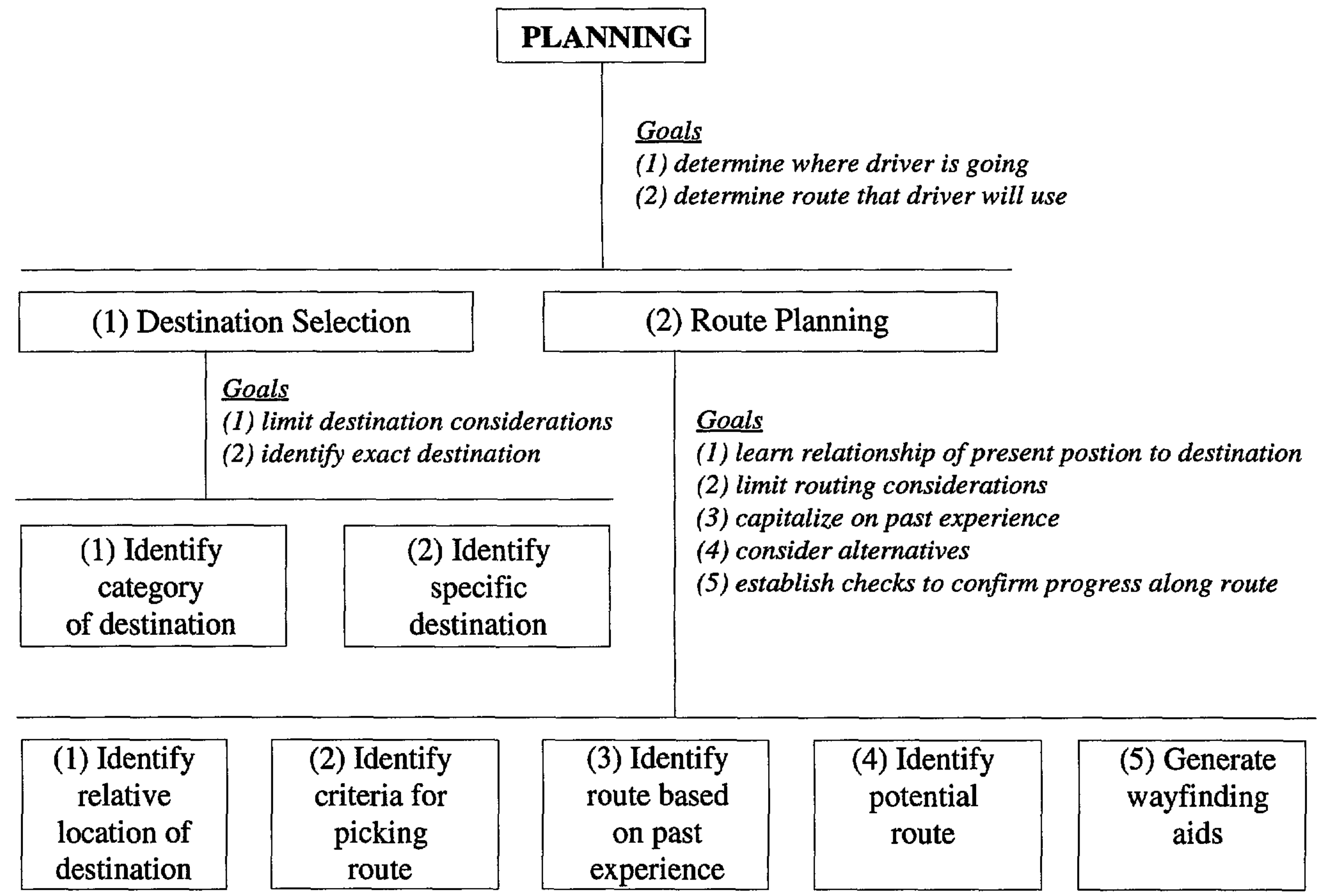
1.3.7 Mirrors
- 1.3.7.1 Adjust mirrors if necessary

1.3.8 Wipers/Windshield Washer
- 1.3.8.1 Turn on wipers/windshield washer as necessary



# Hierarchical Task Description of Commercial Vehicles

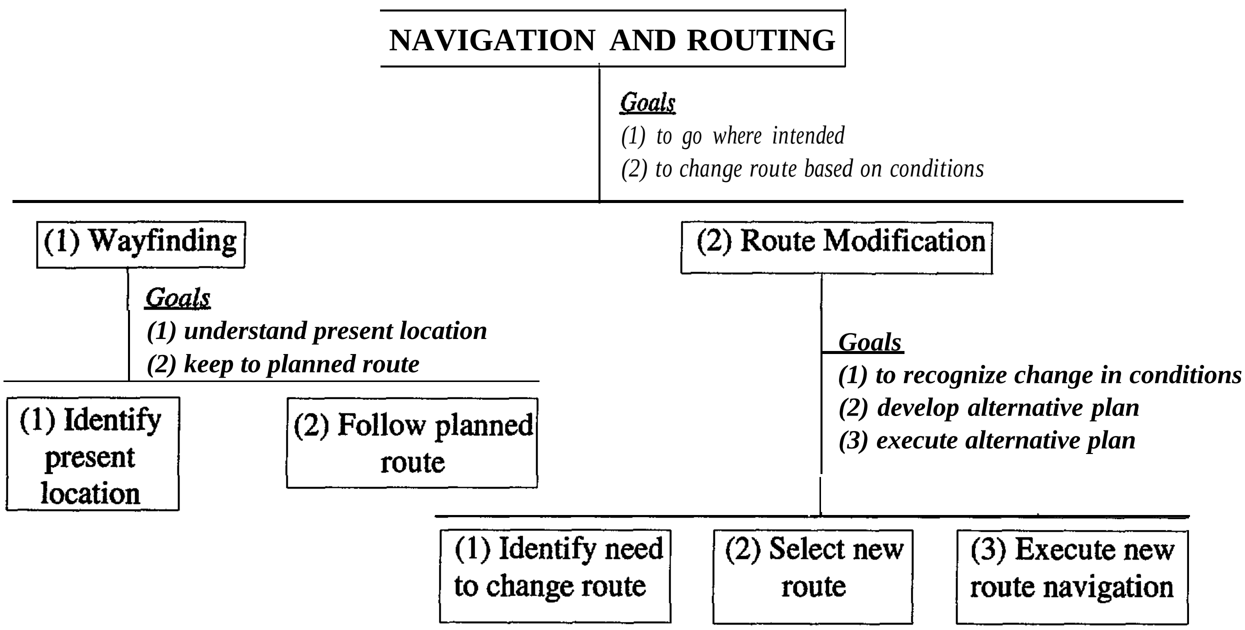
1.4 **PLANNING**
- 1.4.1 Destination Selection
  - 1.4.1.1 Identify category of destination
  - 1.4.1.2 Identify specific destination
- 1.4.2 Route Planning
  - 1.4.2.1 Identify relative location of destination
  - 1.4.2.2 Identify criteria for picking route
  - 1.4.2.3 Identify route based on past experience
  - 1.4.2.4 Identify potential route
  - 1.4.2.5 Generate wayfinding aids



# Hierarchical Task Description of Commercial Vehicles

**2.1 NAVIGATION AND ROUTING**

2.1.1 Wayfinding
2.1.1.1 Navigation
2.1.1.1.1 Identify present location
2.1.1.1.2 Determine relative direction and distance to destination
2.1.1.1.3 Use landmarks to determine orientation and present location
2.1.1.1.4 Compare expected location to map reference points and expectations
2.1.1.2 Route following
2.1.1.2.1 Identify next waypoint
2.1.1.2.2 Identify present location relative to waypoint
2.1.1.2.3 Identify required maneuver to proceed beyond the waypoint
2.1.1.2.4 Execute maneuvers
2.1.1.2.5 Verify present location and direction against expectation
2.1.2 Route Modification
2.1.2.1 Identify need
2.1.2.1.1 Identify traffic conditions and hazard on projected route
2.1.2.1.2 Evaluate consequence of traffic condition and hazard
2.1.2.1.3 Identify descrepancy between planned and actual route
2.1.2.2 Select and change
2.1.2.2.1 Determine position relative to traffic congestion or hazard
2.1.2.2.2 Identify alternate route
2.1.2.2.3 Determine distance to waypoint
2.1.2.2.4 Determine required maneuver
2.1.2.2.5 Verify present location and direction against expectation



# Hierarchical Task Description of Commercial Vehicles

## 2.2 GUIDANCE AND MANEUVERS

2.2.1 Traffic Coordination
- 2.2.1.1 Monitor distance between own vehicle and others
- 2.2.1.2 Execute speed and position control to maintain separation
- 2.2.1.3 Monitor position of vehicle relative to traffic conditions and waypoint
- 2.2.1.4 Execute maneuvers to accommodate traffic conditions and vehicle dynamics

2.2.2 Rule Compliance
- 2.2.2.1 Monitor environment for regulatory signs
- 2.2.2.2 Recall from memory regulatory information
- 2.2.2.3 Evaluate planned route relative to regulatory requirements
- 2.2.2.4 Compare current driving status against regulatory requirements
- 2.2.2.5 Execute driving maneuvers to comply
- 2.2.2.6 Execute speed and position control to comply

2.2.3 Maneuvering
- 2.2.3.1 Identify present speed and position
- 2.2.3.2 Identify distance to waypoint
- 2.2.3.3 Identify traffic condition
- 2.2.3.4 Adjust speed and lane position
- 2.2.3.5 Signal intended maneuver
- 2.2.3.6 Execute desired maneuver

2.2.4 Hazard Observation
- 2.2.4.1 Estimate hazard potential on planned route
- 2.2.4.2 Make adjustment to planned route to accommodate hazard
- 2.2.4.3 Monitor roadway surface and surroundings
- 2.2.4.4 Monitor traffic conditions for hazardous situations
- 2.2.4.5 Estimate hazard potential to vehicle
- 2.2.4.6 Execute speed and position control to compensate for hazard
- 2.2.4.7 Execute driving maneuver to compensate for hazard

---

**GUIDANCE AND MANEUVERS**

*__Goals__*
*(1) keep vehicle at safe distance from other vehicles*
*(2) keep vehicle within regulated safety limits*
*(3) cause vehicle to go where intended*
*(4) avoid hazardous conditions*

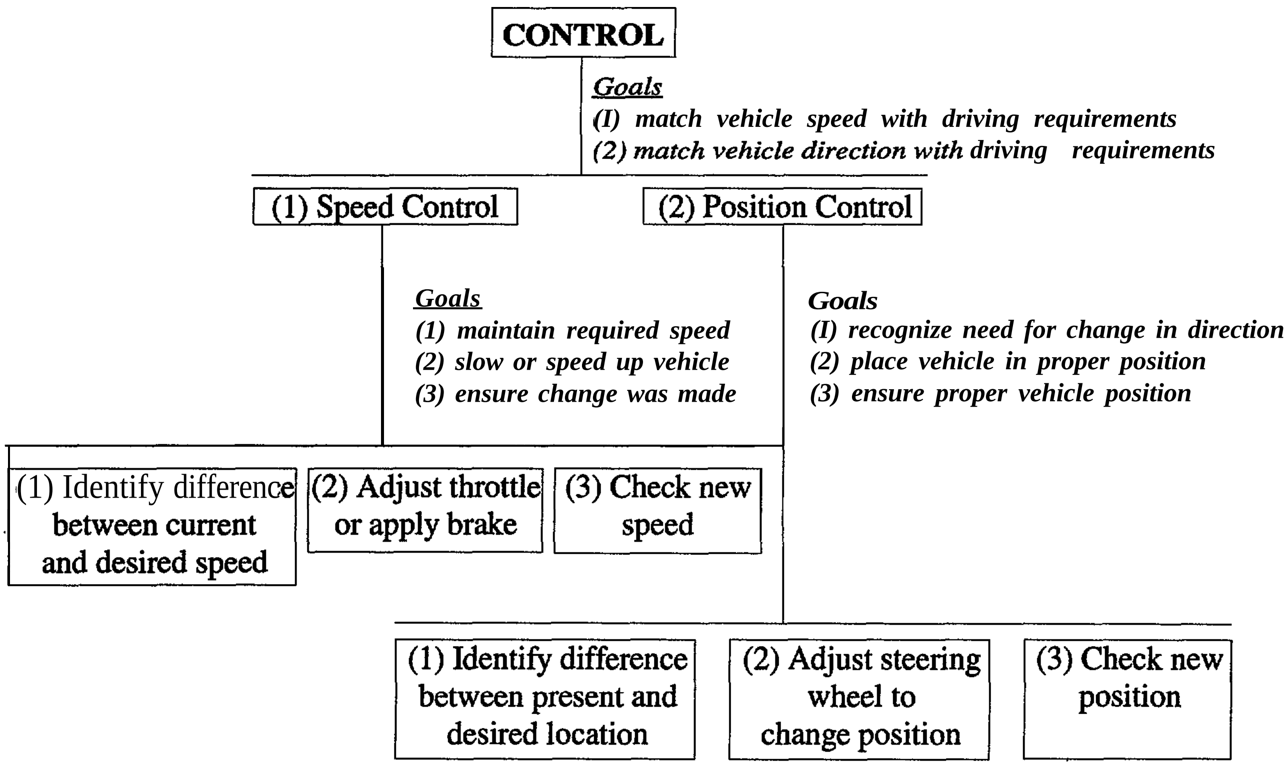
| (1) Coordinate Vehicle Movements With Other Traffic | (2) Keep Speed and Other Activities Within What Regulations Require | (3) Control Car Direction and Speed to Reach Intended Destination | (4) Observe and Take Necessary Actions to Avoid Hazardous Conditions |
|---|---|---|---|

# Hierarchical Task Description of Commercial Vehicles

**2.3 CONTROL**

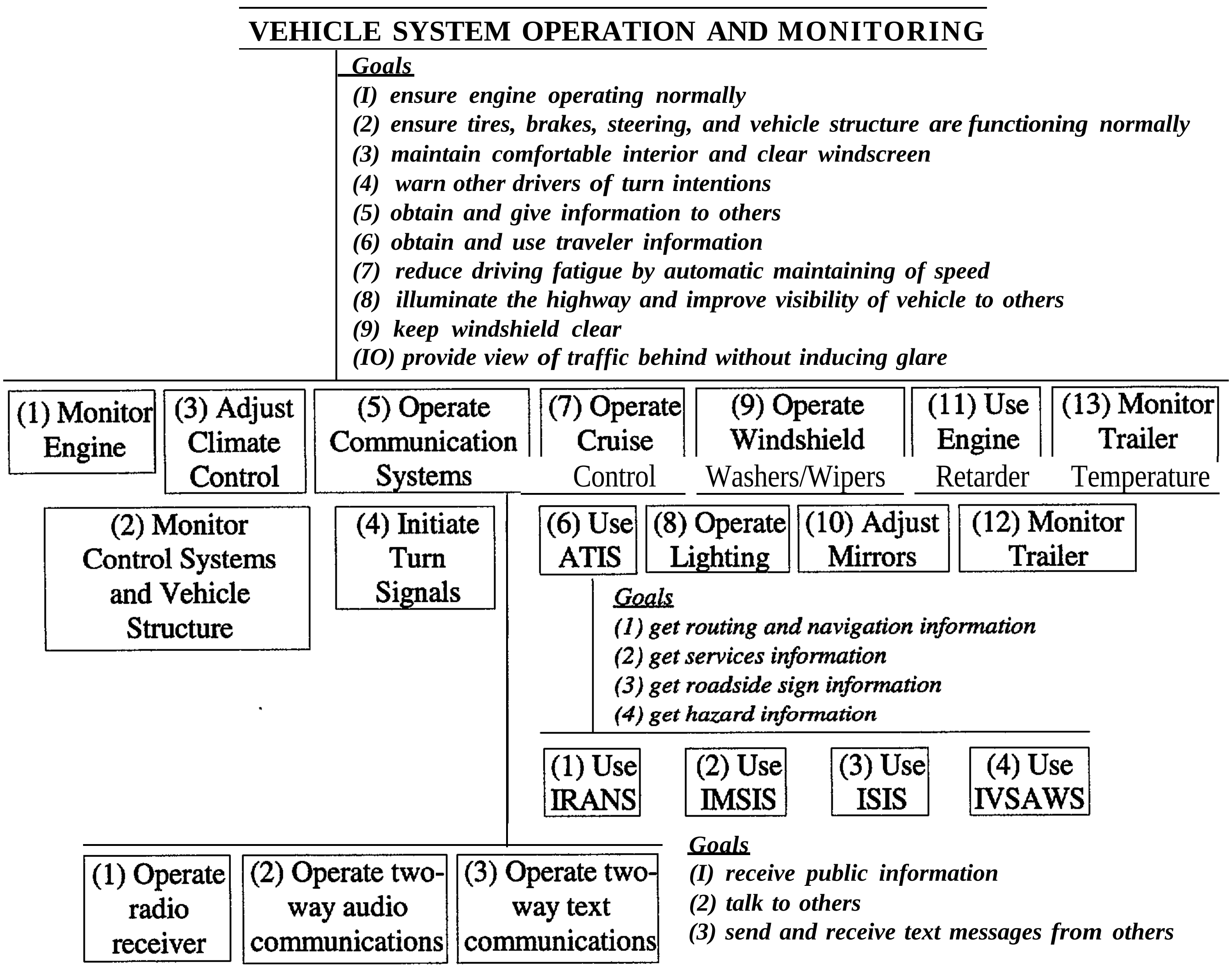
2.3.1 Speed Control
- 2.3.1.1 Identify descrepancy between current and desired speed
- 2.3.1.2 Adjust throttle or brake to control speed
- 2.3.1.3 Verify adjustment of speed

2.3.2 Position Control
- 2.3.2.1 Identify descrepancy between current and desired lane positions
- 2.3.2.2 Adjust steering wheel to compensate
- 2.3.2.3 Verify adjustment of land position



**2.4 VEHICLE SYSTEM OPERATION AND MONITORING**

2.4.1 Monitor Engine Operation
2.4.2 Monitor Control Systems and Vehicle Structure
2.4.3 Adjust Climate Control
2.4.4 Initiate Turn Signals
2.4.5 Operate Communications Systems
  2.4.5.1 Operate broadcast radio/entertainment system
  2.4.5.2 Operate two-way communications (audio)
  2.4.5.3 Operate two-way communications (text)
2.4.6 Use Advanced Traveler Information Systems (ATIS)
  2.4.6.1 Use In-Vehicle Routing and Navigation System (IRANS)
  2.4.6.2 Use In-Vehicle Motorist Services Information System (IMSIS)
  2.4.6.3 Use In-Vehicle Sign Information System (ISIS)
  2.4.6.4 Use In-Vehicle Safety Advisory and Warning System (IVSAWS)
2.4.7 Operate Cruise Control
2.4.8 Operate Lighting Systems
2.4.9 Operate Windshield Washers/Wipers
2.4.10 Adjust Rearview Mirror
2.4.11 User Engine Retarder and Compression Brakes
2.4.12 Monitor Trailer Tracking
2.4.13 Monitor Trailer Refrigeration



# Hierarchical Task Description of Commercial Vehicles

**2.5 REACTING TO EMERGENCIES**

2.5.1 Detect Emergency Condition
2.5.2 Diagnose Situation
2.5.3 Determine Action Required
2.5.4 Take Appropriate Action

---

**REACTING TO EMERGENCIES**

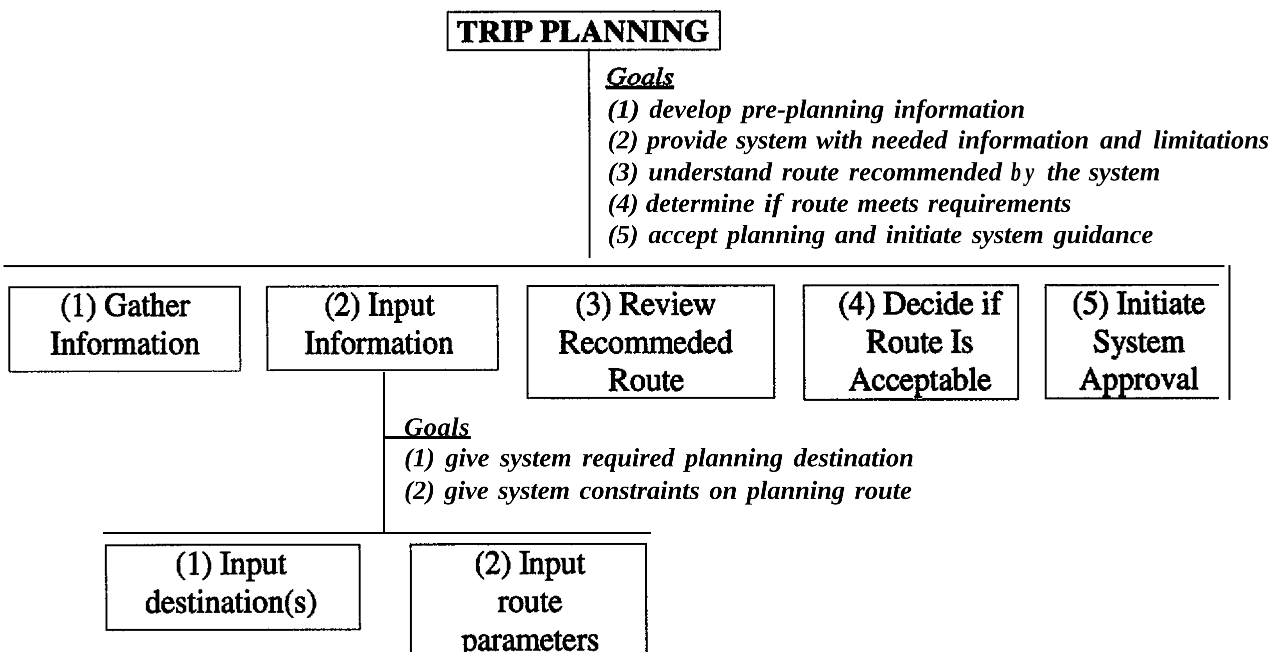
***Goals***

***(I) detect emergency in time to take corrective actions***
***(2) understand what is happening***
***(3) plan actions to mitigate the emergency***
***(4) mitigate the emergency***

| (1) Detect Emergency Condition | (2) Diagnose Situation | (3) Determine Action Required | (4) Take Appropriate Action |
|---|---|---|---|

## Hierarchical Task Description of Commercial Vehicles

5.1 **TRIP PLANNING**
- 5.1.1 Gather Information
  - 5.1.1.1 Destination and stopping points
  - 5.1.1.2 Desired route parameters
- 5.1.2 Input Information
  - 5.1.2.1 Destination(s)
    - 5.1.2.1 .1 Enter destination(s)
    - 5.1.2.1.2 Verify destination(s) entry correct
  - 5.1.2.2 Route parameters
    - 5.1.2.2.1 Enter route parameters
    - 5.1.2.2.2 Verify route parameters correct
- 5.1.3 Review Recommended Route
- 5.1.4 Decide if Route Is Acceptable
- 5.1.5 Jnitiate System Approval



5.2 **MULTI-MODE TRAVEL COORDINATION**

- 5.2.1 Acquire Constraints
- 5.2.2 Enter Constraints
- 5.2.3 Review Inter-Mode Schedule
- 5.2.4 Determine if Inter-Mode Schedule Will Meet Requirements
- 5.2.5 Approve Inter-Mode Schedule
- 5.2.6 Begin First Mode Travel
  - 5.2.6.1 System update of arrival times
    - 5.2.6.1.1 Arrival time for current mode
    - 5.2.6.1.2 Arrival time for next mode
  - 5.2.6.2 System alerts of change in arrival time for next mode
  - 5.2.6.3 System computes change in destination arrival time
  - 5.2.6.4 System proposes new inter-mode schedule
  - 5.2.6.5 Determine if new inter-mode schedule will meet requirments
    - 5.2.6.5.1 If will meet requirements, accept schedule
    - 5.2.6.5.2 If will not meet requirements, request different routing

---

**MULTI-MODE TRAVEL COORDINATION**

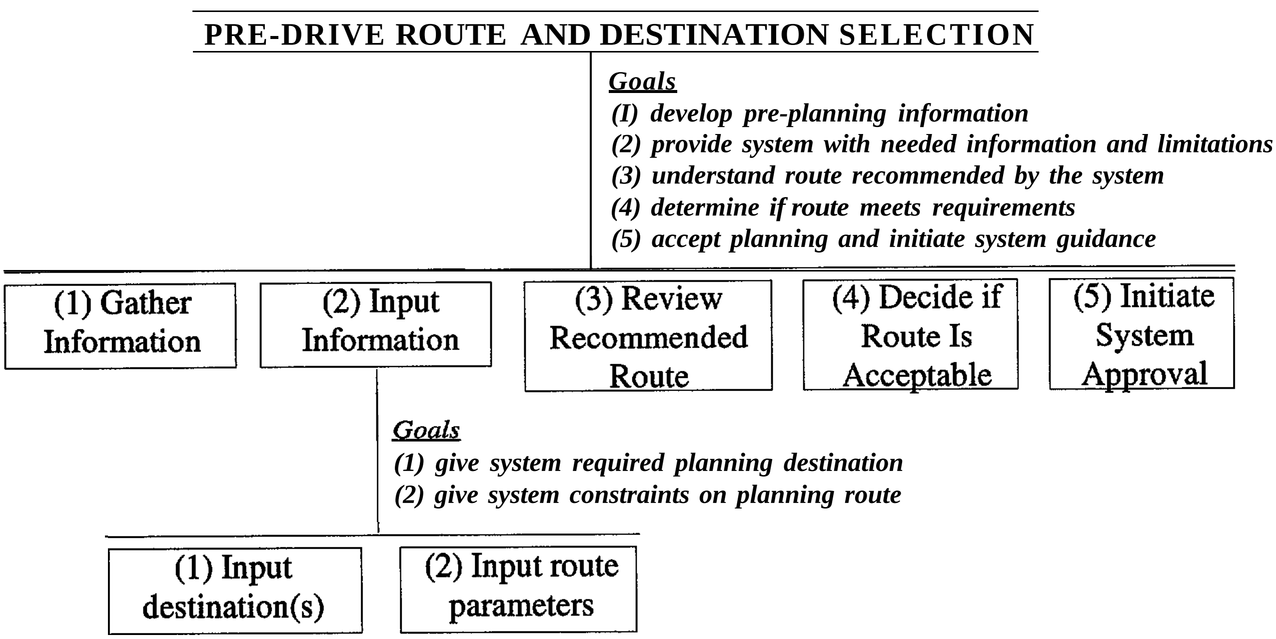
*Goals*

*(1) determine requirements for travel*
*(2) provide system with requirements*
*(3) understand suggested travel plans*
*(4) decide if suggested travel plans will meet needs*
*(5) initiate system coordination*
*(6) begin trip*

| (1) Acquire Constraints | (2) Enter Constraints | (3) Review Inter-Mode Schedule | (4) Determine if Schedule Meets Requirements | (5) Approve Schedule | (6) Begin Travel |
|---|---|---|---|---|---|

**5.3 PRE-DRIVE ROUTE AND DESTINATION SELECTION**

5.3.1 Gather Information
  5.3.1.1 Destination and stopping points
  5.3.1.2 Desired route parameters
5.3.2 Input Information
  5.3.2.1 Destination
    5.3.2.1.1 Enter destination
    5.3.2.1.2 Verify destination entry correct
  5.3.2.2 Route parameters
    5.3.2.2.1 Enter route parameters
    5.3.2.2.2 Verify route parameters correct
5.3.3 Review Recommended Route
5.3.4 Decide if Route Is Acceptable
5.3.5 Intitiate System Approval



# Hierarchical Task Description of Commercial Vehicles

5.4 **DYNAMIC ROUTE SELECTION**
- 5.4.1 Driver-Initiated Dynamic Route Selection
  - 5.4.1.1 Driver recognizes need for revised route
  - 5.4.1.2 Initiate new route request of IRANS
  - 5.4.1.3 System computes new route
  - 5.4.1.4 System presents revised route
  - 5.4.1.5 Driver reviews recommended route
  - 5.4.1.6 Decide if recommended route is satisfactory
  - 5.4.1.7 Initiate route approval
- 5.4.2 System-Initiated Dynamic Route Selection
  - 5.4.2.1 System recognizes need for revised route
  - 5.4.2.2 System alerts driver of change in route condition
  - 5.4.2.3 System computes revised route
  - 5.4.2.4 System presents revised route
  - 5.4.2.5 Driver reviews recommended route
  - 5.4.2.6 Decide if recommended route is satisfactory
  - 5.4.2.7 Initiate route approval

---

**DYNAMIC ROUTE SELECTION**

Driver-Initiated Dynamic Route Selection

*Goals*
*(1) detect change in conditions in time to affect outcome*
*(2) plan new route*
*(3) understand proposed new route*
*(4) determine if new route will meet requirements*
*(5) have system provide directions based on new route*

| | | | | |
|---|---|---|---|---|
| (1) Driver recognizes need for revised route | (2) Initiate request for new route | (3) Review recommended route | (4) Decide if route is satisfactory | (5) Initiate route approval |

---

**DYNAMIC ROUTE SELECTION**

System-Initiated Dynamic Route Selection

*Goals*
*(1) automatic update of route based on conditions*
*(2) provide most efficient route given conditions*
*(3) understand recommendations*
*(4) determine if recommendations are acceptable*
*(5) initiate route guidance along new route*

| | | | | |
|---|---|---|---|---|
| (1) System recognizes need for revised route | (2) System presents revised route | (3) Driver reviews recommended route | (4) Decide if new route is satisfactory | (5) Initiate route approval |

**5.5 ROUTE GUIDANCE**

5.5.1 System Generates Instruction
5.5.2 Driver Observes Instruction for Next Action
5.5.3 Driver Plans for Next Route Action
5.5.4 System Alerts Driver of Approaching Action Point
5.5.5 Driver Confiis Action Is Appropriate
5.5.6 Driver Confirms That Action Is Safe
5.5.7 Driver Initiates Necessary Action
5.5.8 Driver Completes Necessary Action
5.5.9 System Generates Next Instruction

---

**ROUTE GUIDANCE**

*Goals*

*(1) provide driver with guidance along route*
*(2) get instructionsfrom system*
*(3) understand instructions and prepare response in advance*
*(4) provide warning of impending action in time to initiate*
*(5) ensure system guidance is correct*
*(6) ensure maneuver can be safely completed*
*(7) guide vehicle along suggested route*
*(8) prepare for next instruction*
*(9) provide next instruction*

(1) System Generates Instruction

(2) Driver Observes Instruction

(3) Driver Plans Next Action

(4) System Alerts Driver of Approaching Action Point

(5) Driver Confirms Action Is Appropriate

(6) Driver Confirms Action Is Safe

(7) Driver Initiates Action

(8) Driver Completes Action

(9) System Generates Next Instruction

**5.6 ROUTE NAVIGATION**

5.6.1 System Provides Navigation Information

5.6.2 Driver Observes Navigation Information

5.6.3 Driver Takes Action Based on Navigation Information

---

**ROUTE NAVIGATION**

***Goals***

***(I) obtain information on present location relative to destination and landmarks***

***(2) understand navigation information***

***(3) make adjustments to driving based on present location relative to destination and'landmurks***

| (1) System Provides Location Information | (2) Driver Observes Location Information | (3) Driver Takes Action Based on Location |
|---|---|---|

# Hierarchical Task Description of Commercial Vehicles

5.7 **AUTOMATED TOLL COLLECTION**
- 5.7.1 Vehicle Approaches Toll Area
- 5.7.2 System Queries Vehicle for Toll Tag or AVI
- 5.7.3 System Identifies Vehicle
- 5.7.4 System Initiates Automatic Billing or Deducts Toll
- 5.7.5 System Determines if Toll Payment Is Appropriate
  - 5.7.5.1 If yes, indicate to driver that he/she is free to continue
  - 5.7.5.2 If no, indicate driver must stop at toll booth

---

**AUTOMATED TOLL COLLECTION**

*Goals*
*(1) activate automatic toll collection*
*(2) activate toll tag or identification transponder*
*(3) obtain vehicle identification number*
*(4) query toll records to determine payment*
*(5) ensure account is active and working*
*(6) provide driver with either "go ahead" or "pay toll" instructions*

| | | | | | |
|---|---|---|---|---|---|
| (1) Vehicle Approaches Toll Area | (2) System Queries Vehicle for Toll Tag or AVI | (3) System Identifies Vehicle | (4) System Initiates Automatic Billing | (5) System Determines if Toll Payment Is Appropriate | (6) System Provides Directions to Driver |

# Hierarchical Task Description of Commercial Vehicles

6.1 **BROADCAST SERVICES/ATTRACTIONS**
- 6.1.1 Driver Initiates Broadcast Services Receiving Equipment
- 6.1.2 Driver Enters Screening Parameters
  - 6.1.2.1 Services of interest
  - 6.1.2.2 Proximity to route or area of interest
- 6.1.3 System Provides Announcement of Services as Approached
- 6.1.4 Driver Takes Desired Action Regarding Services

---

**BROADCAST SERVICES/ATTRACTIONS**

***Goals***
***(1) prepare equipment to receive broadcast services***
***(2) Limit alert messages by type and proximity***
***(3) provide information desired***
***(4) use information***

(1) Initiate Broadcast Services Receiving Equipment

(2) Enter Screening Parameters

(3) Receive Announcement of Services

(4) Take Desired Action

**6.2 SERVICES/ATTRACTIONS DIRECTORY**

6.2.1 Driver Initiates Services/Attractions Directory
6.2.2 Select Class of Services Desired
6.2.3 Select Parameters for Class of Services
6.2.4 Review Listing
6.2.5 Select Item From Listing
6.2.6 Initiate Route Guidance to Selected Item

---

**SERVICES/ATTRACTIONS DIRECTORY**

**Goals**

*(1) prepare system to provide services/attractions listing*
*(2) reduce search to specific type of services/attractions wanted*
*(3) limit search to specific area, distance, or other characteristic*
*(4) review possible selections*
*(5) determine specific location of desired services/attractions*
*(6) obtain directions to services/attractions*

| | | | | | |
|---|---|---|---|---|---|
| (1) Initiate Services/ Attractions Directory | (2) Select Class of Services Desired | (3) Select Parameters for Class of Services | (4) Review Listing | (5) Select Item From Listing | (6) Initiate Route Guidance |

**6.3 DESTINATION COORDINATION**

6.3.1 Select or Program Destination
6.3.2 Initiate Destination Coordination
6.3.3 Obtain Verification of Coordination
6.3.4 Update Coordination as Required
  6.3.4.1 System update of arrival time
  6.3.4.2 Driver updates changes in services required

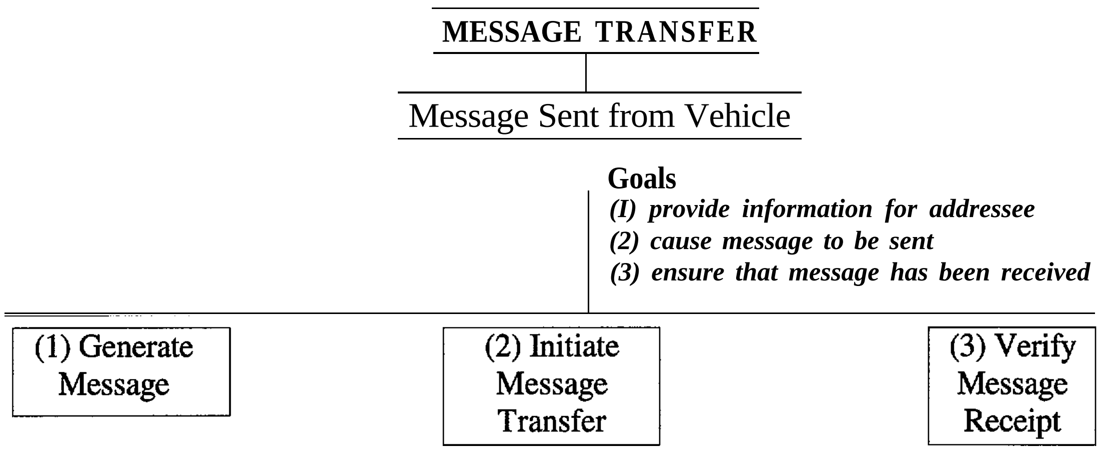
---

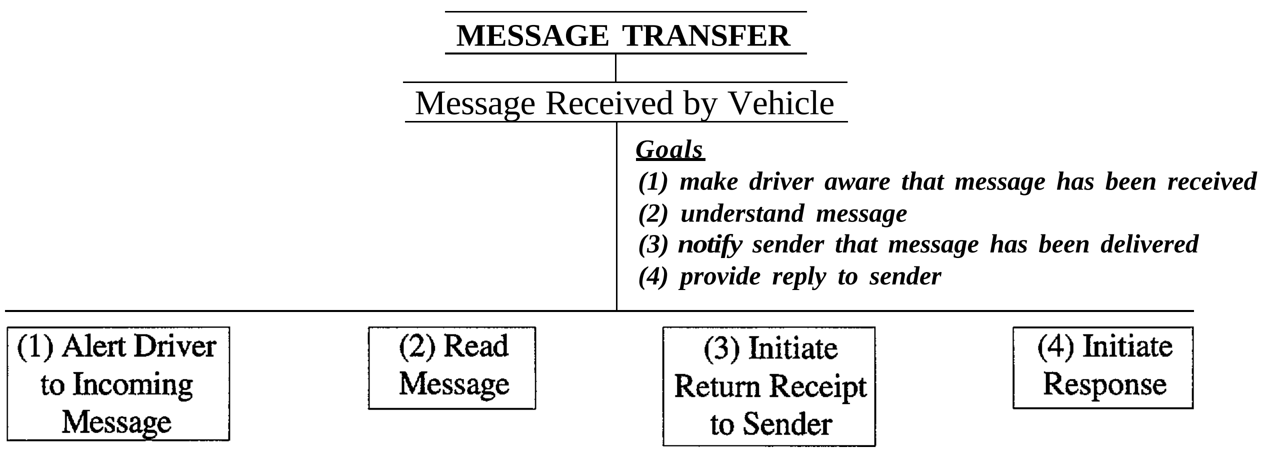
**DESTINATION COORDINATION**

*Goals*
*(I) determine where going*
*(2) have system coordinate modes of travel*
*(3) get coordination information*
*(4) change coordination as required*

| (1) Select or Program Destination | (2) Initiate Destination Coordination | (3) Obtain Verification of Coordination | (4) Update Coordination as Required |
|---|---|---|---|

6.4 **MESSAGE TRANSFER**
- 6.4.1 Message Sent From Vehicle
  - 6.4.1.1 Driver generates message
    - 6.4.1.1.1 Preset message using menu or programmed keys
    - 6.4.1.1.2 Text message generated by keyboard or other device
  - 6.4.1.2 Driver initiates message transfer
  - 6.4.1.3 System indicates message delivery and receipt
- 6.4.2 Message Received by Vehicle
  - 6.4.2.1 System alerts driver to receipt of message
  - 6.4.2.2 Driver reads message
  - 6.4.2.3 System notifies sender that message has been received
  - 6.4.2.4 Driver initiates response if necessary



# Hierarchical Task Description of Commercial Vehicles

7.1 **ROADWAY GUIDANCE SIGN INFORMATION**
- 7.1.1 System Monitors ISIS Input
- 7.1.2 Select Roadway Guidance Sign Information
- 7.1.3 System Presents Selected Sign Information
- 7.1.4 Driver Acts on Sign Information as Desired

---

**ROADWAY GUIDANCE SIGN INFORMATION**

*Goals*
*(1) monitor roadway guidance sign signals or location*
*(2) match signals with desired parameters*
*(3) present information to driver*
*(4) use information*

| (1) Monitor ISIS Input | (2) Select Roadway Guidance Sign Information | (3) Present Selected Sign Information | (4) Act on Sign Information |
|---|---|---|---|

**7.2 ROADWAY NOTIFICATION SIGN INFORMATION**

7.2.1 System Monitors ISIS Input
7.2.2 Select Roadway Notification Sign Information
7.2.3 System Presents Selected Sign Information
7.2.4 Driver Acts on Sign Information as Desired

**ROADWAY NOTIFICATION SIGN INFORMATION**

***Goals***
***(1) monitor roadway notification sign signals or location***
***(2) match signals with desired parameters***
***(3) present information to driver***
***(4) use information***

(1) Monitor ISIS Input

(2) Select Roadway Notification Sign Information

(3) Present Selected Sign Information

(4) Act on Sign Information

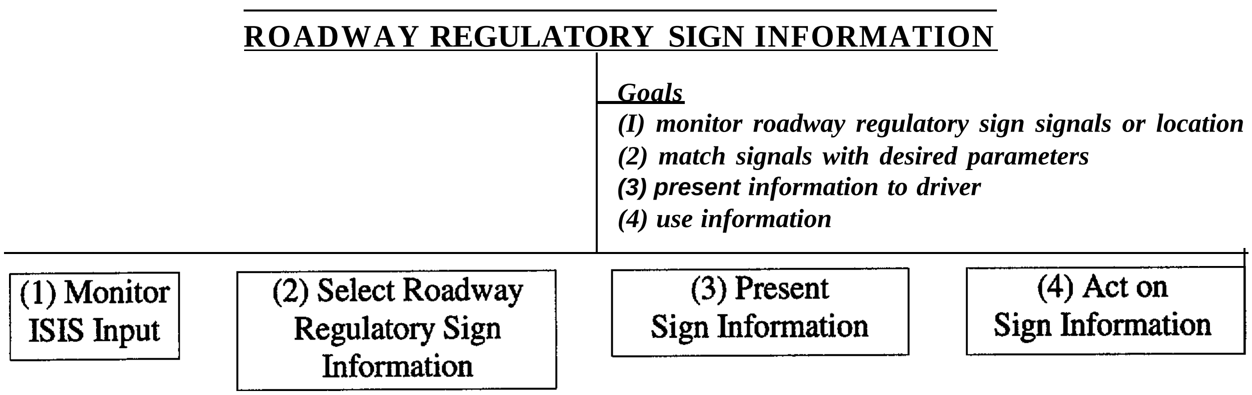
7.3 **ROADWAY REGULATORY SIGN INFORMATION**

7.3.1 System Monitors Input

7.3.2 Select Roadway Regulatory Sign Information

7.3.3 System Presents Selected Sign Information

7.3.4 Driver Acts on Sign Information as Desired



**7.4 ROAD RESTRICTION INFORMATION**

7.4.1 System Monitors CVO Regulatory Information
7.4.2 System Selects CVO Regulatory Information
7.4.3 System Presents CVO Regulatory Information
7.4.4 Driver Acts on CVO Regulatory Information as Desired

**BROADWAY REDUCTION INFORMATION**

***Goals***

***(I) monitor CVO regulatory information or location***
***(2) match signals with desired parameters***
***(3) present information to driver***
***(4) use information***

| (1) Monitor ISIS Inputs | (2) Select CVO Regulatory Information | (3) Present CVO Regulatory Information | (4) Act on CVO Regulatory Information |
|---|---|---|---|

## Hierarchical Task Description of Commercial Vehicles

8.1 IMMEDIATE HAZARD WARNING
- 8.1.1 System Detects Hazard Notification
- 8.1.2 System Alerts Driver of Hazard
- 8.1.3 System Provides Information on Hazard Type
- 8.1.4 Driver Takes Appropriate Action in Response to Hazard

---

IMMEDIATE HAZARD WARNING

*Goals*
***(1) receive hazard condition notification signal or location***
***(2) provide warning of hazardous condition to driver***
***(3) provide information on hazardous condition to driver***
***(4) mitigate the hazard***

| | | | |
|---|---|---|---|
| (1) Detect Hazard Notification Signal | (2) Alert Driver of Hazard | (3) Provide Information on Hazard | (4) Take Appropriate Action |

## 8.2 ROAD CONDITION INFORMATION

8.2.1 System Detects Road Condition Notification
8.2.2 System Alerts Driver of Road Condition Notification
8.2.3 System Provides Information on Road Condition
8.2.4 Driver Takes Appropriate Action in Response to Road Condition

---

**ROAD CONDITION INFORMATION**

***Goals***

***(1) receive road condition notification signal or location***
***(2) provide warning of road condition to driver***
***(3) provide information on road condition to driver***
***(4) mitigate the effects of road condition***

| (1) Detect Road Condition Notification Signal | (2) Alert Driver of Road Condition Information | (3) Provide Information on Road Condition | (4) Take Appropriate Action |
|---|---|---|---|

**8.3 AUTOMATIC AID REQUEST**

8.3.1 System Detects Emergency Condition

8.3.2 System Broadcasts Emergency Request

---

**AUTOMATIC AID REQUEST**

***Goals***

***(I) detect when crash or other emergency has occurred***

***(2) summon help***

(1) Detect Emergency Condition

(2) Broadcast Emergency Request

# Hierarchical Task Description of Commercial Vehicles

**8.4 MANUAL AID REQUEST**

8.4.1 Driver Activates Manual Aid Request

8.4.1.1 Aid required

8.4.1.2 Urgency

8.4.2 System Sends Request As Well As Vehicle Location

8.4.3 System Acknowledges Request Received

8.4.4 System Gets Update of Arrival Time for Aid

8.4.5 Notifies Driver of Arrival Time for Aid

---

**MANUAL AID REQUEST**

*__Goals__*

***(I) activate system to request aid***

***(2) provide vehicle location***

***(3) provide feedback to driver that message has been received***

***(4) obtain information on arrival time for aid***

***(5) provide driver with information on arrival time***

(1) Initiate Manual Aid Request

(2) Send Request and Vehicle Location

(3) Acknowledge Request Received

(4) Receive Update of Arrival Time for Aid

(5) Notifies Driver of Arrival Time for Aid

**8.5 VEHICLE CONDITION MONITORING**

8.5.1 System Monitors Vehicle Parameters
8.5.2 System Detects Abnormal Condition
*8.5.3* System Alerts Driver
8.5.4 System Provides Description of Problem
8.5.5 Driver Takes Appropriate Action

---

**VEHICLE CONDITION MONITORING**

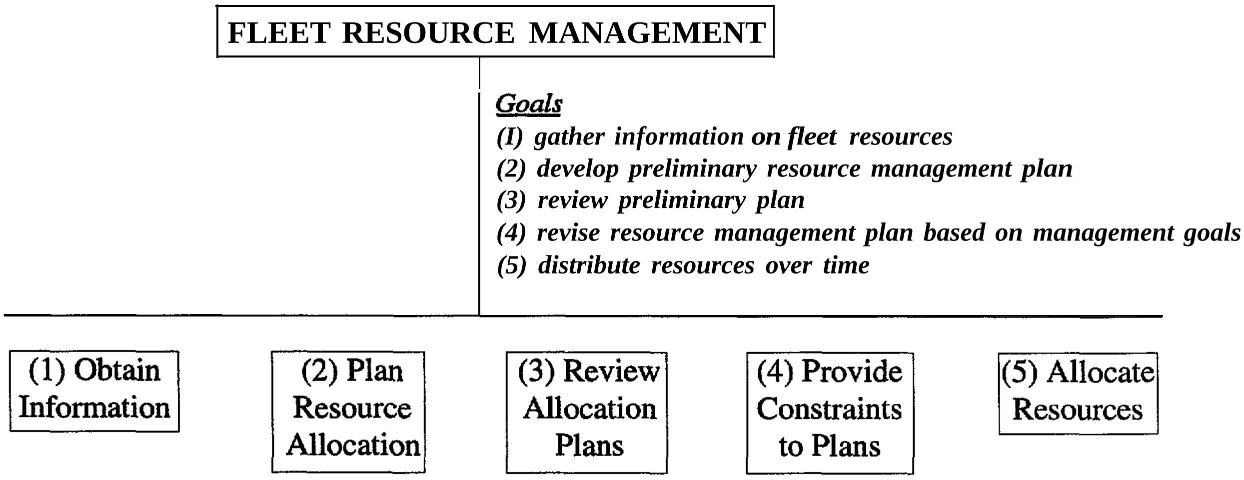
***Goals***
***(1) early detection of mechanical and electrical problems***
***(2) initiate alert sequence when condition exceeds threshold***
***(3) provide driver with warning of problem***
***(4) provide driver with information on the problem***
***(5) mitigate** the **possible consequences of the problem***

| (1) Monitor Vehicle Parameters | (2) Detect Abnormal Condition | (3) Alert Driver | (4) Provide Description of Problem | (5) Take Appropriate Action |
|---|---|---|---|---|

# Hierarchical Task Description of Commercial Vehicles

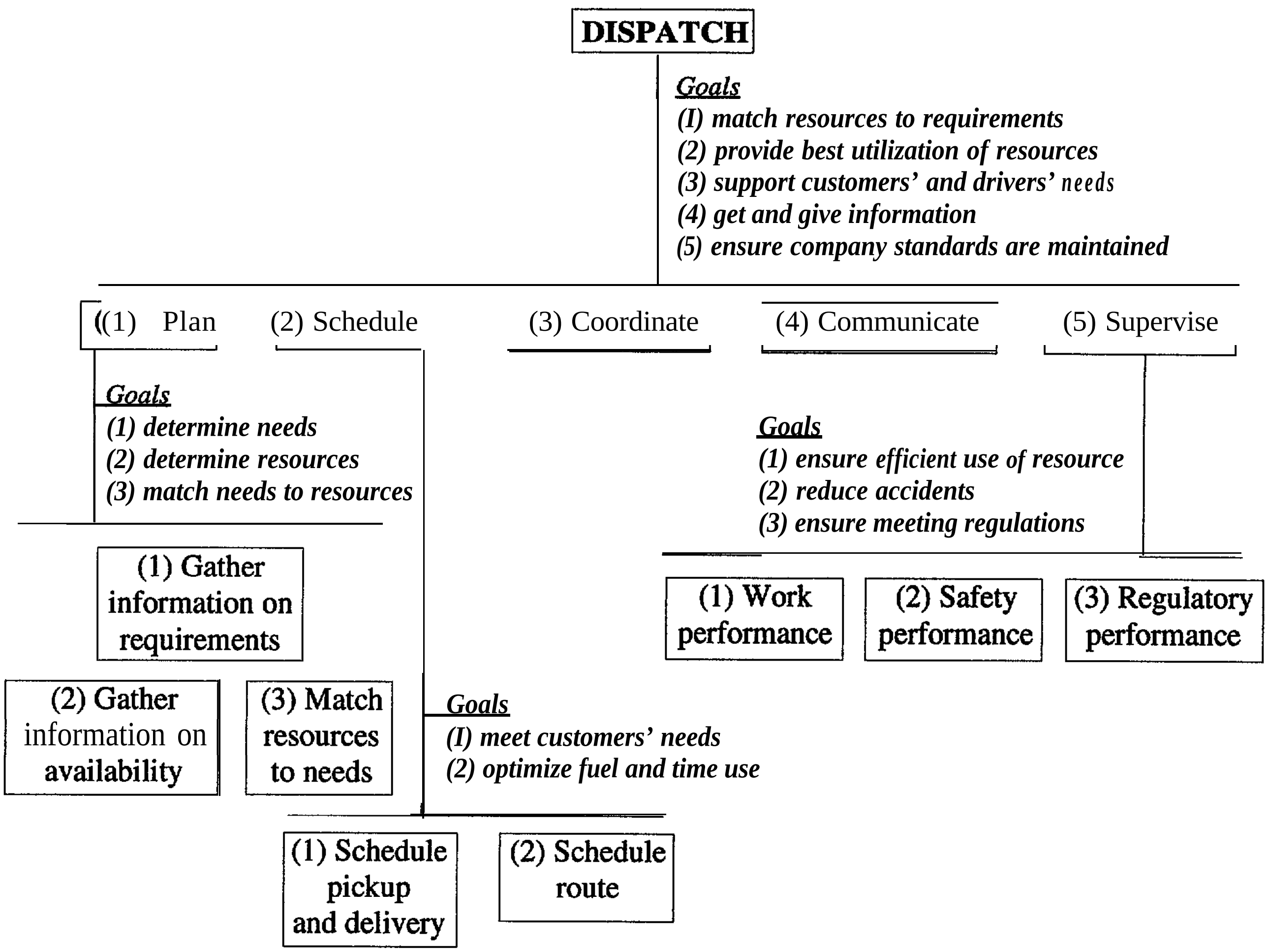
## 9.1 FLEET RESOURCE MANAGEMENT

9.1.1 System Polls Information On the Fleet
9.1.2 System Plans Resource Allocation
9.1.3 Manager Reviews Resource Allocation Plans
9.1.4 Manager Provides Constraints to Allocation
9.1.5 Allocation Plan Developed



## 9.2 DISPATCH

- 9.2.1 Planning
  - 9.2.1.1 Gather information on resource requirements
  - 9.2.1.2 Gather information on resource availability
  - 9.2.1.3 Match resources to needs
- 9.2.2 Scheduling
  - 9.2.2.1 Schedule shipment pickup and delivery
  - 9.2.2.2 Schedule route
- 9.2.3 Coordinating
  - 9.2.3.1 Coordinate drivers' activities
  - 9.2.3.2 Coordinate shipments with customers
- 9.2.4 Communicating
  - 9.2.4.1 Communicating with drivers on the road
  - 9.2.4.2 Communicating with customers
- 9.2.5 Supervising
  - 9.2.5.1 Driver work performance
  - 9.2.5.2 Driver safety performance
  - 9.2.5.3 Driver regulatory performance



**9.3 REGULATORY ENFORCEMENT**

9.3.1 Enforcement of Permit Requirements
9.3.2 Enforcement of Weight Limitations
9.3.3 Enforcement of Vehicle Condition Requirements
9.3.4 Enforcement of Hours of Service Regulations

---

**REGULATORY ENFORCEMENT**

***Goals***

***(I) ensure that State taxes are paid and restrictions are followed***
***(2) reduce wear on roads and provide basis for taxes***
***(3) ensure vehicle safety***
***(4) reduce driver fatigue problems***

| | | | |
|---|---|---|---|
| (1) Enforce Permit Requirements | (2) Enforce Weight Limitations | (3) Enforce Vehicle Condition Requirements | (4) Enforce Hours of Service Regulations |

# APPENDIX D. DETAILED TASK ANALYSIS

This section gathers all the private vehicle scenarios and the commercial vehicle scenarios that were chosen as illustrators of particular characteristics for the task analysis. The purpose of this section is to illustrate the task breakdown for each individual scenario, so that it is easier to integrate the nature of the interactions between the ATE-related tasks and the driving-related tasks.

To facilitate the reader's understanding, this section has been divided into two major portions: (1) all the private vehicle scenarios, and (2) all the commercial vehicle scenarios. For each scenario, the following information is provided: (1) a summary of the scenario's purpose and a brief description of the systems and functions used, (2) a graphical representation of the function interactions, (3) an Operational Sequence Diagram (OSD) of the scenario, and (4) a task breakdown summarizing the driver's activities believed to occur during the scenario.

Assumption. In some of these scenarios, it is assumed that some of the pre-drive activities have already been completed due to the nature of the scenario's environmental conditions. However, the elements pertaining to ATIS may be included if they will be used as part of the scenario's conditions. In addition, in some cases, the scenarios do not describe the driving to destination and, as a consequence, the driving activities have not been included.

**Scenario P6**

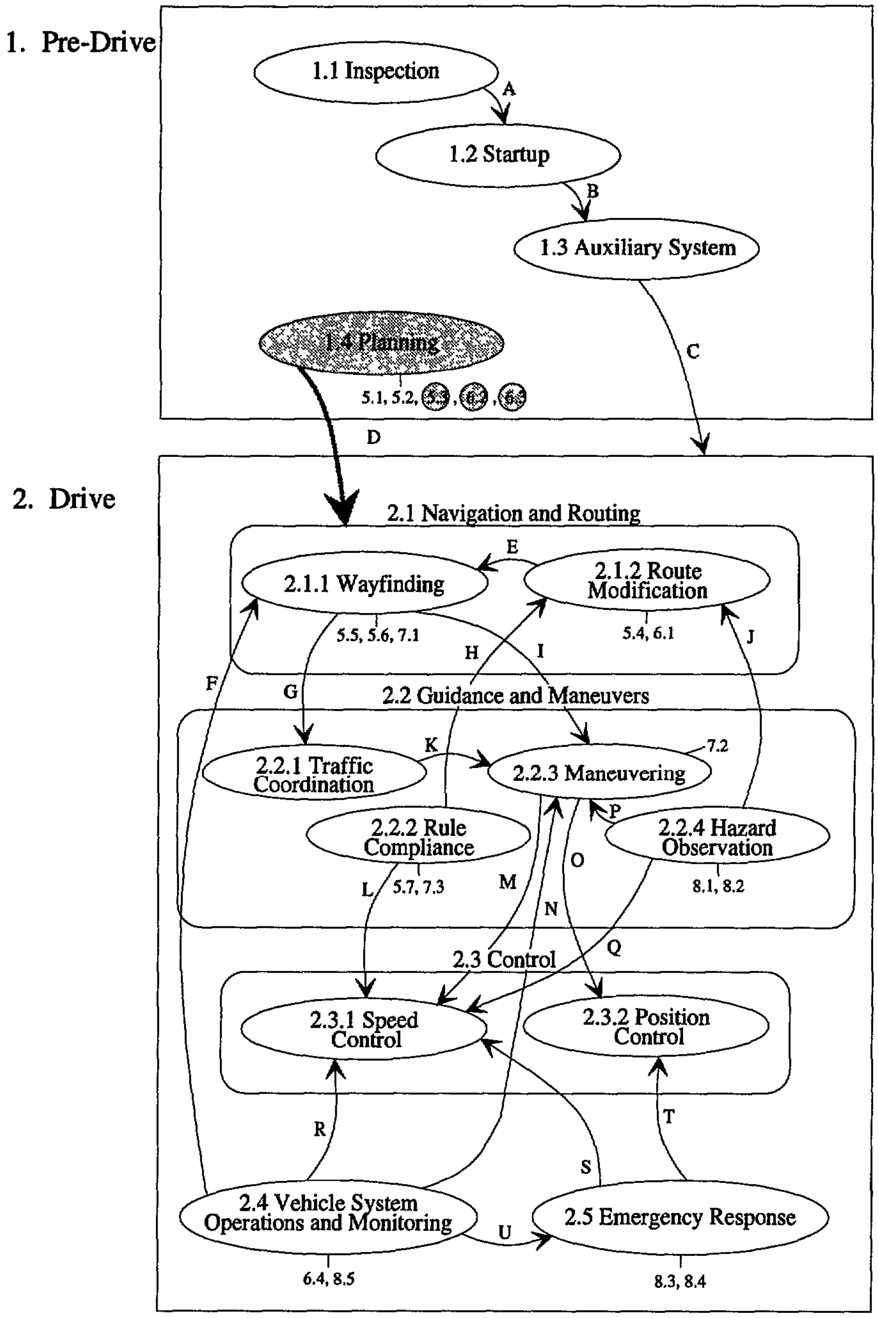
<u>Purpose</u> To show the centrality of pre-drive route and destination selection.

**<u>Summary</u>** A driver is on an extended driving vacation. He has stopped approximately 50 mi (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.

<u>Function Interaction Diagram</u> See figure 29.

<u>Operational Sequence Diagram</u> See figure 30.

<u>Task Characterization</u> See table 55.




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

**Figure 29. Function interaction diagram for Scenario P6.**

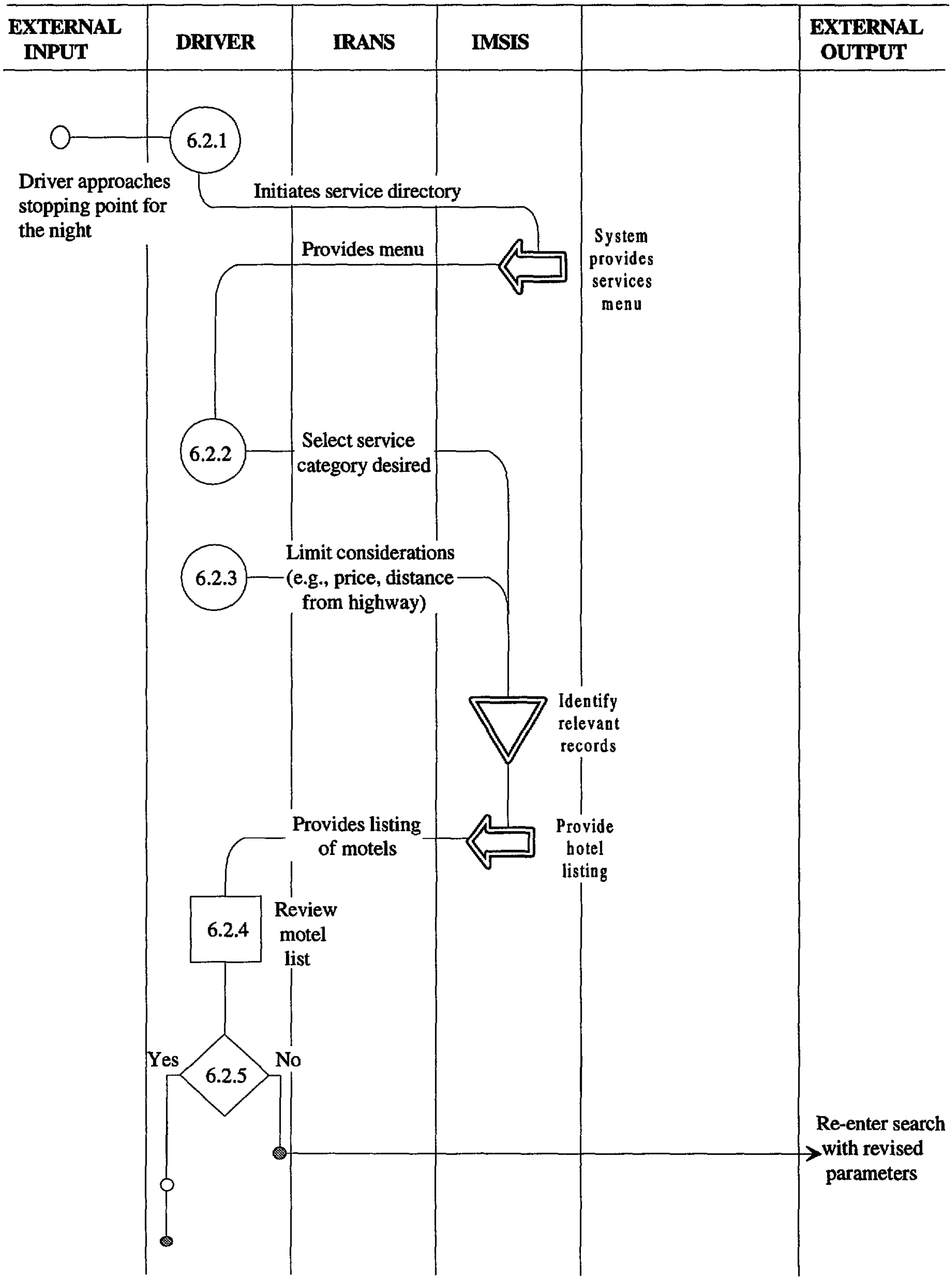



**Figure 30. Operational sequence diagram for Scenario P6.**

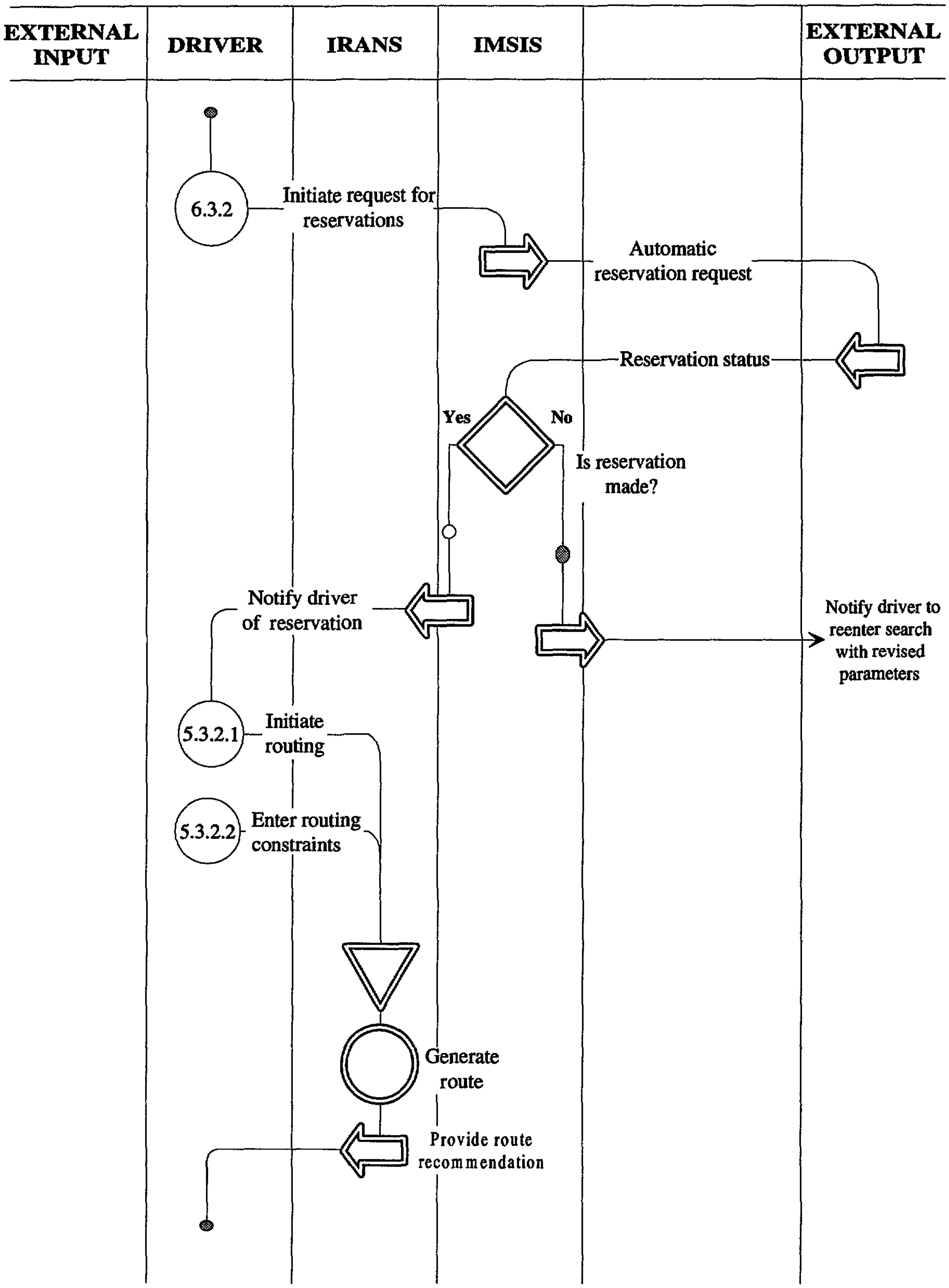



**Figure 30. Operational sequence diagram for Scenario P6 (continued).**

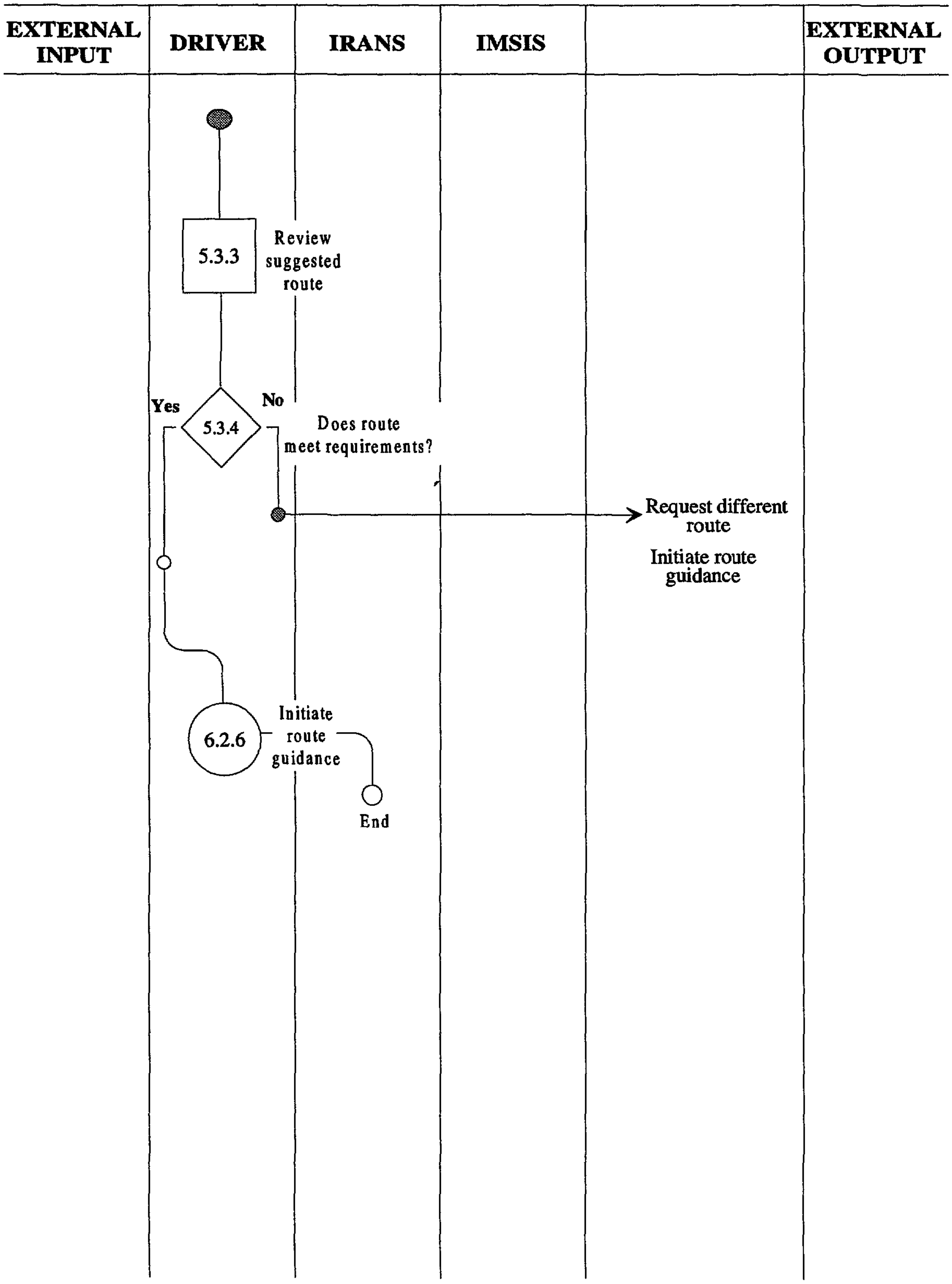



**Figure 30. Operational sequence diagram for Scenario P6 (continued).**

## Table 55. Task characterization of Scenario P6.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 6.2.1 | DRIVER INITIATES SERVICES/ ATTRACTIONS DIRECTORY | Make a system ready to use | Goal initiation | CONTROL | Requirements don't exceed driver's response capabilities. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 6.2.2 | SELECT CLASS OF SERVICES DESIRED | Limit system considerations | System demand | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 6.2.3 | SELECT PARAMETERS FOR CLASS OF SERVICES | Limit system considerations | System demand | CODE | Motor actions within human capabilities. Input requirements compatible with knowledge. Input requirements direct. | E.g., cost of room, location, amenities. Special services required. |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 6.2.4 | REVIEW LISTING | Obtain system information | Completion of previous step | SEARCH | Information presented must be consistent with user's knowledge base. | |

## Table 55. Task characterization of Scenario P6.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 6.2.5 | SELECT ITEM FROM LISTING | Approve system output and initiate next step | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| 6.3.2 | INITIATE DESTINATION COORDINATION | Invoke system operation | System demand | CONTROL | System provides indication that the system is responding to input. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 5.3.2.1 | DESTINATION | Provide system information | System demand | CODE | Input requirements directly. | Transfer action from IMSIS to IRANS. |
| 5.3.2.2 | ROUTE PARAMETERS | Limit system considerations | System demand | CODE | Input requirements compatible with knowledge. | May be automated function or limited by system design. |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 5.3.3 | REVIEW RECOMMENDED ROUTE | Environmental change | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |

**Table 55. Task characterization of Scenario P6.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.3.4 | DECIDE IF ROUTE IS ACCEPTABLE | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 6.2.6 | INITIATE ROUTE GUIDANCE TO SELECTED ITEM | Invoke system operation | Change of goals | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| END OF SCENARIO | | | | | | |

**Scenario P14**

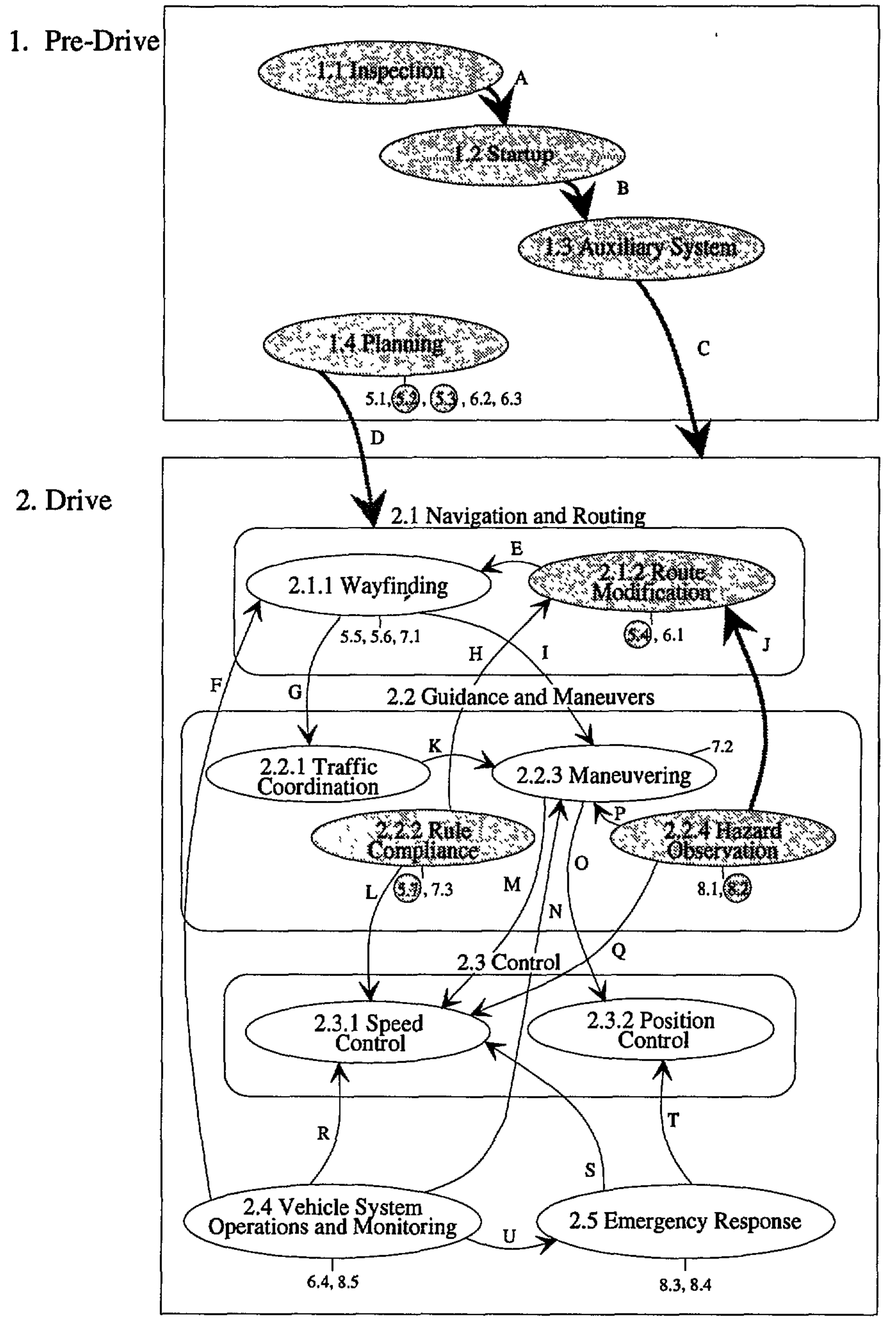
Purpose — To illustrate a grouping of functional characteristics from Cluster 1 (5.1, 5.2, 5.3, 5.4, 5.6, 7.1, and 8.2).

Summary — A driver commutes between her home and the office. The commute requires coordination between three different modes of transportation. She drives the first 10 mi (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 mi (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 mi (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 her 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.

Function Interaction Diagram — See figure 31.

Operational Sequence Diagram — See figure 32.

Task Characterization — See table 56.




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 traffic
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 31. Function interaction diagram for Scenario P14.**

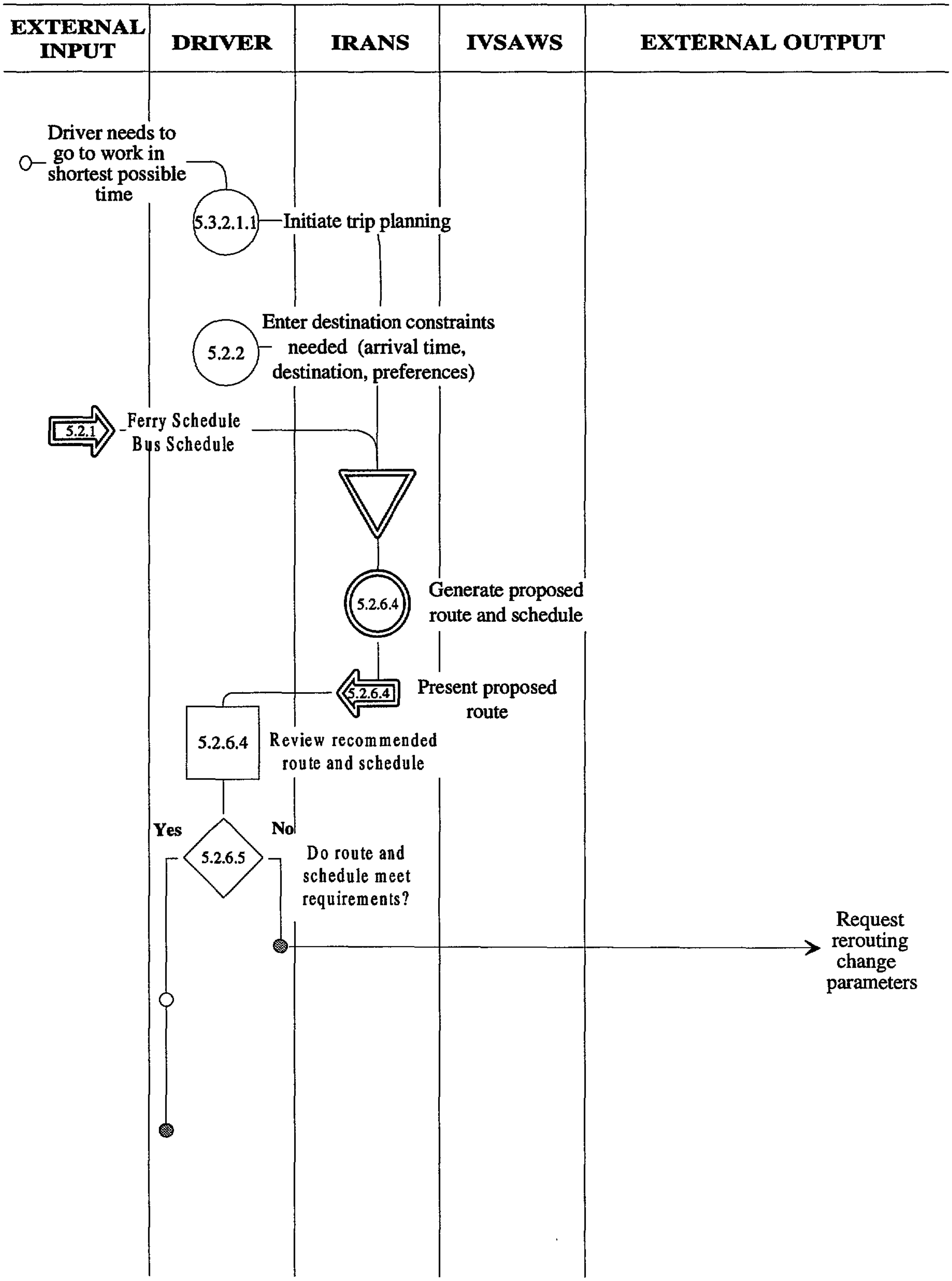



**Figure 32. Operational sequence diagram for Scenario P14.**

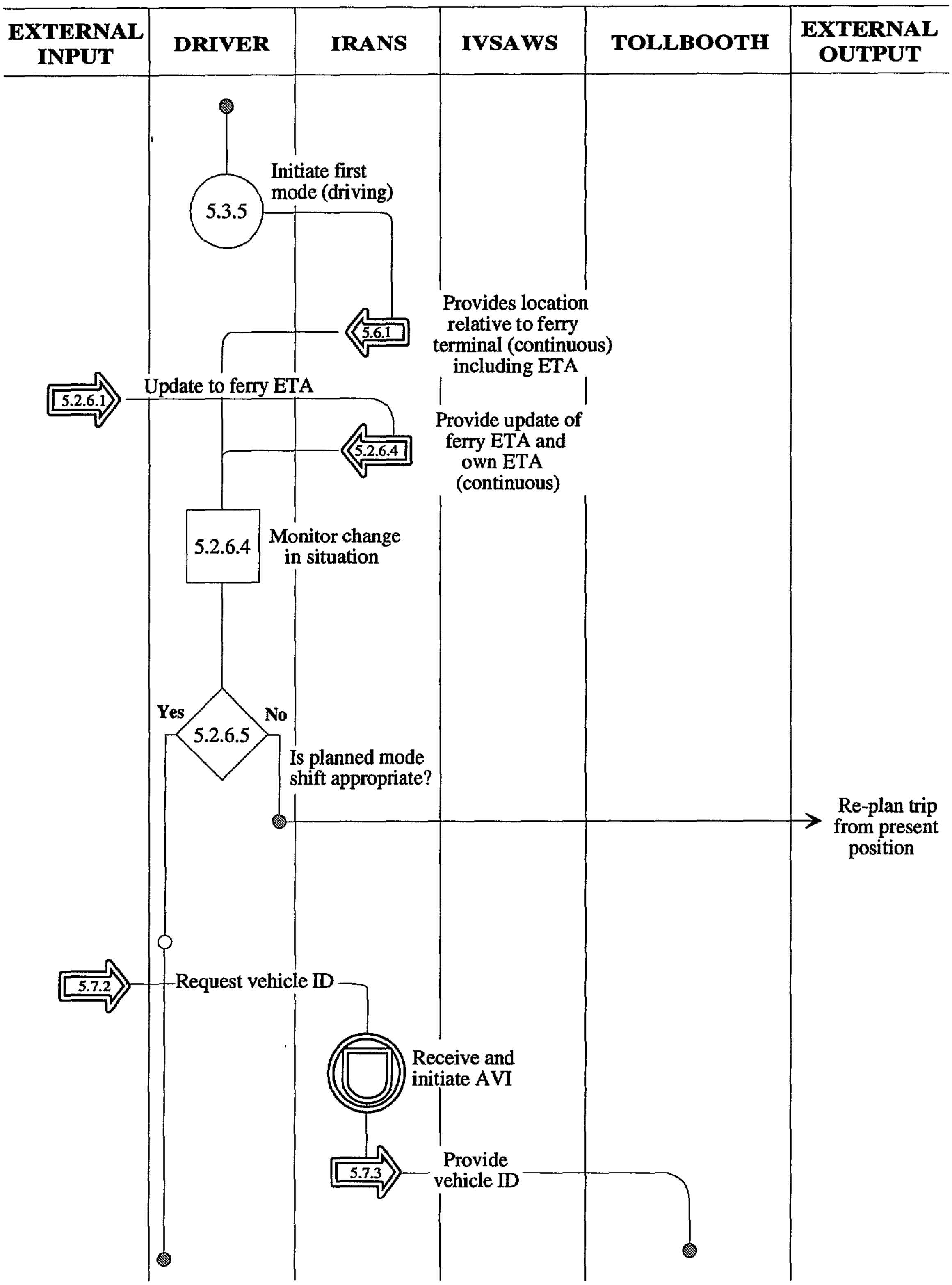



**Figure 32. Operational sequence diagram for Scenario P14 (continued).**

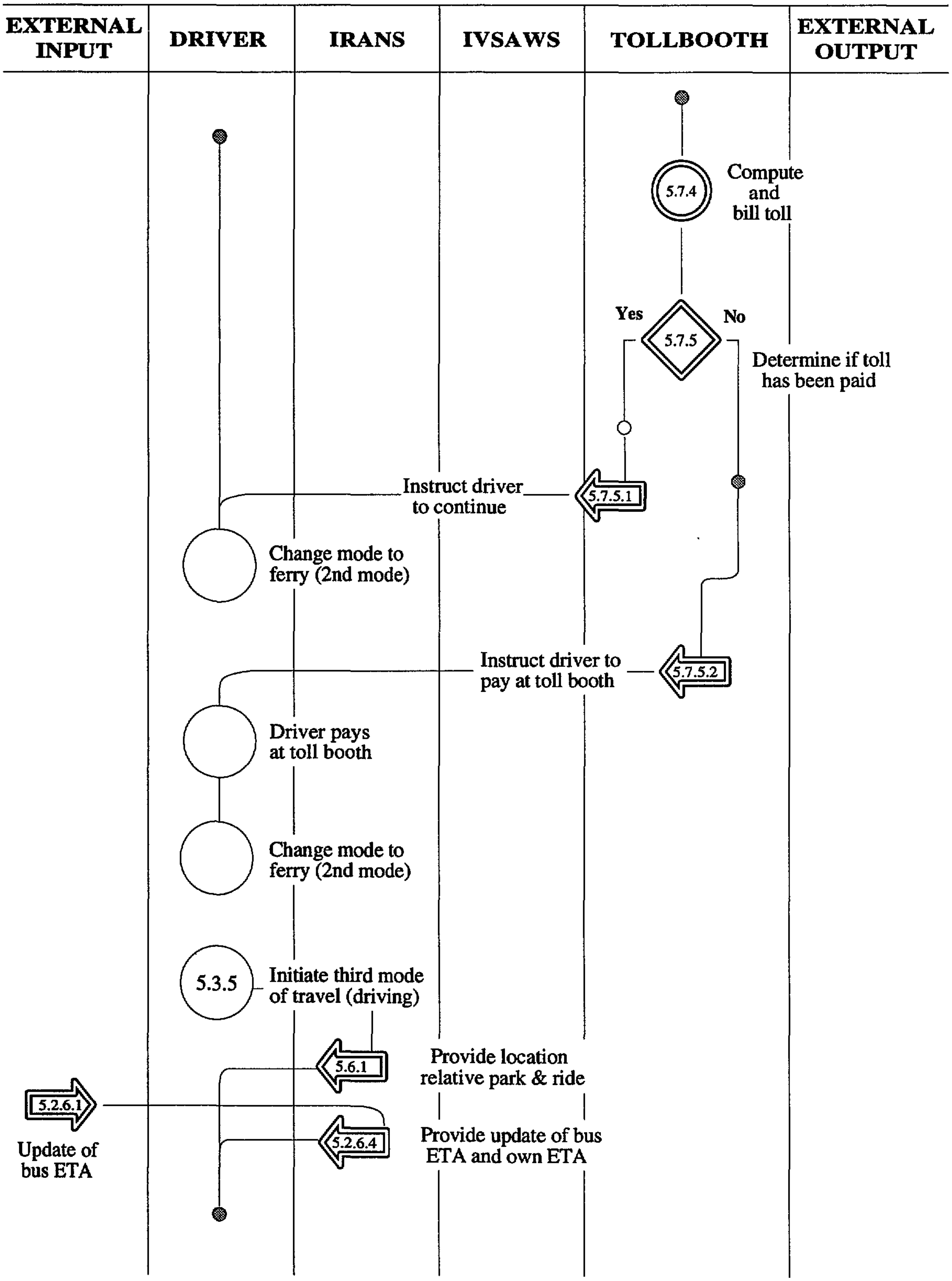



**Figure 32. Operational sequence diagram for Scenario P14 (continued).**

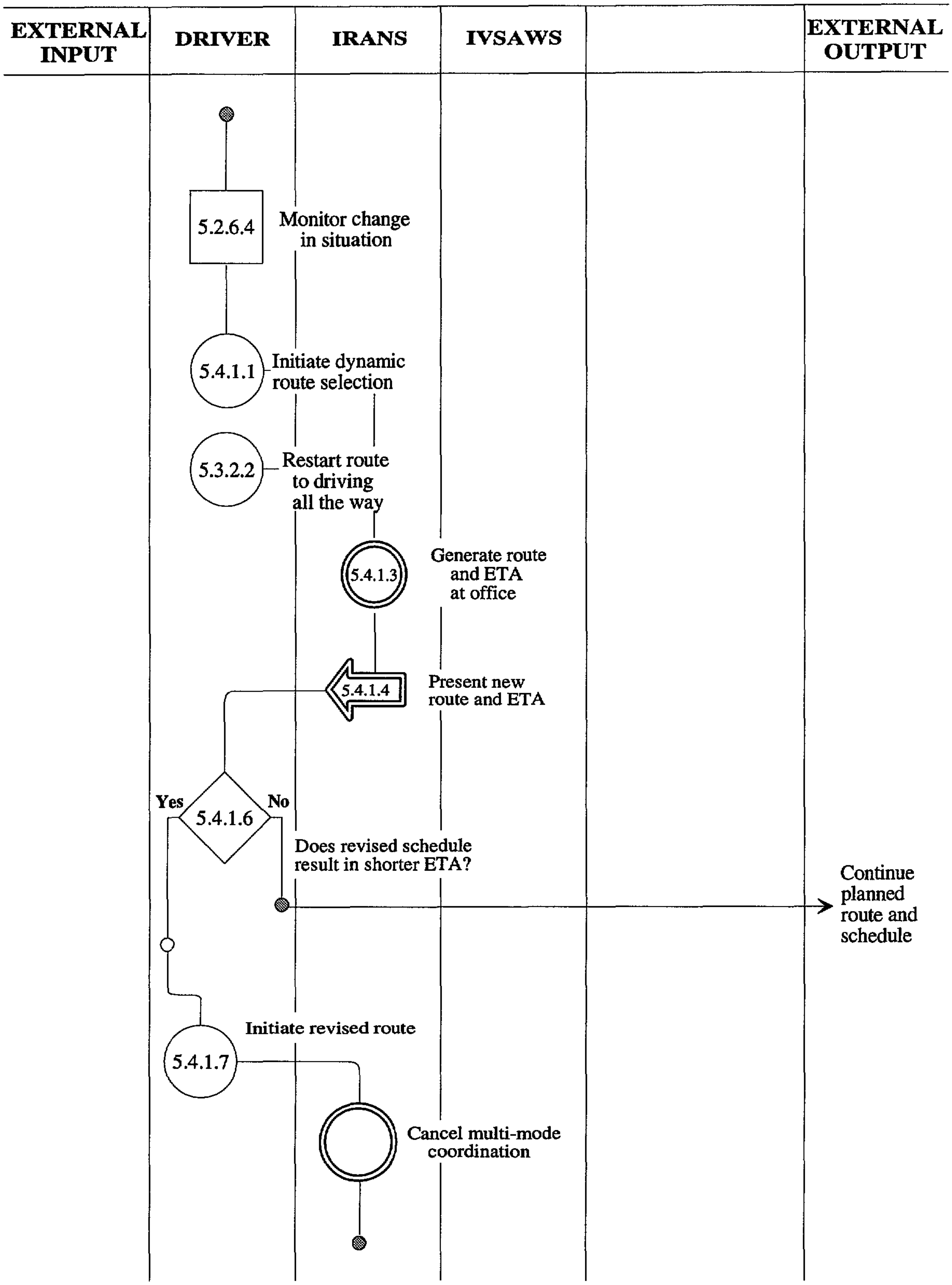



**Figure 32. Operational sequence diagram for Scenario P14 (continued).**

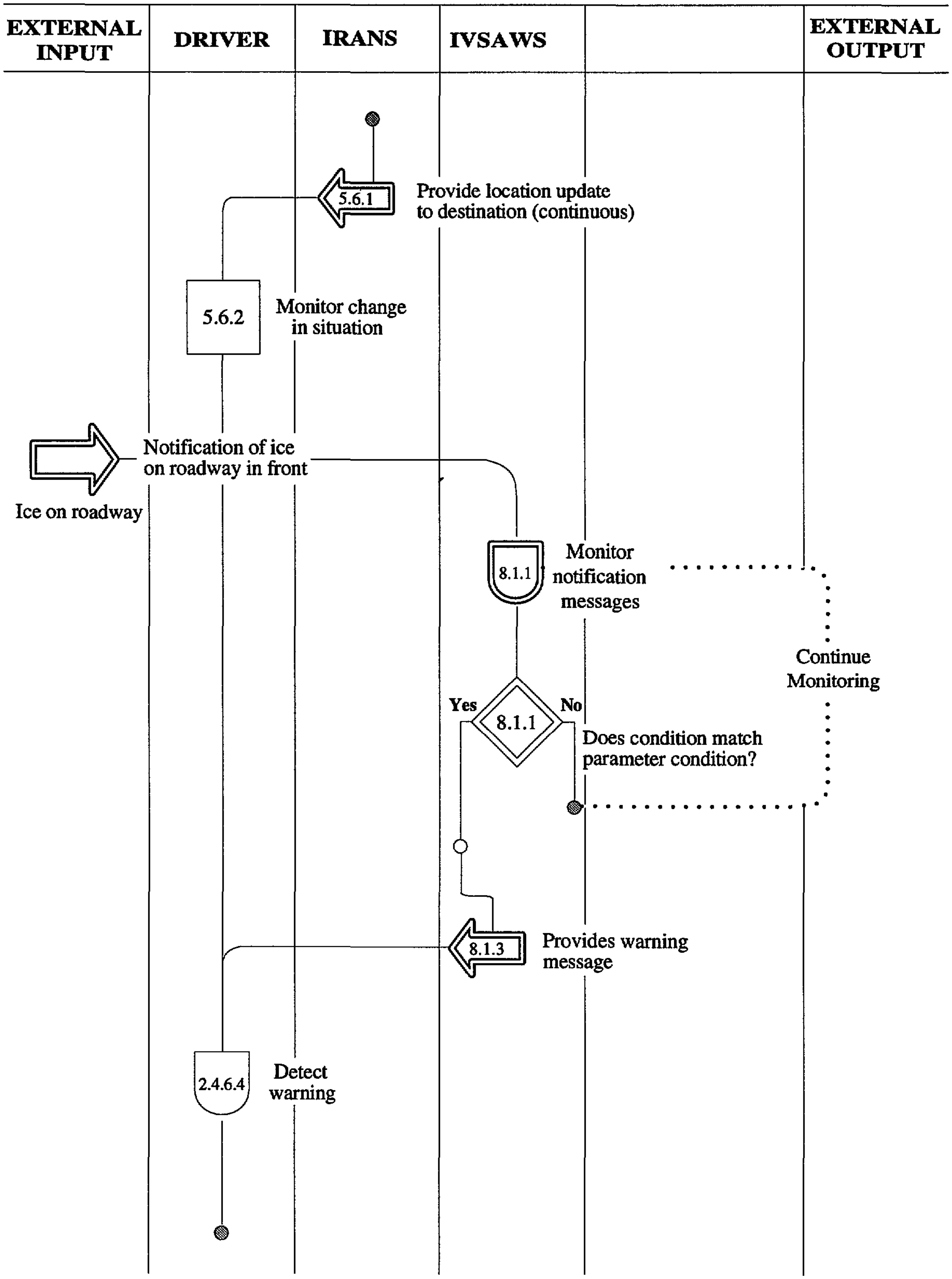



**Figure 32. Operational sequence diagram for Scenario P14 (continued).**

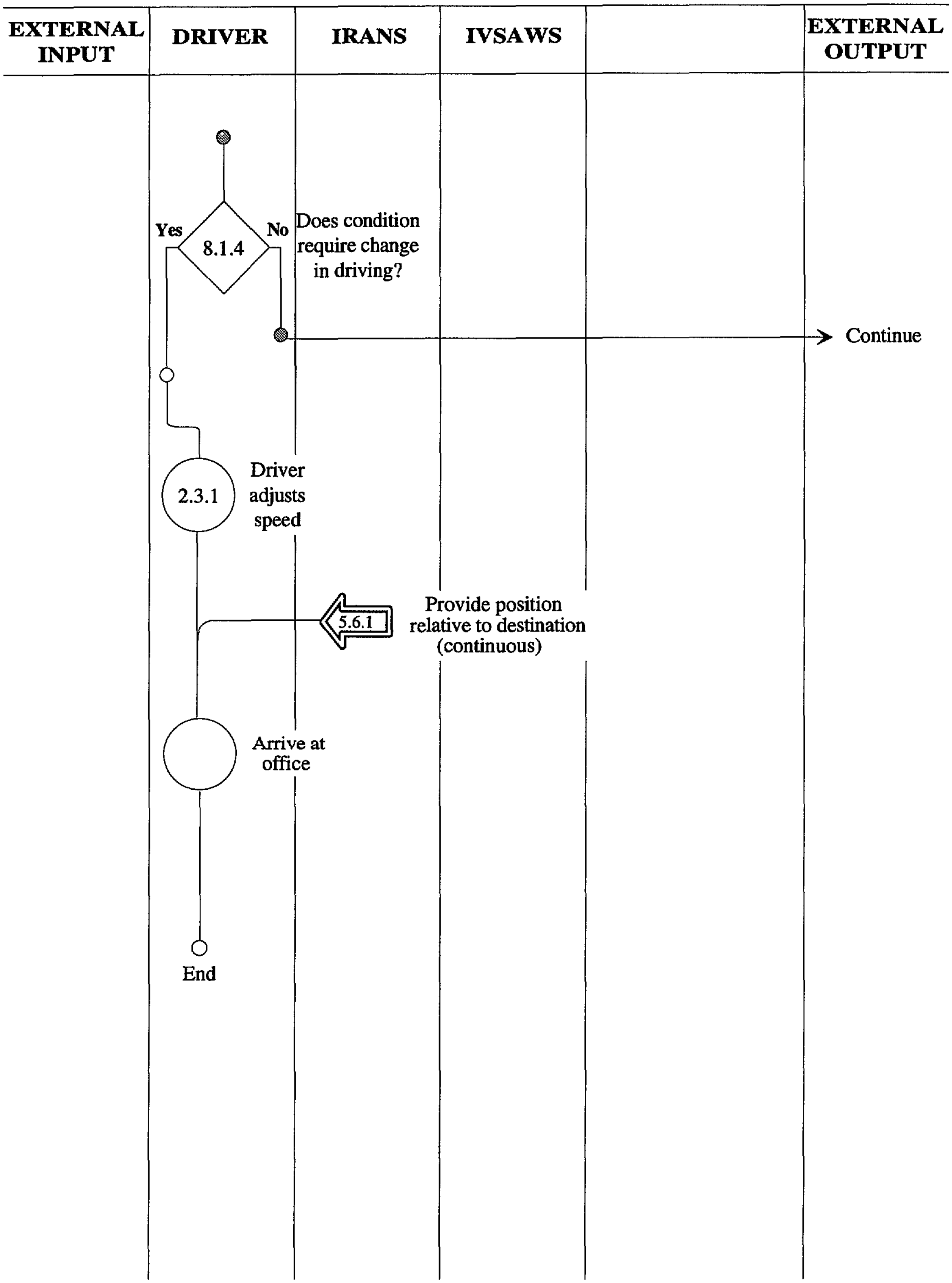



**Figure 32. Operational sequence diagram for Scenario P14 (continued).**

**Table 56. Task characterization of Scenario P14.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 5.3.2.1.1 | ENTER DESTINATION | Provide system information | System demand | CODE | Motor actions within human capabilities. Input requirements directly. | Commonly used destination might be in pre-developed route menu. |
| 5.2.2 | ENTER CONSTRAINTS | Provide system information | System demand | CODE | Motor actions within human capabilities. Input requirements directly. | May be preselected preference information. |
| 5.2.1 | ACQUIRE CONSTRAINTS | Obtain environment information | System demand | IDENTIFY | | May be done in combination with automated transfer of information (e.g., updated bus and train schedules). Automatic System Action. |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 5.2.6.4 | SYSTEM PROPOSES NEW MULTI-MODE SCHEDULE | Narrow user considerations | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. | |

**Table 56. Task characterization of Scenario P14.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.2.6.5 | DETERMINE IF NEW MULTI-MODE SCHEDULE WILL MEET REQUIREMENTS | Evaluate system recommendation | System demand | TEST | Recommendations in appropriate detail to identify compatibility with constraints. | |
| 5.3.5 | INITIATE SYSTEM APPROVAL | Approve system output and initiate next step | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. | Transfer task from IRANS planning to nulti-mode coordination. |
| 5.6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. This scenario assumes use of IRANS for navigation, but not guidance. |
| 5.2.6.1 | SYSTEM UPDATE OF ARRIVALTIMES | Provide system information | Environmental change | MONITOR | | (E.g., arrival time of current mode, arrival time of next mode.) Automatic system action. |
| 5.2.6.4 | SYSTEM PROPOSES NEW MULTI-MODE SCHEDULE | Narrow user considerations | Completion of previous step | CODE | | Automatic system function. |

**Table 56. Task characterization of Scenario P14.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.2.6.4 | SYSTEM PROPOSES NEW MULTI-MODE SCHEDULE | Narrow user considerations | Completion of previous step | CODE | | |
| 5.2.6.5 | DETERMINE IF NEW MULTI-MODE SCHEDULE WILL MEET REQUIREMENTS | Evaluate system recommendation | System demand | TEST | Recommendations in appropriate detail to identify compatibility with constraints. Level of detail does not increase workload. | |
| 5.7.2 | SYSTEM QUERIES VEHICLE FOR TOLL TAG OR AVI | Invoke system operation | Completion of previous step | SEARCH | | Automatic system action. |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 5.7.3 | SYSTEM IDENTIFIES VEHICLE | Involve system operation | Completion of previous step | CODE | | Automatic system action. |
| 5.7.4 | SYSTEM INITIATES AUTOMATIC BILLING OR DEDUCTS TOLL | Invoke system operation | Completion of previous step | CONTROL | | Automatic system action. |

## Table 56. Task characterization of Scenario P14.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.7.5 | SYSTEM DETERMINES IF TOLL PAYMENT. IS APPROPRIATE | Invoke system operation | Completion of previous step | DECIDE/SELECT | | Automatic system action. |
| .7.5.1 | IF YES, INDICATE TO DRIVER THAT HE/SHE IS FREE TO CONTINUE | Obtain system information | Completion of previous step | CODE | | Conditional outcome of 5.7.5. Automatic system action. |
| .7.5.2 | IF NO, INDICATE DRIVER MUST STOP AT TOLL BOOTH | Obtain system information | Completion of previous step | CODE | | Conditional outcome of 5.7.5. automatic systen action. |
| UNCODED DRIVER ACTIONS | | | | | | |
| .3.5 | INITIATE SYSTEM APPROVAL | Approve system output and initiate next step | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| .6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |

**Table 56. Task characterization of Scenario P14.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.2.6.1 | SYSTEM UPDATE OF ARRIVAL TIMES | Provide system information | Environmental change | MONITOR | | (E.g., arrival time of current mode, arrival time of next mode.) Automatic system action. |
| 5.2.6.4 | SYSTEM PROPOSES NEW MULTI-MODE SCHEDULE | Narrow user considerations | Completion of previous step | CODE | | Automatic system action. |
| 5.4.1.1 | DRIVER RECOGNIZES NEED FOR REVISED ROUTE | Modify system operation | Change of goals | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |
| 5.3.2.2 | ROUTE PARAMETERS | Limit system considerations | System demand | CODE | Input requirements directly. | May be automated function or limited by system design. |
| 5.4.1.3 | SYSTEM COMPUTES NEW ROUTE | Invoke system operation | Completion of previous step | COMPUTE | | Automatic system action. |
| 5.4.1.4 | SYSTEM PRESENTS REVISED ROUTE | Obtain system information | Completion of previous step | CODE | | Automatic system action. |

Table 56. Task characterization of Scenario P14.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.4.1.6 | DECIDES IF RECOMMENDED ROUTE IS SATISFACTORY | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. | |
| 5.4.1.7 | INITIATE SYSTEM APPROVAL | Invoke system operation | Goal initiation | CONTROL | System provides indication of responding to system input. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 5.6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 5.6.2 | DRIVER OBSERVES NAVIGATION INFORMATION | Understand system/ environmental information | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 8.1.1 | SYSTEM DETECTS HAZARD NOTIFICATION | Automatic system operation | System demand | DETECT | | Automatic system action. |

## Table 56. Task characterization of Scenario P14.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 8.1.3 | SYSTEM PROVIDES INFORMATION ON HAZARD TYPE | Automatic system operation | System demand | CODE | | Automatic system action. |
| 2.4.6.4 | USE IVSAWS | Invoke system operation | Goal initiation | IDENTIFY | Information presented must be consistent with user's knowledge base. | |
| 8.1.4 | DRIVER TAKES APPROPRIATE ACTION IN RESPONSE TO HAZARD | Understand system/ environmental information | Change of goals | DECIDE/SELECT | Recommendations consistent with driver's experience. | |
| 2.3.1 | SPEED CONTROL | Invoke system operation | Goal initiation | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 5.6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action on demand or continuous. |
| END OF SCENARIO | | | | | | |

**Scenario P22**

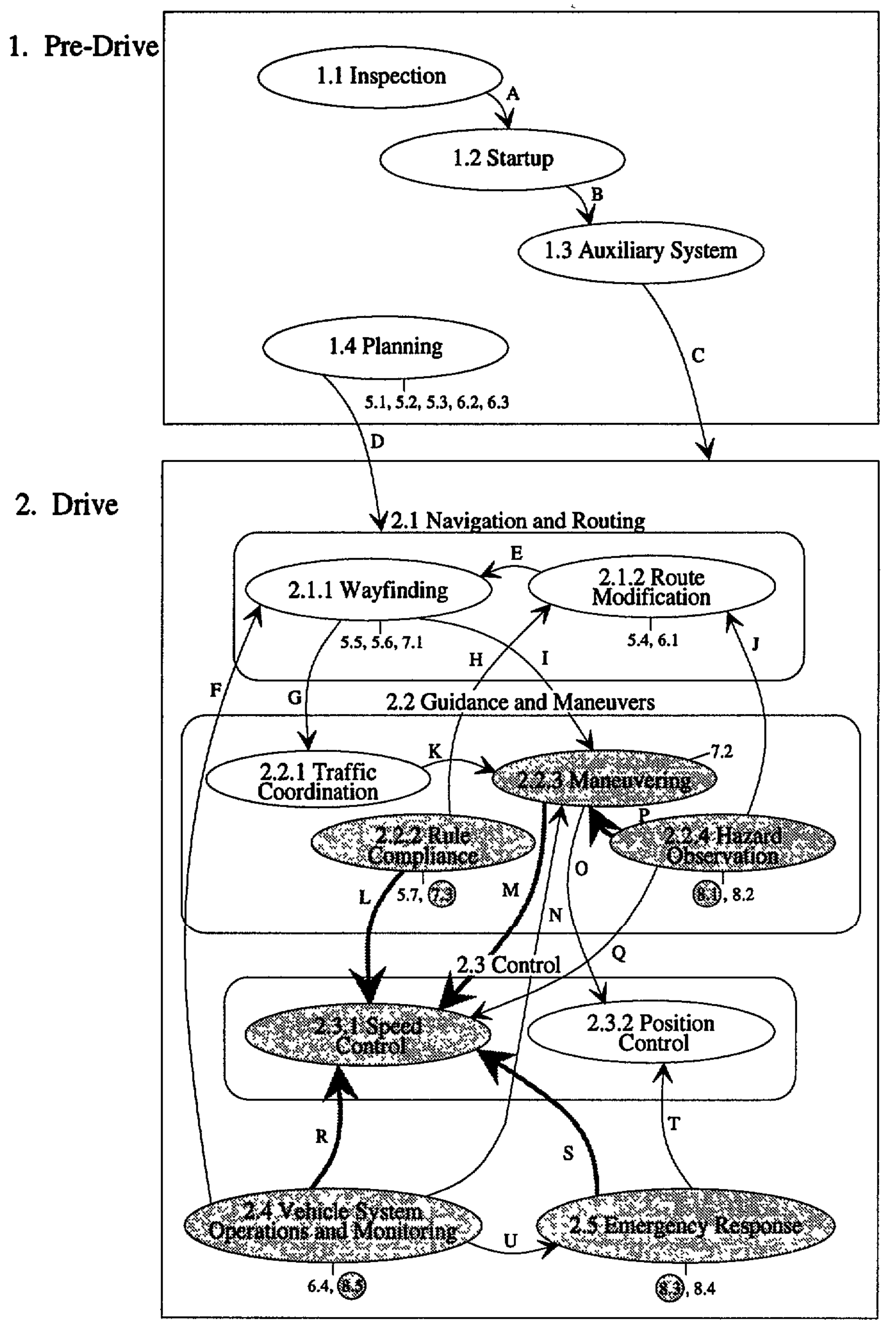
Purpose: To illustrate a grouping of the functional characteristics found in Cluster 2 (6.2, 8.1, 8.3, 8.4, and 8.5).

Summary: 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.

Function Interaction Diagram: See figure 33.

Operational Sequence Diagram: See figure 34.

Task Characterization: See table 57.




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

**Figure 33. Function interaction diagram for Scenario P22.**

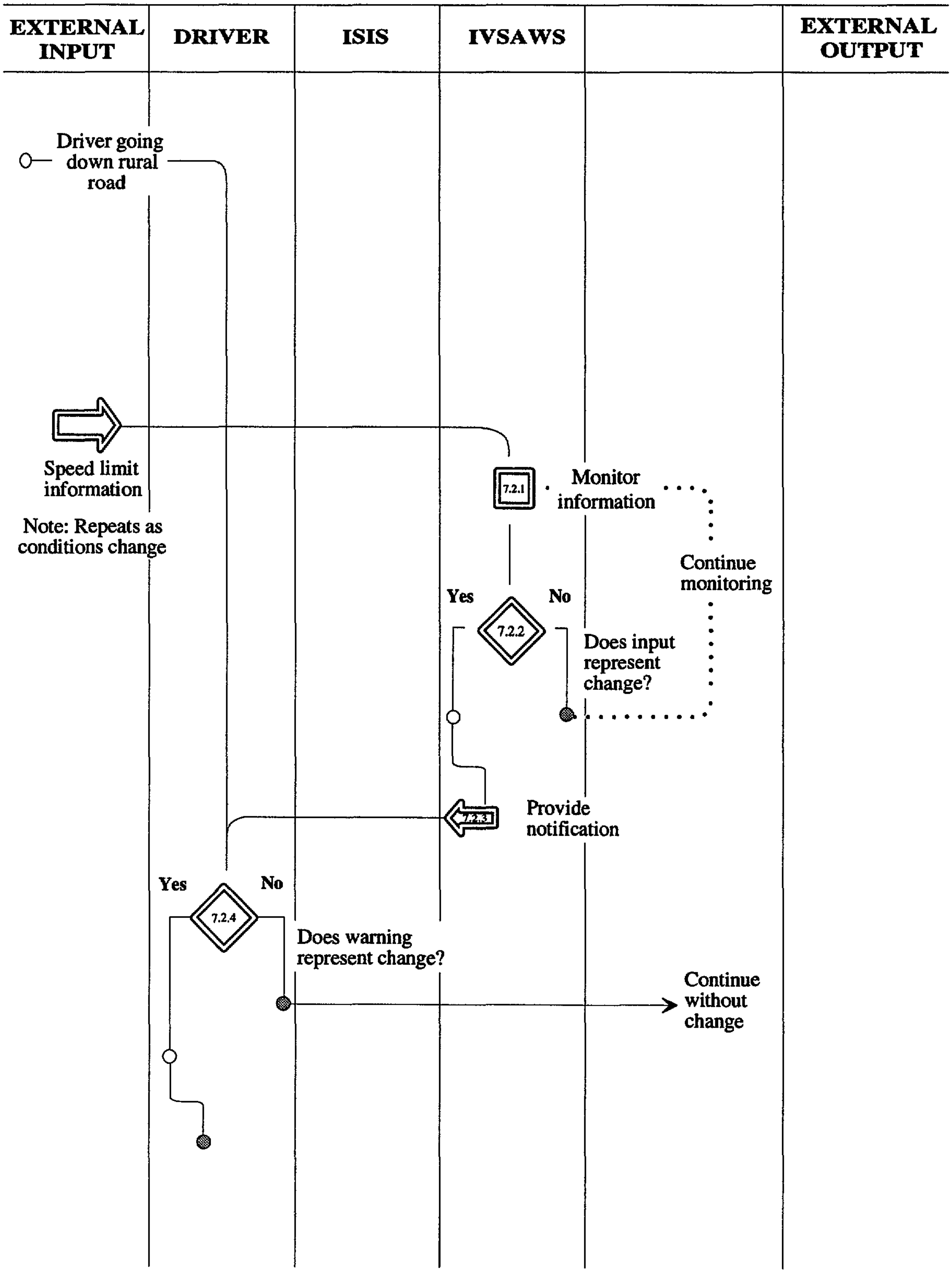



Figure 34. Operational sequence diagram for Scenario P22.

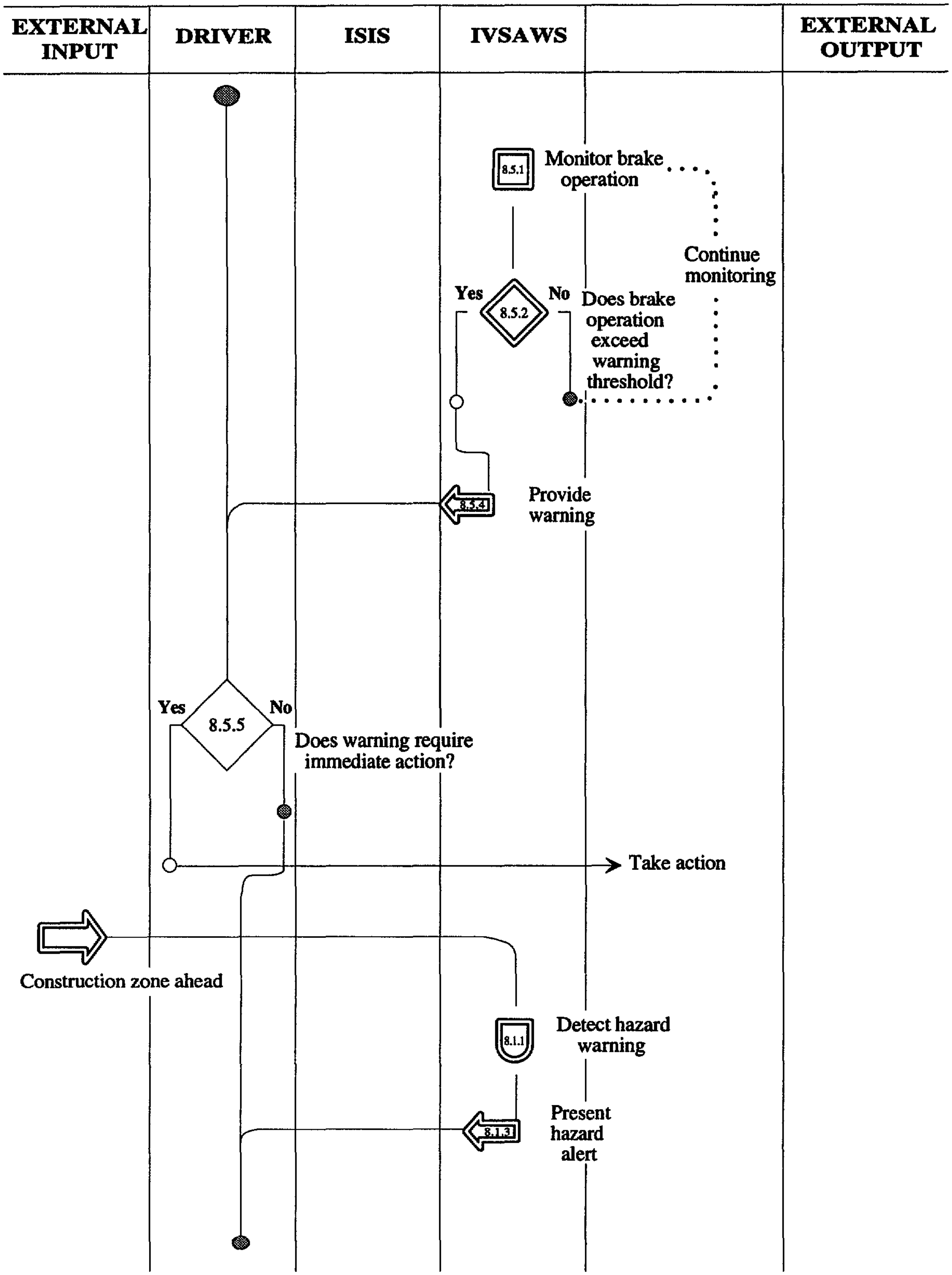



**Figure 34. Operational sequence diagram for Scenario P22 (continued).**

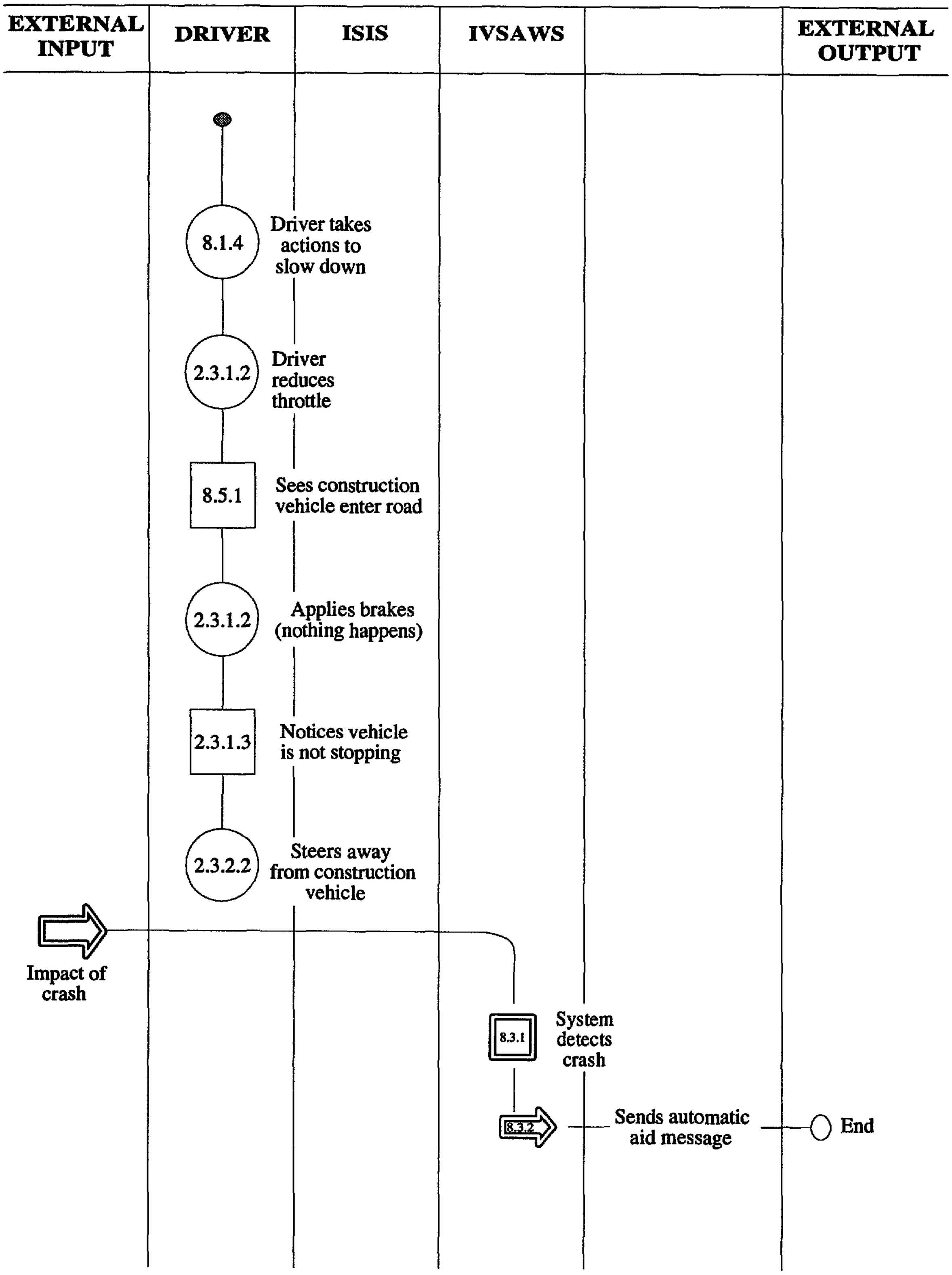



**Figure 34. Operational sequence diagram for Scenario P22 (continued).**

Table 57. Task characterization of Scenario P22.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 7.2.1 | SYSTEM MONITORS ISIS INPUT | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 7.2.2 | SELECTS ROADWAY SIGN NOTIFICATION INFORMATION | Automatic system operation | System demand | TEST | | System matches received signal against preset parameters. Automatic system action. |
| 7.2.3 | SYSTEM PRESENTS SELECTED SIGN INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 7.2.4 | DRIVER ACTS ON SIGN INFORMATION AS DESIRED | Understand system/ environmental information | Change of goals | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 8.5.1 | SYSTEM MONITORS VEHICLE PARAMETERS | Maintain safe conditions (general) | System demand | MONITOR | | Automatic system action. |
| 8.5.2 | SYSTEM DETECTS ABNORMAL CONDITION | Obtain system information | Environmental change | TEST | | Automatic system action. |

Table 57. Task characterization of Scenario P22.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 8.5.4 | SYSTEM PROVIDES DESCRIPTION OF PROBLEM | Obtain system information | Completion of previous step | CODE | | |
| .5.5 | DRIVER TARES APPROPRIATE ACTION | Understand system/ environmental information | Change of goals | DECIDE/SELECT | | Adequate information for user to predict outcome. |
| .1.1 | SYSTEM DETECTS HAZARD NOTIFICATION | Automatic system operation | System demand | DETECT | | Automatic system action. |
| .1.3 | SYSTEM PROVIDES INFORMATION ON HAZARD TYPE | Automatic system operation | System demand | CODE | | Automatic system action. |
| .I.4 | DRIVER TARES APPROPRIATE ACTION IN RESPONSE TO HAZARD | Understand system/ environmental information | Change of goals | CONTROL | Requirements don't exceed driver's response capabilities. | |

**Table 57. Task characterization of Scenario P22.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 2.3.1.2 | ADJUST THROTTLE OR BRAKE TO CONTROL SPEED | Modify system operation | System demand | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 2.3.1.3 | VERIFY ADJUSTMENT OF SPEED | Verify output meets expectations | Completion of previous step | INTERPRET | Information present must be consistent with user's knowledge base. | |
| 2.3.2.2 | ADJUST STEERING WHEEL TO COMPENSATE | Modify system operation | System demand | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 8.3.1 | SYSTEM DETECTS EMERGENCY CONDITION | Invoke system operation | System demand | DETECT | | Automatic system action. |
| 8.3.2 | SYSTEM BROADCASTS EMERGENCY REQUEST | Automatic system operation | Completion of previous step | CONTROL | | Automatic system action. |
| END OF SCENARIO | | | | | | |

**Scenario P16**

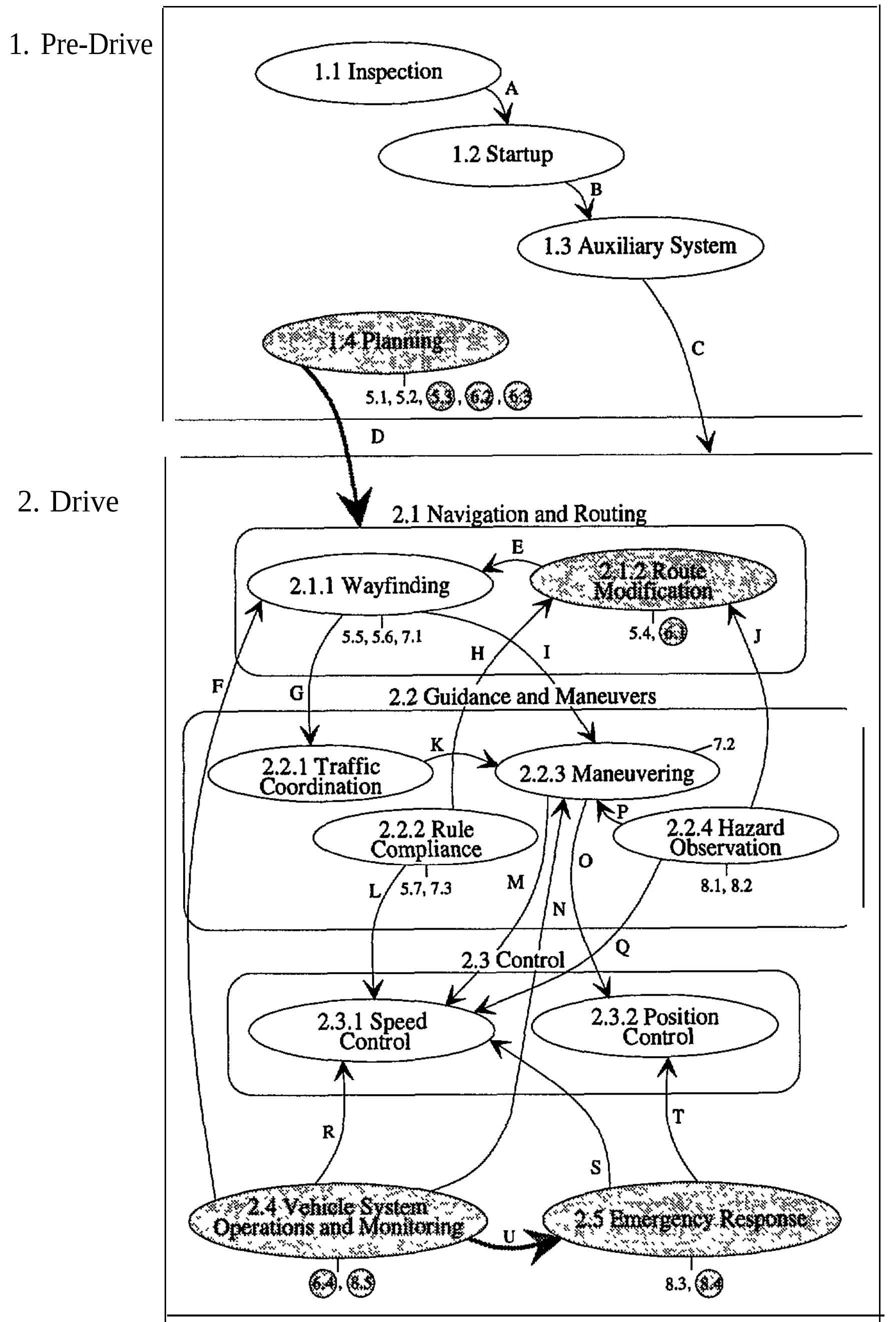
Purpose — To illustrate a grouping of functional characteristics from Cluster 3 (6.1, 6.3, and 6.4).

Summary — A driver uses 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.

Function Interaction Diagram — See figure 35.

Operational Sequence Diagram — See figure 36.

Task Characterization — See table 58.




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 traffic
L Deviation from regulations
M Requires speed increase/decrease
N Failure requires change in speed/ position
0 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 35. Function interaction diagram for Scenario P16.**

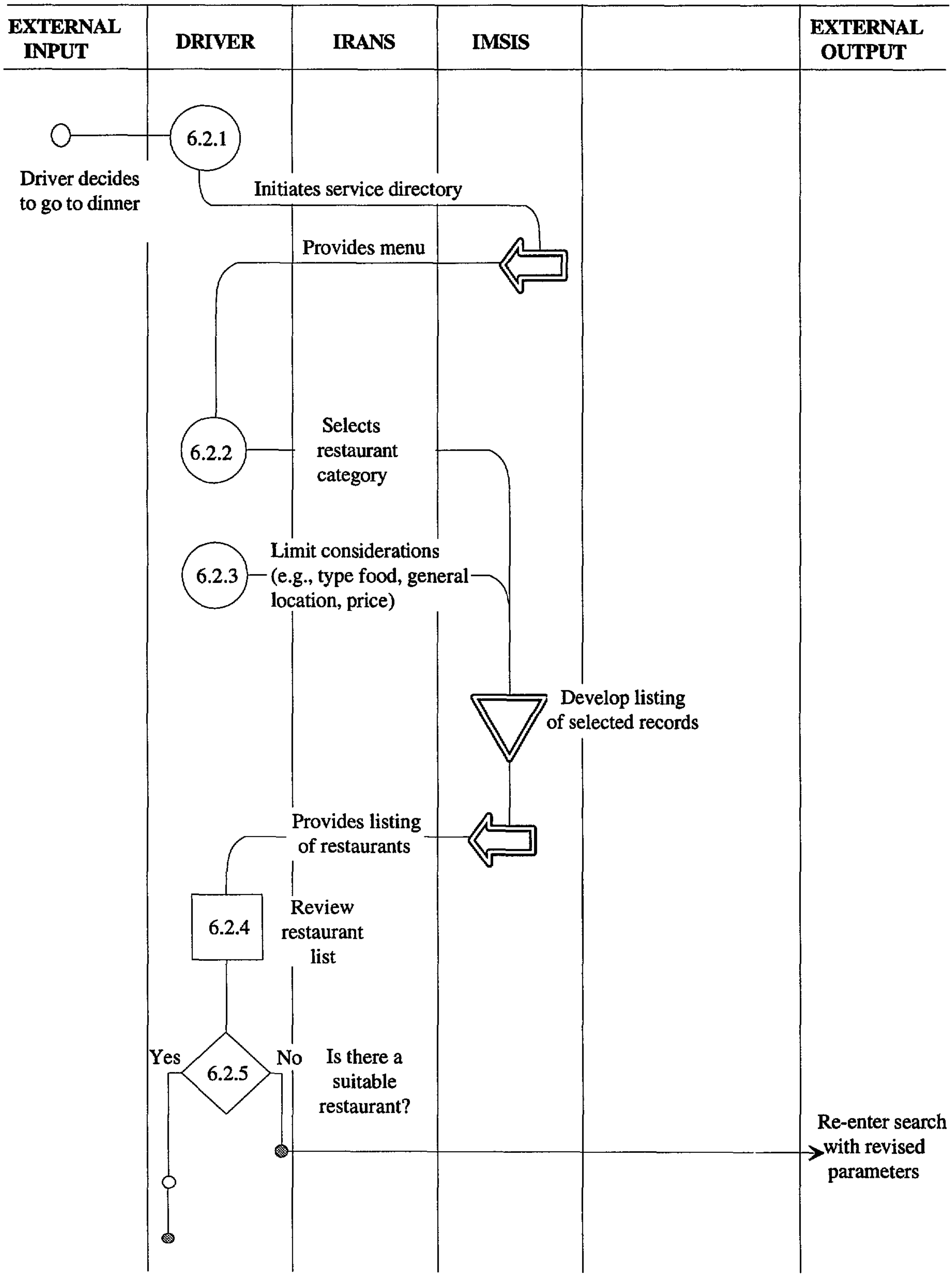



**Figure 36. Operational sequence diagram for Scenario P16.**

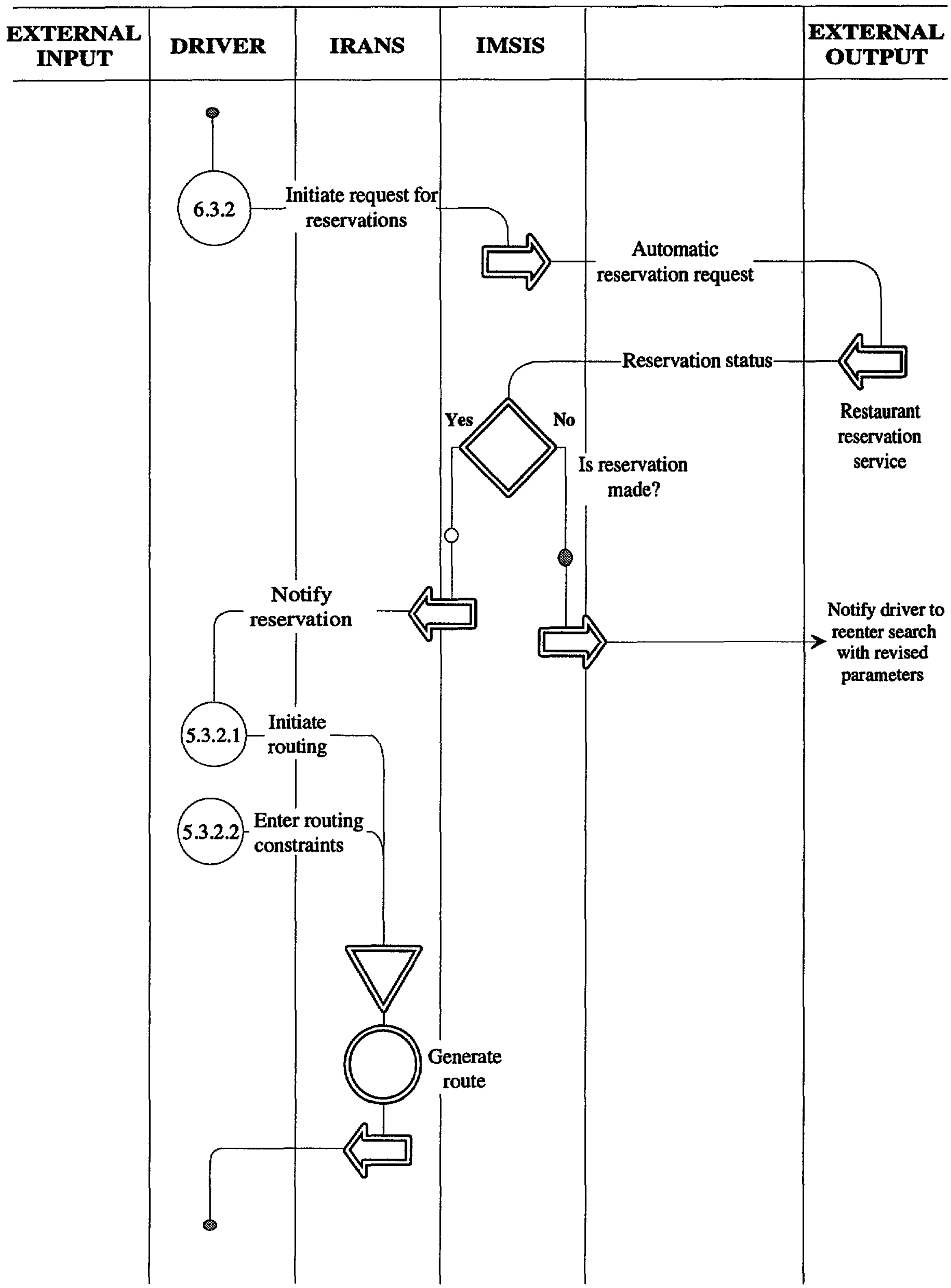



**Figure 36. Operational sequence diagram for Scenario P16 (continued).**

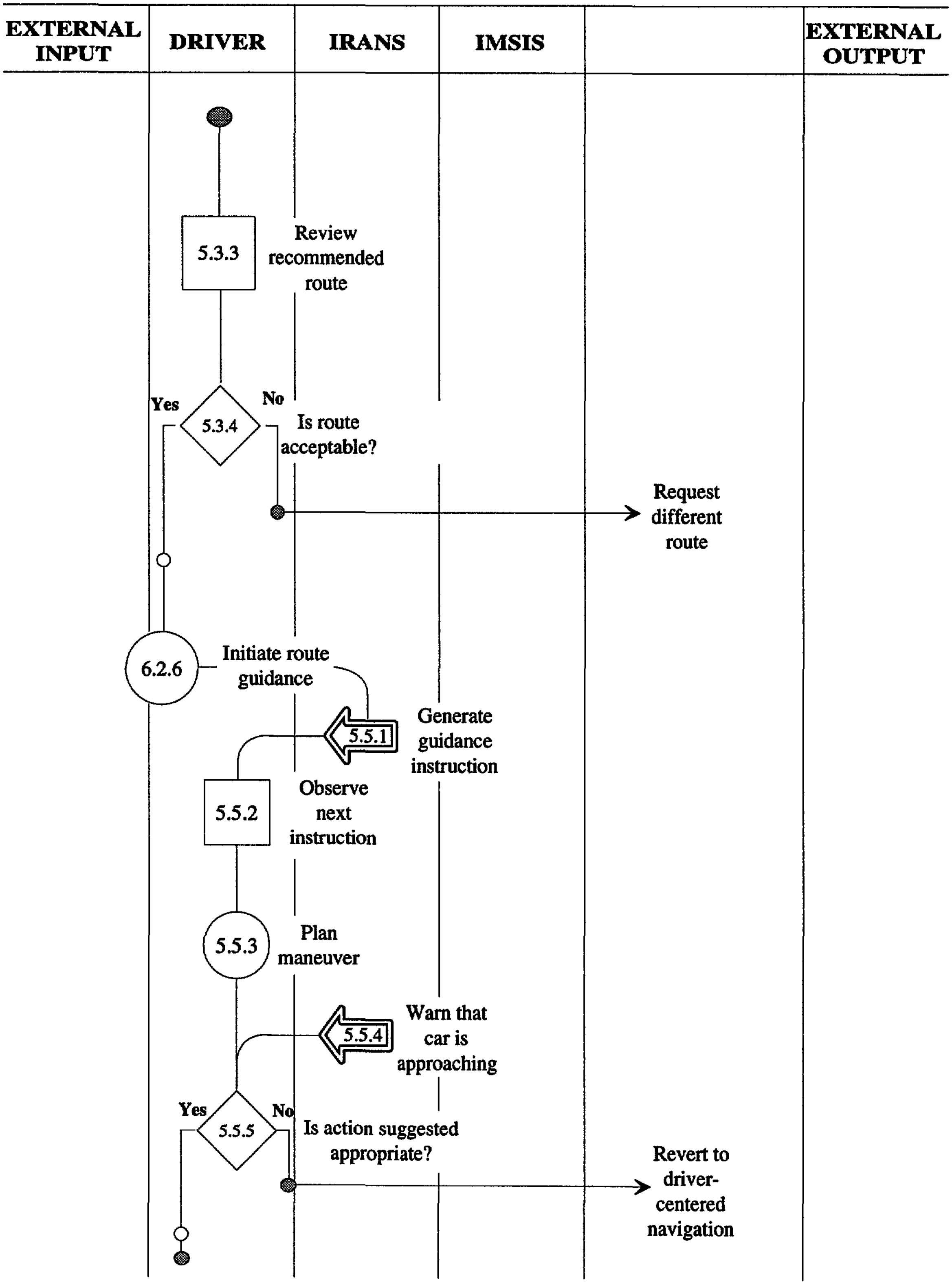



**Figure 36. Operational sequence diagram for Scenario P16 (continued).**

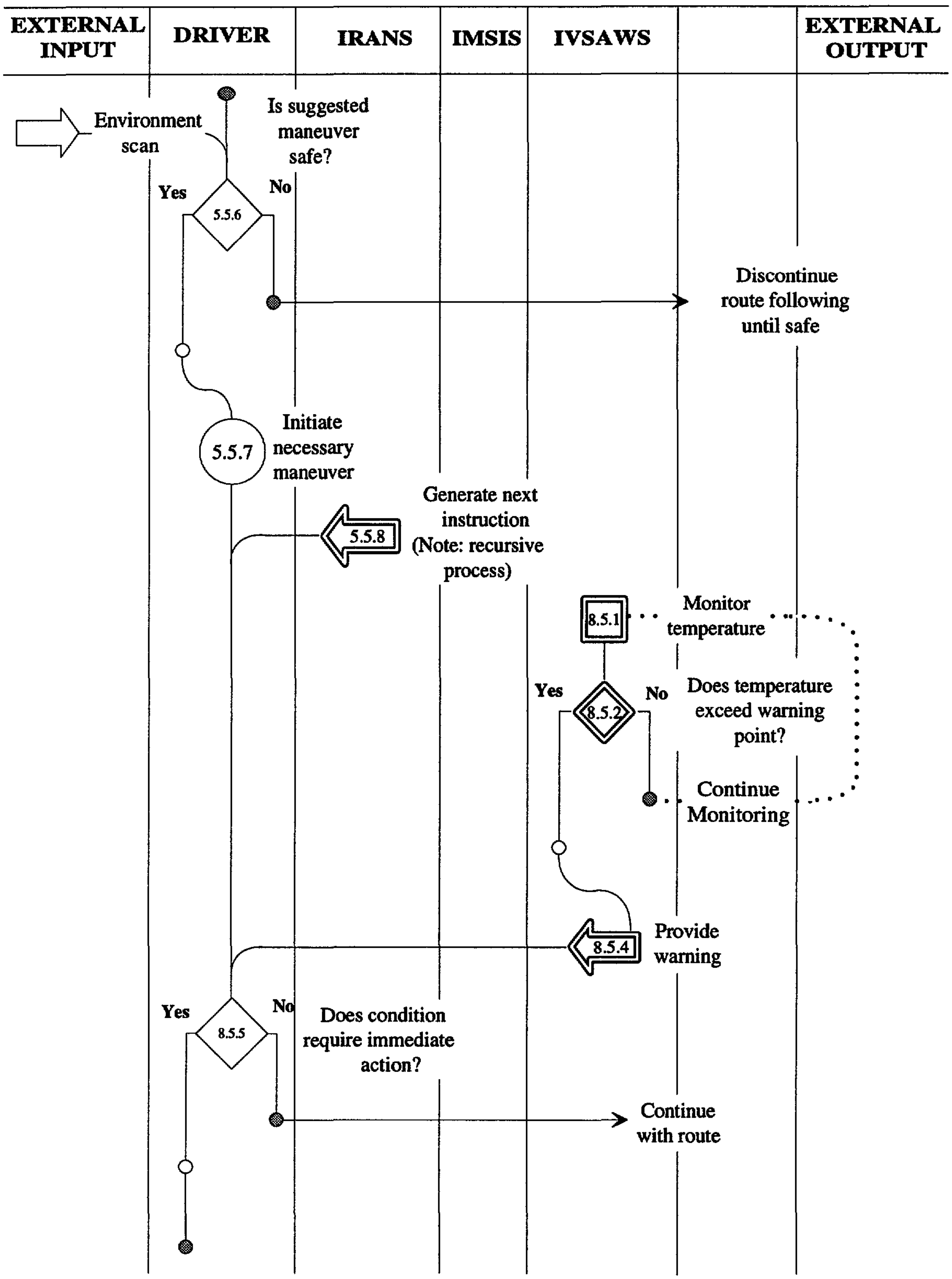



Figure 36. Operational sequence diagram for Scenario P16 (continued).

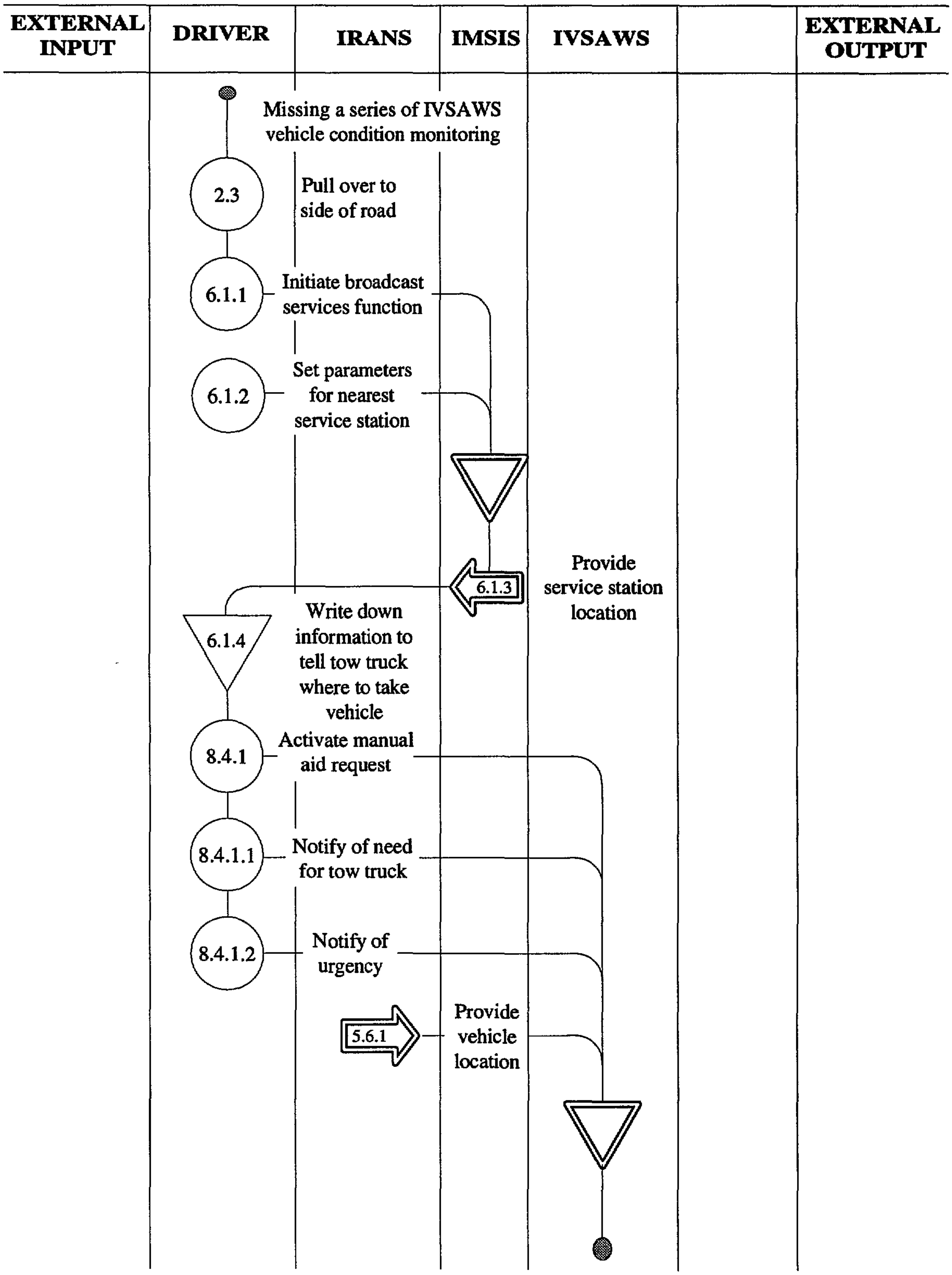



Figure 36. Operational sequence diagram for Scenario P16 (continued).

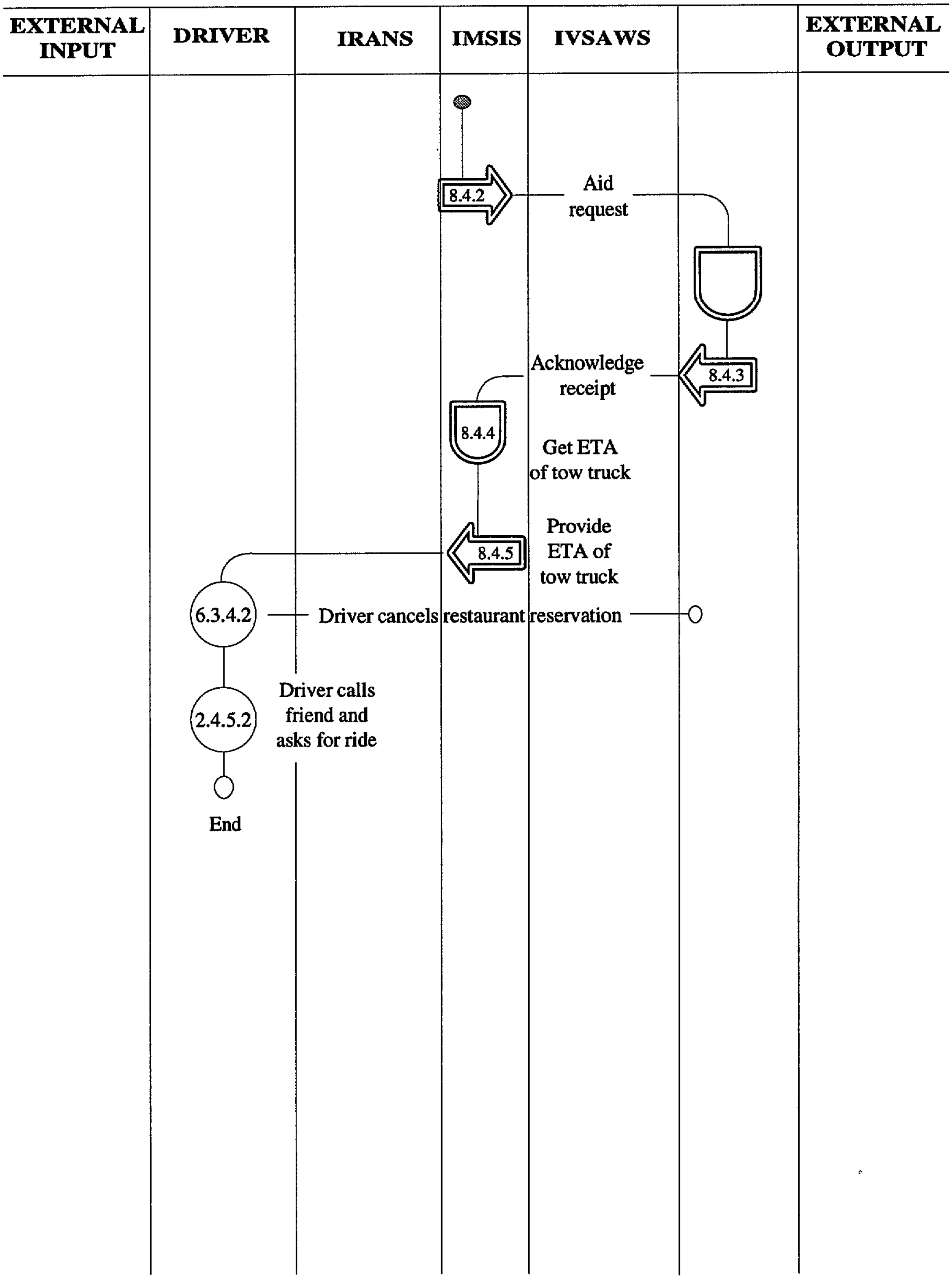



**Figure 36. Operational sequence diagram for Scenario P16 (continued).**

**Table 58. Task characterization of Scenario P16.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 5.2.1 | DRIVER INITIATES SERVICES/ ATTRACTIONS DIRECTORY | Make a system ready to use | Goal initiation | CONTROL | Requirements don't exceed driver's response capabilities. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| i.2.2 | SELECT CLASS OF SERVICES DESIRED | Limit system considerations | System demand | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| .2.3 | SELECT PARAMETERS FOR CLASS OF SERVICES | Limit system considerations | System demand | CODE | Motor actions within human capabilities. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| **.2.4** | REVIEW LISTING | Obtain system information | Completion of previous step | SEARCH | Information presented must be consistent with user's knowledge base. | |
| .2.5 | SELECT ITEM FROM LISTING | Approve system output and initiate next step | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| .3.2 | INITIATE DESTINATION COORDINATION | Invoke system operation | System demand | CONTROL | System provides indication of action completion. System provides indication that the system is responding to input. | |

Table 58. Task characterization of Scenario P16.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | & CODED SYSTEM ACTIONS | | | |
| 1.3.2.1 | DESTINATION | Provide system information | System demand | CONTROL | System provides indication that the system is responding to input. | Transfer of destination from IMSIS to IRANS route guidance. |
| .3.2.2 | ROUTE PARAMETERS | Limit system considerations | System demand | CODE | Input requirements compatible with knowledge. | May be automated function or limited by system design. |
| | | | UNCODED SYSTEM ACTIONS | | | |
| **.3.3** | REVIEW RECOMMENDED ROUTE | Environmental change | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |
| .3.4 | DECIDE IF ROUTE IS ACCEPTABLE | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |

## Table 58. Task characterization of Scenario Pl6.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.2.6 | INITIATE ROUTE GUIDANCE TO SELECTED ITEM | Invoke system operation | Change of goals | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| 5.5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| i.5.2 | DRIVER OBSERVES INSTRUCTION FOR NEXT ACTION | Understand system/ environmental information | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |
| i.5.3 | DRIVER PLANS FOR NEXT ROUTE ACTION | Understand system/ environmental information | Completion of previous step | PLAN | System allows adequate time for execution. System provides necessary information. | |
| 5.5.4 | SYSTEM ALERTS DRIVER OF APPROACHING ACTION POINT | Invoke system operation | Completion of previous step | IDENTIFY | | Automatic system action. |

**Table 58. Task characterization of Scenario P16.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.5.5 | DRIVER CONFIRMS ACTION IS APPROPRIATE | Evaluate system recommendation | Completion of previous step | TEST | Recommendations in appropriate detail to identify compatibility with constraints. | |
| 5.5.6 | DRIVER CONFIRMS THAT ACTION IS SAFE | Obtain environment information | Completion of previous step | TEST | Recommendations in appropriate detail to identify compatibility with constraints. | Driver is checking to make sure that ATIS directions are not in conflict with the primary task of driving, |
| 5.5.7 | DRIVER INITIATES NECESSARY ACTION | Execute system recommendation | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. | Maneuvers the vehicle to the necessary point. |
| 5.5.8 | DRIVER COMPLETES NECESSARY ACTION | Make a system ready to use | Completion of previous step | CONTROL | System provides indication of action completion. | |
| 5.5.1 | SYSTEM MONITORS VEHICLE PARAMETERS | Maintain safe conditions (general) | System demand | MONITOR | | Automatic system action. |
| 3.5.2 | SYSTEM DETECTS ABNORMAL CONDITION | Obtain system information | Environmental change | TEST | | Automatic system action comparing measured conditon against trip point. |

## Table 58. Task characterization of Scenario P16.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 8.5.4 | **SYSTEM PROVIDES** DESCRIPTION OF PROBLEM | **Obtain system** information | **Completion of** previous step | **CODE** | | Automatic system action. |
| 8.5.5 | DRIVER TARES APPROPRIATE ACTION | Understand system/ environmental information | Change of goals | DECIDE | Adequate information for user to predict outcome. | |
| [redacted] | CONTROL | Invoke system operation | Goal initiation | CONTROL | Requirements don't exceed driver's response capability. | |
| [redacted] | DRIVER INITIATES BROADCAST SERVICES RECEIVING EQUIPMENT | Make a system ready to use | **Goal initiation** | **CONTROL** | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| 6.1.2 | DRIVER ENTERS SCREENING PARAMETERS | Limit system considerations | System demand | CODE | Input requirements directly. | (E.g., services of interest and proximity to route.) |
| | | | UNCODED SYSTEM ACTIONS | | | |
| 6.1.3 | SYSTEM PROVIDES ANNOUNCEMENTOF SERVICES AS APPROACHED | Invoke system operation | Environmental change | CODE | | Automatic system action. |

## Table 58. Task characterization of Scenario P16.

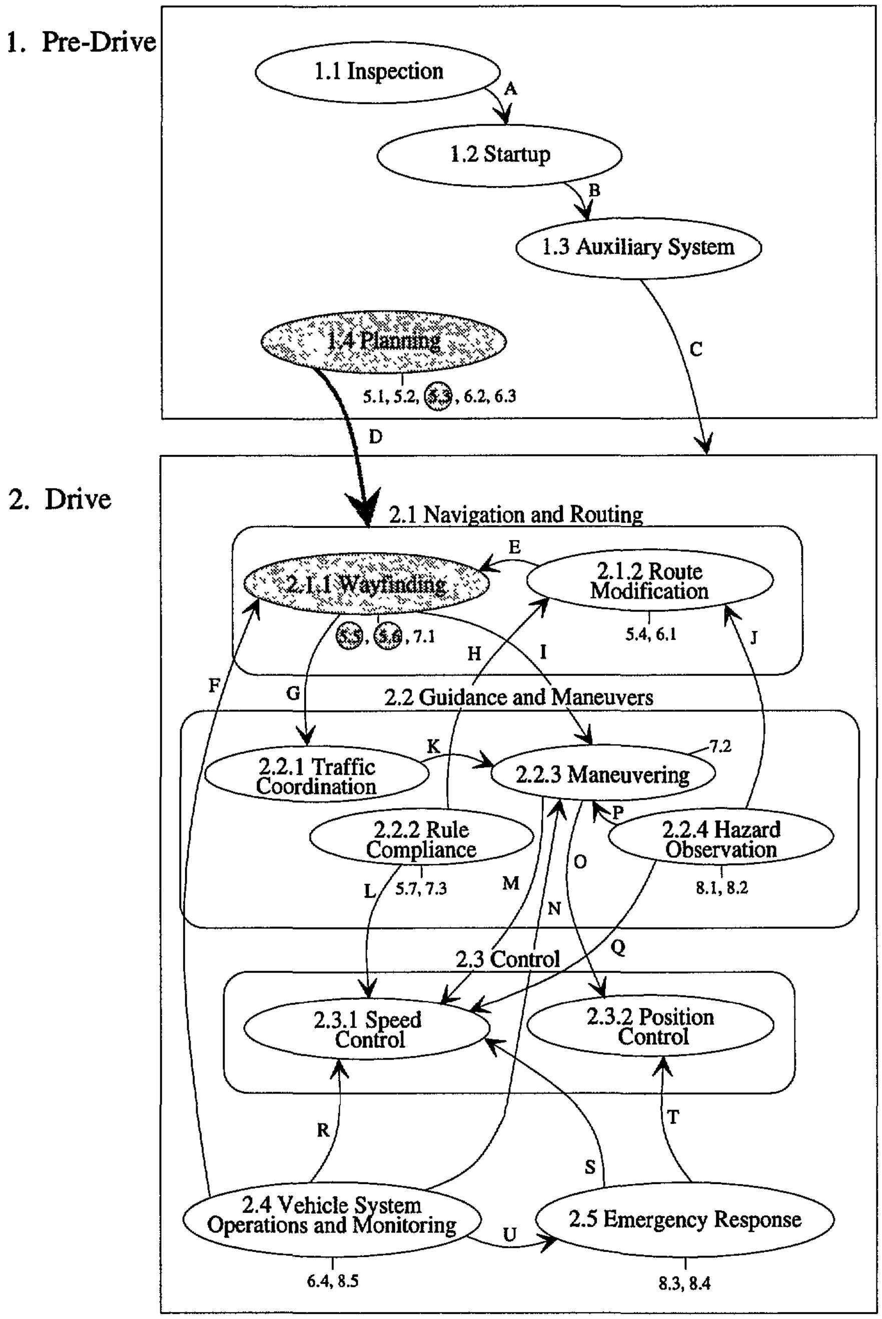
| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 6.1.4 | DRIVER TARES DESIRED ACTION REGARDING SERVICES | Execute system recommendation | Change of goals | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 8.4.1 | DRIVER ACTIVATES MANUAL AID REQUEST | Invoke system operation | Goal initiation | CODE | Motor actions within human capabilities. Input requirements compatible with knowledge. | (E.g., aid required, urgency.) |
| 8.4.1.1 | AID REQUIRED | Provide system information | System requirements | CODE | Motor actions within human capabilities. Input requirements compatible with knowledge. | |
| 8.4.1.2 | URGENCY | Provide system information | System requirements | CODE | Motor actions within human capabilities. Input requirements compatible with knowledge. | |
| 5.6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action transfer from IRANS to IVSAWS. |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 8.4.2 | SYSTEM SENDS REQUEST AS WELL AS VEHICLE LOCATION | Automatic system operation | Completion of previous step | CONTROL | | Automatic system function. |

**Table 58. Task characterization of Scenario P16.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| UNCODED SYSTEM ACTIONS | | | | | | |
| .4.3 | SSYSTEM ACKNOWLEDGES REQUEST RECEIVED | Automatic system #operation | Completion of previous step | CODE | | External system action to provide feedback to driver that request has been received. May be automatic. |
| .4.4 | SSYSTEM GETS UPDATE OF ARRIVAL TIME FOR AID | Obtain system information | Environmental Change | INTERPRET | | Automatic system action in this scenario. |
| .4.5 | NOTIFIES DRIVER OF ARRIVAL TIME FOR All | Obtain system information | Environmental Change | CODE | | To provide feedback to driver as to when aid will arrive. Automatic system action. |
| .3.4.2 | DRIVER UPDATES CHANGES IN SERVICE REQUIRED | Invoke system operation | Change in goals | CONTROL | System provides indications of action completion. | |
| .4.5.2 | OPERATE TWO-WAY COMMUNICATIONS (AUDIO) | Invoke system operation | ioal initiation | CODE | Input requirement directly. | |
| END OF SCENARIO | | | | | | |

**Scenario Pl**

| | |
|---|---|
| Purpose | To illustrate the sequencing type of interactions among various functional characteristics. |
| 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 mi (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. |
| Function Interaction Diagram | See figure 37. |
| Operational Sequence Diagram | See figure 38. |
| Task Characterization | See table 59. |




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

**Figure 37. Function interaction diagram for Scenario P1.**

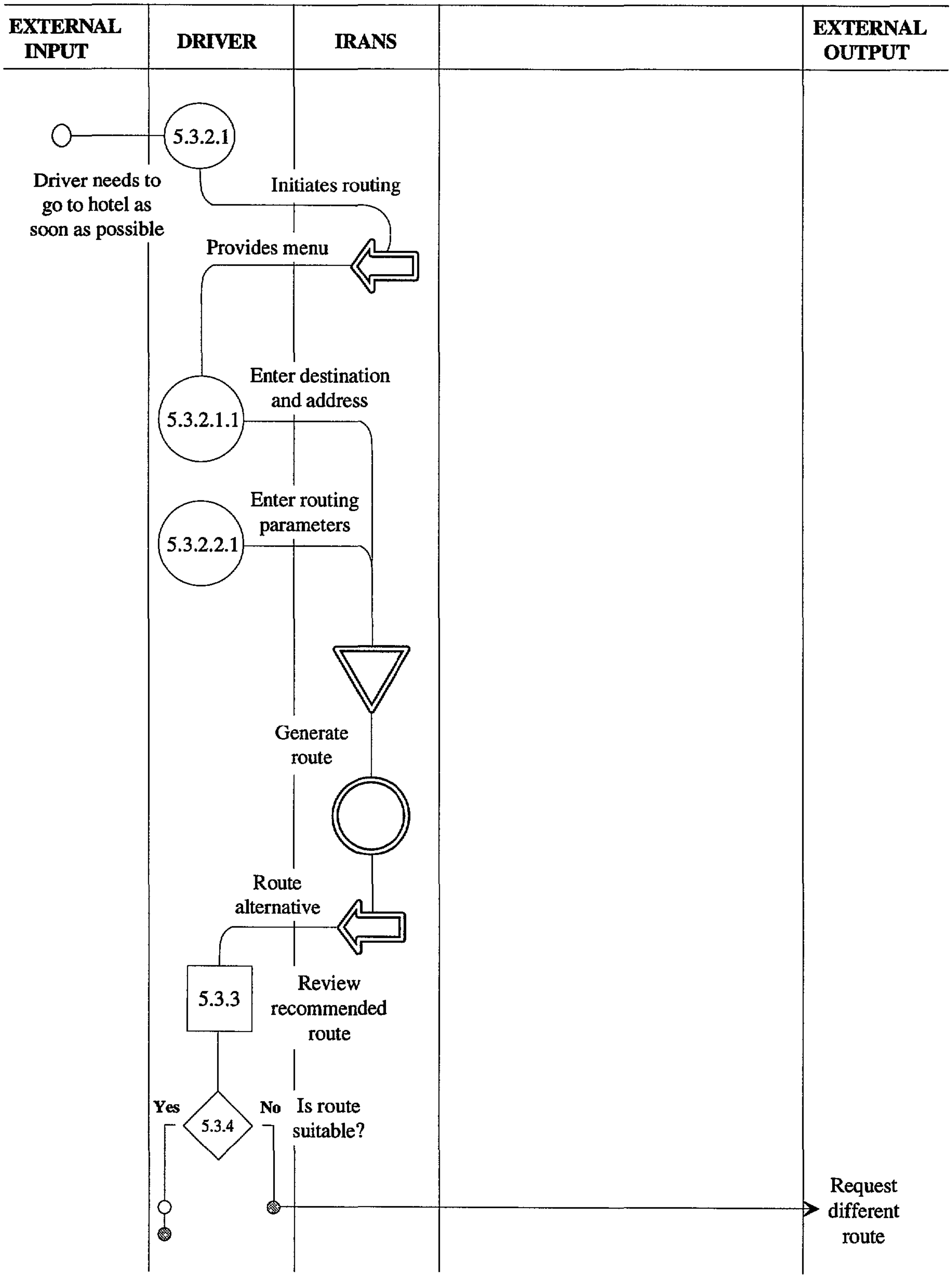



**Figure 38. Operational sequence diagram for Scenario P1.**

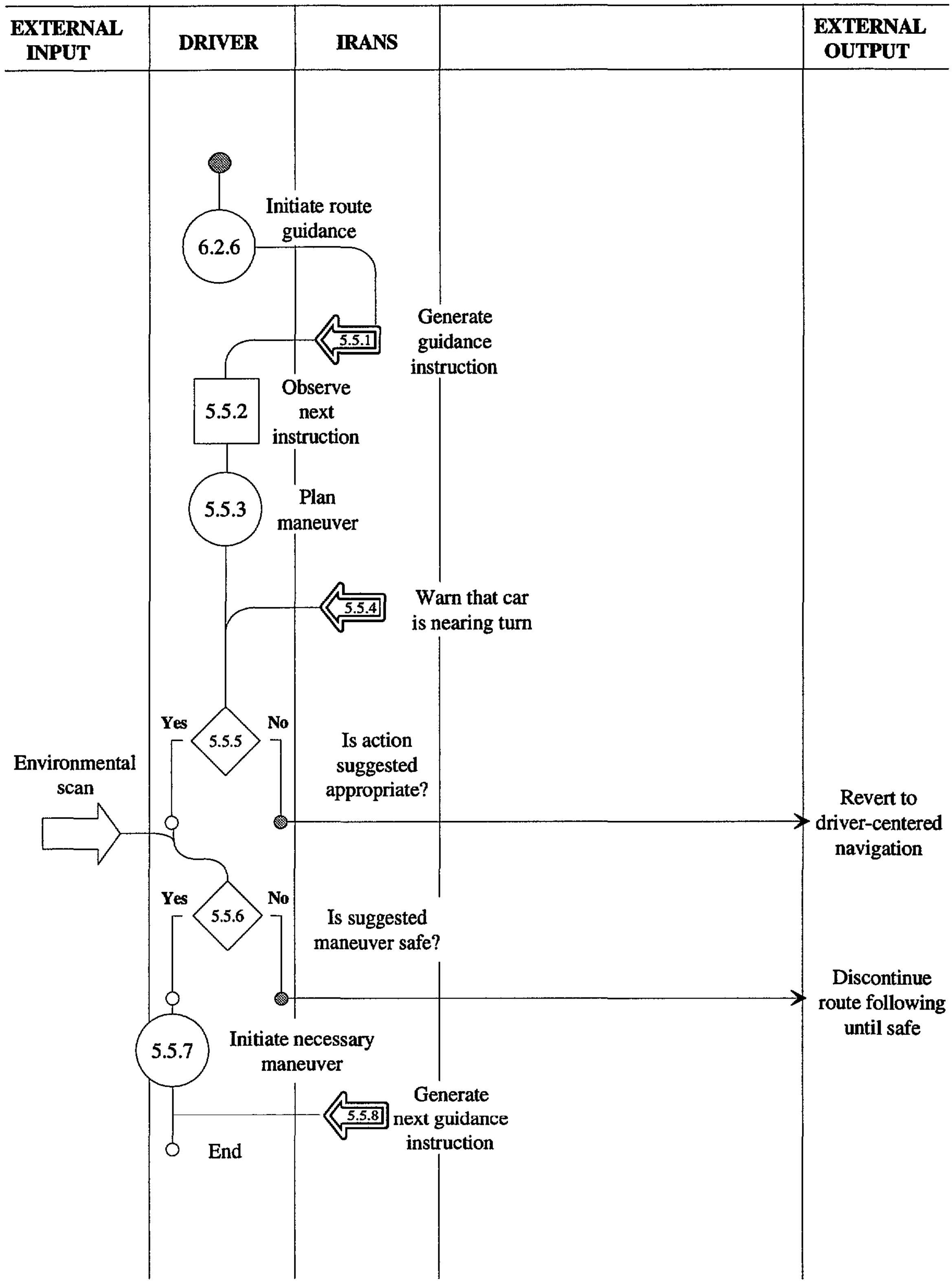



**Figure 38. Operational sequence diagram for Scenario P1 (continued).**

Table 59. Task characterization of Scenario Pl.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | START OF SCENARIO | | | |
| .3.2.1 | DESTINATION | Provide system information | System demand | CONTROL | Requirements don't exceed driver's response capabilities. | |
| | | | UNCODED SYSTEM ACTIONS | | | |
| 5.3.2.1.1 | ENTER DESTINATION | Provide system information | System demand | CODE | Motor actions within human capabilities. Input requirements direct. | |
| 5.3.2.2.1 | ENTER ROUTING PARAMETERS | Provide system information | System demand | CODE | Input requirements compatible with knowledge. | |
| | | | UNCODED SYSTEM ACTIONS | | | |
| 5.3.3 | REVIEW RECOMMENDED ROUTE | Environmental change | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |

**Table 59. Task characterization of Scenario Pl.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.3.4 | DECIDE IF ROUTE IS ACCEPTABLE | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |
| 5.2.6 | INITIATE ROUTE GUIDANCE TO SELECTED ITEM | Invoke system operation | Change of goals | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | Transfer of informatior from IMSIS to IRANS may be automatic. |
| 5.5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| 5.5.2 | DRIVER OBSERVES INSTRUCTION FOR NEXT ACTION | Understand system/ environmental information | Completion of previous step | lNTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |

**Table 59. Task characterization of Scenario P1.**

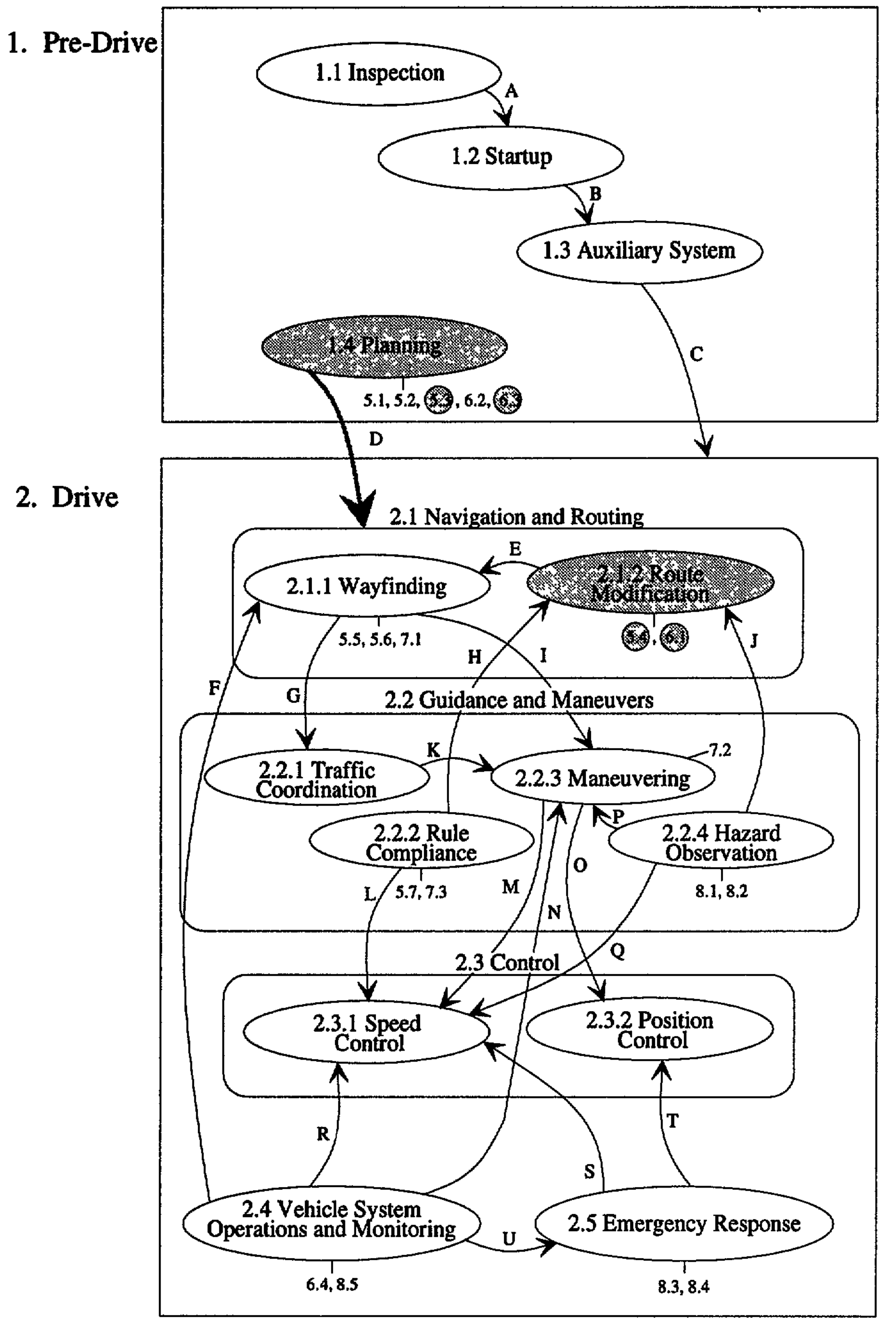
| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.5.3 | DRIVER PLANS FOR NEXT ROUTE ACTION | Understand system/ environmental information | Completion of previous step | PLAN | System allows adequate time for execution. System provides necessary information. | |
| 5.5.4 | SYSTEM ALERTS DRIVER OF APPROACHING ACTION POINT | Invoke system operation | Completion of previous step | IDENTIFY | | Automatic system action. |
| 5.5.5 | DRIVER CONFIRMS ACTION IS APPROPRIATE | Evaluate system recommendation | Completion of previous step | TEST | Recommendations in appropriate detail to identify compatibility with constraints. Level of detail does not increase workload. | |
| 5.5.6 | DRIVER CONFIRMS THAT ACTION IS SAFE | Obtain environment information | Completion of previous step | TEST | Recommendations in appropriate detail to identify compatibility with constraints. Recommendations compatible with short-term memory. Level of detail does not increase workload. | Driver is checking to ensure directions do not conflict with the primary driving task. |
| 5.5.7 | DRIVER INITIATES NECESSARY ACTION | Execute system recommendation | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. | Maneuvers vehicle to the necessary point. |

**Table 59. Task characterization of Scenario Pl.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.5.8 | DRIVER COMPLETES NECESSARY ACTION | Make system ready to use | Completion of previous step | CONTROL | | Automatic system action. |
| END OF SCENARIO | | | | | | |

**Scenario P20**

| | |
|---|---|
| Purpose | To illustrate the branching type of interactions among various functional characteristics. |
| Summary | 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. |
| Function Interaction Diagram | See figure 39. |
| Operational Sequence Diagram | See figure 40. |
| Task Characterization | See table 60. |




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

**Figure 39. Function interaction diagram for Scenario P20.**

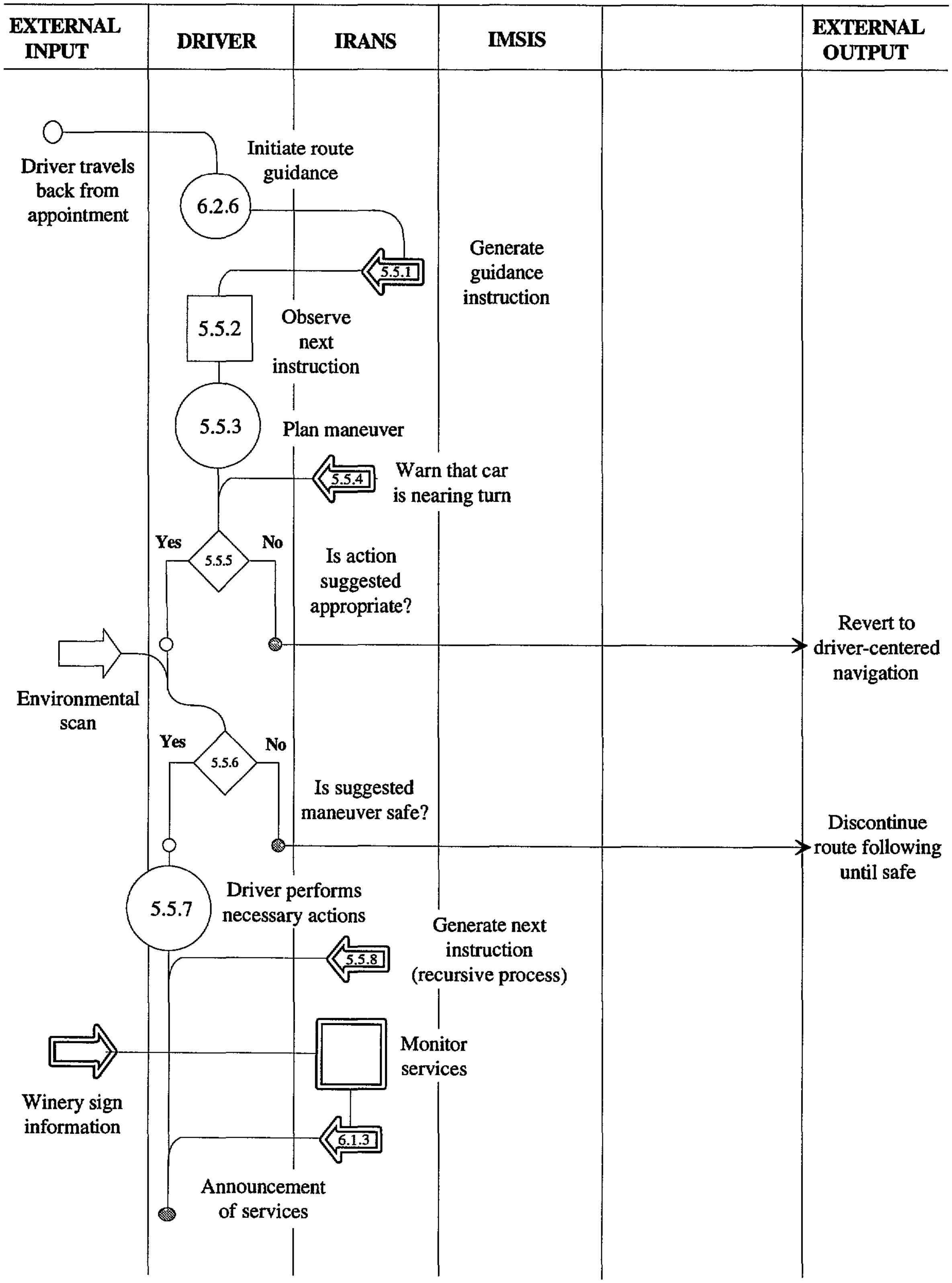



**Figure 40. Operational sequence diagram for Scenario P20.**

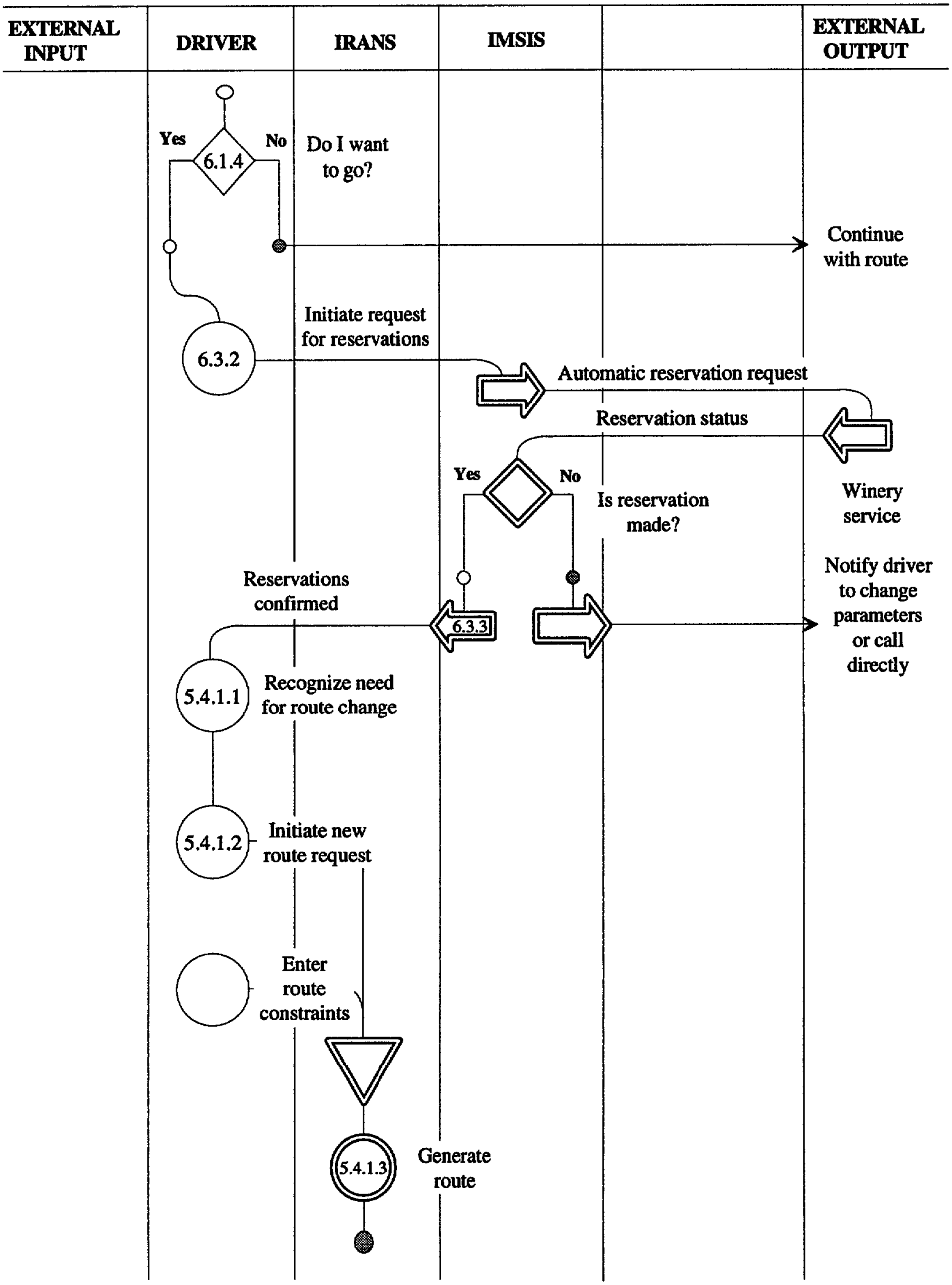



**Figure 40. Operational sequence diagram for Scenario P20 (continued).**

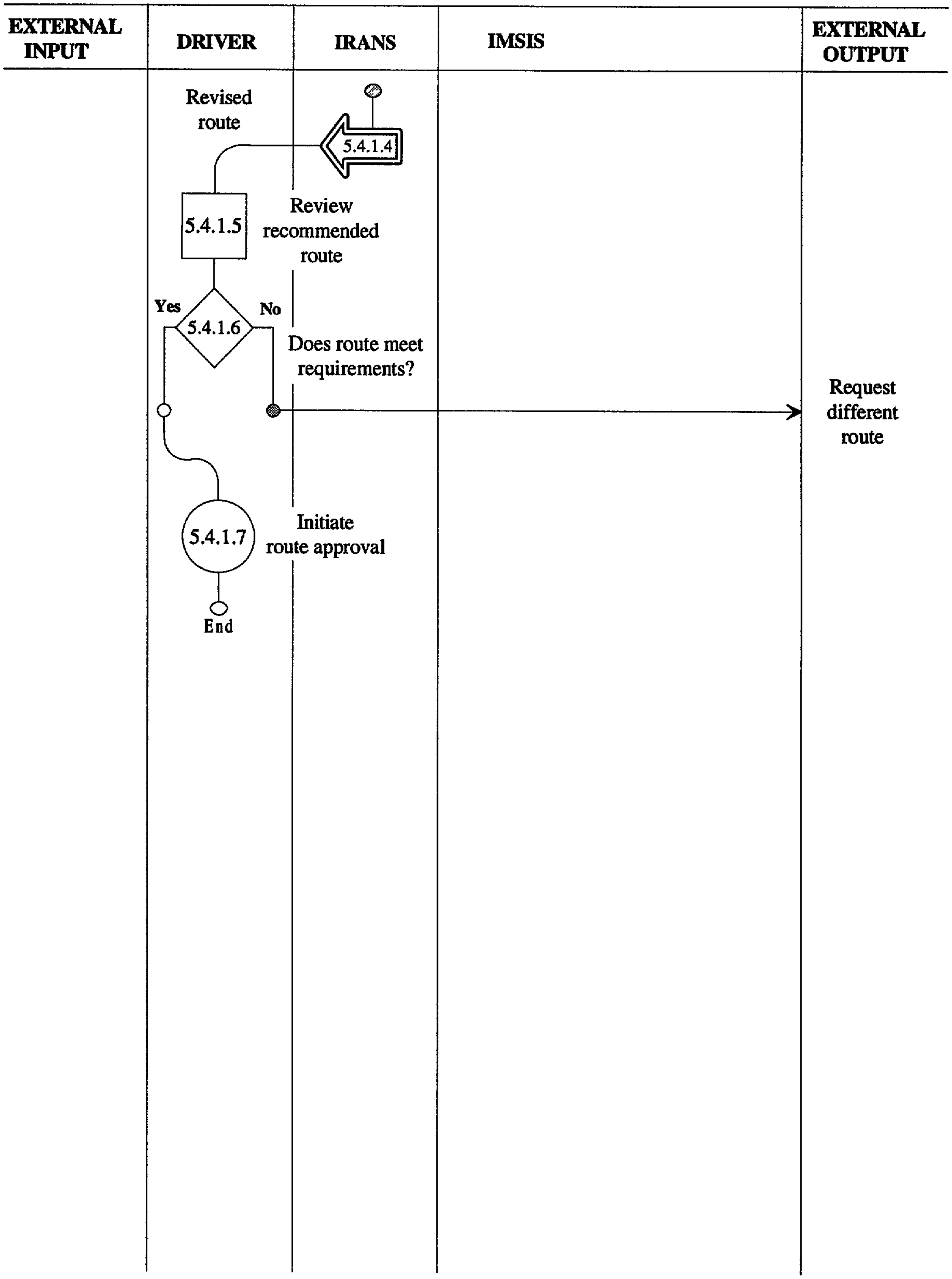



**Figure 40. Operational sequence diagram for Scenario P20 (continued).**

## Table 60. Task characterization of Scenario P20.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 2.6 | INITIATE ROUTE GUIDANCE TO SELECTED ITEM | Invoke system operation | Change of goals | CONTROL | System provides indication that the system is responding to input. | |
| 5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| ,5.2 | DRIVER OBSERVES INSTRUCTION FOR NEXT ACTION | Understand system/ environmental information | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |
| ,5.3 | DRIVER PLANS FOR NEXT ROUTE ACTION | Understand system/ environmental information | Completion of previous step | PLAN | System allows adequate time for execution. System provides necessary information. | |
| .5.4 | SYSTEM ALERTS DRIVER OF APPROACHING ACTION POINT | Invoke system operation | Completion of previous step | IDENTIFY | | Automatic system action. |

**Table 60. Task characterization of Scenario P20.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.5.5 | DRIVER CONFIRMS ACTION IS APPROPRIATE | Evaluate system recommendation | Completion of previous step | DECIDE/SELECT | System must provide adequate information for user to predict outcome of each option presented. | |
| 5.6 | DRIVER CONFIRMS THAT ACTION IS SAFE | Obtain environment information | Completion of previous step | DECIDE/SELECT | System must provide adequate information for user to predict outcome. | Task is linked to primary driving task. |
| 5.7 | DRIVER INITIATES NECESSARY ACTION | Execute system recommendation | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 5.8 | DRIVER COMPLETES NECESSARY ACTION | Make system ready to use | Completion of previous step | CODE | | Automatic system action. |
| | | | UNCODED SYSTEM ACTIONS | | | |
| 1.3 | SYSTEM PROVIDES ANNOUNCEMENT OF SERVICES AS APPROACHED | Invoke system operation | Environmental change | CODE | | Automatic system action. |

Table 60. Task characterization of Scenario P20.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.1.4 | DRIVER TARES DESIRED ACTION REGARDING SERVICES | Execute system recommendation | Change of goals | DECIDE/SELECT | System must provide adequate information to predict outcome. | |
| 5.3.2 | INITIATE DESTINATION COORDINATION | Invoke system operation | System demand | CONTROL | System provides indication that the system is responding to input. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 6.3.3 | OBTAIN VERIFICATION OF COORDINATION | Verify output meets expectations | Completion of previous step | TEST | | Automatic system action. |
| 5.4.1.1 | DRIVER RECOGNIZES NEED FOR REVISED ROUTE | Modify system operation | Change of goals | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |

**Table 60. Task characterization of Scenario P20.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.4.1.2 | INITIATE NEW ROUTE REQUEST OF IRANS | Provide system information | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. System provides indication that the system is responding to input. | |
| | | | UNCODED DRIVER ACTIONS | | | |
| 4.1.3 | SYSTEM COMPUTES NEW ROUTE | Invoke system operation | Completion of previous step | COMPUTE | | Automatic system action. |
| 4.1.4 | SYSTEM PRESENTS REVISED ROUTE | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 4.1.5 | DRIVER REVIEWS RECOMMENDED ROUTE | Evaluate system recommendation | Completion of previous step | TEST | Recommendations in appropriate detail to identify compatibility with constraints. Recommendations compatible with short-term memory. Level of detail does not increase workload. | |

**Table 60. Task characterization of Scenario P20.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.4.1.6 | DECIDES IF RECOMMENDED ROUTE IS SATISFACTORY | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |
| 5.4.1.7 | INITIATE ROUTE APPROVAL | Approve system output and initiate next step | Completion of previous step | CONTROL | System provides indication that the system is responding to input. | |
| END OF SCENARIO | | | | | | |

**Scenario P2**

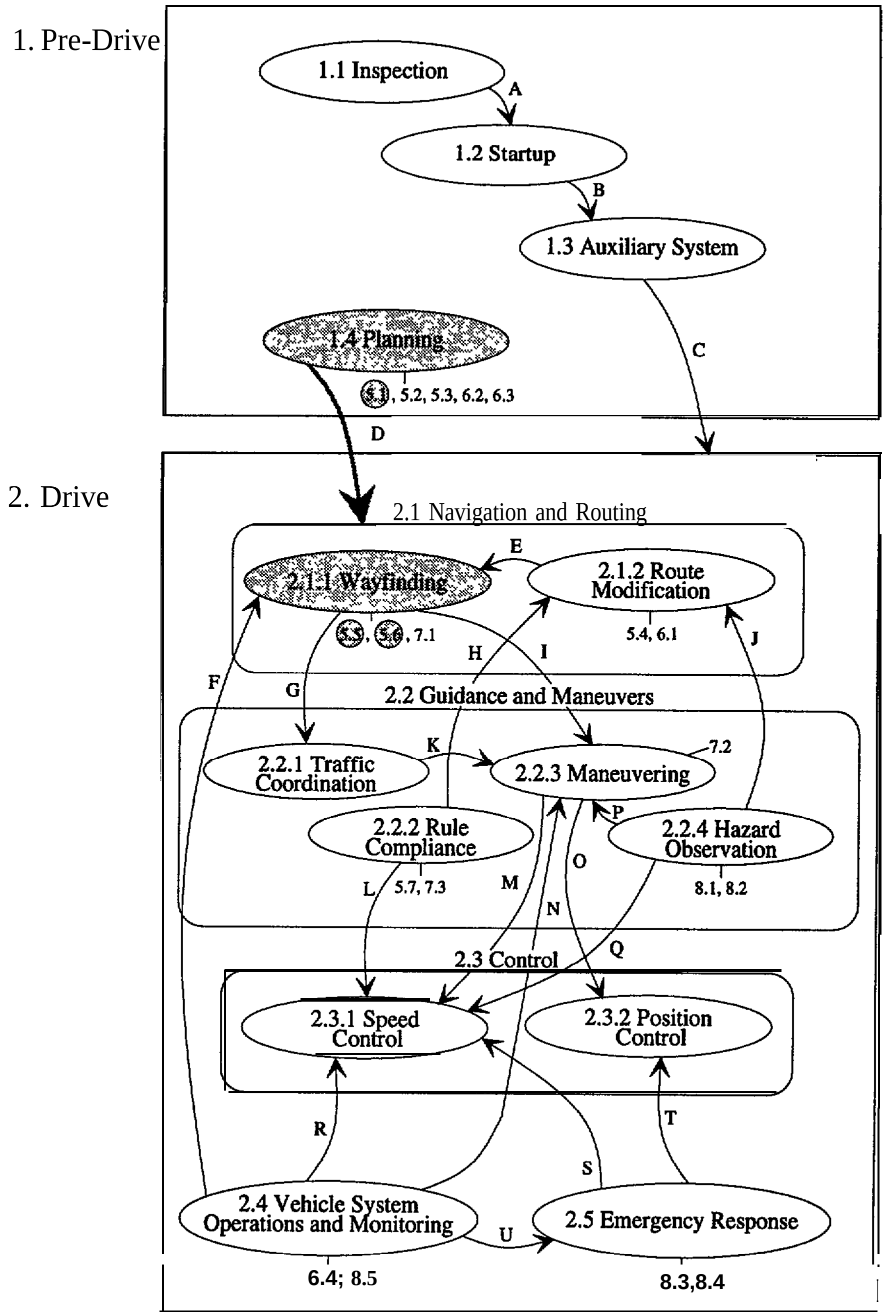
<u>**Purpose**</u> To illustrate the interactions among various functional characteristics.

<u>**Summary**</u> 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.

<u>Function Interaction Diagram</u> See figure 41.

<u>Operational Sequence Diagram</u> See figure 42.

<u>Task Characterization</u> See table 61.




| | | |
|---|---|---|
| A Vehicle safety verified | I Maneuver required | 0 Requires change in lane position |
| B Vehicle initiated | J Potential hazards identified in upcoming roadway | P Hazard identified |
| C Auxiliary systems initiated | K Identification of safe path through traffic | Q Immediate hazard identified |
| D Destination and route selected | L Deviation from regulations | R Vehicle failure |
| E Route change identified | M Requires speed increase/decrease | S Conditions requiring immediate response |
| F Vehicle service required | N Failure requires change in speed/ position | T Conditions requiring immediate response |
| G Maneuver required | | U Minimize injury/damage |
| H Regulatory limits on roadway | | |

**Figure 41. Function interaction diagram for Scenario P2.**

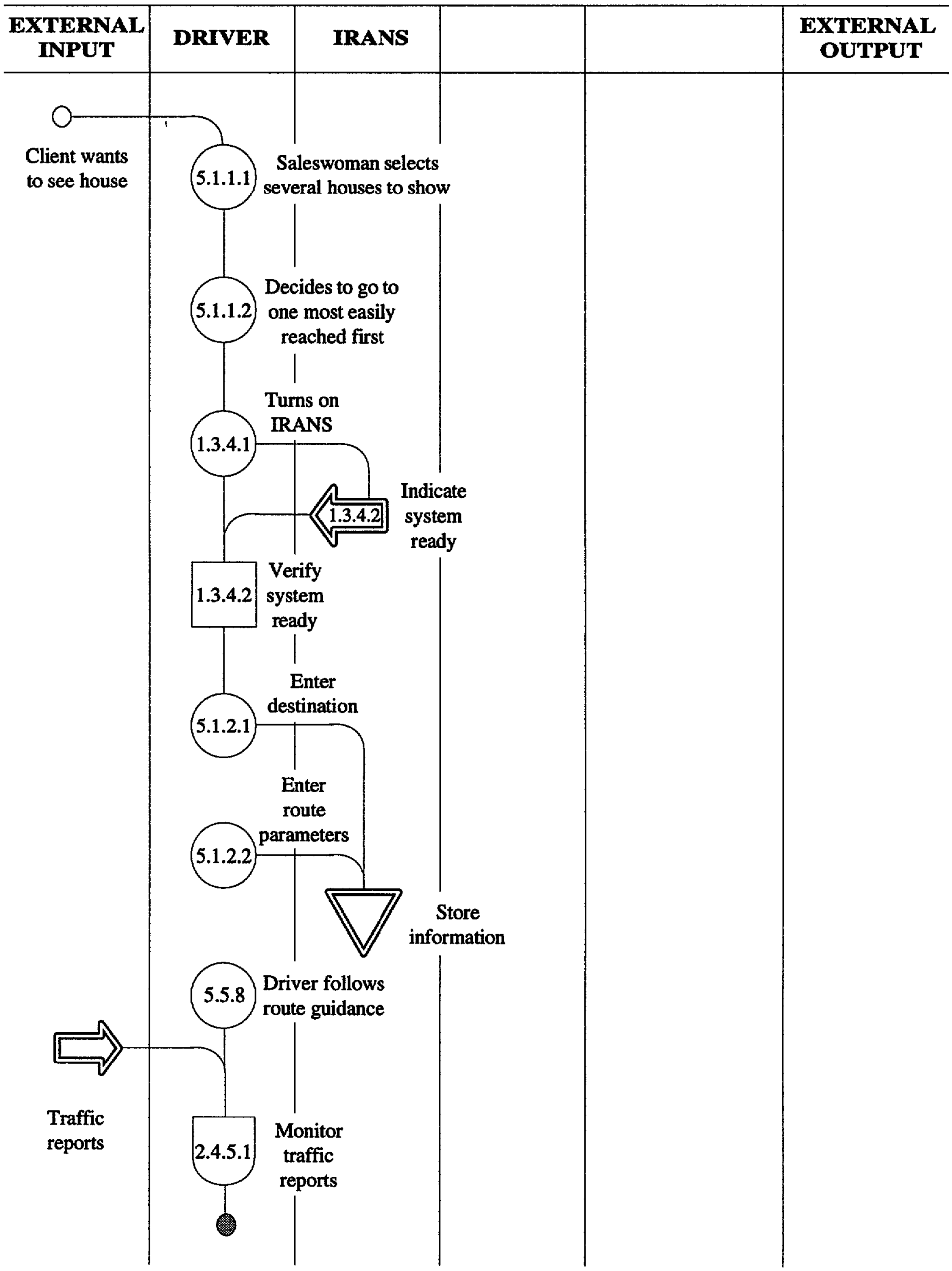



**Figure 42. Operational sequence diagram for Scenario P2.**

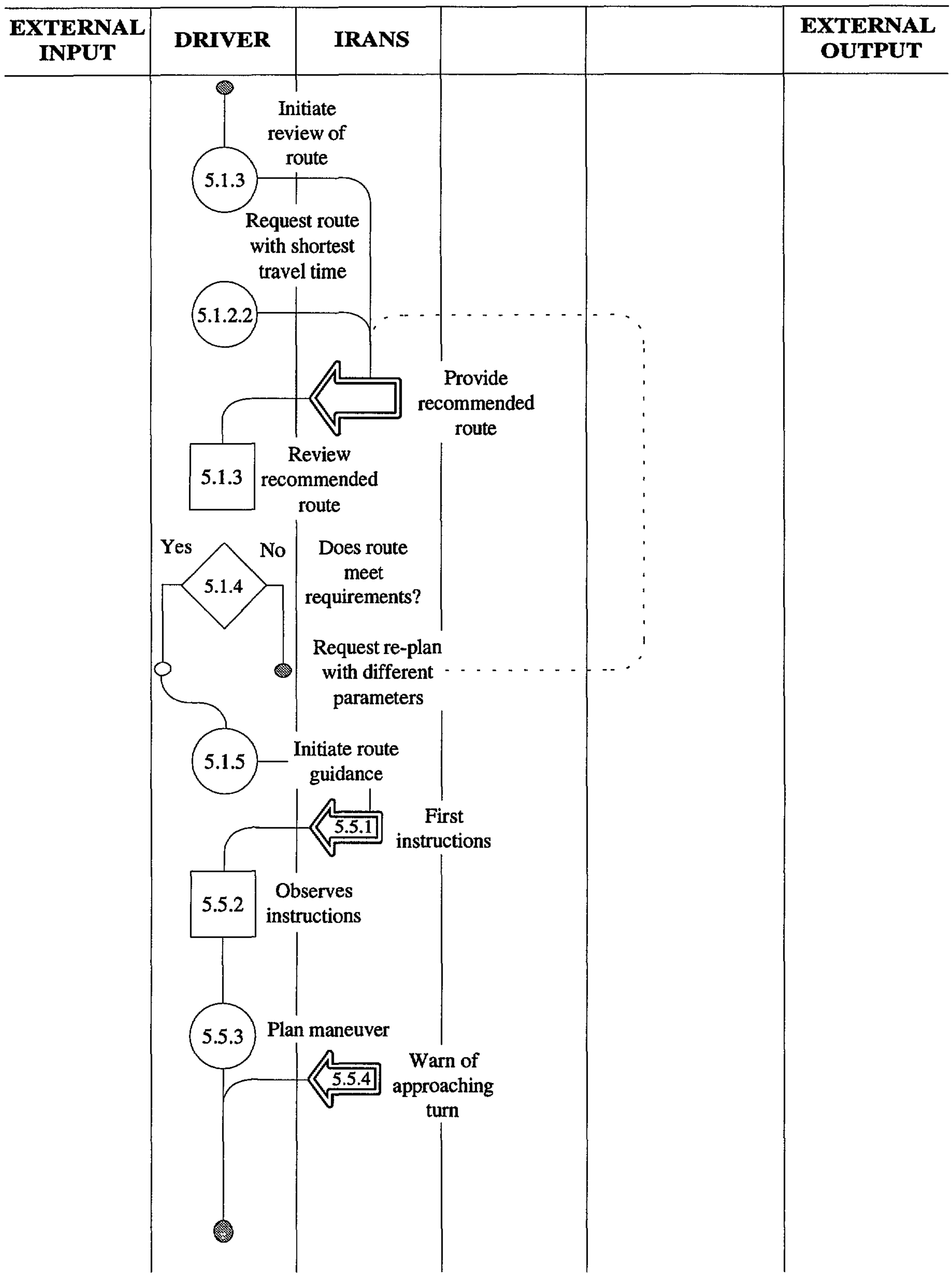



**Figure 42. Operational sequence diagram for Scenario P2 (continued).**

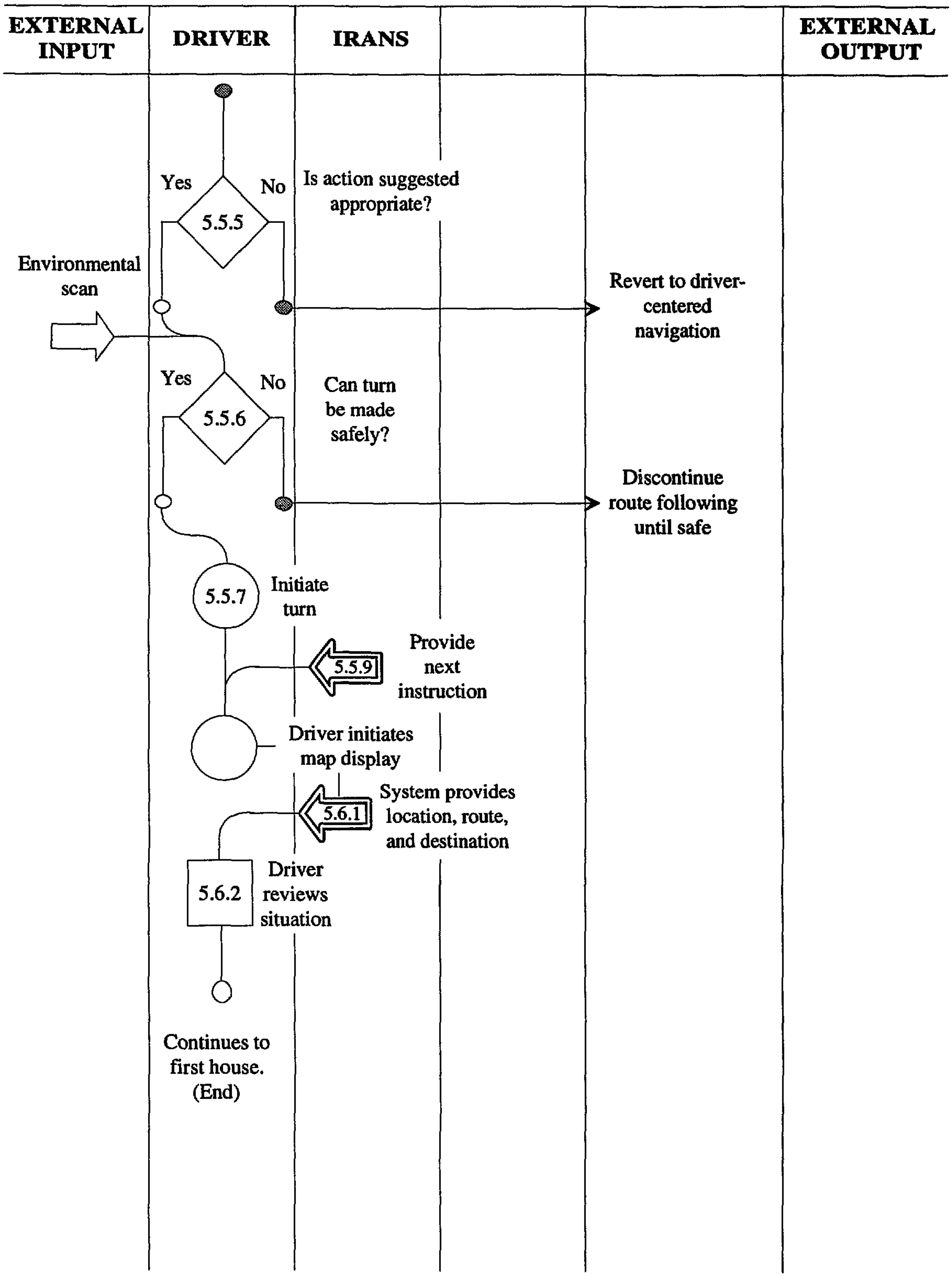



**Figure 42. Operational sequence diagram for Scenario P2 (continued).**

Table 61. Task characterization of Scenario P2.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 5.1.1.1 | DESTINATION AND STOPPING POINTS | Narrow user considerations | System demand | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 5.1.1.2 | DESIRED ROUTE PARAMETERS | Narrow user considerations | System demand | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 1.3.4.1 | TURN ON | Invoke system operation | System demand | CONTROL | System provides indication that the system is responding to input. | |
| 1.3.4.2 | VERIFY SYSTEM READINESS | Evaluate system recommendation | Goal initiation | TEST | Recommendations in appropriate detail to identify compatibility with constraints. | |
| 5.1.2.1 | ENTER DESTINATION(S) | Provide system information | System demand | CODE | Input requirements compatible with knowledge. Input actions direct. Input actions do not exceed short-term memory. | |
| 5.1.2.2 | ROUTE PARAMETERS | Limit system considerations | Ensure input accuracy | CODE | Input requirements compatible with knowledge. Input actions directly. Input actions do not exceed short-term memory. | |

## Table 61. Task characterization of Scenario P2.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| UNCODED SYSTEM ACTIONS | | | | | | |
| 2.4.5.1 | OPERATE BROADCAST RADIO/ ENTERTAINMENT SYSTEM | Invoke system operation | Goal initiation | INTERPRET | Information presented must be consistent with user's knowledge base. | |
| 5.1.3 | REVIEW RECOMMENDED ROUTE | Understand system/ environmental information | System demand | CONTROL | System provides indication of responding to input. | Initiate review of route, point by point. |
| 5.1.2.2 | ROUTE PARAMETERS | Limit system considerations | Ensure input accuracy | CODE | Input requirements directly. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 5.1.3 | REVIEW RECOMMENDED ROUTE | Understand system/ environmental information | System demand | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |
| 5.1.4 | DECIDE IF ROUTE IS ACCEPTABLE | Evaluate system recommendation | Completion of previous step | DECIDE/ SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |

## Table 61. Task characterization of Scenario P2.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.1.5 | INITIATE SYSTEM APPROVAL | Approve system output and initiate next step | Change of goals | CONTROL | System provides indication that the system is responding to input. | Bridging task from route planning to route guidance. |
| 5.5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| 5.5.2 | DRIVER OBSERVES INSTRUCTION FOR NEXT ACTION | Understand system/ environmental information | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. | |
| 5.5.3 | DRIVER PLANS FOR NEXT ROUTE ACTION | Understand system/ environmental information | Completion of previous step | PLAN | System provides necessary information. | |
| 5.5.4 | SYSTEM ALERTS DRIVER OF APPROACHING ACTION POINT | Invoke system operation | Completion of previous step | IDENTIFY | | Automatic system action. |
| 5.5.5 | DRIVER CONFIRMS ACTION IS APPROPRIATE | Evaluate system recommendation | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. | |
| 5.5.6 | DRIVER CONFIRMS THAT ACTION IS SAFE | Obtain environment information | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. | Task is in response to needs of the primary task of driving. |

**Table 61. Task characterization of Scenario P2.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.5.7 | DRIVER INITIATES NECESSARY ACTION | Execute system recommendation | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 5.5.9 | SYSTEM GENERATES NEXT INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| UNCODED DRIVER ACTIONS | | | | | | |
| 5.6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 5.6.2 | DRIVER OBSERVES NAVIGATION INFORMATION | Understand system/ environmental information | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. | |
| END OF SCENARIO | | | | | | |

**Scenario P8**

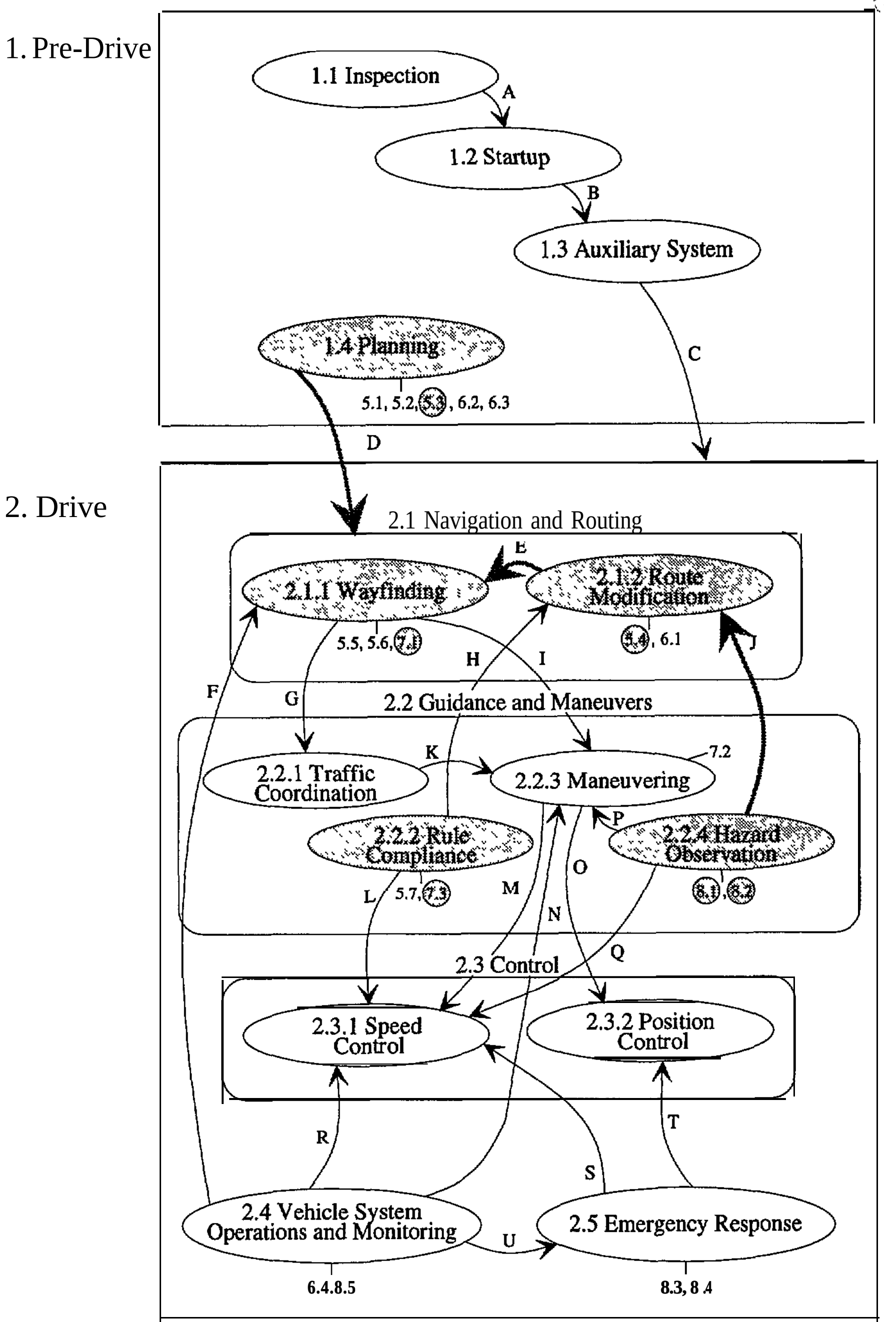
Purpose: To illustrate that the requirements generated by ATIS may impose high workload demands on the driver.

**Summary**: A business traveler is driving in the suburbs of a major city that he is not familiar with, during a heavy snowstorm, at dinner time. He has selected a 20-mi (32.2km) drive, recommended by the ATIS, from his hotel to his first destination that 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.

Function Interaction Diagram: See figure 43.

Operational Sequence Diagram: See figure 44.

Task Characterization: See table 62.




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 traffic
L Deviation from regulations
M Requires speed increase/decrease
N Failure requires change in speed/ position
0 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 43. Function interaction diagram for Scenario PS.**

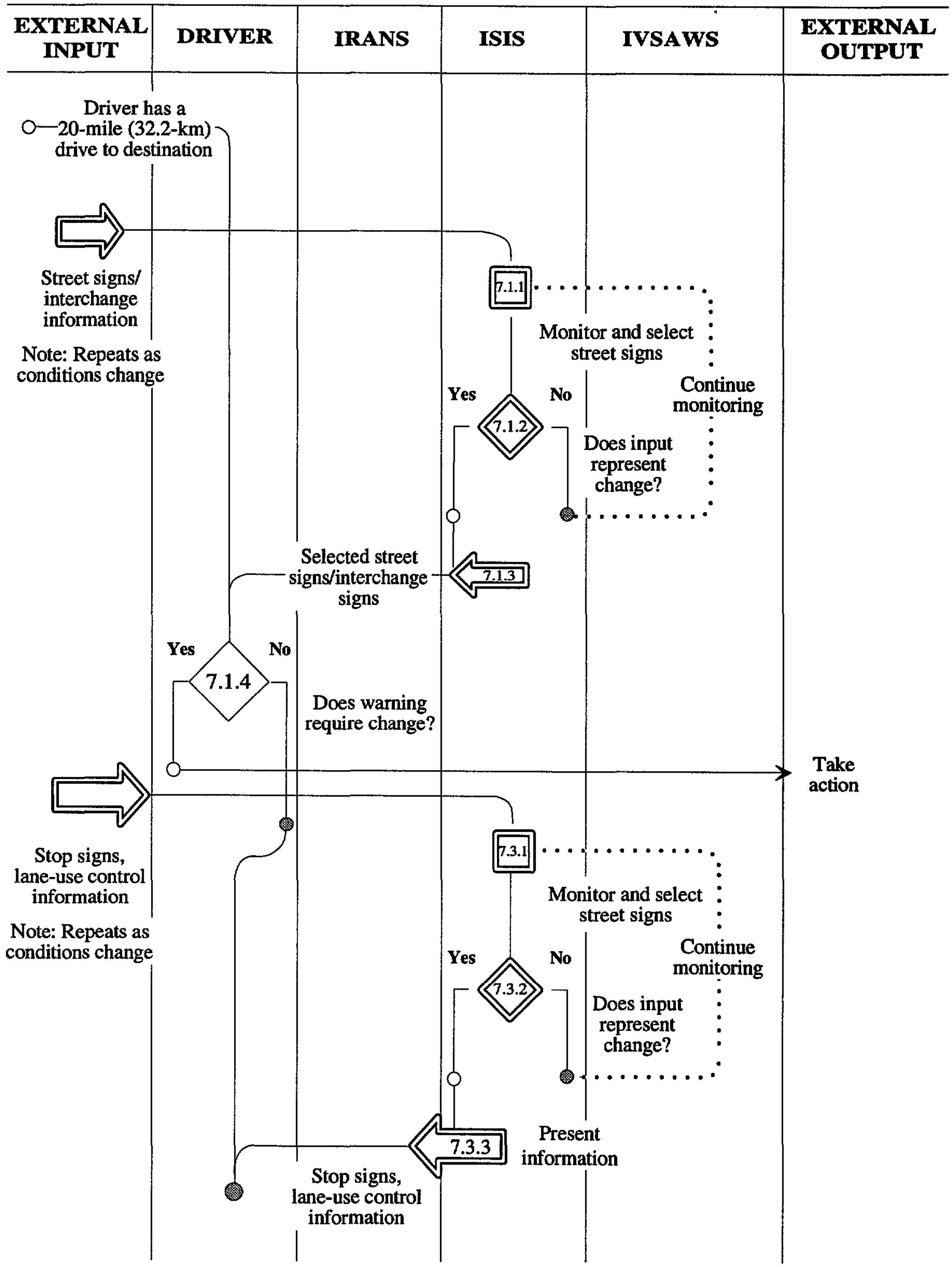



**Figure 44. Operational sequence diagram for Scenario P8.**

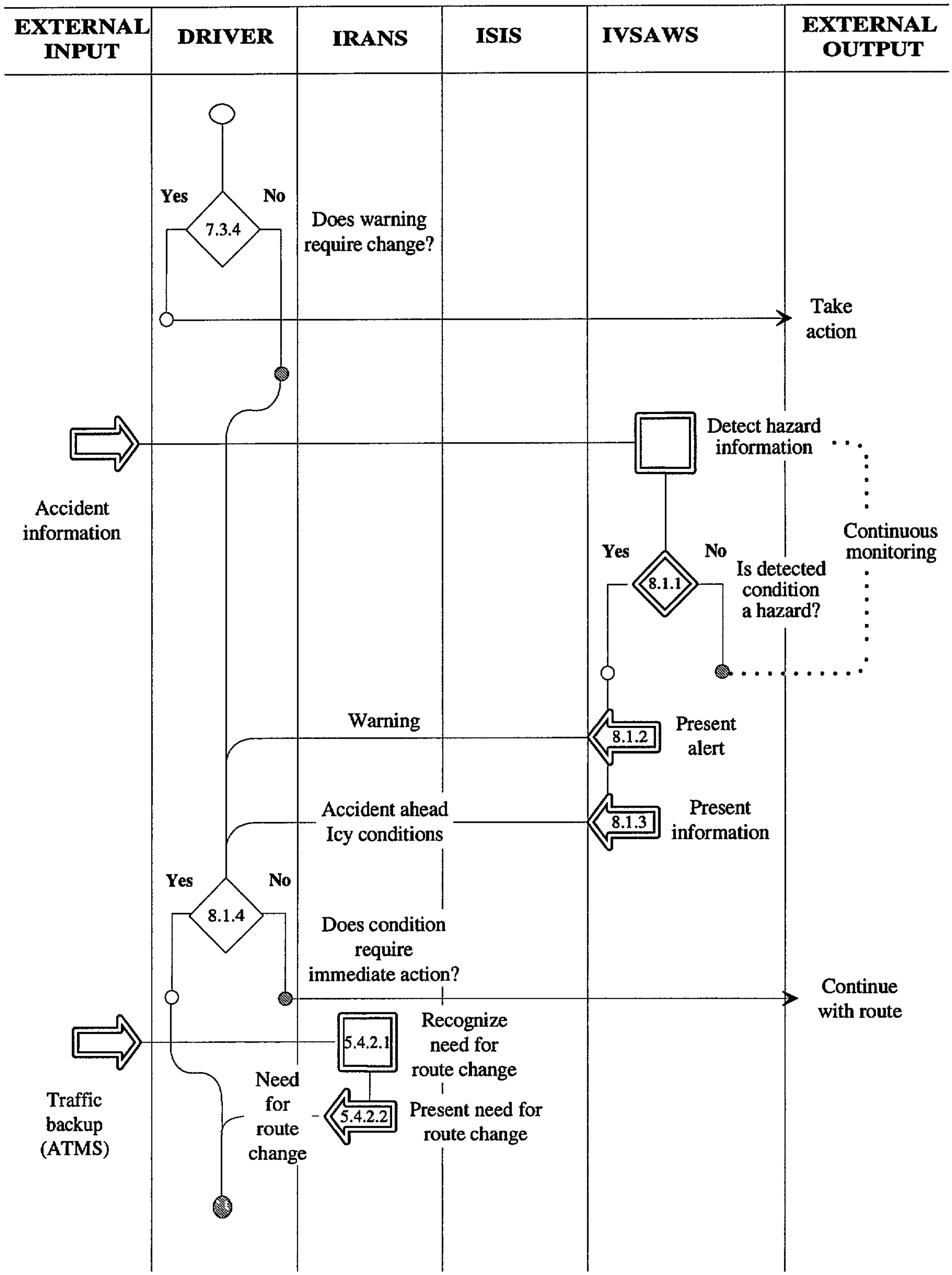



**Figure 44. Operational sequence diagram for Scenario P8 (continued).**

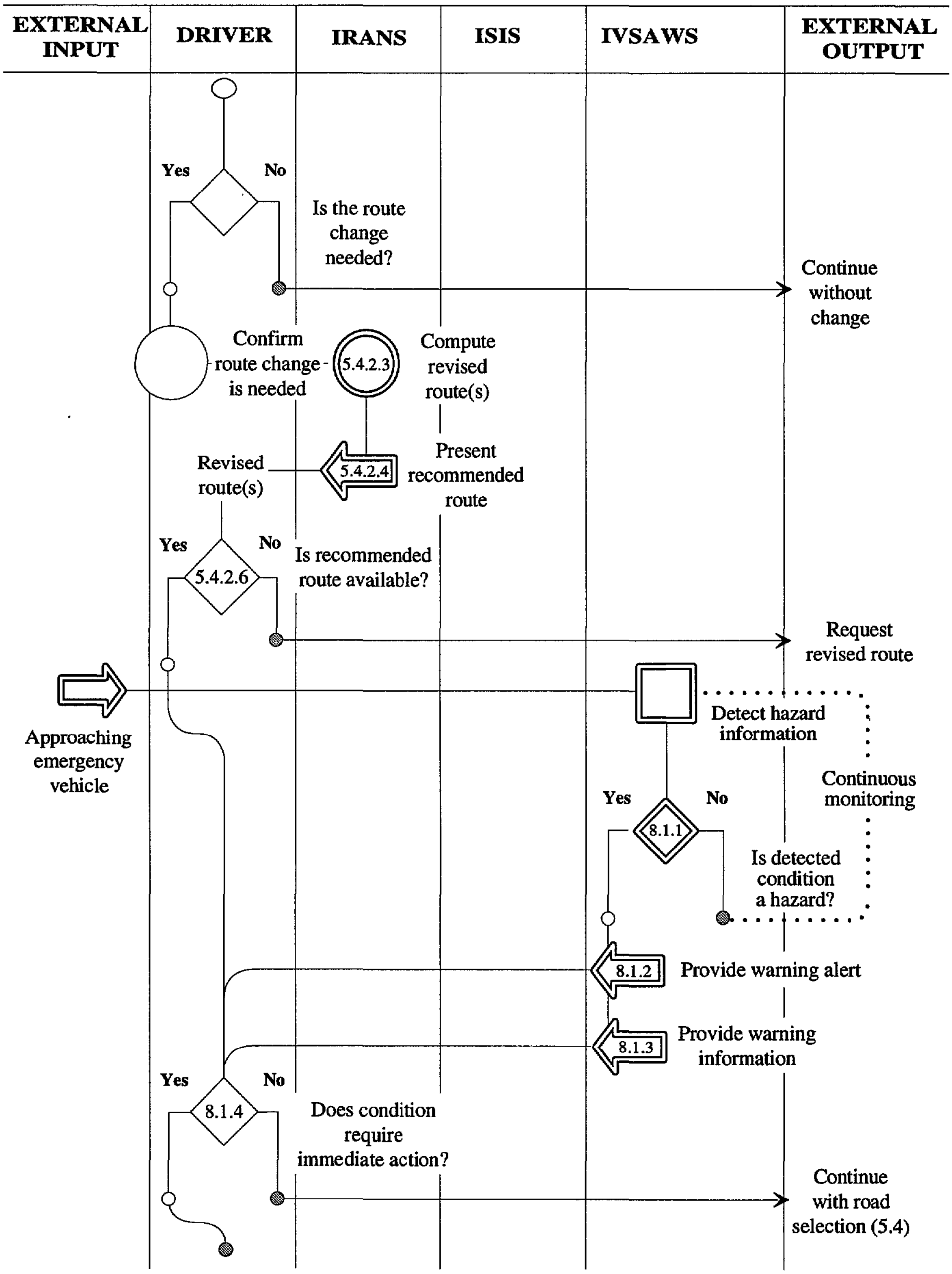



**Figure 44. Operational sequence diagram for Scenario P8 (continued).**

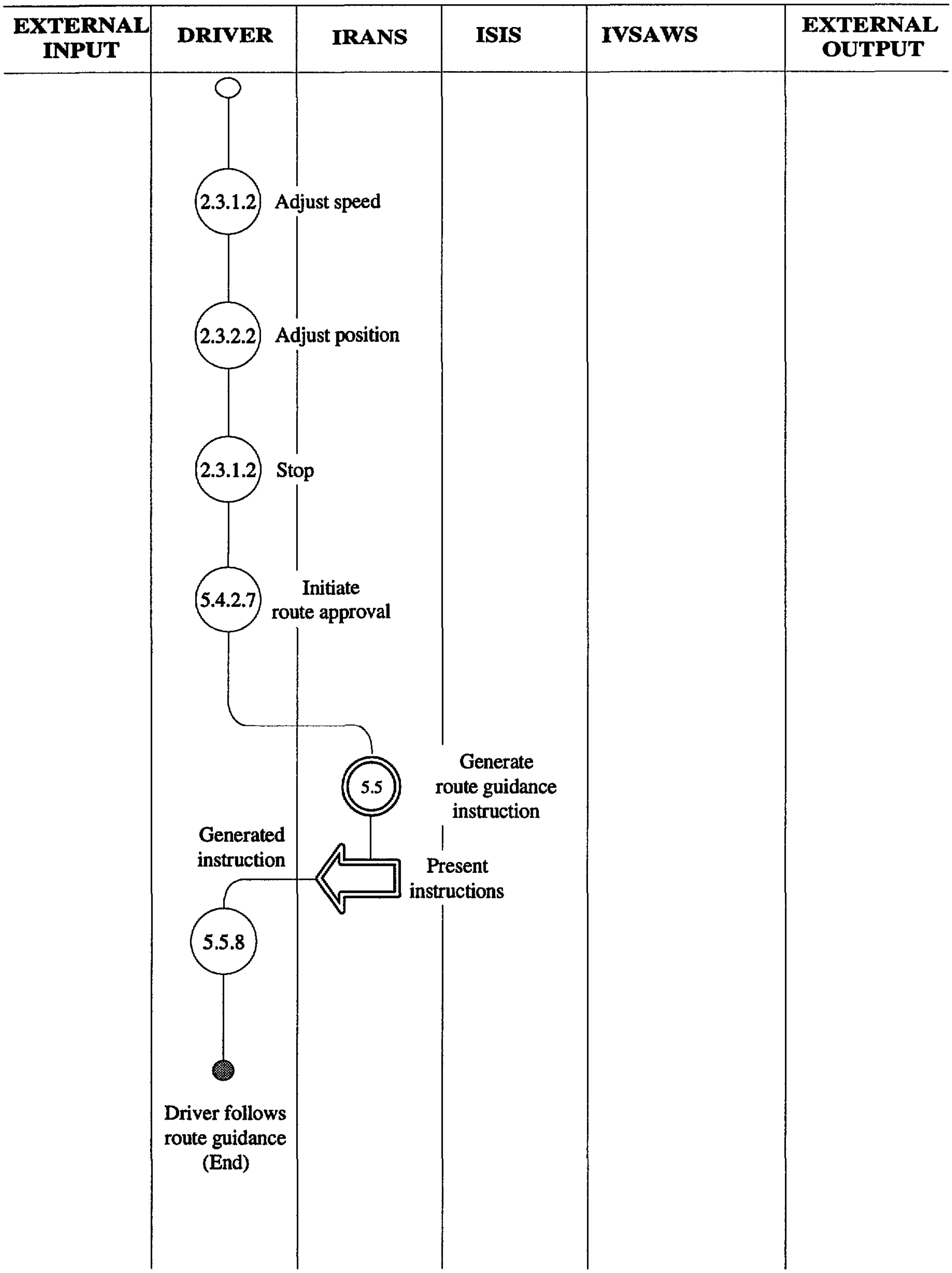



**Figure 44. Operational sequence diagram for Scenario P8 (continued).**

**Table 62. Task characterization of Scenario P8.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 7.1.1 | SYSTEM MONITORS ISIS INPUT | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 7.1.2 | SELECTS ROADWAY GUIDANCE SIGN INFORMATION | Automatic system operation | System demand | TEST | | System action to match signal against parameters. |
| 7.1.3 | SYSTEM PRESENTS SELECTED SIGN INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 7.1.4 | DRIVER ACTS ON SIGN INFORMATION AS DESIRED | Understand system/ environmental information | Change of goals | DECIDE/SELECT | Recommendation consistent with driver's experience. | |
| 7.3.1 | SYSTEM MONITORS ISIS INPUT | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 7.3.2 | SELECTS ROADWAY REGULATORY SIGN INFORMATION | Automatic system operation | System demand | TEST | | System matches received signal against present parameters. |

Table 62. Task characterization of Scenario P8.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 7.3.3 | SYSTEM PRESENTS SELECTED SIGN INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 7.3.4 | DRIVER ACTS ON SIGN INFORMATION AS DESIRED | Understand system/ environmental information | Change of goals | DECIDE/SELECT | Adequate information for driver to predict outcome. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 3.1.1 | SYSTEM DETECTS HAZARD NOTIFICATION | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 3.1.2 | SYSTEM ALERTS DRIVER OF HAZARD | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 3.1.3 | SYSTEM PROVIDES INFORMATION ON HAZARD TYPE | Automatic system operation | System demand | CODE | | Automatic system action. |
| 3.1.4 | DRIVER TAKES APPROPRIATE ACTION IN RESPONSE TO HAZARD | Understand system/ environmental information | Change of goals | DECIDE/SELECT | | Adequate information for driver to predict outcome. |

Table 62. Task characterization of Scenario P8.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 4.2.1 | SYSTEM RECOGNIZES NEED FOR REVISED ROUTE | Obtain environment information | Environmental change | COMPUTE | | Automatic system action. |
| 4.2.2 | SYSTEM ALERTS DRIVER OF CHANGE IN ROUTE CONDITIONS | Obtain system information | Environmental change | CODE | | Automatic system action. |
| UNCODED DRIVER ACTIONS | | | | | | |
| 4.2.3 | SYSTEM COMPUTES REVISED ROUTE! RECOMMENDATION | Invoke system operation | Completion of previous step | COMPUTE | | Automatic system action. |
| 4.2.4 | SYSTEM PRESENTS REVISED ROUTE | Obtain system information | Environmental change | CODE | | Automatic system action. |
| 4.2.6 | DECIDES IF RECOMMENDED ROUTE IS SATISFACTORY | Verify output meets expectations | Completion of previous step | DECIDWSELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |

## Table 62. Task characterization of Scenario PS.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| UNCODED SYSTEM ACTIONS | | | | | | |
| 1.1.1 | SYSTEM DETECTS HAZARD NOTIFICATION | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 1.1.2 | SYSTEM ALERTS DRIVER OF HAZARD | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 1.1.3 | SYSTEM PROVIDES INFORMATION ON HAZARDTYPE | Automatic system operation | System demand | CODE | | Automatic system action. |
| 8.1.4 | DRIVER TARES APPROPRIATE ACTION IN RESPONSE TO HAZARD | Understand system/ environmental information | Change of goals | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |
| 2.3.1.2 | ADJUST THROTTLE OR BRAKE TO CONTROL SPEED | Modify system operation | System demand | CONTROL | Requirements don't exceed driver's response capabilities. | |

## Table 62. Task characterization of Scenario PS.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 2.3.2.2 | ADJUST STEERING WHEEL TO COMPENSATE | Modify system operation | System demand | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 2.3.1.2 | ADJUST THROTTLE OR BRAKE TO CONTROL SPEED | Modify system operation | System demand | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 5.4.2.7 | INITIATE ROUTE APPROVAL | Approve system output and initiate next step | Completion of previous step | CONTROL | System provides indication that the system is responding to input. | |
| **5.5** | ROUTE GUIDANCE | Obtain system information | Goal initiation | CODE | | Automatic system action. |
| | | | UNCODED SYSTEM ACTIONS | | | |
| **5.5.8** | DRIVER COMPLETES NECESSARY ACTION | Make a system ready to use | Completion of previous step | CONTROL | Requirements don't exceed driver's response capabilities. | |
| | | | END OF SCENARIO | | | |

**Scenario Cl2**

<u>Purpose</u>

To illustrate the functional characteristic that had the greatest frequency count (dynamic route selection) and the one that was considered the most central (dispatch).

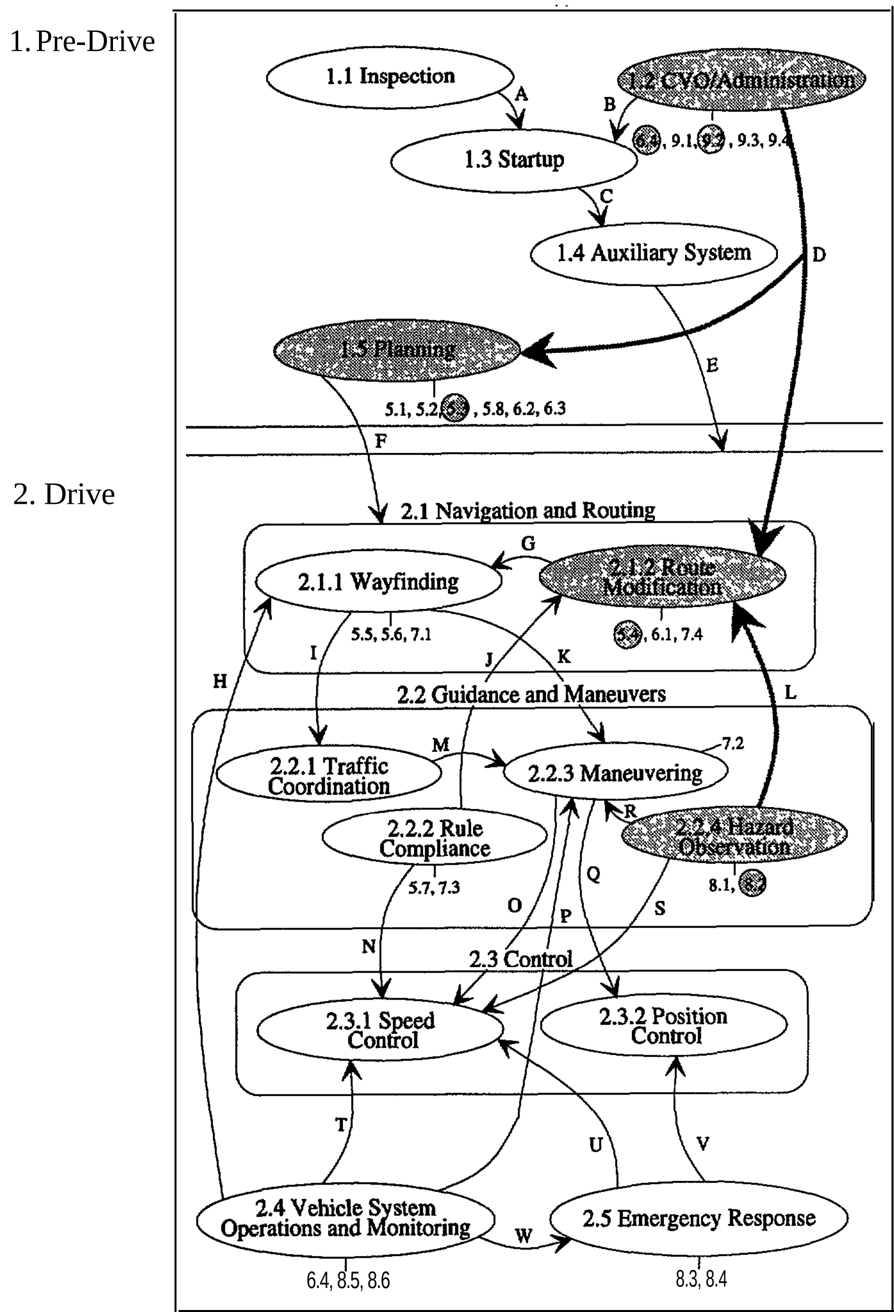
**<u>Summary</u>**

It is Friday evening, during rush hour traffic, just before a holiday. The commute is slow because it is snowing and several accidents obstruct 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 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.

<u>Function Interaction Diagram</u> See figure 45.

<u>Operational Sequence Diagram</u> See figure 46.

<u>Task Characterization</u> See table 63.




| | | |
|---|---|---|
| A Vehicle safety verified | I Maneuver required | P Failure requires change in speed/ lane position |
| B Paperwork completed | J Regulatory limits on roadway | Q Requires change in lane position |
| C Vehicle initiated | K Maneuver required | R Hazard identified |
| D Resource allocation | L Potential hazards identified in upcoming roadway | S Hazard identified |
| E Auxiliary systems initiated | M Identification of safe path through traffic | T Vehicle failure |
| F Destination and route selected | N Deviation from regulations | U Conditions requiring immediate response |
| G Route change identified | 0 Requires speed increase/decrease | V Conditions requiring immediate response |
| H Vehicle service required | | W Minimize injury/damage |

**Figure 45. Function interaction diagram for Scenario C12.**

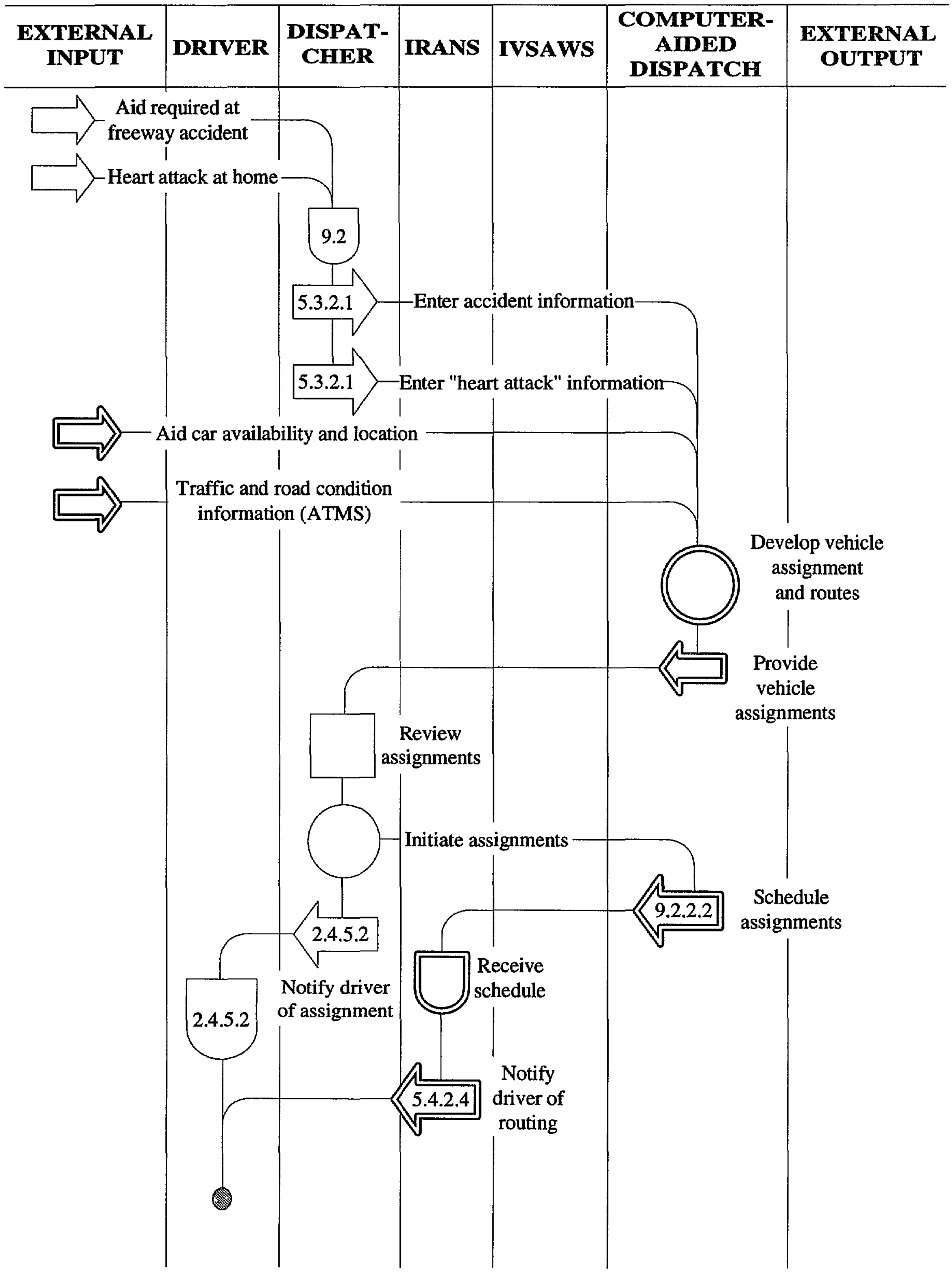



**Figure 46. Operational sequence diagram for Scenario C12.**

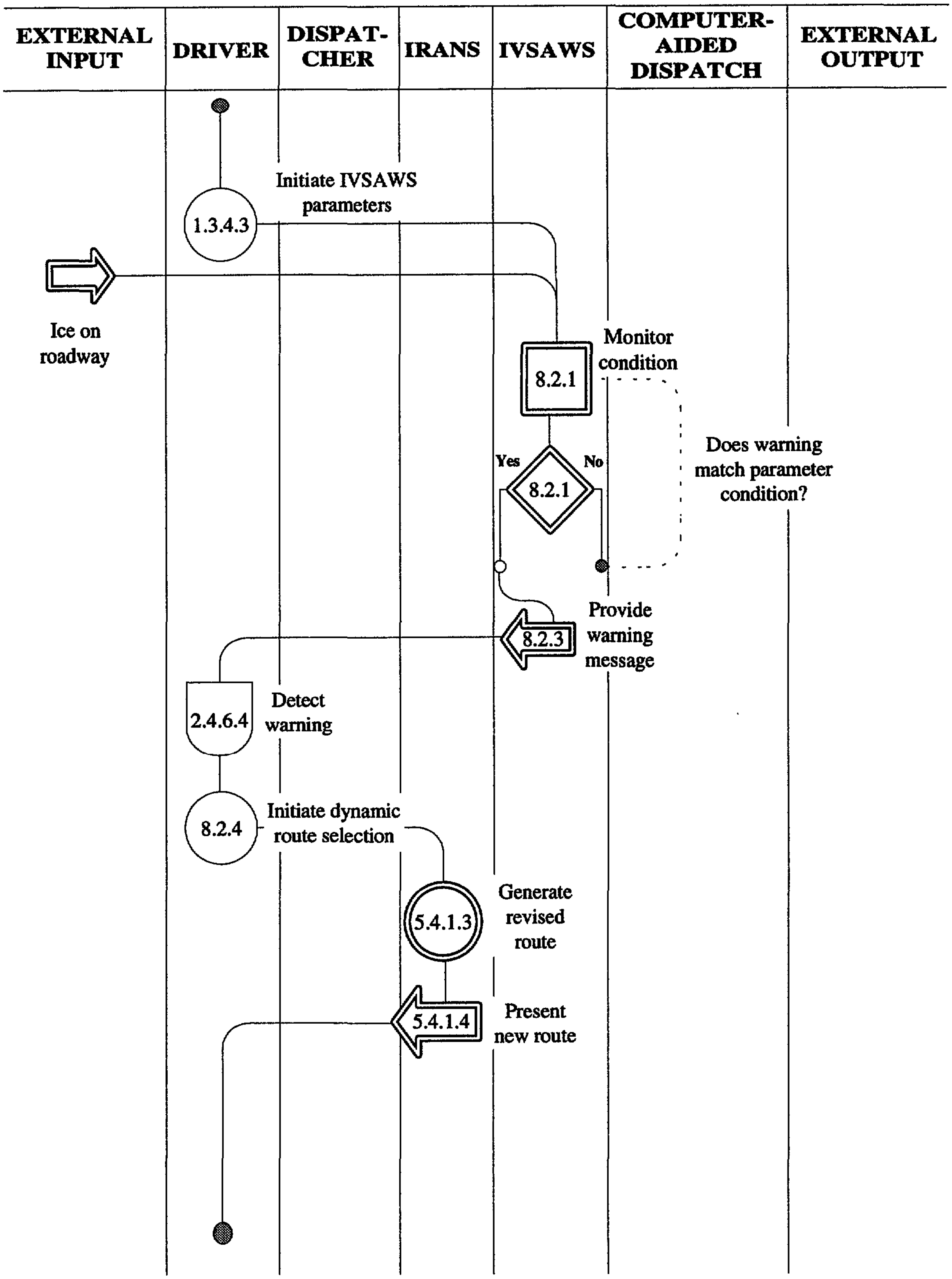



**Figure 46. Operational sequence diagram for Scenario C12 (continued).**

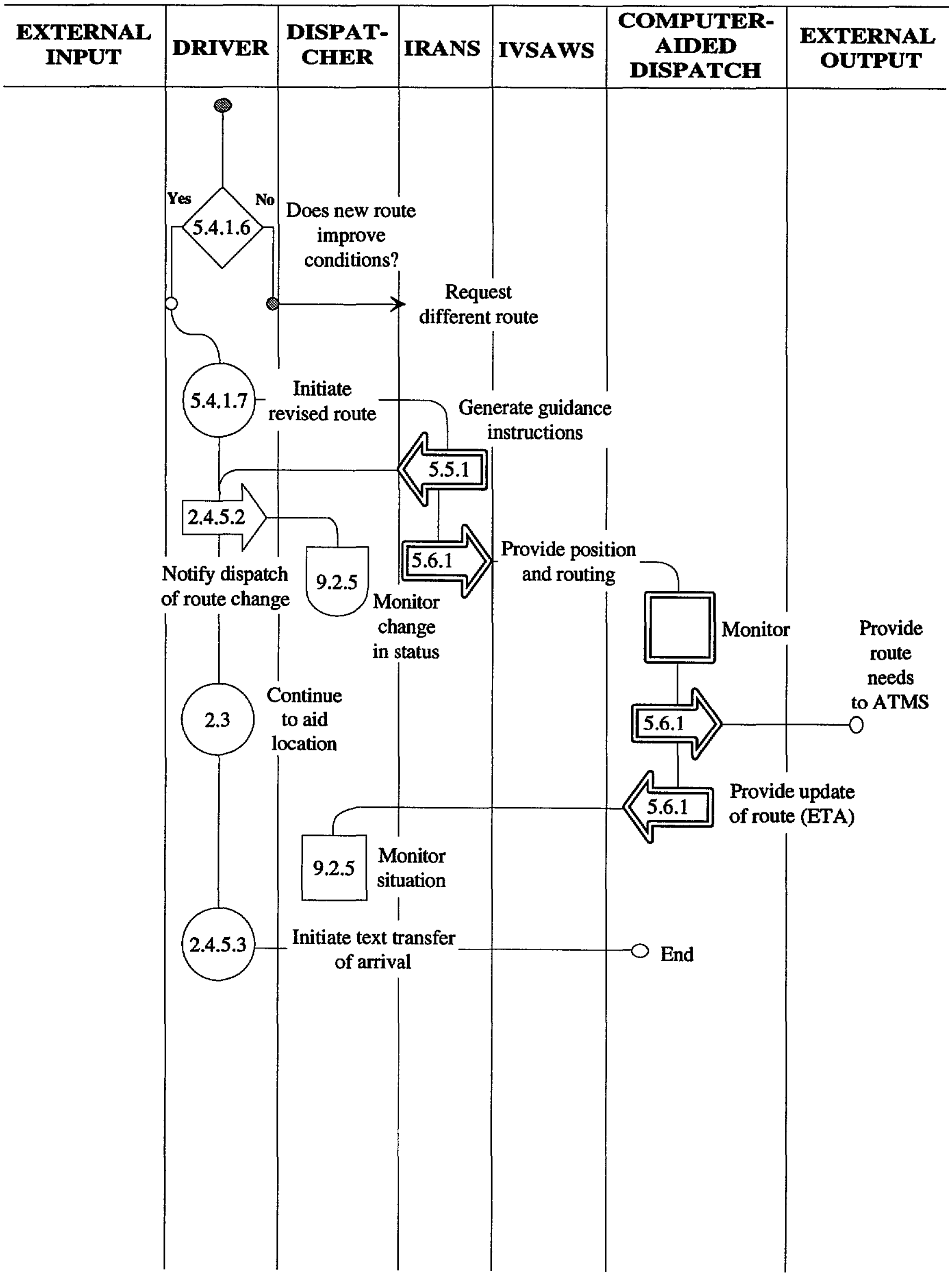



Figure 46. Operational sequence diagram for Scenario C12 (continued).

## Table 63. Task characterization of Scenario C12.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | START OF SCENARIO | | | |
| 9.2 | DISPATCH | Manually execute system functions | Goal initiation | CODE | System input requirements consistent with user's knowledge base. | |
| 5.3.2.1 | DESTINATION | Provide system information | System demand | CODE | System input requirements consistent with user's knowledge base. | First aid request . |
| 5.3.2.1 | DESTINATION | Provide system information | System demand | CODE | System input requirements consistent with user's knowledge base. | Second aid request. |
| | | | UNCODED DISPATCHER ACTIONS | | | |
| 2.4.5.2 | OPERATE TWO-WAY COMMUNICATIONS (AUDIO) | Invoke system operation | Goal initiation | CODE | System input requirements must not require user translation. | |
| 9.2.2.2 | SCHEDULE ROUTE | Evaluate system recommendation | Completion of previous step | CODE | | Automatic system action. |

## Table 63. Task characterization of Scenario C12.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | UNCODED SYSTEM ACTIONS"' | | | |
| 5.4.2.4 | **SYSTEM PRESENTS REVISED ROUTE** | **Evaluate system recommendation** | Completion of previous step | CODE | Recommendations in appropriate detail to identify compatibility with constraints. | Automatic system action. |
| 1.3.4.3 | **INITIATE SYSTEM OPERATION** | **Invoke system operation** | System demand | CONTROL | System must provide driver with indication that the system is responding. | |
| 3.2.1 | SYSTEM DETECTS ROAD CONDITION NOTIFICATION | Automatic system operation | System demand | DETECT | | Automatic system **action.** |
| 3.2.3 | SYSTEM PROVIDES INFORMATION ON ROAD CONDITION | Automatic system operation | System demand | CODE | | Automatic system **action.** |
| 2.4.6.4 | MONITORING IVSAWS WARNING | Obtain system information | Environmental change | IDENTIFY | Information presented must be consistent with user's knowledge base. | |
| 3.2.4 | DRIVER TAKES APPROPRIATE ACTION IN RESPONSE TO ROAD CONDITION | Understand system/ environmental information | Change of goals | CONTROL | System provides indication that the system is responding to input. | Automatic system action. |
| 5.4.1.3 | SYSTEM COMPUTES NEW ROUTE | Invoke system operation | Completion of previous step | COMPUTE | | Automatic system action. |

Table 63. Task characterization of Scenario C12.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.4.1.4 | SYSTEM PRESENTS REVISED ROUTE | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 5.4.1.6 | DECIDES IF RECOMMENDED ROUTE IS SATISFACTORY | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |
| 5.4.1.7 | INITIATE ROUTE APPROVAL | Approve system output and initiate next step | Completion of previous step | CONTROL | System provides indication that the system is responding to input. | |
| 5.5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| 5.6.1 | SYSTEM PROVIDES NAVIGATION INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |

Table 63. Task characterization of Scenario C12.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | UNCODED SYSTEM ACTIONS | | | |
| 9.2.5 | SUPERVISING | Obtain system information | Completion of previous step | MONITOR | System must provide dispatcher indication of present state. System must provide dispatcher indications of progress toward planning goal. | |
| 2.4.5.2 | OPERATE TWO-WAY COMMUNICATIONS (AUDIO) | Invoke system operation | Goal initiation | CODE | Input requirements directly. Input actions do not exceed short-term memory. | |
| 9.2.5 | SUPERVISING | Obtain system information | Change in environment | MONITOR | System must provide dispatcher indication of present state. System must provide dispatcher indications of progress toward planning goal. | |
| 2.3 | CONTROL | Manual execution of system function | System requirement | CONTROL | System requirements do not exceed driver's response capabilities. | |
| 2.4.5.3 | OPERATE TWO-WAY COMMUNICATIONS (TEXT) | Invoke system operation | Goal initiation | CODE | Input requirements directly. | |
| | | | END OF SCENARIO | | | |

**Scenario Cl3**

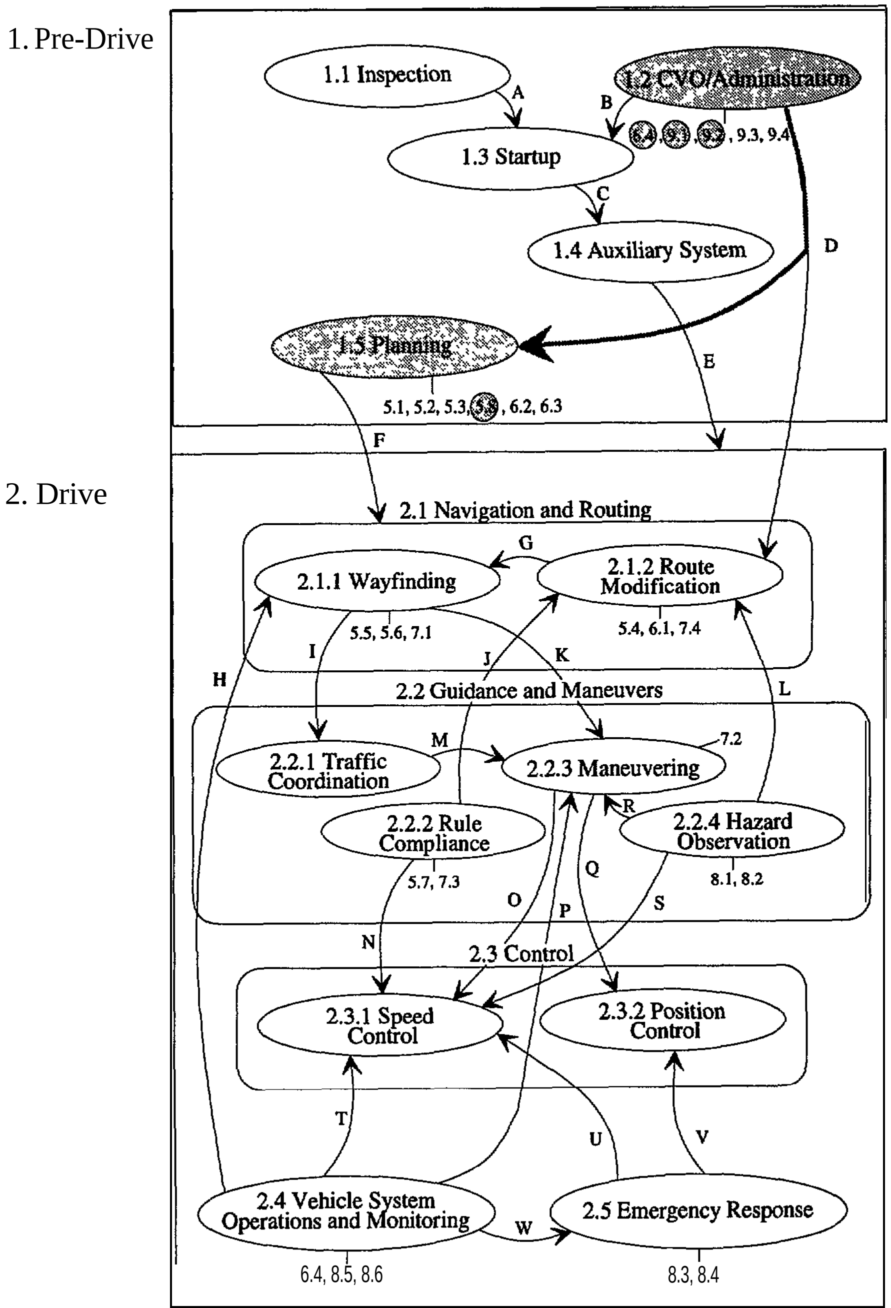
Purpose — To illustrate a grouping of functional characteristics from Cluster 1 (5.3, 5.8, 6.3, 6.4, 8.2, 9.1, and 9.2).

**Summary** — 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.

Function Interaction Diagram — See figure 47.

Operational Sequence Diagram — See figure 48.

Task Characterization — See table 64.




A Vehicle safety verified
B Paperwork completed
C Vehicle initiated
D Resource allocation
E Auxiliary systems initiated
F Destination and route selected
G Route change identified
H Vehicle service required

I Maneuver required
J Regulatory limits on roadway
K Maneuver required
L Potential hazards identified in upcoming roadway
M Identification of safe path through traffic
N Deviation from regulations
0 Requires speed increase/decrease

P Failure requires change in speed lane position
Q Requires chgn e in lane position
R Hazard identified
S Immediate hazard identified
T Vehicle failure
U Conditions requiring immediate response
**V Conditions requiring immediate response**
**W Minimize injury/damage**

**Figure 47. Function interaction diagram for Scenario C13.**

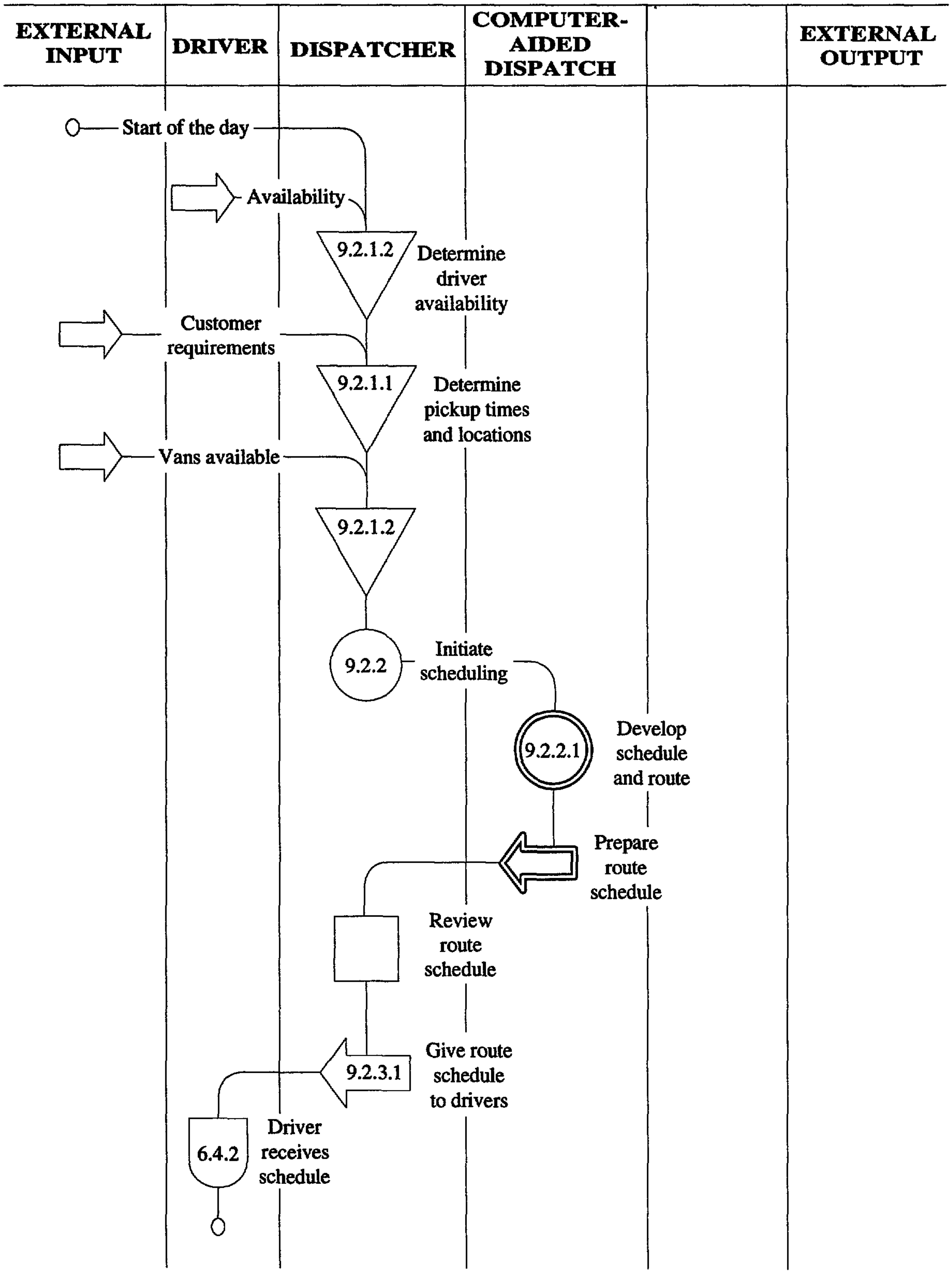



**Figure 48. Operational sequence diagram for Scenario C13.**

Table 64. Task characterization of Scenario C13.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 9.2.1.2 | GATHER INFORMATION ON RESOURCE AVAILABILITY | Provide system information | Goal initiation | INTERPRET | Information presented must be consistent with user's knowledge base. | |
| 9.2.1.1 | GATHER INFORMATION ON RESOURCE REQUIREMENTS | Provide system information | Goal initiation | INTERPRET | Information presented must be consistent with user's knowledge base. | |
| 9.2.2 | SCHEDULING | Invoke system operation | System demand | CONTROL | System provides indication that system is responding to input. | |
| 9.2.2.1 | SCHEDULE SHIPMENT PICKUP AND DELIVERY | Automatic system operation. | Completion of previous step | COMPUTE | | Automatic system action. |
| UNCODED DISPATCHER ACTIONS | | | | | | |
| 9.2.3.1 | COORDINATE DRIVERS' ACTIVITIES | Provide system information | Goal initiation | CODE | System output requirements must not require user interpretation. | |
| 6.4.2 | MESSAGE RECEIVED BY VEHICLE | Obtain system information | Goal initiation | | | |
| END OF SCENARIO | | | | | | |

**Scenario C4**

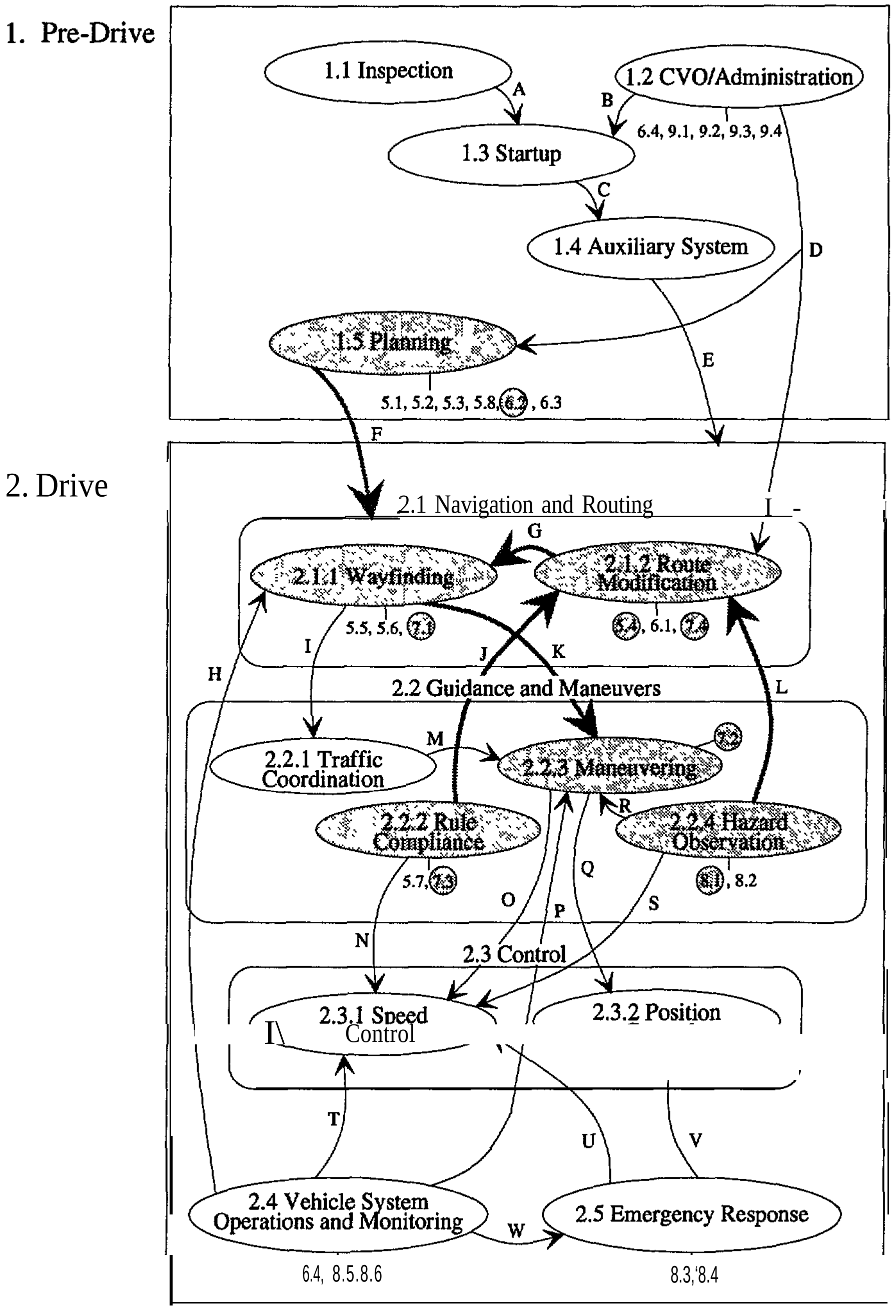
Purpose: To illustrate a grouping of the functional characteristics found in Cluster 2 (5.4, 5.6, 7.1, 7.2, and 8.1).

**Summary**: 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.

Function Interaction Diagram: See figure 49.

Operational Sequence Diagram: See figure 50.

Task Characterization: See table 65.




| | | |
|---|---|---|
| A Vehicle safety verified | I Maneuver required | P Failure requires change in speed/ lane position |
| B Paperwork completed | J Regulatory limits on roadway | Q Requires change in lane position |
| C Vehicle initiated | K Maneuver required | R Hazard identr |
| D Resource allocation | L Potential hazards identified in upcoming roadway | S Immediate hazard identified |
| E Auxiliary systems initiated | M Identification of safe path through traffic | T Vehicle failure |
| F Destination and route selected | N Deviation from regulations | U Conditions requiring immediate response |
| G Route change identified | 0 Requires speed increase/decrease | V Conditions requiring immediate response |
| H Vehicle service required | | W Minimize injury/damage |

**Figure 49. Function interaction diagram for Scenario C4.**

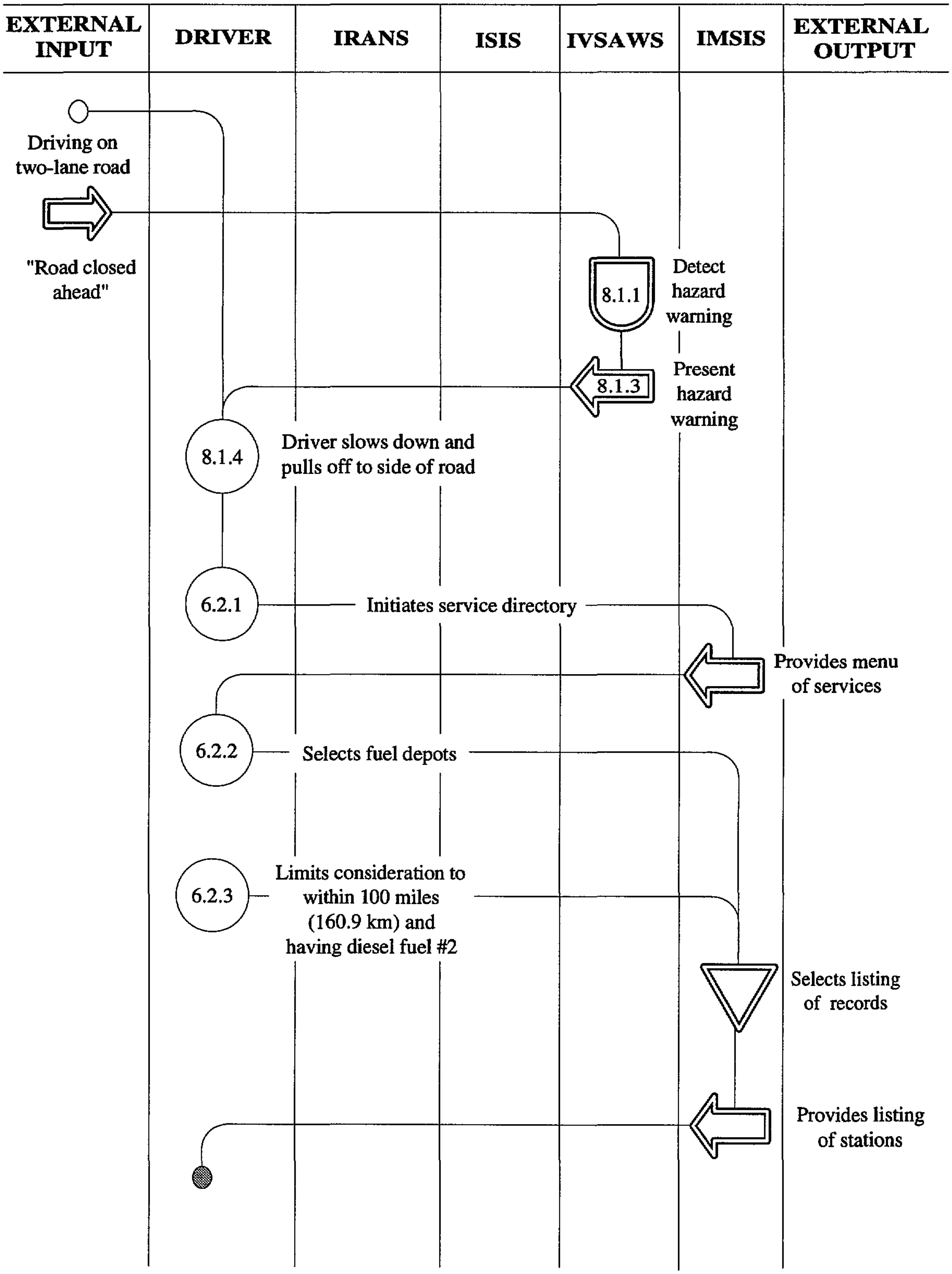



**Figure 50. Operational sequence diagram for Scenario C4.**

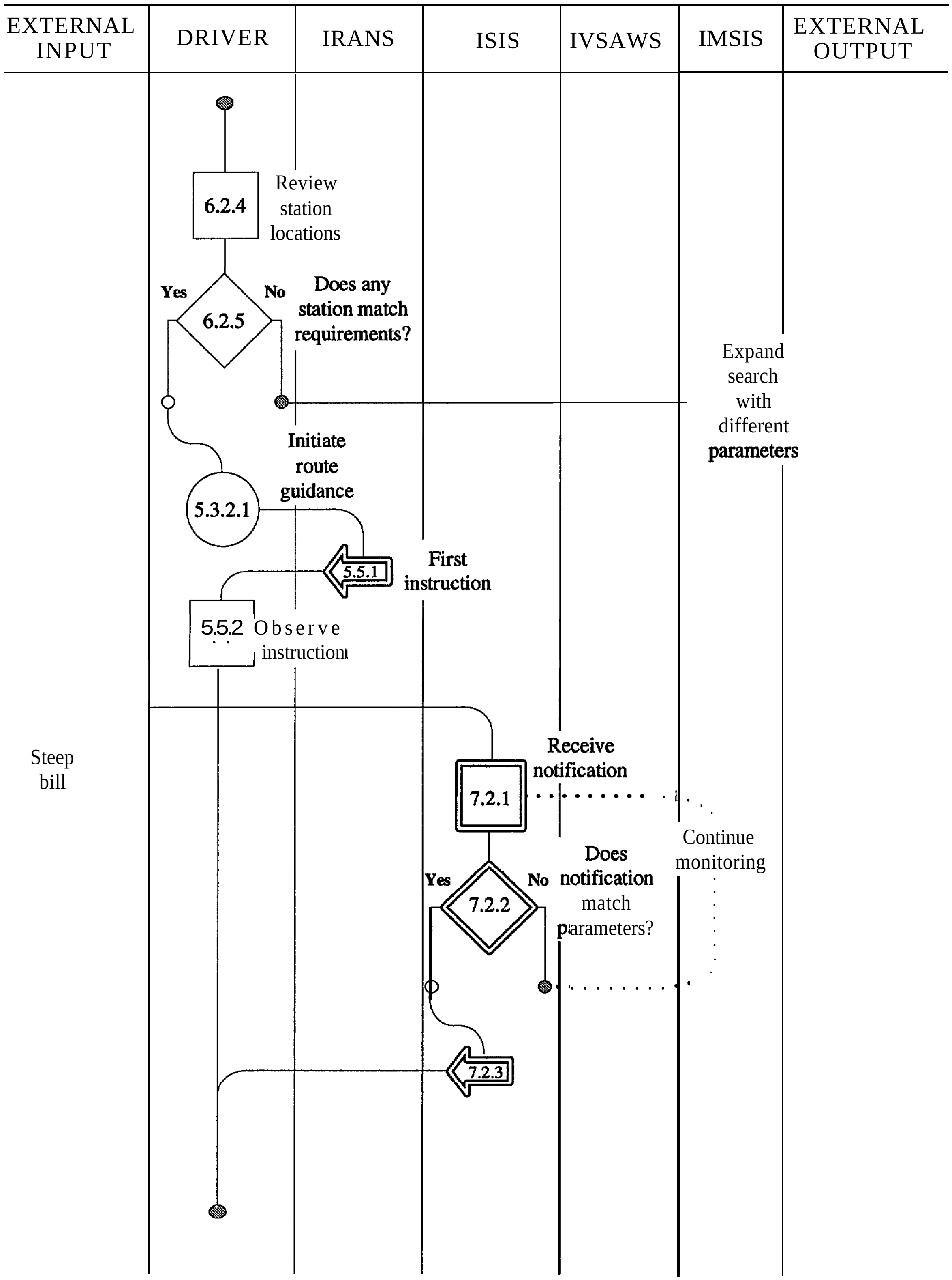



**Figure 50. Operational sequence diagram for Scenario C4 (continued).**

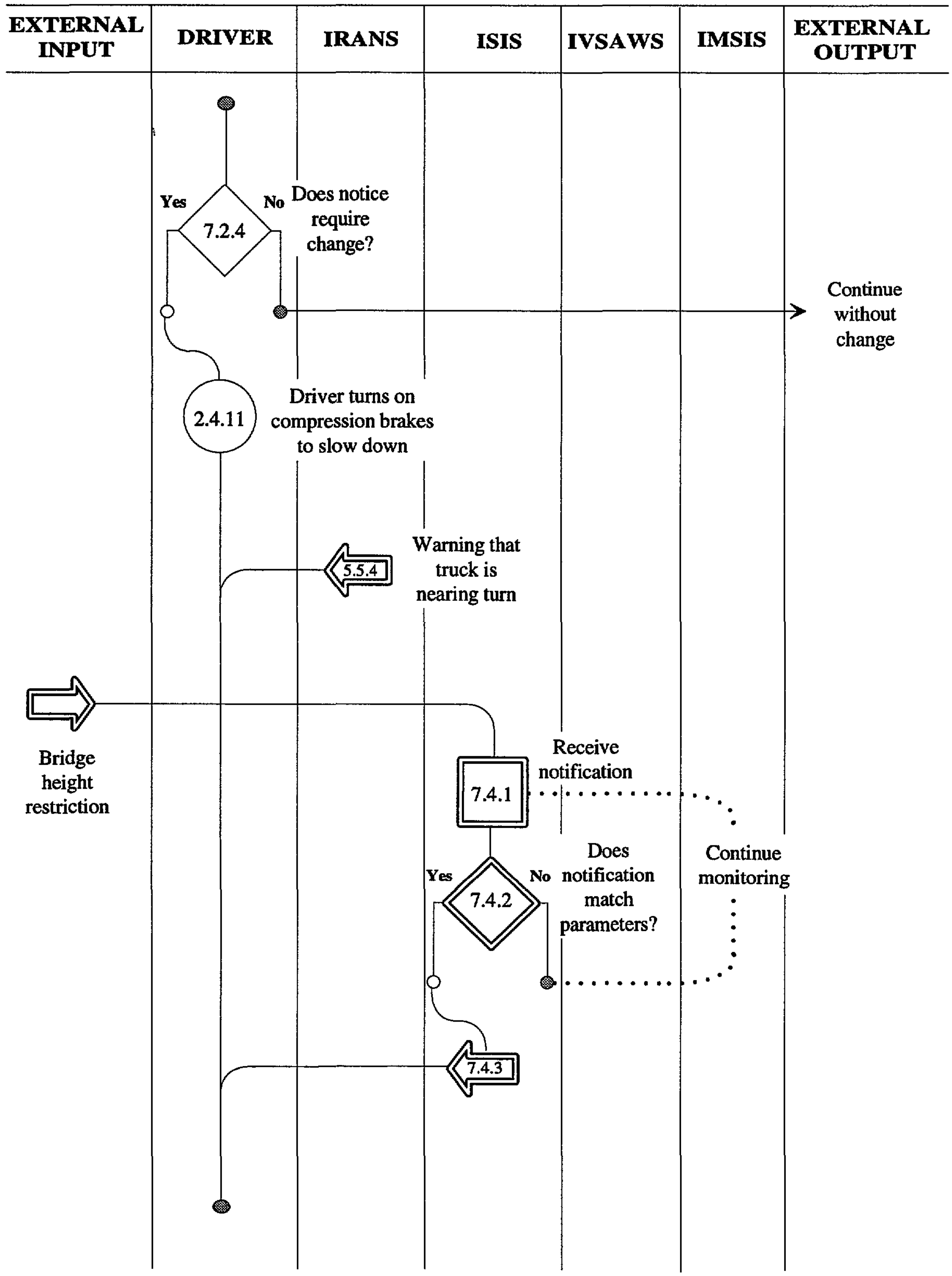



**Figure 50. Operational sequence diagram for Scenario C4 (continued).**

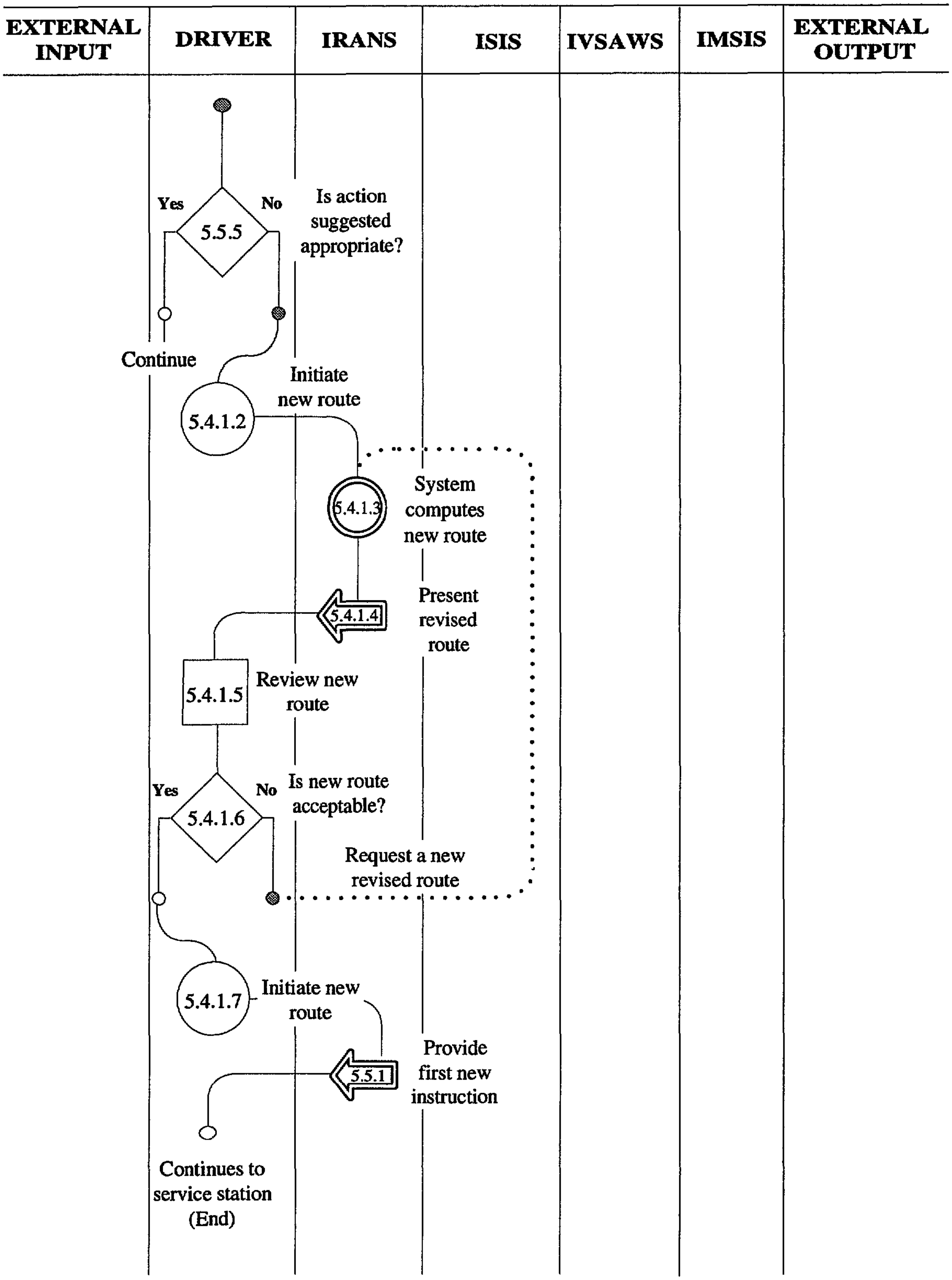



**Figure 50. Operational sequence diagram for Scenario C4 (continued).**

## Table 65. Task characterization of Scenario C4.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 8.1.1 | SYSTEM DETECTS HAZARD NOTIFICATION | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 8.1.3 | SYSTEM PROVIDES INFORMATION ON HAZARD TYPE | Automatic system operation | System demand | CODE | | Automatic system action. |
| 8.1.4 | DRIVER TAKES APPROPRIATE ACTION IN RESPONSE TO HAZARD | Understand system/ environmental information | Change of goals | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 6.2.1 | DRIVER INITIATES SERVICES/ ATTRACTIONS DIRECTORY | Make system ready to use | Goal initiation | CONTROL | System provides indication that the system is responding to input. | |
| UNCODED SYSTEM ACTIONS | | | | | | |
| 6.2.2 | SELECT CLASS OF SERVICES DESIRED | Limit system considerations | System demand | CODE | Input requirements directly. | |

Table 65. Task characterization of Scenario C4.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 6.2.3 | SELECT PARAMETERS FOR CLASS OF SERVICES | Limit system considerations | System demand | CODE | Input requirements compatible with user's knowledge. Input requirements directly. | |
| | | | UNCODED SYSTEM ACTIONS | | | |
| 6.2.4 | REVIEW LISTING | Obtain system information | Completion of previous step | SEARCH | Information presentation must not exceed short-term memory capabilities. Information presented must be consistent with user's knowledge base. | |
| 6.2.5 | SELECT ITEM FROM LISTING | Approve system output and initiate next step | Completion of previous step | DECIDE/SELECT | System must provide adequate information for user to predict outcome. | |
| 5.3.2.1 | DESTINATION | Provide system information | System demand | CONTROL | System provides indication that system is responding to input. | Task moves destination information from IMSIS to IRANS |
| 5.5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |

**Table 65. Task characterization of Scenario C4.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.5.2 | DRIVER OBSERVES INSTRUCTION FOR NEXT ACTION | Understand system/ environmental information | Completion of previous step | INTERPRET | Information presented must be consistent with user's knowledge base. Information presented must be consistent with user's understanding of system goals. | |
| 7.2.1 | SYSTEM MONITORS ISIS INPUT | Automatic system operation | System demand | DETECT | | Automatic system action. |
| 7.2.2 | SELECTS ROADWAY NOTIFICATION SIGN INFORMATION | Automatic system operation | System demand | TEST | | System matches received signal against preset parameters. Automatic system action. |
| 7.2.3 | SYSTEM PRESENTS SELECTED SIGN INFORMATION | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 7.2.4 | DRIVER ACTS ON SIGN INFORMATION AS DESIRED | Understand system/ environmental information | Change of goals | DECIDE/SELECT | System must provide adequate information for user to predict outcome. | |

**Table 65. Task characterization of Scenario C4.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 2.4.11 | USE ENGINE RETARDER AND COMPRESSION BRAKES | Invoke system operation | Change in environment | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 5.5.4 | SYSTEM ALERTS DRIVER OF APPROACHING ACTION POINT | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| 7.4.1 | SYSTEM MONITORS CVO REGULATORY INFORMATION | Make system ready to use | Goal initiation | MONITOR | | Automatic system action. |
| 7.4.2 | SYSTEM SELECTS CVO REGULATORY INFORMATION | Understand system/ environmental information | Changes in environment | TEST | | Automatic system action. |
| 7.4.3 | SYSTEM PRESENTS CVO REGULATORY INFORMATION | Provide system information | Completion of previous step | CODE | | Automatic system action. |
| 5.5.5 | DRIVER CONFIRMS ACTION IS APPROPRIATE | Evaluate system recommendation | Completion of previous step | DECIDE/SELECT | | System must provide adequate information for user to predict outcome. |

## Table 65. Task characterization of Scenario C4.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.4.1.2 | INITIATE NEW ROUTE REQUEST OF IRANS | Provide system information | Completion of previous step | CONTROL | System provides indication that the system is responding to input. | |
| 5.4.1.3 | SYSTEM COMPUTES NEW ROUTE | Invoke system operation | Completion of previous step | COMPUTE | | Automatic system action. |
| 5.4.1.4 | SYSTEM PRESENTS REVISED ROUTE | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 5.4.1.5 | DRIVER REVIEWS RECOMMENDED ROUTE | Evaluate system recommendation | Completion of previous step | TEST | Recommendations in appropriate detail to identify compatibility with constraints. Recommendations compatible with short-term memory. Level of detail does not increase workload. | |

**Table 65. Task characterization of Scenario C4.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| 5.4.1.6 | DECIDES IF RECOMMENDED ROUTE IS SATISFACTORY | Verify output meets expectations | Completion of previous step | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |
| 5.4.1.7 | INITIATE ROUTE APPROVAL | Approve system output and initiate next step | Completion of previous step | CONTROL | System provides indication that the system is responding to input. | |
| 5.5.1 | SYSTEM GENERATES INSTRUCTION | Invoke system operation | Completion of previous step | CODE | | Automatic system action. |
| END OF SCENARIO | | | | | | |

**Scenario Cl1**

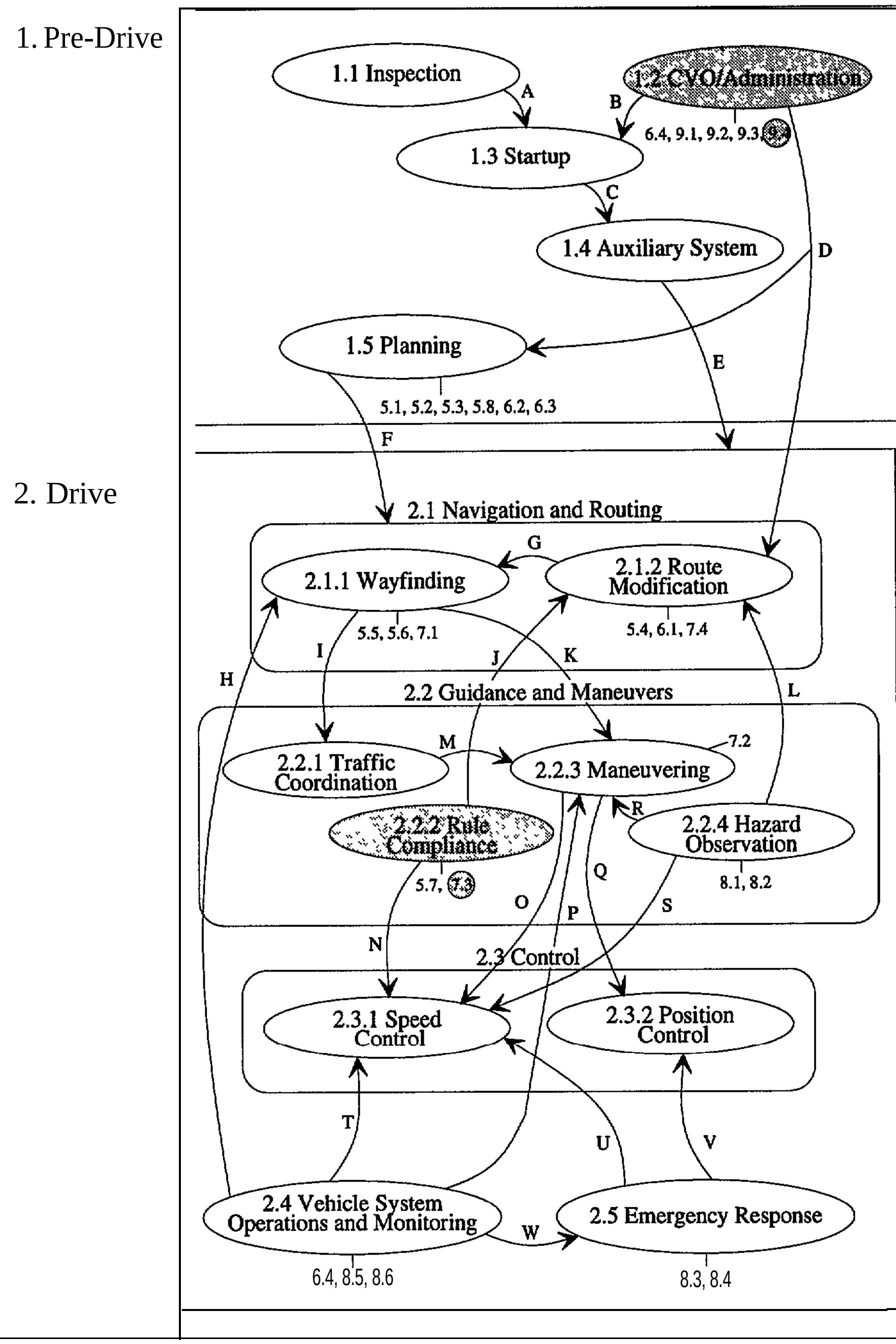
Purpose — To illustrate a grouping of functional characteristics from Cluster 3 (5.1, 5.2, 5.7, 9.3, and 9.4).

Summary — An experienced interstate truck operator is passing between two States at nighttime. Prior to reaching the inspection point, her 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.

Function Interaction Diagram — See figure 51.

Operational Sequence Diagram — See figure 52.

Task Characterization — See table 66.




A Vehicle safety verified
B Paperwork completed
C Vehicle initiated
D Resource allocation
E Auxiliary systems initiated
F Destination and route selected
G Route change identified
H Vehicle service required

I Maneuver required
J Regulatory limits on roadway
K Maneuver required
L Potential hazards identified in upcoming roadway
M Identification of safe path through traffic
N Deviation from regulations
0 Requires speed increase/decrease

P Failure requires change in speed/lane position
Q Requires change in lane position
R Hazard identified
S Immediate hazard identified
T Vehicle failure
U Conditions requiring immediate response
V Conditions requiring immediate response
W Minimize injury/damage

**Figure 51. Function interaction diagram for Scenario C11.**

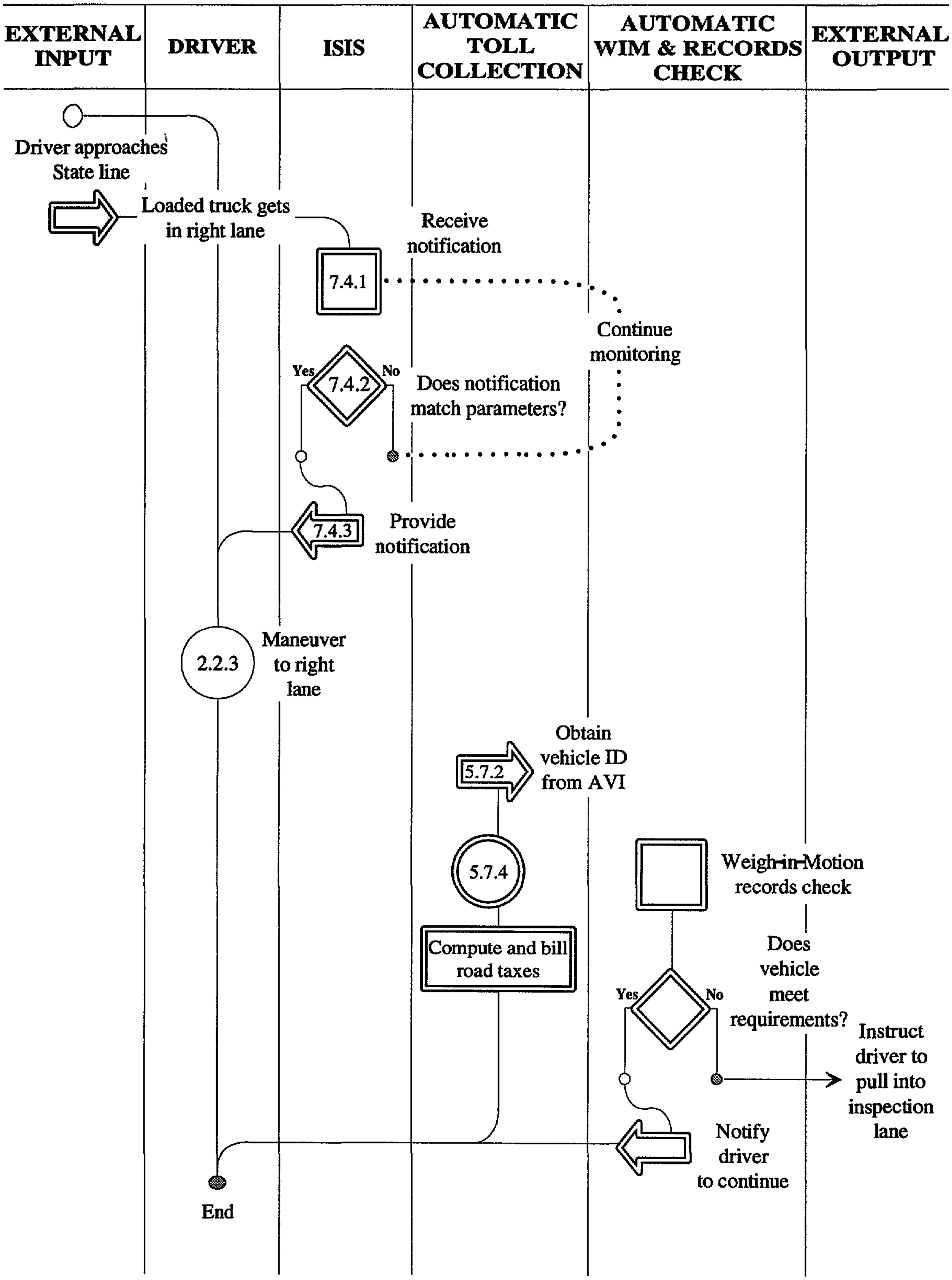



**Figure 52. Operational sequence diagram for Scenario C11.**

**Table 66. Task characterization of Scenario C11.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| START OF SCENARIO | | | | | | |
| 7.4.1 | SYSTEM MONITORS CVO REGULATORY INFORMATION | Automatic system operation | Goal initiation | MONITOR | | Automatic system action. |
| 7.4.2 | SYSTEM SELECTS CVO REGULATORY INFORMATION | Automatic system operation | System demand | TEST | | Automatic system action. |
| 7.4.3 | SYSTEM PRESENTS CVO REGULATORY INFORMATION | Direct vehicle | Environmental change | CODE | | Automatic system action. |
| 2.2.3 | MANEUVERING | Invoke system operation | Goal initiation | CONTROL | Requirements don't exceed driver's response capabilities. | |
| 5.7.2 | SYSTEM QUERIES VEHICLE FOR TOLL TAG OR AVI | Invoke system operation | Completion of previous step | SEARCH | | Automatic operation. |
| 5.7.4 | SYSTEM INITIATES AUTOMATIC BILLING OR DEDUCTS TOLL | Invoke system operation | Completion of previous step | CONTROL | | |
| END OF SCENARIO | | | | | | |

**Scenario Cl5**

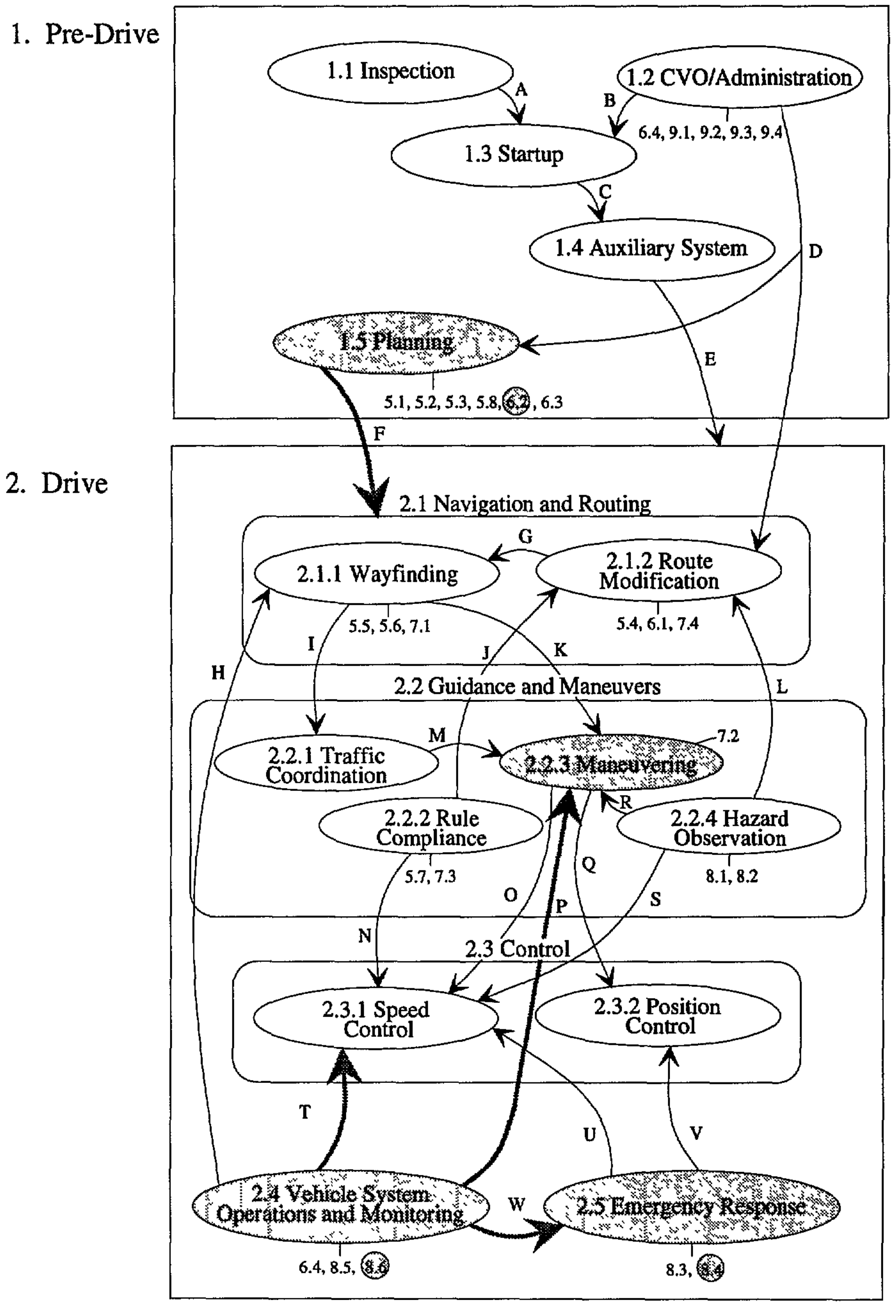
<u>Purpose</u> To illustrate a grouping of functional characteristics from Cluster 5 (6.1, 6.2, 8.4, 8.5, and 8.6).

**Summary** 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.

Function Interaction Diagram See figure 53.

Operational Sequence Diagram See figure 54.

Task Characterization See table 67.




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

**Figure 53. Function interaction diagram for Scenario C15.**

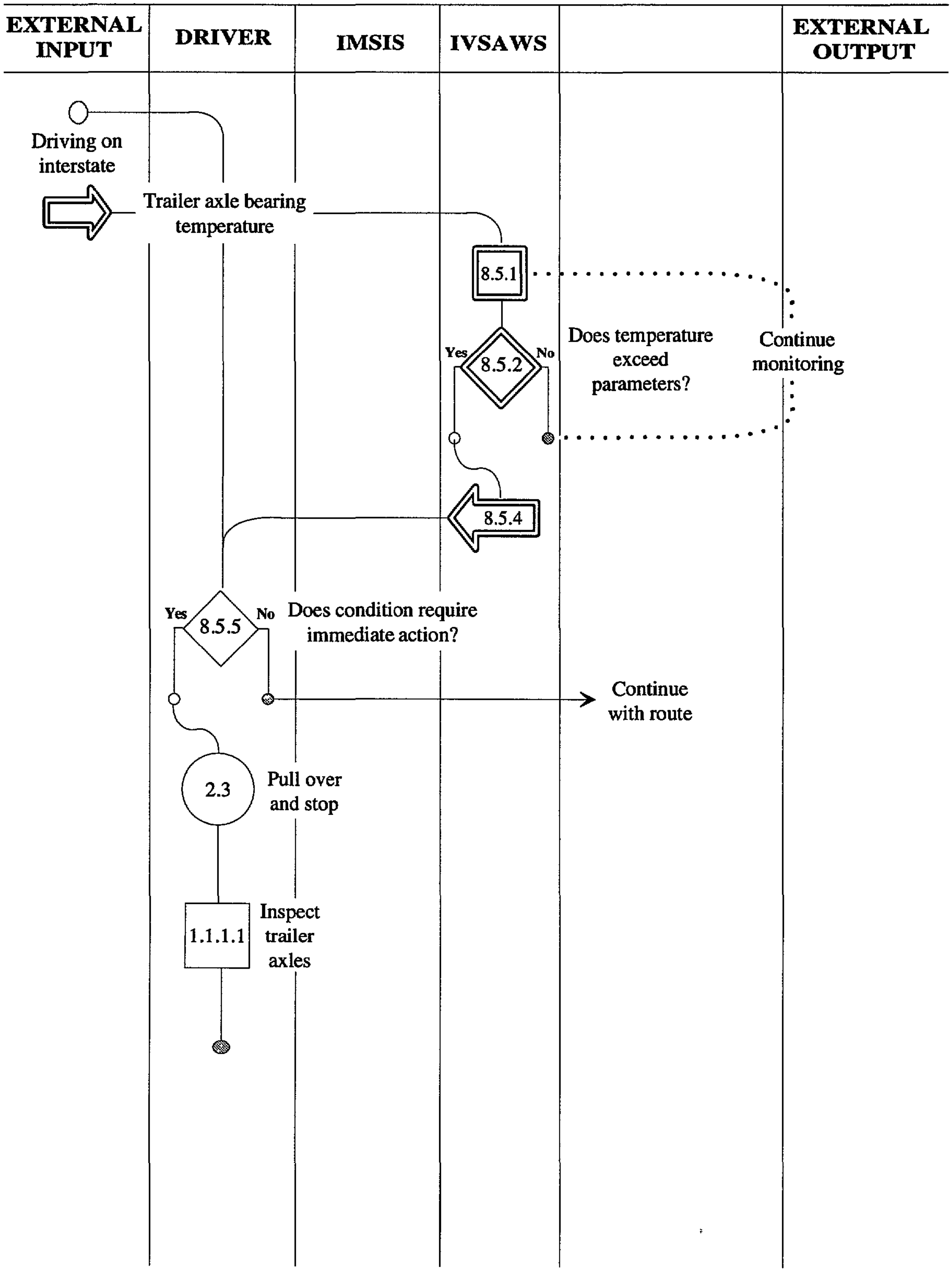



**Figure 54. Operational sequence diagram for Scenario C15.**

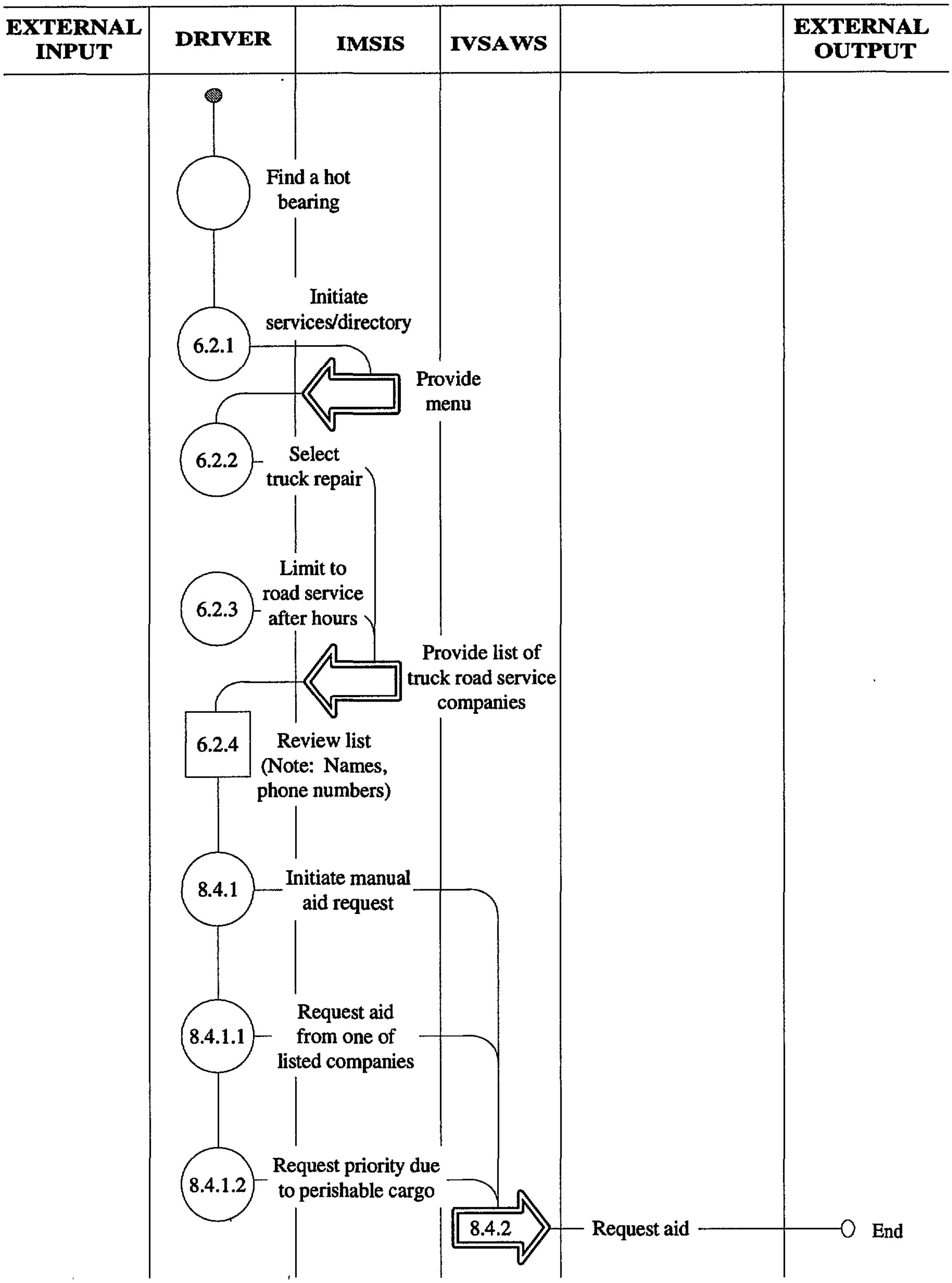



**Figure 54. Operational sequence diagram for Scenario C15 (continued).**

## Table 67. Task characterization of Scenario C15.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | START OF SCENARIO | | | |
| 8.5.1 | SYSTEM MONITORS VEHICLE PARAMETERS | Maintain safe conditions (general) | System demand | MONITOR | | Automatic system action. |
| 8.5.2 | SYSTEM DETECTS ABNORMAL CONDITION | Obtain system information | Environmental change | DETECT | | Automatic system action. |
| 8.5.4 | SYSTEM PROVIDES DESCRIPTION OF PROBLEM | Obtain system information | Completion of previous step | CODE | | Automatic system action. |
| 8.5.5 | DRIVER TAKES APPROPRIATE ACTION | Understand system/ environmental information | Change of goals | DECIDE/SELECT | | System must provide adequate information for user to predict outcome. |
| 2.3 | CONTROL | Invoke system operation | Goal initiation | CONTROL | Requirements don't exceed driver's response capabilities. | Pull over and stop. |
| 1.1.1.1 | INSPECT WHEELS | Understand system/ environmental information | System requirement | INTERPRET | Information presented must be consistent with user's knowledge base. | |

## Table 67. Task characterization of Scenario C15.

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | | | UNCODED DRIVER ACTIONS | | | |
| 6.2.1 | DRIVER INITIATES SERVICES/ ATTRACTIONS DIRECTORY | Make system ready to use | Goal initiation | CONTROL | | System provides indication that the system is responding to input. |
| | | | UNCODED SYSTEM ACTIONS | | | |
| 6.2.2 | SELECT CLASS OF SERVICES DESIRED | Limit system considerations | System demand | DECIDE/SELECT | Adequate information for user to predict outcome. Recommendations consistent with driver's experience. Recommendations don't violate known conditions or limitations. | |
| 6.2.3 | SELECT PARAMETERS FOR CLASS OF SERVICES | Limit system considerations | System demand | CODE | Input requirements compatible with user's knowledge. Input requirements directly. | |

**Table 67. Task characterization of Scenario C15.**

| REF # | FUNCTION OR TASK ELEMENT | PURPOSE | INITIATING CONDITION | DECISION ELEMENT | TASK PERFORMANCE CONSIDERATIONS | COMMENTS |
|---|---|---|---|---|---|---|
| | UNCODED SYSTEM ACTIONS | | | | | |
| 6.2.4 | REVIEW LISTING | Obtain system information | Completion of previous step | SEARCH | Information presentation must not exceed short-term memory capabilities. Information presented must be consistent with user's knowledge base. | |
| 8.4.1 | DRIVER ACTIVATES MANUAL AID REQUEST | Invoke system operation | Goal initiation | CONTROL | | (E.g., aid required, urgency.) System provides indication that system is responding to input. |
| 8.4.1.1 | AID REQUIRED | Make system ready to use | System requirement | CODE | Input requirements compatible with user's knowledge. | |
| 8.4.1.2 | URGENCY | Make system ready to use | System requirement | CODE | Input requirements compatible with user's knowledge. | |
| 8.4.2 | SYSTEM SENDS REQUEST AS WELL AS VEHICLE LOCATION | Automatic system operation | Completion of previous step | CONTROL | | Automatic system action. |
| | END OF SCENARIO | | | | | |

# APPENDIX E. INTEGRATION OF ATIS TASKS A THROUGH E

## BACKGROUND

### Structure of the Project

This project was designed to develop human factors design guidelines for ATIS/CVO systems that are based on a thorough understanding of the characteristics and limitations of potential ATIS/CVO users. To accomplish this, the project is divided into three major phases. The first phase is analytical and is used to collect, evaluate, and understand the present state of knowledge concerning human capabilities and limitations as they will affect the use of ATIS/CVO systems. This phase is nearing completion and is the primary focus of this appendix. The second phase of the project will be a series of empirical studies designed to advance the level of understanding related to ATIS/CVO system use and human capabilities and use. This phase of the project will be undertaken over the next 2 years. The last phase will integrate the findings of the analytical and empirical work into a final report and human factors design guidelines.

Task Objectives

Each task in the ATIS/CVO project has its own objectives as well as those that support the primary goals of the project.

Task A. Literature Review. Task A had four major objectives:

- Identify human factors research issues, hypotheses, empirical findings, principles, and guidelines that are applicable to ATIS/CVO systems.
- Identify relevant documentation describing existing IVHS, ATMS, ATIS, and comparable system objectives, functions, and configurations.
- Identify present and likely near-term technological and cost constraints that will necessarily drive human factors-related ATIS/CVO issues.
- Identify existing guidelines, including an analysis of the known benefits and deficiencies arising from the use of these guidelines, that are relevant to ATIS/CVO systems.

Task B. System Objectives and Performance Requirements. Task B had three major objectives:

- Identify the transportation community's performance criteria that will be used to evaluate the successful design and implementation of fully operational ATIS/CVO systems.

- Identify the common and unique characteristics of the ATIS and CVO environments.

- Describe the transportation community's conceptualization of ATIS/CVO systems in terms of operational capabilities and projected benefits based on specified system performance objectives.

Task C. Function Description. Task C had two major objectives:

- Specify system functions required to achieve the objectives defined in Task B for ATIS/CVO systems. They shall encompass routine traveling conditions, emergency conditions, and high workload conditions.

- Consider (for each PRIVATE function) who makes decisions, the types of decisions, and how they are made; the current information resources; the willingness of users to provide information/work with system; and the types of data/responses desired as input and output.

Task D. Comparable Systems Analysis. Task D had five major objectives:

- Identify a minimum of five existing systems that include features and functions comparable to ATIS/CVO functions.

- Indicate the extent to which existing systems have comparable features, functions, and engineering design concepts with the proposed ATIS/CVO. Identify the areas that are not being addressed by the existing systems, the conflicts that have arisen during system design, and the conflicts among the various systems.

- Conduct an analysis of the lessons learned in design and development of the systems examined in terms of user interface, visual information display, auditory information display, user input, communications system, cognitive demands, and system temporal requirements.

- Recommend design specifications for: (1) displaying information in a vehicle, (2) storing and retrieving information needed for licenses and permits, and (3) communicating between the driver and ATMS, as well as between the driver and the fleet manager.

- Evaluate the effectiveness of human factors handbooks used by comparable system designers.

Task E. Task Analvsis. Task E had two major objectives:

- Form a basis (along with Task F) for developing system design guidelines that will ensure that the tasks required of the user do not exceed his or her capabilities.

- Provide a detailed description of the way the user of the system needs to interact with the technology for the system to perform as intended.

**Project Goals**

The ATIS/CVO project as a whole has four primary objectives:

- Develop a precise and detailed set of human factors design guidelines to facilitate the development of safe, acceptable, and usable in-vehicle ATIS and CVO components of the IVHS.

- Help establish a common set of display standards across ATIS and ATMS, thereby ensuring the future inter-operability of these two systems.

  Assess what information travelers will need to make effective use of IVHS.

  Perform an assessment of what information travelers, drivers of both private and commercial vehicles, and system operators in commercial operations will need to receive from the Advanced Traffic Management Systems in order to make the decisions they want and/or need to make.

**Research Issues**

Many of the current ATIS/CVO human factors research issues have been identified in the strategic plan for IVHS in the United States (Department of Transportation, 1992). This strategic plan highlights the importance of human factors research and timely, appropriate guidance to designers of ATIS/CVO systems and other IVHS. Some issues of consideration are:

- Driver interface.
- Driver information.
- Behavioral issues.
- User demographics.
- Traffic management centers.

The 11 major research issues that have been identified as particularly important in the development of human factors design guidelines for ATIS are described below.

Issue 1: Existing Status of Research and Development

Both the development of guidelines and the implementation of ATIS will depend on the state of current technology and its application; therefore, an important issue for the development of human factors design guidelines is an understanding of the current state of development.

Issue 2: Formatting of Information

A key issue for the development of effective ATIS displays is the formatting of information. An understanding of the trade-offs involved in the use of various formats is important to the design of effective human factors design guidelines.

Issue 3: Driver Capacity to Assimilate Information

Developing an understanding of the capacity of drivers to assimilate and use information provided by ATIS is an important prerequisite to developing effective human factors design guidelines.

Issue 4: Knowledge, Skills, and Abilities Requirements

Understanding the knowledge, skills, and abilities needed to use ATIS/CVO systems is an important prerequisite to developing human factors design guidelines.

Issue 5: Information Requirements of ATIS/CVO Users

A comprehensive understanding of the information needs of ATIS/CVO users is necessary to developing human factors design guidelines that adequately represent those requirements.

Issue 6: Driver Acceptance of ATIS/CVO

Understanding the characteristics that will encourage driver acceptance of ATIS/CVO systems and compliance with recommendations provided by the system is an essential prerequisite to developing human factors design guidelines that adequately reflect those characteristics.

Issue 7: Driver Decision Strategies for Trip Taking

Understanding the strategies that drivers use to: (1) integrate information from several sources and several modalities, (2) engage in multi-task performance, (3) act as a supervisory controller, and (4) make decisions in rapidly changing dynamic environments is important to developing human factors design guidelines for ATIS/CVO systems.

Issue 8: Factors Influencing the Performance of Drivers

In order to develop useful human factors design guidelines for ATIS/CVO systems, it is essential to understand the factors that influence driver performance. Of particular interest are the factors that may be associated with age.

Issue 9: Issues Related to CVO Svstem Use

Developing an understanding of the specific conditions of ATIS/CVO use by commercial truckers, emergency vehicle operators, and others is important to the development of human factors design guidelines that will be appropriate for systems used in commercial vehicles.

Issue 10: Interactions Between ATIS Use and Driving

Understanding the way drivers use ATIS/CVO systems in association with driving tasks is an essential requirement for developing human factors design guidelines that will maintain and enhance driving safety.

Issue 11: ATIS System Interactions

Understanding how the various systems within ATIS will interact with one another is important to the development of human factors design guidelines.

## FINDINGS AND OBSERVATIONS RELATED TO PROJECT GOALS AND TASK OBJECTIVES

### Findings and Observations Related to Project Goals

The current state of human factors design guidelines suitable for use in development of safe, acceptable, and usable in-vehicle ATIS/CVO components of the IVHS is characterized by the availability of considerable numbers of disorganized and often conflicting guidelines that have potential application, but are obviously flawed in this application. The ATIS project identified many of these guidelines and more are discovered as the project progresses. At this point in the project, it appears that two issues will need to be developed related to the guidelines.

- Little is known about how guidelines are used by designers. Resolution of this issue is important, because to actually influence the design of ATIS/CVO systems guidelines developed by this project, their presentation will need to be compatible with the designers' needs.

- Conflicting guidelines and design situations for which no guidelines exist will need to be resolved.

Although traveler information needs will be analyzed further in the context of the national survey that was developed as part of Task F, initial indications from the focus group exercises conducted as part of Task C indicate that two distinctly different sets of information are needed by the CVO community and private drivers. The primary basis for these differences appears to be the relative mobility of the two types of vehicles and differences in the regulatory requirements that apply to each. Present systems that support ATIS development, particularly those related to IRANS and IMSIS, are most appropriate to private vehicle operations. This is particularly true of the map data bases that support IRANS data bases.

Whether CVO-related restrictions and other information would support CVO use of an IRANS would simply be a matter of adding information to these data bases or developing a different data base. The potential importance of ATIS use by commercial vehicle operators in achieving IVHS objectives makes the apparent lack of attention to CVO-specific requirements in the ATIS support structure a cause for concern.

Both private and CVO users of the ATIS require a traffic management infrastructure that is consistent across geo-political boundaries. One of the major problems that is likely to face the ATIS as it reaches the point in development where ATMS information is used by the system will be the lack of effective inter-agency and multi-district coordination. For CVO systems, this coordination will mean that common standards for permits, vehicle documentation, vehicle condition requirements, and related regulatory activities will have to be developed.

## Findings Related to Task Objectives

### Findings Related to Task A. Literature Review

The primary findings related to Task A were that the scientific literature presently available for ATIS/CVO systems is primarily oriented toward descriptions of the system and not how it will be used.

There are several ongoing demonstration projects for ATIS/CVO systems. These projects are primarily based on the demonstration of single functions (e.g., route planning, route guidance, weigh in motion, or automatic toll collection). Most of the IRANS demonstration projects do not include traffic or road condition information.

The IVHS functional design concept is still being developed with the attendant problem that basic issues related to function and task allocation are poorly developed.

Whereas IRANS, IMSIS, and many CVO subsystems of ATIS are well defined and far enough into the development stage to have prototype and even operational systems available, the ISIS and IVSAWS are just beginning to reach this stage of development. The probable reason for this is that warning and notification systems require significant infrastructure support and have less direct commercial viability. The potential importance of these systems to IVHS objectives indicates that they may require additional support from government sources than would be required by systems with more direct consumer appeal.

## Findings Related to Task B. System Objectives and Performance Requirements

The transportation community expressed some difficulty in establishing performance criteria for evaluating the success of the design and implementation of fully operational ATIS/CVO systems. Although the community has historical measures of performance (e.g., accidents per passenger mile), they have not developed the cut-off criteria they would use to indicate success. The most likely source of such criteria will be the various cost/benefit analyses that will be done when the infrastructure to support full system implementation is done.

The transportation community had different, though perhaps interrelated assessments of the relative importance of achieving IVHS/ATIS objectives. For private applications, the community rated the IVHS goals in the following order of importance: (1) decrease traffic congestion, (2) increase safety, and (3) increase and provide a higher quality of transportation mobility. For CVO applications, the community rated the IVHS goals in the following order of importance: (1) increase economic productivity, and (2) increase safety. In both the private and CVO applications, the goals of improving environmental quality and energy conservation were considered the least important objectives of the system.

Of ATIS subsystems for both private and CVO applications, IRANS was considered a significantly more important system than the other three. The basis for this appeared to be perceptions of the possible contribution that IRANS would make to a reduction in traffic congestion, safety, and mobility. Since little empirical or systematic analysis has been done on how each system would contribute to each of the problems addressed by the IVHS goals, it is difficult to know if this assessment of the importance of IRANS is justified.

## Findings Related to Task C. Function Description

This task provided two general results: (1) a general framework for describing mappings between different levels of system description, and (2) a comprehensive description of ATIS functional characteristics and their interaction.

In addition to characterizing the mapping between levels of abstraction, the functional description also depicts interactions between elements at several levels of description. Most importantly, Task C describes interactions between functional characteristics. In many cases, these interactions are positive; the value of any one functional characteristic is enhanced by others that are implemented simultaneously. However, the potential for many negative interactions exists as well. For example, route and destination selection will likely facilitate route guidance. Conversely, incorporating a multitude of advertising messages in in-vehicle displays may inhibit the driver’s ability to assimilate hazard warning information. These interactions suggest that an integrated design philosophy is needed to avoid a piecemeal approach that will result in multiple elements that compete for the driver’s limited attention.

Failing to integrate and prioritize the information provided by the various elements of an ATIS will potentially overwhelm the driver with information.

As a functional description of ATIS, the analysis focused on the functional level of abstraction; a level that is abstract enough not to specify a particular physical system, but concrete enough to identify general mechanisms and decision processes that might occur with an ATIS. Therefore, the mapping between levels of abstraction begins with the functional characteristics. Understanding the mapping between the functional characteristics of ATIS and the higher levels of abstraction depends on establishing how well ATIS functional characteristics achieve the overall IVHS goals. Similarly, understanding the mapping between ATIS functions and a description of ATIS at a lower level of abstraction involves identifying how functional characteristics may be realized in terms of physical components, such as video screens and push-button controls. For example, the functional characteristic route guidance may serve the goals of increased mobility and decreased congestion. Similarly, a synthetic voice, Liquid Crystal Display (LCD) icon, or high-resolution Cathode Ray Tube (CRT) might all be used to generate this functional characteristic.

While Task C identified prototypical decision cycles that would likely occur with individual functions, it did not address transitions between functions. These transitions may require unexpectedly large efforts on the part of the driver (i.e., remembering information to transfer from one element of the ATIS to another). These transitions will be especially important when driving, as drivers' attentional resources are already shared among several tasks.

Findings Related to Task D. Comparable Systems Analysis

Comparable systems that were evaluated include two that are prototypes of the IRANS/IMSIS. These evaluations indicate that relatively naive drivers using these systems performed better when using certain display configurations (i.e., combined audio and visual displays of guidance information) than when using other combinations.

The comparable systems analysis of the TravTek prototype IRANS/IMSIS indicates that, in terms of driver perception, "near-miss" observations and accident data that make use of these systems need not degrade safe driving performance.

Existing prototype IRANS/IMSIS are limited by the accuracy of the data bases currently available to support them. In both of the prototypes, the navigation data base provided guidance instructions that were either not legal (e.g., directing travel the wrong way on a one-way street) or impossible (e.g., directing a turn at a cross-street from an underpass with no entry ramp).

One of the comparable systems (OmniTRACS) had been designed using customer requirements as the primary design guide. In this case, the system design requirements were largely established by commercial trucking fleet managers. Therefore, some of the features of the system (i.e., ease of installation in different truck configurations, use of a standard keyboard, and use of a rugged but physically limited display) are not designed with the user in mind. This implies that ATIS/CVO systems need to be designed for both marketability (i.e., to meet buyers' requirements) and use.

The major standard used by the designers of comparable systems has been MIL-STD 1472 and related documents. For many of the designs, this standard has provided a starting point for control and display features, but it does not provide necessary guidance in such areas as digitized map displays. Perhaps more importantly is the fact that MIL-STD 1472 deals almost exclusively with the mechanical aspects of the design and does not properly consider the effect of workload and multi-task activities.

Findings Related to Task E. Task Analysis

The development of a task analysis for ATIS/CVO systems is both an important and efficient way to gather information that can be used in developing human factors design guidelines. The level of detail and, therefore, the potential uses of the task analysis are dependent on the state of development of the system under consideration. In the case of IRANS destination planning and route guidance functions, prototype systems provide a reasonable basis on which to build the task analysis. The same is also true for use of IMSIS services directories and some advanced CVO systems. Less developed systems such as ISIS and IVSAWS have no prototypes upon which to base a task analysis. At the present time, these systems also lack sufficiently well-established system design requirements to provide the basis for a task analysis based on prospective techniques without running a significant risk. This implies that task analyses of ATIS/CVO systems should be an interactive process that is repeated as the system design requirements are specified and prototypes are developed.

The task analysis in Task E was developed using the "decision element" approach previously used in Task C as the basis for categorizing human actions. This approach was adopted to maintain continuity between the tasks. While the approach had significant advantages for the project, it appeared during the analysis that there are some limitations to the "decision element" approach when applied to more general descriptions of what a driver does with the system. In particular, use of the "decision element" approach appears to be better suited to descriptions of tasks at a lower level in a task hierarchy than was possible in this analysis. Future task analyses along this line might benefit from use of a different taxonomy of driver actions.

## FINDINGS RELATED TO RESEARCH ISSUES

### Findings Related to Issue 1: Existing Status of Research and Development

Findings from Task A. Literature Review

- The ATIS/CVO literature review is very much oriented towards a system description.

- There are several demonstration projects in progress.

- Some basic aspects of the IVHS are still being defined.

- There is a gap in the research for IVSAWS and ISIS in general.

- Research status for ATIS/CVO systems is mixed. Both are relatively new, yet both are in operational test phases due to the public-private partnership specified in the IVHS Strategic Plan.

- ATIS/CVO research to date has tended to be system description-oriented, with details of the organization of research that is being or needs to be conducted.

- There are many human factors research issues that remain to be addressed before a comprehensive set of guidelines can be developed.

- ATIS research and development (R&D) will focus on navigation software, map and services data bases, and communications alternatives.

- Operational testing is now occurring on navigation route planning.

- Identification/location (AWAVL) and delivery modes systems have undergone testing and are now becoming operational.

- CVO R&D will focus on weigh in motion (WIM), electronic toll collection, driver warning, and electronic recordkeeping.

- Operational testing is now underway for AWAVL, electronic credential checking, and electronic permitting.

- The majority of IVHS literature produced to date contains descriptions of research plans and proposed frameworks for evaluating systems.

- Many of the initial operational tests are still under way and no empirical findings are currently available.

- Few documents discuss specific design guidelines or empirical results related to safety and human factors of ATIS/CVO systems.

<u>Findings from Task E. Task Analysis</u>

- Task analyses of prototype ATIS have either not been performed or are not available.

- Methodologies for performing task analyses of systems that have poorly specified operational and physical characteristics have not been developed.

## Findings Related to Issue 2: Formatting of Information

Findings from Task A. Literature Review

- Some studies indicate that either symbolic guidance displays or textual lists are easier to use than maps while navigating to unknown destinations. Note, however, that maps provide additional information that textual lists do not. Therefore, whether a map, symbolic guidance screen, or list is selected should necessarily depend on the desired task and required information.

- Literally thousands of design guidelines apply, at least to some extent, to the formatting of ATIS/CVO systems. Developing a way to organize this information and eliminate conflicting guidelines is a major problem in the development of human factors design guidelines for ATIS.

Findings from Task C. Function Description

- Because complex mapping exists between functions and the physical aspects of the systems, a variety of mechanisms could be used to implement ATIS/CVO functions. The relative efficiency and desirability of each of these mechanisms are potential issues for further research.

Findings from Task E. Task Analysis

- 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.

- 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.

## Findings Related to Issue 3: Driver Capacity to Assimilate Information

Findings from Task B. System Objectives and Performance Requirements

- Respondents to the interviews expressed a concern that in-vehicle ATIS introduction might cause excessive mental workload requirements in the case of heavily instrumented commercial vehicles, especially emergency vehicles.

- Respondents to the interviews stated that ATIS could reduce the frequency of drivers simultaneously holding a map or a portable hand-held system while driving, which the respondents cited as an unsatisfactory and unsafe condition.

Findings from Task C. Function Description

- Since drivers, dispatchers, regulators, and managers represent system elements that are integral to ATIS/CVO functions, it is important **to** consider how knowledge, attitudes, and perceptual, motor, and decision-making limitations might compromise system functions and objectives.

- Human constraints need to be addressed in the human factors design guidelines.

**Findings Related to Issue 4: Knowledge, Skills, and Abilities Requirements**

Findings from Task E. Task Analysis

- Tasks to initiate ATIS/CVO systems involve relatively limited knowledge and skill requirements.

- Tasks to code uncataloged destinations and select common services from large lists of possibilities will require both specialized information (e.g., geographical area name) and the ability to accurately remember relatively complex information long enough to complete the destination entry process.

- Tasks associated with review and approval of route recommendations will require some knowledge of map reading, an understanding of the way that the system selects routes, and an ability to visualize how the route will proceed.

- Use of IRANS route guidance functions will require that the driver maintain situational awareness and alertness to driving hazards.

- Whereas some ATIS functions (e.g., route planning and guidance) will require increased knowledge and skills by the driver, some will effectively reduce those requirements.

**Findings Related to Issue 5: Information Requirements of ATIS/CVO Users**

Findings from Task C. Function Description

- There is a need to consider requirements imposed by the environment (e.g., weather and crime-prone areas) as part of the information that drivers need.

- There are major differences in the type of information required by commercial drivers as opposed to private drivers.

Findings from Task E. Task Analysis

- Alternative methods for entering destination information (e.g., bar coding of business cards, cross-referencing 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 not only to review a proposed route, but to review the assumptions made by the system when establishing that route.

- Driver-set preferences 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 that are presented to the driver.

- Setup features for IRANS should include the ability to enter and retain short lists of frequently selected destinations and routes.

**Findings Related to Issue 6: Driver Acceptance of ATIS/CVO**

Findings from Task B. System Objectives and Performance Requirements

- Respondents to the interviews suggested that a portable ATIS might be introduced as an emergency technology, which could facilitate driver acceptance prior to the introduction of dedicated in-vehicle systems.

- Surveys indicate that most commuters see IVHS as a possible solution to traffic congestion.

- Introduction of the technology should first be made using less complex systems that include limited subsets of ATIS subsystems. This would both reduce initial costs and provide an introduction to the technology.

Findings from Task C. Function Description

- Driver acceptance will depend on the driver's trust of automation.

- Driver acceptance will depend on the driver's confidence in his or her ability to effectively use the system.

Findings from Task E. Task Analysis

- Use of sophisticated ATIS/CVO functions (e.g., manual aid) to replace existing technology (e.g., cellular phone) is considered unnecessary.

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

**Findings Related to Issue 7: Driver Decision Strategies for Trip Taking**

Findings from Task A. Literature Review

- Drivers have been shown to be resistant to diverting from their present route to avoid congestion. However, some navigation system characteristics can effectively change the driver's behavior.

Findings from Task C. Function Description

- The diversity of functions associated with ATIS/CVO systems reflect a diversity in the types of decisions that will need to be made.

- Decision strategies need to be expressed within a theoretical framework in order to be understandable.

Findings from Task E. Task Analysis

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

## Findings Related to Issue 8: Factors Influencing the Performance of Drivers

Findings from Task A. Literature Review

- The in-transit functions should be limited to necessity and convenience. In fact, all efforts must be made to limit the functionality of the in-transit mode to those tasks that: (1) do not significantly interfere with the driving task, (2) have convenience benefits that outweigh the cost of including the function, and (3) will be used frequently.

- Subjects using complex navigational devices drove more slowly than those using less complex devices. These effects were also more prevalent in older drivers than in younger drivers.

- Special consideration must be given to older drivers. Minimization of glance time in design of a navigation information display is critically important, as it was found that elderly drivers spend twice as much time looking at a given display.

Findings from Task C. Function Analysis

- The public will tolerate little in the way of training associated with ATIS/CVO use.

Findings from Task E. Task Analysis

- A complete understanding of how ATIS/CVO systems might influence driving performance depends on addressing the broader tasks of driving by describing the interaction of ATIS-specific and driving-specific tasks.

- 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 using 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.

## Findings Related to Issue 9: Issues Related to CVO System Use

Findings from Task A. Literature Review

- Several dispatching and routing navigation systems are in existence for CVO applications.

Findings from Task B. System Obiectives and Performance Requirements

- The least important objective for private applications-economic productivity-was rated the most important objective for CVO applications.

Findings from Task C. Function Analysis

- Most ATIS functional characteristics apply to both private and CVO drivers. In most cases, CVO applications differ only slightly at the level of system physical features.

- The restrictions of CVO equipment and operations will require different levels of support at the data base and infrastructure level of ATIS/CVO system design.

- There are major differences in the type and level of detail needed for CVO as opposed to private driving applications of ATIS.

**Findings Related to Issue 10: Interactions Between ATIS Use and Driving**

Findings from Task C. Function Analysis

- A complete understanding of how ATIS/CVO systems might influence driving performance depends on addressing the broader tasks of driving by describing the interaction of ATIS-specific and driving-specific tasks.

- Functional descriptions and scenarios provide a starting point for considering the task demands associated with assessing and responding to ATIS/CVO information in the driving context.

**Findings Related to Issue 11: ATIS Interactions**

Findings from Task B. System Obiectives and Performance Requirements

- Interviews with the driving community indicate that IRANS is judged to have a central role in meeting ATIS objectives for both private and CVO applications, especially in decreasing traffic congestion.

- There are at least four interrelated ATIS architecture issues in developing a unified system architecture: (1) data flows between ATIS and ATMS, (2) the distribution of ATIS functions, (3) data flows among ATIS subsystems, and (4) IVHS and ATIS maturity.

Findings from Task C. Function Analysis

- There are both positive and negative interactions among ATIS/CVO functions.

- There are both positive and negative interactions within and among ATIS/CVO subsystems.

- The value of a function and its performance may depend on how functions are paired and integrated into an ATIS/CVO system.

- Most use of ATIS/CVO will require the use of more than one function.

## RECOMMENDATIONS

### Recommendations Related to Human Factors Design Guidelines

The human factors design guidelines will need to be presented in a way that allows rapid and efficient indexing and accessing of the particular information of interest. Present guidelines are far too complex and difficult to access for designers to use except when an issue of critical importance has been highlighted. In the past, this has often been done through the mechanism of the military procurement system, which provided economic stimulus for designers and manufacturers to comply with both guidelines and standards even when producing a product for civilian use. As military procurement becomes less important to the development of systems, however, the use of guidelines such as are being developed in this project will depend primarily on their perceived usefulness and ease of use to the designer.

### Recommendations Related to Research Issues

For ISIS and IVSAWS, there has been no research done on the type of information that should be displayed to the driver. There should be additional research done on the nature and requirements regarding the time and content of the information presented to the user.

Modeling of ATIS/CVO system use remains an open research issue.

CVO drivers can be trained. As a consequence, they can be given more information to work with, they can handle more information better, and they can make better use of that information than untrained private drivers. However, how much is too much?

Additional research is still needed to determine what information the driver needs to have displayed, what mode of display should be used, and when the driver should have access to the information. It is particularly important that this research be done in connection with simulated or actual driving requirements.

A driver's capacity varies over time due to the dynamic nature of the task. Research needs to be done to determine how ATIS can capitalize on the fluctuating availability of driver cognitive capacity. During periods of low driving demand, systems should utilize the excess capacity available, while at the same time avoiding overloading the driver with system demands during periods of lowered cognitive capacity.

Little is known of the actual safety consequences, benefits, and costs associated with ATIS/CVO system implementation. Developing an understanding of the likely consequences of system implementation is a necessary prerequisite to the development of an infrastructure that will support ATIS/CVO systems. Decisions about how the infrastructure will be developed and what features it will include are, in turn, necessary prerequisites to the development of the final design characteristics that will be used for in-vehicle equipment.

Research into driver acceptance of ATIS/CVO systems is still a major area that needs to be developed, both to determine the economic and political viability of the systems and to determine how much they will be used.

The ATIS/CVO systems probably represent the first major technological system for which there is a real need to develop systems that require little or no training for their use. Both from the standpoint of driver acceptance and as a practical matter of eliminating the need for developing a training infrastructure to support the system, these systems must be designed to minimize training requirements to an extent not previously attempted. Research is needed on both how to design the systems to avoid the need for training and how to provide training that may be needed in the most efficient manner possible.

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 prolonged use of destination-focused approaches will affect driver reliance, comfort, and use of ATIS/CVO systems needs to be explored, both in terms of driver acceptance and driver stress.

Under some conditions, ATIS/CVO recommendations are likely to exceed the ability of the driver to follow 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.

As the state of ATIS development progresses, task analyses should be conducted on prototype systems to better understand and evaluate how drivers will use these systems.

## REFERENCES


Allen, R.W., Stein, A.C., Rosenthal, T.J., Ziedman, D., Torres, J.F., & Halati, A. (199 1). A human factors simulation investigation of driver route diversion and alternate route selection using in-vehicle navigation systems. ***Vehicle Navigation and Information Systems Conference Proceedings*** (pp. 9-26). Dearborn, MI.

Allen, T.M., Lunenfeld, H., & Alexander, G.J. (1971). Driver information needs. ***Highway Research Record, 366,*** pp. 102-l 15.

Alm, H., & Nilsson, L. (1991). ***Changes in driver behaviour as a function of hands-free mobile telephones: A simulator study.*** Linkoeping, Sweden: National Swedish Road and Traffic Research Institute.

Baker, C.C., Johnson, J.H., Malone, M.T., & Malone, T.B. (1979). ***Human factors engineering for Navy weapons systems.*** Alexandria, VA: Essex Corporation.

Barrow, K. (1990). Human factors issues surrounding the implementation of in-vehicle navigation and information systems. ***SAE Technical Paper Series (SAE No.*** 910870, pp. l-15). Warrendale, PA: Society of Automotive Engineers.

Battelle Seattle Research Center. (1992). Technical proposal for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) components of the Intelligent Vehicle-Highway System (IVHS). Seattle, WA: Battelle Seattle Research Center.

Bhaskar, R., & Simon, H.A. (1977). Problem solving in semantically rich domains: An example from engineering thermodynamics. ***Cognitive Science, I,*** pp. 193-215.

Biggs, S.F., Rosman, A.J., & Sergenian, G.K. (1993). Methodological issues in judgment and decision-making research: Concurrent verbal protocol validity and simultaneous traces of process. ***Journal of Behavioral Decision Making, 6,*** pp. 187-206.

Bittner, A.C., Jr. (1993). Requirements testing and evaluation: Human-in-the-loop systems, ***Ergonomics in Design,*** in press.

Bittner, A.C., Jr., Kantowitz, B.H., & Bramwell, A.T. (1993). ***Workload assessment of automatedflight decks: Analysis of ASRS incident reports*** (Final Report). Seattle, WA: Battelle Human Affairs Research Centers.

Borgatti, S.P., Everett, M.G., & Freeman, L.C. (1992). ***UCINET IV version 1.0 reference manual.*** Columbia, SC: Analytic Technologies.

Bowers, V.A., & Snyder, H.L. (1990). Concurrent versus retrospective verbal protocol for comparing window usability. ***Proceedings of the Human Factors Society 36th Annual Meeting*** (pp. 1270-1274). Santa Monica, CA: Human Factors Society.

Carey, M., & Walley, S. (1990). Cognitive task analysis techniques in the design and evaluation of complex technological systems. ***I I th Advances in Reliability Technology Symposium*** (pp. 1 l-26). London: Elsevier.

Chubb, G. (1991). Some system analysis techniques. ***System Development Technical Group Newsletter.*** Santa Monica, CA: Human Factors Society.

Coury, B.G., Weiland, M.Z., & Cuqlock-Knopp, V.G. (1992). Probing the mental models of system state categories with multidimensional scaling. ***International Journal of Man-Machine Studies, 36,*** pp. 673-696.

Denning, S., Hoiem, D., Simpson, M., & Sullivan, K. (1990). The value of thinking-aloud protocols in industry: A case study at Microsoft Corporation. ***Proceedings of the Human Factors Society 34th Annual Meeting*** (pp. 1285-1289). Santa Monica, CA: Human Factors Society.

Department of Transportation. (1992). ***IVHS strategic plan: Report to Congress.*** Washington, DC: Author.

Dingus, T.A., Antin, J.F., Hulse, M.C., & Wierwille, W.W. (1989). Attentional demand requirements of an automobile moving-map navigation system. ***Transportation Research, 23A(4),*** pp. 301-315.

Drury, C.G., Paramore, B., Van Cott, H.P., Grey, S .M., & Corlett, E.N. (1987). Task analysis. In G. Salvendy (Ed.), ***Handbook of Human Factors*** (pp. 370-401). New York: Wiley & Sons.

Ericsson, K.A., & Simon, H.A. (1984). ***Protocol analysis: Verbal reports as data.*** Cambridge, MA: The MIT Press.

Erlichman, J. (1992). A pilot study of the in-vehicle safety advisory and warning system (IVSAWS) driver-alert warning system design. ***Proceedings of the Human Factors Society 36th Annual Meeting*** (pp. 480-484). Santa Monica, CA: Human Factors Society.

Fath, J.L., & Bias, R.G. (1992). Taking the task out of task analysis. ***Proceedings of the Human Factors Society 36th Annual Meeting*** (pp. 379-383). Santa Monica, CA: Human Factors Society.

Freeman, L.C. (1979). Centrality in social networks: Conceptual clarification. ***Social Networks, I,*** pp. 215-239.

Haselkorn, M.P. (1992). Making sense of advanced traveler information systems by understanding travelers. ***ITE Compendium of Technical Papers*** (pp. 52-56).

Kantowitz, B.H. (1993). Pilot workload and flight deck automation. ***Proceedings of the Workload Assessment and Aviation Safety Conference*** (pp. 6.1-6.10). London: Royal Aeronautical Society.

King, G.F. (1986). Driver attitudes concerning aspects of highway navigation. ***Transportation Research Record, 1093,*** pp. 1 l-2 1.

***Kletz,*** T.A. (1985). ***What went wrong: Case histories of process plant disasters.*** Houston, TX: Gulf Publishers Book Division.

Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentations. ***Proceedings of the Human Factors Society 34th Annual Meeting*** (pp. 623-627). Santa Monica, CA: Human Factors Society.

Labiale, G. (1989). Influence of in-car navigation map displays on drivers performance. ***SAE Technical Paper Series*** (SAE No. 891683, pp. 11-18). Warrendale, PA: Society of Automotive Engineers.

Lee, J.D., Morgan, J.M., Wheeler, W.A., Hulse, M.C., & Dingus, T.A. (1993). Development of human factors guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations. Task C working paper: Description of ATIS/CVO functions. Seattle, WA: Battelle Seattle Research Center.

Lute, D., & Perry, A. (1949). A method of matrix analysis of group structure. ***Psychometrika, 14,*** pp. 95-l 18.

Lunenfeld, H. (1990). Human factor considerations of motorist navigation and information systems. ***Proceedings of First Annual Vehicle Navigation and Information Systems Conference*** (pp. 35-42). Warrendale, PA: Society of Automotive Engineers.

MacAdam, ***C.C.*** (1992). ***Truck driver information overload: Fiscal year*** 1992 (Final Report, No. UMTRI-92-36). Ann Arbor, MI: University of Michigan Transportation Research Institute.

McKnight, A.J., ***&*** Adams, B.B. (1970). ***Driver education task analysis. Volume I: Task descriptions.*** (Report No. DOT-HS-800-367, HUMPRO-TR-70-103). Washington, DC: National Highway Traffic Safety Administration.

McKnight, A.J., ***&*** Adams, B.B. (1970). ***Driver education task analysis. Volume 2: Task analysis methods.*** (Report No. DOT-HS-800-368, HUMPRO-IR-DI-70- 1). Washington, DC: National Highway Traffic Safety Administration.

Meister, D. (1985). ***Behavioral analysis and measurement methods*** (pp. 66-68). New York: John Wiley & Sons.

Miller, R.B. (1953). ***A method for man-machine task analysis.*** Wright-Patterson Air Force Base, OH: Wright Air Development Center, Air Research and Development Command.

Miller, R.B. (1974). ***A method for determining task strategies*** (Tech Report AFHRL-TR-74-26). Washington, DC: American Institutes for Research.

Moe, G.L., Kelley, G.R., & Farlow, D.E. (1973). ***Truck and bus driver task analysis*** (Report No. DOT-HS-800-835). Goleta, CA: Human Factors Research, Inc.

Noy, Y.I. (1989). Intelligent route guidance: Will the new horse be as good as the old? ***Vehicle Navigation and Information Systems Conference Proceedings*** (pp. 49-55). Toronto, Ontario, Canada.

Nystuen, J.D. (1990). A framework for assessing travel behavior response to Intelligent Vehicle-Highway Systems. ***SAE Technical Paper Series (SAE No.*** 901509, pp. 103-l 11). Warrendale, PA: Society of Automotive Engineers.

Petchenik, B.B. (1989). The nature of navigation: Some difficult cognitive issues in automatic vehicle navigation. ***Vehicle Navigation and Information System Conference Proceedings (No.*** CH2789-6/89/0000-0043). Toronto, Ontario, Canada.

Redding, R.E. (1989). Perspective on cognitive task analysis: The state of the art. ***Proceedings of the Human Factors Society 33rd Annual Meeting*** (pp. 1348-1352). Santa Monica, CA: Human Factors Society.

Redding, R.E. (1990). Taking cognitive task analysis into the field: Bridging the gap from research to application. ***Proceedings of the Human Factors Society 34th Annual Meeting*** (pp. 1304-1308). Santa Monica, CA: Human Factors Society.

Road Transport Research. (1988). ***Route guidance and in-car communication systems.*** Chapter VIII: Conclusions and recommendations for future research (pp. 85-104). Paris: OECD Scientific Experts Group.

Roth, E., Bennett, K., & Woods, D.D. (1988). Human interaction with an “intelligent” machine. In E. Hollnagel, G. Mancini, & D.D. Woods (Eds.), ***Cognitive Engineering in Complex Dynamic Worlds.*** New York: Academic Press.

Sanderson, P.M., James, J.M., & Seidler, K.S. (1989). SHAPA: An interactive software environment for protocol analysis. ***Ergonomics,*** 11, pp. 1271-1302.

Senders, J.W., Kristofferson, A.B., Levison, W.H., Dietrich, C.W., & Ward, J.L. (1967). The attentional demand of automobile driving. ***Highway Research Record, 195,*** pp. 15-33.

Smiley, A. (1989). Mental workload and information management. ***Vehicle Navigation and Information Systems Conference Proceedings*** (pp. 435-438). Toronto, Ontario, Canada.

Thordsen, M.L. (1991). A comparison of two tools for cognitive task analysis: Concept mapping and the critical decision method. ***Proceedings of the Human Factors Society 35th Annual Meeting*** (pp. 283-285). Santa Monica, CA: Human Factors Society.

Tolbert, C.A., & Bittner, A.C., Jr. (1991). Applications of verbal protocol analysis during the system development cycle. In W. Karwowski & J.W. Yates (Eds.), ***Advances in Industrial Ergonomics and Safety IZZ*** (pp. 855-862). Bristol, PA: Taylor & Francis, Inc.

Triggs, T.J., Kantowitz, B.H., Terrill, B.S., Bittner Jr., A.C., & Fleming, T.F. (1990). The playback method of protocol analysis applied to a rapid aiming task. ***Proceedings of the Human Factors Society, 34,*** pp. 1275- 1279.

Walley, S.P., & Shepherd, A. (1992). The task analysis process. In B. Krwan, & L.K. Ainsworth (Eds.), ***A guide to task analysis.*** Washington, DC: Taylor & Francis, Inc.

Wheeler, W.A., & Toquam, J. (1991). A task analytic investigation of safety in industrial radiography. ***Proceedings of the Human Factors Society 35th Annual Meeting*** (pp. 1105-1109). Santa Monica, CA: Human Factors Society.

Wierwille, W., Hulse, M., Fisher, T., & Dingus, T. (1988). ***Effects of variations in driving task attentional demand on in-car navigation system usage.*** General Motors Research Laboratories Contract Report No. CR-88/02/05. Warren, MI.

Woods, D.D., & Hollnagel, E. (1987). Mapping cognitive demands in complex problem-solving worlds. ***International Journal of Man-Machine Studies, 26,*** pp. 257-275,

Zachary, W., Zaklad, A., & Davis, D. (1987). A cognitive approach to multisensor correlation in an advanced tactical environment. Paper presented at 1st Tri-Service Data Fusion Symposium, Johns Hopkins University, Columbia, MD.

Zaklad, A., Deimler, J., Iavecchia, H., & Stokes, J. (1982). ***Multisensor correlation and TACCO workload in representative ASW and ASUW environment*** (Analytics Tech Report 1753A). Willow Grove, PA: Analytics.