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Functions and Features of Future Driver Information Systems

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16. Abstract

This report describes advanced driver information systems that should appear in cars of the early 21st century, and proposes a systems engineering method for selecting the most beneficial systems. Systems (functions) of interest were cellular phone, navigation/route guidance, roadway hazard warning, traffic information, vehicle monitoring, entertainment, in-car signing, motorist services, and in-car offices.

For each system, the reduction of accidents (59.3 percent), benefits to traffic operations (39.4 percent), and driver wants (0.5 percent) and needs (0.8 percent) were considered. The accident scores were based on the impact of features on causal factors of accidents (e.g., inattention, excessive speed, etc.). Benefits to traffic operations were estimated from changes in mode choice (e.g., use of public transportation), route choice, and traffic flow (e.g., eliminating peak congestion). Driver wants were based on a focus group study. Driver needs were assessed from the impact of each feature on driver behavior for three representative trip scenarios (work, personal business, and social/recreational).

Using these schemes, features of each system were ranked from most to least beneficial. From this and other information, the first five systems listed above were chosen for further study. Features ranked as particularly beneficial provided information about roadway hazards (crash site, construction, railroad crossing), congestion, traffic rules, freeway management, path control (e.g., headlight out), and trip planning. Information elements (specific units of information) were identified for these features and prioritized.

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PREFACE

As outlined in the Request For Proposal (RFP), the purpose of this project is to identify information systems most likely to benefit drivers, to prototype the driver interfaces, and to test the usability of those interfaces. Resulting from those tests will be human factors design guidelines and test protocols, as well as candidate interfaces.

This report describes our efforts to develop a selection scheme and our judgments of which systems should be the focus of further research. Readers should remember that time, resources, and other contractual constraints limited the detail of our examination. The focus of this project is on the human factors studies to follow, not the systems engineering analysis described in this report. Hence, our intent was to determine systems that would be reasonable to explore. We hope that this report stimulates debate on the functions and features that should be in cars of the future.

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INTRODUCTION

This is the third of a series of documents produced under a U.S. Department of Transportation contract concerned with human factors and future driver information systems. The first two documents included a report on focus groups (Brand, 1990) and a workplan (Green, Boreczky, Serafin, Paelke, Williams, Finnegan, Levison, and Pew, 1990). The research is being conducted by a team led by The University of Michigan Transportation Research Institute. Other team members include Bolt, Beranek, and Newman of Cambridge, Massachussetts and Brand Consulting Group of Southfield, Michigan.

The project goals are:

1. To provide human factors guidelines for driver information systems.
2. To provide methods for testing the safety and ease of use of the systems.
3. To develop a human performance model that predicts the time required and errors made in using these systems.

At the highest level, the project tasks can be grouped into five phases—literature review and planning, development of preliminary driver information system designs, laboratory tests, field tests, and report production/guidelines development.

To achieve those goals, the project Request For Proposal (RFP) identified 16 tasks (A-P) that are listed in table 4. Task A, a literature review, called for (1) a general description of future driver information systems, (2) a critique of existing evaluation methods, (3) identification of the human factors research issues, and (4) conduct of focus group analyses to identify current problems with advanced instrumentation systems. The work from the focus groups is presented in Brand (1990), research conducted for the University by the Brand Consulting Group.

Table 4. Sixteen tasks identified in the RFP.

Task	Description
A	Literature Review
B	Workplan
C	Identify Functions
D	Select a Preliminary Sensory Mode for Each Information Element - Prioritize and Format Elements
E	Determine Candidate Display(s), Control Interface(s), and System Architecture(s) for Each Function
F	Develop and Analyze a Matrix
G	Establish Preliminary Evaluation Methodologies and Select Measures of Effectiveness (MOEs)
H	Select Preliminary Acceptance/Rejection Criteria and Testing Procedures

I	Separately Test Each of Five Selected Functions
J	Test a Partially Integrated System
K	Test a Fully Integrated System
L	Validation Experiment
M	Develop Comprehensive Human Factors Guidelines
N	Annotated Outlines
O	Draft Technical Summary
P	Final Reports and Technical Summary

Task B called for the development of a workplan. The workplan (Green et al., 1990), a document intended for limited circulation, includes a summary of the literature review.

To serve as a framework for developing human factors guidelines and conducting human factors tests, the RFP called for the development of information systems that could be provided in cars now and in the near future, including navigation, vehicle monitoring, traffic information, in-vehicle safety advisory and warning system (IVSAWS), and motorist services. It is admittedly unusual to have a government contract support the development of an in-vehicle system intended for the consumer. However, it is only by examining and developing real systems that one can become fully aware of the practical design problems and required human factors data and guidelines.

The authors want to emphasize that this is not a product development effort. Product development would require an examination of the interface that is much more detailed than is being supported here. Furthermore, that effort would require exploration of a whole host of issues not considered here — detailed hardware design, manufacturability, etc. The research reported here, however, can provide a firm basis for the driver interface for real products.

The development of these information systems was undertaken in tasks C through F (listed in table 4). Specifically, the RFP called for the evaluation of those systems on three dimensions—(1) driver safety, which here is interpreted to mean reduction in accidents, (2) benefits to traffic operations, and (3) driver needs. It is important to note that the emphasis of these criteria is different from those used by the vehicle manufacturers. Their primary concern is in selling a product and hence they tend to concentrate on driver wants. This project addresses the public good and emphasizes the government's perspective that accident reduction and benefits to traffic operations are at least as important as, if not more important than, driver wants. There are many other dimensions that could have been considered (reduced vehicle operating costs, reduced air pollution, etc.) but expanding the domain was beyond the scope of this project.

Specifically, this report is concerned with nine systems listed in table 5. Each of the systems can provide useful information to drivers, but using them can also be distracting and possibly make driving hazardous. Two systems likely to appear in future vehicles were not considered — driver fatigue/alertness monitoring and collision warning/collision avoidance. Those systems are or will be covered by other Department of Transportation research projects. To keep the project within the limits of the time and funds available, this project is concerned only with the application of the nine systems to cars (not trucks and buses) and for normal adult drivers (not the disabled). While other contexts are important, they are beyond the scope of this project.

Table 5. Nine Systems Evaluated.

System	Purpose	Example
Communication	Allow interaction with others	Telephone, CB radio
Entertainment	Provide diversion	Radio, CD player
In-Car Signing	Provide detailed information about driving environment	Traffic light status Street names
Motorist Services	Provide general information about businesses and public services	Restaurant hours Bus schedules
Navigation	Orient or guide driver to destination	Turn here, Bear to left
Office	Increase worker's productivity	Fax, Computer
Road Hazard	Warn of impending hazard on road	Accident, Slick road
Traffic Information	Provide traffic/road information	Congestion, Speed limits
Vehicle Monitoring	Provide vehicle repair/status reports	Oil change needed Tire pressure low

Jargon used in the RFP appears in this report as well. For example, rather than referring to systems and subsystems, DOT refers to functions and features. The specific terms are illustrated in figure 1.

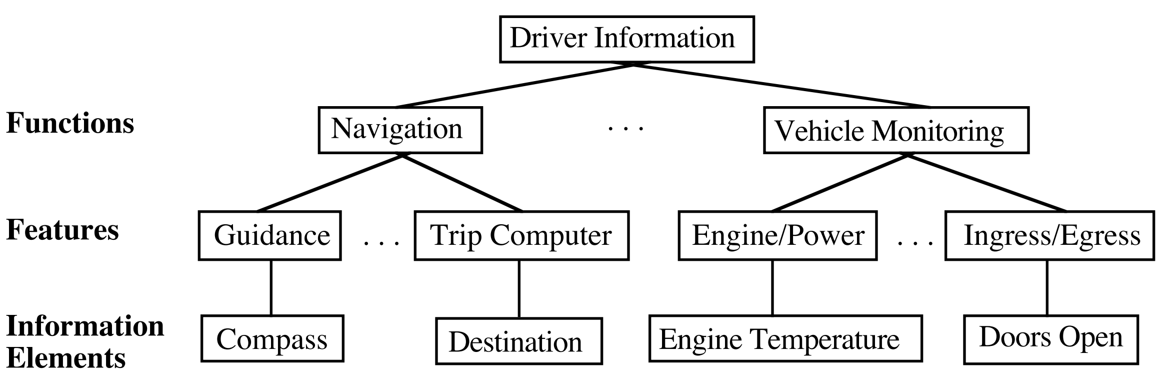


Figure 1. Driver information system terminology and organization.

In order to characterize the functions that driver information systems can provide in the future, the following steps were completed:

Step 1. Identification of functions and features.
Step 2. Identification of categories for criticality scoring.
Step 3. Feature scoring and prioritization.
Step 4. Selection of five functions for further design and evaluation,
Step 5. Identification of information elements.
Step 6. Information element scoring and prioritization.

Although this list suggests that the analysis was top down and strictly serial, some of the steps were completed in parallel. For example, the information elements that might be included in each feature (step 5) were partially enumerated when functions and features (step 1) were identified.

STEP 1. IDENTIFICATION OF FUNCTIONS AND FEATURES

Functions and features currently in use in vehicles, in addition to those with the possibility of future implementation, were identified using four sources of information: (1) technical literature, (2) concept cars, (3) industrial liaisons, and (4) in-house expertise.

Literature reviewed included Delphi data (Ribbens and Cole, 1989; Underwood, 1990; Underwood, Chen, and Ervin, 1989), information from Mobility 2000 Workshops (Harris and Bridges, 1989; Mobility 2000, 1990), and research literature that presents state-of-the-art vehicle information systems (Burger, Smith, and Ziedman, 1989; Esterberg, Sussman, and Walter, 1986; Parviainen, French, and Zwahlen, 1988; Tsugawa, Kitoh, Fujii, Koide, Harada, Miura, Yasunobu, and Wakabayashi, 1991).

Of particular interest to this project as required by the RFP is IVSAWS (In-Vehicle Safety Advisory and Warning Systems), a system under development by Hughes Aircraft Company and UMTRI (Division of Social and Behavioral Analysis) as a subcontractor. Because the problem is important enough that independent views are desired, the authors are independently designing the interface. A current report on IVSAWS (Streff, Ervin, and Blower, 1991 — confidential draft) describes situations that drivers should be warned about on the road. These situations were identified as the features of IVSAWS.

Two versions of a predecessor to IVSAWS, SHAWS (Safety Hazard Advance Warning System) have been documented in Peterson and Boyer (1975) (initial version) and Meyer, Reaser, Keller, Wilson, and Vadeboncoeur (1982) (second version). The initial system, deemed not cost effective, was proposed to reduce crashes at grade crossings and with emergency vehicles. The second version, designed to warn against a wider range of hazards (blind curves, one lane bridges, accidents, etc.), was identified as technically feasible, cost effective, and implementable. Although neither of these reports document the driver interface or contain usability tests of proposed designs, they helped identify possible features of IVSAWS.

Concept cars produced within the last two years were examined to identify functions and features. Much of this information was provided by industrial liaisons (through photographs), although some visits were made to local design studios to follow up on observations made at the North American International Auto Show in Detroit. Overall, concept cars did not provide valuable information since most of the vehicles were exterior treatments only. (This was less true for the Japanese cars than the American cars.)

Further, UMTRI in-house expertise was utilized to identify functions and features in vehicles. Over the past years, visits to showrooms and the International Auto Show have allowed the authors to compile an extensive file of brochures on production vehicles.

The functions and features identified are provided in table 6. This listing simply did not emerge, but rather was the result of several iterations of effort and successive steps that varied from function to function. For example, only after all the information elements for the Vehicle Monitoring Function were enumerated were they grouped into features.

Table 6. Functions and features of driver information systems.

Function	Feature
Communication	CB radio Cellular phone Radar detector
Entertainment	Cassette/CD player Radio Television
In-Car Signing	Destination assistance Street signs Traffic control
IVSAWS (Road Hazard)	Compounding hazards Construction Crash site Emergency vehicle Railroad crossing School bus/other special vehicles Supplemental traffic control
Motorist Services	Banking Customs information Destination assistance Transportation Yellow pages/commercial
Navigation/Route Guidance	Guidance Orientation Trip computer Trip planning
Office	Calculator Computing Dictation Electronic calendar Electronic directory Fax
Traffic Information	Congestion Construction Freeway management Parking Traffic rules (one-way, no left turn) Vehicle access (toll roads, size and weight restrictions) Weather

Vehicle Monitoring	Climate Drivetrain Engine/Power Ingress/Egress (doors, trunk) Path control (tires, brakes) Safety systems

Because some of the entries in table 6 may be unfamiliar to readers, less common features are further defined. Television, under Entertainment, refers to drivers watching broadcast TV or videotapes, which will help keep drivers alert on long trips (Schiffman, 1987). Destination assistance (In-Car Signing) will inform highway drivers that a restaurant or gas station is at the next exit. For IVSAWS, compounding hazards refers to a road situation made worse by a temporary state (e.g., curve is dangerous when slippery) and supplemental traffic control refers to traffic control measures (e.g., stop signs, traffic lights, etc.) that may present an unfamiliar situation (new stop sign at a corner). Destination assistance in Motorist Services will give the driver much more detailed information; it will provide drivers on any type of road with information (hours, location, phone number, etc.) about restaurants, hotels, and other public facilities. Transportation, included in Motorist Services, will provide drivers with information (time schedules, rates, etc.) for other modes of transportation (bus, train, airport, etc.) in the area. Computing (Office) includes word processing, spreadsheets, graphics, programming, electronic mail, and file management. Freeway management, under Traffic Information, refers to such items as advisory speed postings and ramp and lane closures. Finally, the safety systems feature for Vehicle Monitoring includes air bags and seat belts.

STEP 2. IDENTIFICATION OF CATEGORIES FOR CRITICALITY SCORING

In the next stage of the project, the functions and features were ranked according to criticality scores based on three dimensions: (1) reduction of accidents, (2) benefit to traffic operations, and (3) driver needs. These dimensions were specified in the RFP. In order to score the criticality of the features based on these dimensions, sources of information were identified that provided a framework. For example, accident data were reviewed in order to enumerate factors of accident causation. For benefits to traffic operations, documents on traffic operations were reviewed. Driver needs were assessed in two ways—through "wants" and "needs/convenience." Wants were determined through a focus group study, while needs/convenience were assessed using driving scenarios that represented typical car trips of the driving population. Details on how categories were identified for criticality scoring follow.

Accident Data

Data on the causes of accidents were gathered from several sources. One of the most commonly referred to studies on motor vehicle accident causation was conducted at Indiana University's Institute for Research in Public Safety (Treat, Tumbas, McDonald, Shinar, Hume, Mayer, Stansifer, and Castellan, 1979). In addition to why accidents occurred, they identified what kinds of accidents and injuries were most common and when such accidents most likely happened (by time of day, driving task, etc). Treat et al. (1979) also examined who was most likely to be involved in an accident and where the accidents commonly occurred. While the Treat et al. (1979) data serves as the framework for the discussion that follows, accident data from other sources were also examined. Particularly useful were *Accident Facts* (National Safety Council, 1989), the National Accident Sampling System (NASS) file for accidents in 1988 (The University of Michigan Transportation Research Institute, 1989), and the Fatal Accident Reporting System (FARS) file for 1988 accidents (The University of Michigan Transportation Research Institute, 1989).

The Treat et al. (1979) study concerned a five-phase analysis of accidents in Monroe County, Indiana. The study employed a tri-level method which included baseline data (level A), on-site investigations of accidents by technicians (level B), and in-depth investigations by a multi-disciplinary team (level C). The baseline data were police reports and information provided to the state (location, date, etc.), drivers licensed in Monroe County, vehicles registered in Monroe County, and details concerning Monroe County roadways. For the on-site investigations, 24-h/d accident coverage was maintained. Throughout the study, 13,568 police reports were obtained, 2,258 accidents were investigated on-site, and 420 were analyzed in-depth. Table 7 shows the believed causes (by percent) of the accidents studied. The totals exceed 100 percent because most accidents were associated with more than one cause.

Table 7. Factors that cause accidents (Treat et al., 1979).

Cause	% Accidents*	
Driver	92.6	
improper lookout		23.1
excessive speed		16.9
inattention		15.0
improper evasive action		13.3
internal distraction		9.0
improper driving technique		9.0
inadequate defensive driving		8.8
false assumption		8.3
improper maneuver		6.2
overcompensation		6.0
other (blackout, dozing, etc.)		5.8
Environmental	33.8	
view obstructions		12.1
slick roads		9.8
transient hazards		5.2
design problems		4.8
control hindrances		3.8
inadequate signs & signals		2.9
other (ambient vision limitations, maintenance, etc.)		1.6
Vehicular	12.6	
gross brake failure		3.1
inadequate tire depth		2.6
brake imbalances		1.9
tire underinflation		1.4
vehicle-related vision obstructions		1.0
other (steering, powertrain, etc.)		3.2

*Most accidents were associated with more than one cause.

In the following sections, each of the three classes of causal factors (driver, environmental, vehicular) is examined in greater detail.

Driver-Related Causal Factors

As shown in table 7, the vast majority of accidents studied in Indiana were caused by human error (possibly as many as 93 percent). The leading specific cause was "improper lookout," accounting for one-fourth of the investigated accidents in situations such as drivers changing lanes, passing, or pulling out from intersections without carefully watching for oncoming traffic. In half of the improper lookout accidents, drivers failed entirely to survey for traffic, while the others looked but did not see obstacles that should have been visible (approximately 40 percent of these faced view obstructions). Older drivers were especially susceptible to improper lookout accidents. Approximately half of the accidents caused by drivers over 65 years old were due to improper lookout.

In the Treat et al. (1979) study, accidents caused by "excessive speed" were most prevalent among drivers under 20 years of age. For example, 18.1 percent of the men under 20 had accidents attributed to excessive speed, compared to only 10.2 percent of all accidents involving men. Accidents involving women followed similar but less extreme trends; 8.6 percent of women drivers under 20 had accidents due to excessive speed compared to 5.2 percent for all accidents involving women. Roadway familiarity also played a role, as most excessive speed accidents resulted from critical speed areas (curves) where drivers failed to slow the vehicle and lost control. Risk taking behavior for young drivers (especially men), vehicle handling skills, and judgment of roadway requirements were also factors in excessive speed accidents.

"Inattention" was cited as a possible cause for 15 percent of the Indiana accidents (Treat et al., 1979). In most cases, this was the result of failing to detect that upcoming traffic was slowed or stopped in time to avoid collision. "Inattention" accidents occurred less frequently by failing to follow critical road signs and signals. To avoid this cause of accidents, Treat et al. (1979) suggested the following: (1) environmental changes to reduce sudden stops, (2) improved size, prominence, or placement of road signs and signals, (3) use of in-vehicle communication systems, and (4) improved brake lights. The third improvement is anticipated as a result of IVHS-related (Intelligent Vehicle Highway Systems) programs.

Many accidents (about 13 percent) were the result of "improper evasive action" in which drivers either failed to attempt an appropriate evasive steer (for some other reason than inattention), or negated the effect of the evasive steer by over-braking and locking the wheels. According to Treat et al. (1979), these accidents may be avoided by (1) employing anti-lock brakes and improving braking pedal displacement, force, and/or power tradeoffs, (2) increasing driver education awareness of accidents due to improper evasive action, and (3) using a driving simulator to teach correct evasive action.

Information from the National Safety Council's *Accident Facts* (1989) also indicates the importance of human error in accidents. Table 8 shows that improper driving habits (human error) caused at least 67 percent of all accidents in 1988. The two major causes of accidents due to improper driving were excessive speed and failing to give right of way (yielding, stopping, etc.).

Table 8. Percent of accidents in 1988 due to improper driving.

Improper Driving	Rural (%)	Urban (%)	All (%)
Excessive Speed	26.0	17.9	20.4
Right of Way	15.3	26.3	22.8
Failed to Yield	12.6	19.3	17.1
Passed Stop Sign	1.6	1.8	1.8
Disregarded Signal	1.1	5.2	3.9
Drove Left of Center	5.5	1.5	2.8
Improper Overtaking	2.9	2.3	2.5
Made Improper Turn	1.6	3.0	2.6
Followed Too Closely	4.3	7.1	6.2
Other Improper Driving	9.9	9.9	9.9
Total	65.5	68.0	67.2

Physiological, physical, or experiential factors (e.g., fatigue, driver experience, and alcohol impairment) may also affect a driver's information processing and vehicle controlling abilities. The most common condition involved in accidents is alcohol impairment. The percentage of alcohol related accidents is much higher among serious or fatal accidents (about 50 percent) than minor accidents involving only property damage or minimal personal injury (about 9 percent) (Treat et al., 1979). Treat et al. (1979) comment that it is difficult to assess the involvement of these "human conditions and states" as the causal effect in accidents with assurance. Perhaps this is why they do not include human conditions and states (physiological, physical, or experiential factors) in their category of driver-related causal factors of accidents.

The National Safety Council's *Accident Facts* (1989) shows alcohol consumption to be a factor in 50-55 percent of the fatal motor-vehicle accidents (22,000 accidents), 29 percent of all serious injury accidents (350,000 accidents), and 7 percent of accidents involving property damage only (1,400,000). Alcohol-related accidents are 3 times more likely to occur at night than during the daytime. Of those fatally injured in drunk-driving accidents, one-third were non-drinking drivers, passengers, pedestrians, and pedal-cyclists. It was shown that personal characteristics such as driver vision and personality (poor personal and social adjustment) were related to accident involvement, but knowledge of the driving task was not.

Environmental Causal Factors

The leading environmental cause of accidents in the Treat et al. (1979) study was "view obstructions" (12 percent). These accidents primarily occurred at road/road intersections having stop signs at two of the legs. (The erring driver was typically on a controlled leg and was usually turning left or continuing straight through the intersection. There were few accidents associated with right turns.) While many of the obstructions could not be removed (buildings, large embankments, etc.), more than half of the accident-causing obstructions were trees and bushes that could be controlled to reduce the hazard.

"Slick road" was another common cause of environmentally caused accidents (10 percent). Rain-slickened roads were the most common culprit, while snow or ice caused about 4 percent of the accidents. NASS (The University of Michigan Transportation Research Institute, 1989) and FARS (The University of Michigan Transportation Research Institute, 1989) data show that road slickness played a higher role in recent accidents nationwide. (Table 9 shows the roadway surface conditions found in NASS and FARS data for accidents in 1988.) Although most accidents occurred on dry pavement (78 percent), adverse roadway surface conditions, especially wet pavement, were encountered in about one-fifth of all accidents. Fatal accidents showed a slight increase due to abnormal roadway surfaces. For instance, 18 percent of the fatal accidents occurred on wet surfaces, compared to 16 percent of overall accidents. Further, ice was a factor in 6 percent of fatal accidents but in only 3 percent of all accidents.

Vehicular Causal Factors

Vehicular factors played an interactive role with road surface conditions in many of the Indiana accidents, particularly tire tread depth and other tire problems (especially on damp surfaces and among control losses around curves). One major problem of slick roads is that drivers may not perceive the road as hazardous, and thus do not drive cautiously. Treat et al. (1979) suggests improved tire design and inspection programs, as well as increased driver knowledge of wet road conditions (that might be provided by an IVHS information product) as being ways of reducing such accidents.

Table 9. Percentage of accidents for roadway surface conditions in 1988 from FARS and NASS Data (The University of Michigan Transportation Research Institute, 1989).

	Fatal Accidents (FARS)		All Accidents (NASS)	
Road Surface Condition	Frequency	%	Frequency	%
Dry	35547	72.8	14189	78.5
Wet	8951	18.3	2837	15.7
Snow or slush	560	1.2	326	1.8
Ice	2777	5.7	500	2.8
Sand, dirt, oil	120	0.3	20	0.1
Other	156	0.3	28	0.2
Unknown	720	1.5	179	1.0
Total	48831	100.1	18079	100.1

Braking systems were the most common vehicular cause of accidents (5 percent). Such failures were the result of gross brake failure or brake imbalances. Tires and wheels were the cause of 4 percent of all accidents studied. In particular, inadequate tread depth or underinflation were to blame.

Summary

Through the accident data reviewed above, nine factors emerged as causes of accidents. These categories are listed in table 10. The main causes of accidents were broken down into three categories: (1) driver, (2) environmental, and (3) vehicular.

Table 10. Leading causes of accidents.

Driver	Improper Lookout Excess Speed Inattention Improper Evasive Action Alcohol Impairment
Environmental	View Obstruction Slick Roads
Vehicular	Tires Brakes

Traffic Operations

The authors have not been able to find a scheme that characterizes traffic operations as was possible for accidents. Hence, the assessment of the benefits of various driver information systems on traffic operations is difficult.

The categories within traffic operations evolved from the literature on traffic congestion and commuting (Gardes and May, 1990; Harris and Bridges, 1989; Meyer et al., 1989; Stafford, 1990) as well as by talking to experts in the field of traffic engineering. The literature mainly dealt with road network improvement and traffic flow aspects of traffic operations. Table 11 lists traffic categories that could possibly be improved by in-vehicle systems. These categories are broken down into the following three areas: (1) mode choice, (2) route choice, and (3) traffic flow. The authors' logic behind this partitioning was to reduce wasted travel by (1) reducing the number of cars on the road, (2) changing the roads that drivers travel on (based on uniform speed, potential for sudden stops, and optimum traffic density), and (3) stabilizing the flow of traffic on roads. It should be noted that this may not be an optimum scheme, but it is adequate for the purposes of this exercise.

Table 11. Categories for improved traffic operations.

Mode Choice	Carpool Public Transportation
Route Choice	Corridors Surface Streets
Traffic Flow Time	Reduce Rush Hour Peak Spread Reduce Accident/Breakdown Clean-up

Driver Needs

Driver needs for in-vehicle systems were assessed in two ways: through the evaluation of (1) driver wants as identified in a focus group study (Brand, 1990) and (2) driver needs/convenience as assessed through walk-throughs of typical driving scenarios. Views drawn out of the focus group study provide data on driver wants, while the scenario walk-throughs provide information on the need for, or convenience of having, in-vehicle systems.

Focus Groups

As called for by the RFP, a focus group study was conducted to examine driver attitudes toward advanced automotive information systems (Brand, 1990). Forty-six drivers participated in 1 of 4 groups--2 in Los Angeles and 2 in New York. All drove model year 1987 or newer cars equipped with at least one and, in most cases, several forms of advanced instrumentation (cellular phone, trip computer, head-up display, touch screen CRT, CD player, etc.). Two-thirds of the participants were men and almost half of the participants were in the 51-65 year age group, though adults of all ages were included. Each focus group session lasted just under two hours and was videotaped using a hidden camera.

During each session a facilitator asked a series of questions about instrumentation and attempted to get the group to reach a consensus response. As part of the initial introductions, the following questions were asked:

- Who are you?
- What do you do for a living?
- What kind of car do you drive?
- What kinds of instrumentation do you have in your car?

The group discussion concerned the following issues:

- When and how often is the advanced instrumentation in your car used?
- Are warning lights or gauges preferred and for what?
- What kinds of auditory feedback should be provided for warnings? (alerting tones, speech)?
- What kinds of problems have you had using the entertainment system?
- Have you ever used a touch screen CRT system? Was it easy to use?
- Have you ever used a car phone? Was it easy to use?
- How and when do you use maps when driving (either paper or electronic)?
- Would you want an in-car navigation system?

Trip Scenarios

It is very difficult to identify out of context if various information systems would be beneficial or convenient to drivers. Therefore, three trip scenarios were constructed to assist in such decisions. Those scenarios were based on the most common types of trips reported in the Nationwide Personal Transportation Study (NPTS), a national survey on personal travel (Klinger and Kuzmyak, 1986). This survey contains information on personal travel such as distributions of driver age, trip purpose, trip distance, and time of day. To assess the benefits of specific information systems and features, however, more detail was needed. Using the NPTS statistics, specific trip scenarios in the Ann Arbor-Detroit area were constructed that fit the summary statistics. These embellished scenarios (which included specific streets at specific times of the day) were used to assess driver needs/convenience. The Ann Arbor-Detroit area was selected because it is familiar to both the authors and the domestic motor vehicle manufacturers, who have their headquarters and engineering staffs in the area.

Following is a summary of the statistics from Klinger and Kuzmyak (1986) that were used to develop the driving scenarios. All data are from the year 1983. A person trip was defined as "one person traveling in any mode of transportation" (Klinger and Kuzmyak, 1986, p. 6-1).

Driver Age

Table 12 shows the percentage of car and van drivers as a function of age. Approximately 45 percent of all car and van drivers are 20 to 39 years of age.

Table 12. Distribution of car and van drivers by age.

Age	16-19	20-29	30-39	40-49	50-59	60-64	65+
% Drivers	5.8	22.9	22.5	15.2	14.2	6.7	12.7

Trip Type

The three most common trip purposes, as shown in table 13, are family and personal business (35.5 percent of all person trips), social and recreational (27.6 percent of all person trips), and earning a living (22.8 percent of all person trips). Of family and personal business, the most common trip purpose is shopping. For earning a living, the most common trip purpose is traveling to or from work.

Table 14 shows the percentage of car and van drivers as a function of trip purpose and age. As indicated in the table, 20 to 29 year olds are more likely than any other age group to drive cars and vans for the purposes of earning a living and social/recreational trips. For family/ personal business trips and educational/religious trips, car and van drivers are most likely to be 30 to 39 year olds and 16 to 19 year olds, respectively.

Table 13. Distribution of person trips by purpose.

Purpose	% of Trips
Earn living	22.8
to or from work	20.4
work related	2.4
Family and personal business	35.5
shopping	18.2
doctor	1.2
other	16.1
Civic, educational, religious	11.8
Social and recreational	27.6
vacation	0.3
visit friends	11.0
pleasure drive	0.5
other	15.8
Other	2.3
Total	100.0

Table 14. Distribution of car and van driver person trips by purpose and age.

	Percent of person trips (car and van drivers) by age						
Trip Purpose	16-19	20-29	30-39	40-49	50-59	60-64	65+
Earning a living	5.0	26.5	24.2	17.5	16.5	6.1	4.3
Family and personal business	5.2	19.6	21.2	14.5	13.5	7.3	18.6
Civic, educational, religious	28.6	21.1	13.5	7.9	10.8	4.1	13.9
Social and recreational	11.8	25.9	18.1	11.7	11.2	6.1	15.2
Other	9.4	18.0	18.4	12.6	13.7	5.4	22.4

Trip Distance

The average trip length for the most common trip purposes are listed in table 15. Social/recreational trips and earning a living were the longest trips, whereas family/personal business and educational/religious trips required less travel.

Table 15. Mean trip length by trip purpose.

Trip Purpose	Length (mi)

Earn living	10.2
Family and personal business	6.3
Civic, educational, religious	5.7
Social and recreational	13.3
Other	7.6
Weighted Average	9.2

1 mi = 1.61 km

Time of Day

As shown in table 16, the most likely time period during the week (Monday-Friday) for trips involving earning a living and civic/educational/religious purposes is between 6:00 a.m. and 3:59 p.m. Trips for family and personal business, as well as social and recreational trips, are made between the hours of 9:00 a.m. and 3:59 p.m. A substantial percentage of social/recreational trips also occur from 7:00 p.m. -11:59 p.m.

Table 16. Distribution of person trips by purpose and time of day (Monday-Friday).

	Percent of Person Trips by Tme of Day					
Trip Purpose	6:00 a.m. 8:59 a.m. (3 h)	9:00 a.m. 3:59 p.m. (7 h)	4:00 p.m. 6:59 p.m. (3 h)	7:00 p.m. 11:59 p.m (5 h)	12:00 a.m 5:59 a.m. (6 h)	unknown
Earn living	31.2	29.0	24.6	8.8	6.0	0.4
Family/personal business	7.4	55.1	22.1	12.4	2.4	0.6
Civic, educational, religious	38.5	42.2	9.1	8.2	2.0	0.0
Social/recreational	4.5	33.0	24.8	33.6	3.6	0.5
Other	12.0	44.6	22.5	17.7	2.4	0.8
Weighted Average	17.1	41.1	21.9	15.7	3.6	0.6

Three Most Common Trip Scenarios

The three most common trip scenarios reflect the most prevalent situation in terms of trip purpose (e.g., personal business, recreational), driver age, trip length, and time of day. These scenarios are listed in table 17. One scenario involves a car or van driver on a personal business trip approximately six miles long during the day. In the other two scenarios, social/recreational and earning a living, young car or van drivers are traveling on 13- and 10-mi (21- and 16-km) trips, respectively. The social/recreational scenario takes place throughout most of the day while earning a living is only for three hours in the morning.

Table 17. Three most common trip scenarios.

	Purpose	Age Group (years)	Trip Length (miles)	Time of Day (weekdays)
1	family/personal business (shopping)	30-39	6.3	9:00 AM-3:59 PM

2	social/recreational	20-29	13.3	7:00 PM-11:59 PM 9:00 AM-3:59 PM
3	earn living (to or from work)	20-29	10.2	6:00 AM-8:59 AM

1 mi = 1.61 km

The distribution of accident times for 1988 (NASS data as cited in The University of Michigan Transportation Research Institute, 1990) is shown in table 18. Comparing the purposes of the most common trip scenarios (table 17) with accident times reveals that family/personal business and social/recreational trips occur during the highest accident distribution time; 36.2 percent of all accidents occurred during the day. The scenario for earning a living occurs during the second lowest accident distribution time; only 11 percent of accidents occurred during the morning rush hour.

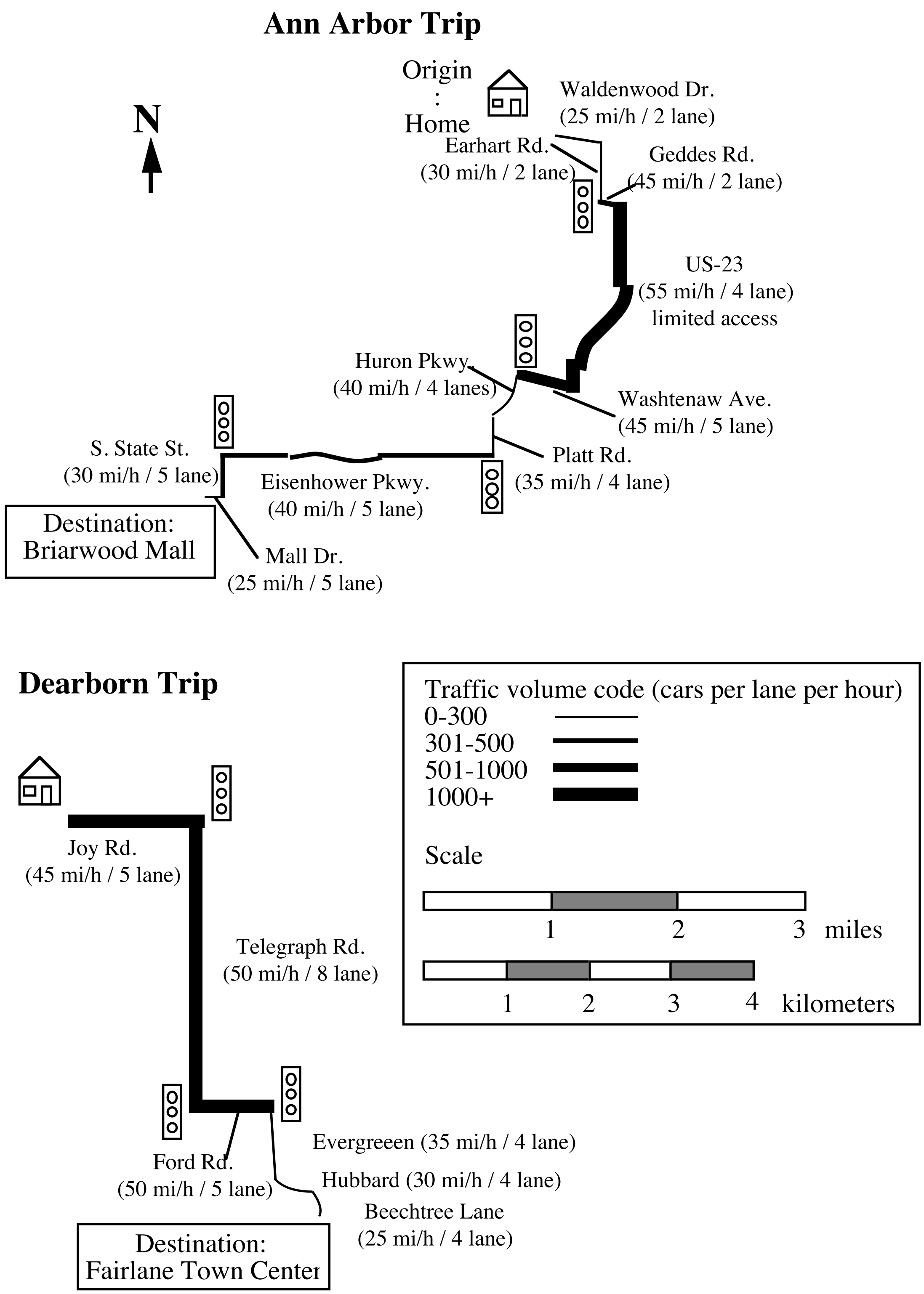
Table 18. Distribution of accident times for 1988 from NASS data (The University of Michigan Transportation Research Institute, 1990).

	Time of Day					
	6:00 AM 8:59 AM (3 hours)	9:00 AM 3:59 PM (7 hours	4:00 PM 6:59 PM (3 hours)	7:00 PM 11:59 PM (5 hours)	12:00 AM 5:59 AM (6 hours)	unknown
% Accidents	11	36.2	21.6	19.3	10.8	1.1

Local Versions of Trip Scenarios

In order to properly assess the usefulness and effectiveness of potential in-vehicle systems, representative trips were plotted out on local roads for use in structured walk-throughs. Local roads were used to generate trips because they are easiest to obtain information on, as well as most convenient for additional details not available from maps. Furthermore, they could be used in later phases to compare actual driving behavior with paper and pencil analyses. Using maps of Metropolitan Detroit, Washtenaw County, and Ann Arbor-Ypsilanti areas, at least two representative trips were generated for each scenario. The speed limits and traffic volumes for a majority of the roads (Washtenaw County Road Commission, 1989) are included as an indicator of the odds of encountering other vehicles by either following another vehicle, driving next to another vehicle, or encountering oncoming traffic. This is a good measure of the attentional demands of traffic. All traffic volume data are in cars per lane per hour.

Family and personal business (shopping). The two trips generated for this scenario, one in Ann Arbor and the other in Dearborn, both originate from areas of high residential density and end in areas of high shopping density. The Ann Arbor trip originates in a relatively large, isolated residential area (limited number of roads leading into and out of area) and concludes at Briarwood Mall, a high density commercial area. Figure 2 shows this route. The Dearborn trip originates in a residential area in a direction diagonal from the destination and concludes at Fairlane Town Center, a local mall. (See figure 2.)



1mi = 1.61 km

Figure 2. Routes for family/personal business trips in Ann Arbor and Dearborn, MI.

Social and recreational. Both trips generated for this scenario are in Washtenaw County. The first trip, shown in figure 3, is recreational and originates at the University of Michigan Sailing Club. This area contains several large park areas including Hudson Mills Metro Park and Pinckney State Recreational Area. This trip concludes at the Barton Hills Country Club on the north edge of Ann Arbor. The second trip is social and originates in Saline, another outlying community of Ann Arbor, and concludes in a residential area on the north side of Ypsilanti. (See figure 4.) There are a fair number of dirt roads and gravel tracks in this area of Saline. Also, it is particularly devoid of signs or landmarks and thus a navigation system could be quite useful.

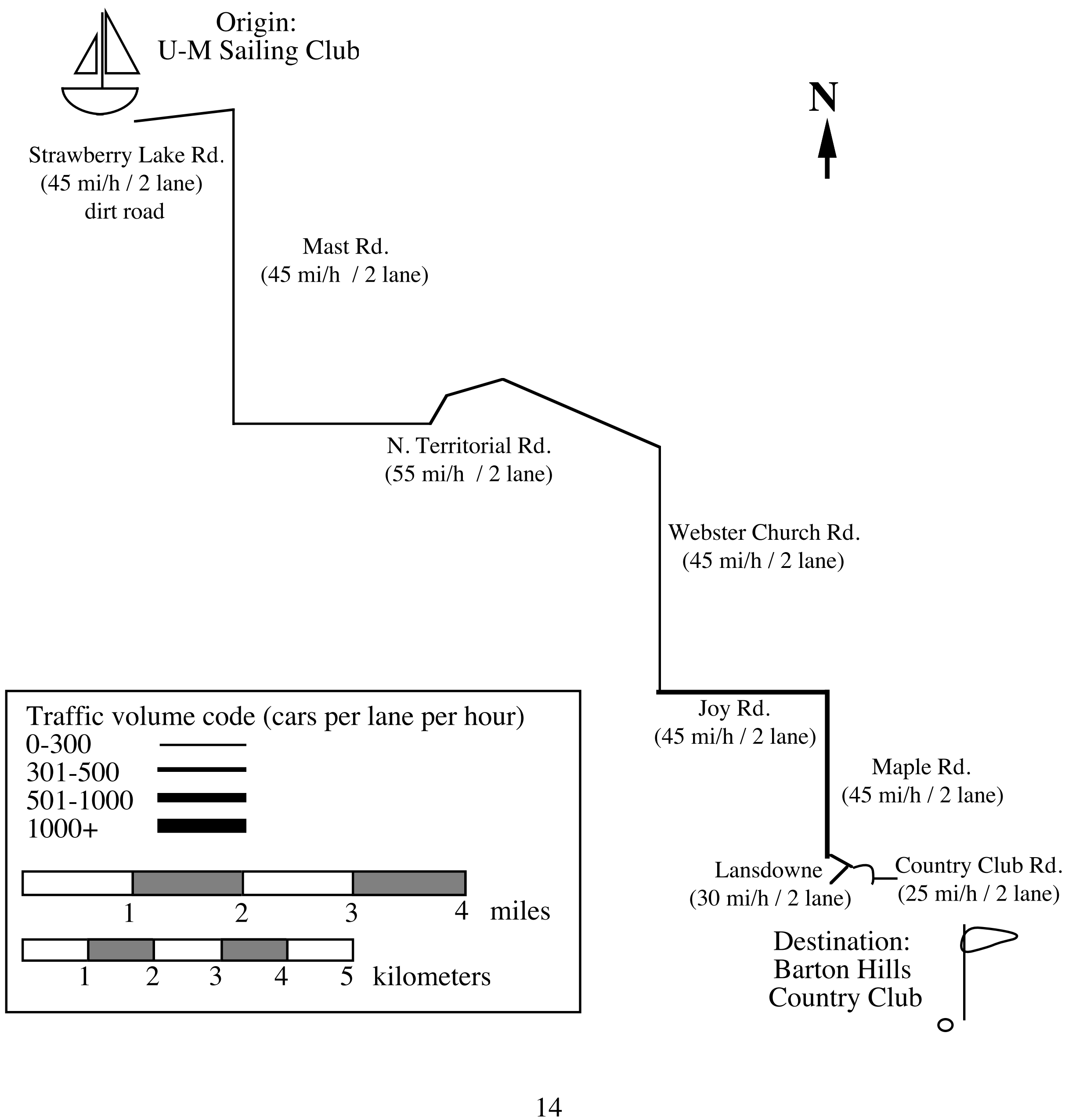


Figure 3. Route for recreational trip in Washtenaw County.

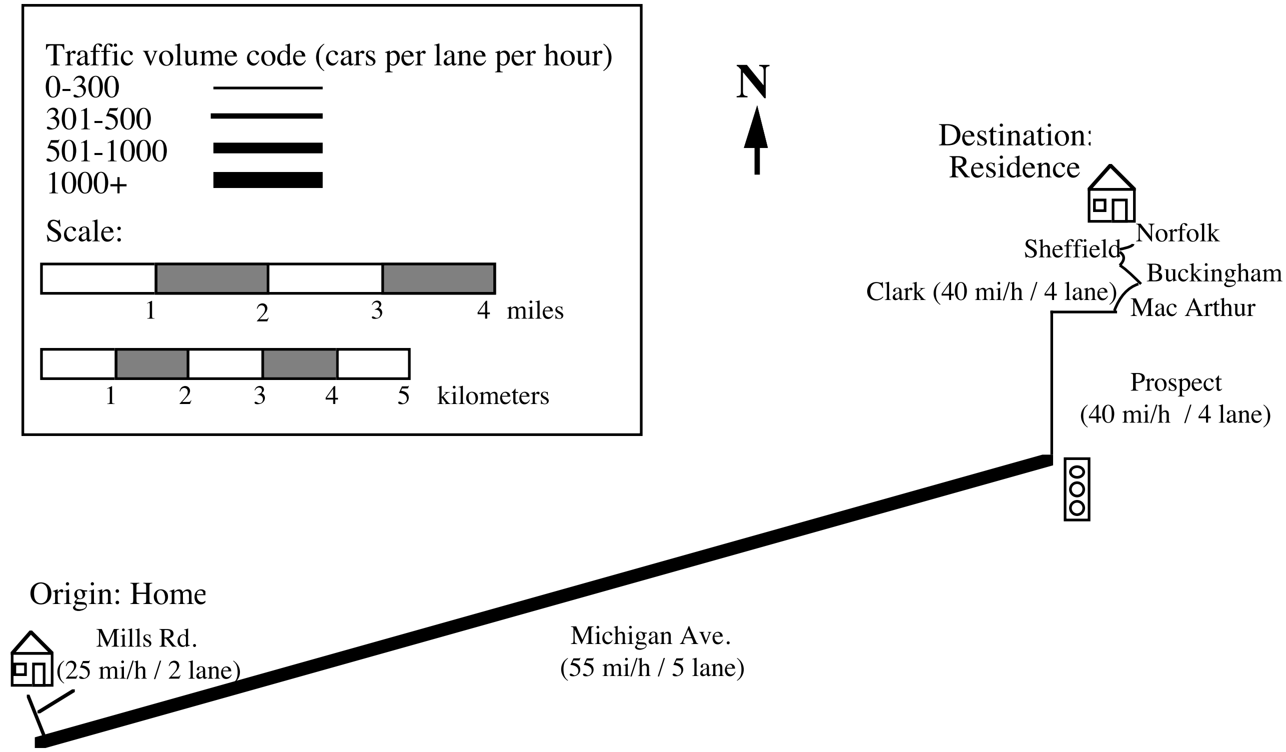


Figure 4. Route for social trip in Washtenaw County.

<u>Earning a living</u>. Three trips were generated for this scenario, one in Ann Arbor and two in Detroit suburbs. The Ann Arbor trip originates in Dexter, one of several outlying communities, and concludes in downtown Ann Arbor. (See figure 5.) Both of the Detroit trips originate in a residential area of Farmington Hills and conclude at a General Motors plant on the edge of Detroit proper. (See figures 6 and 7.) One of the Detroit trips is an optional route for the same destination. This trip could be used in alternate route selection should a system (IVSAWS or Traffic Information) indicate a problem on the current route. The optional route is longer but includes expressway travel.

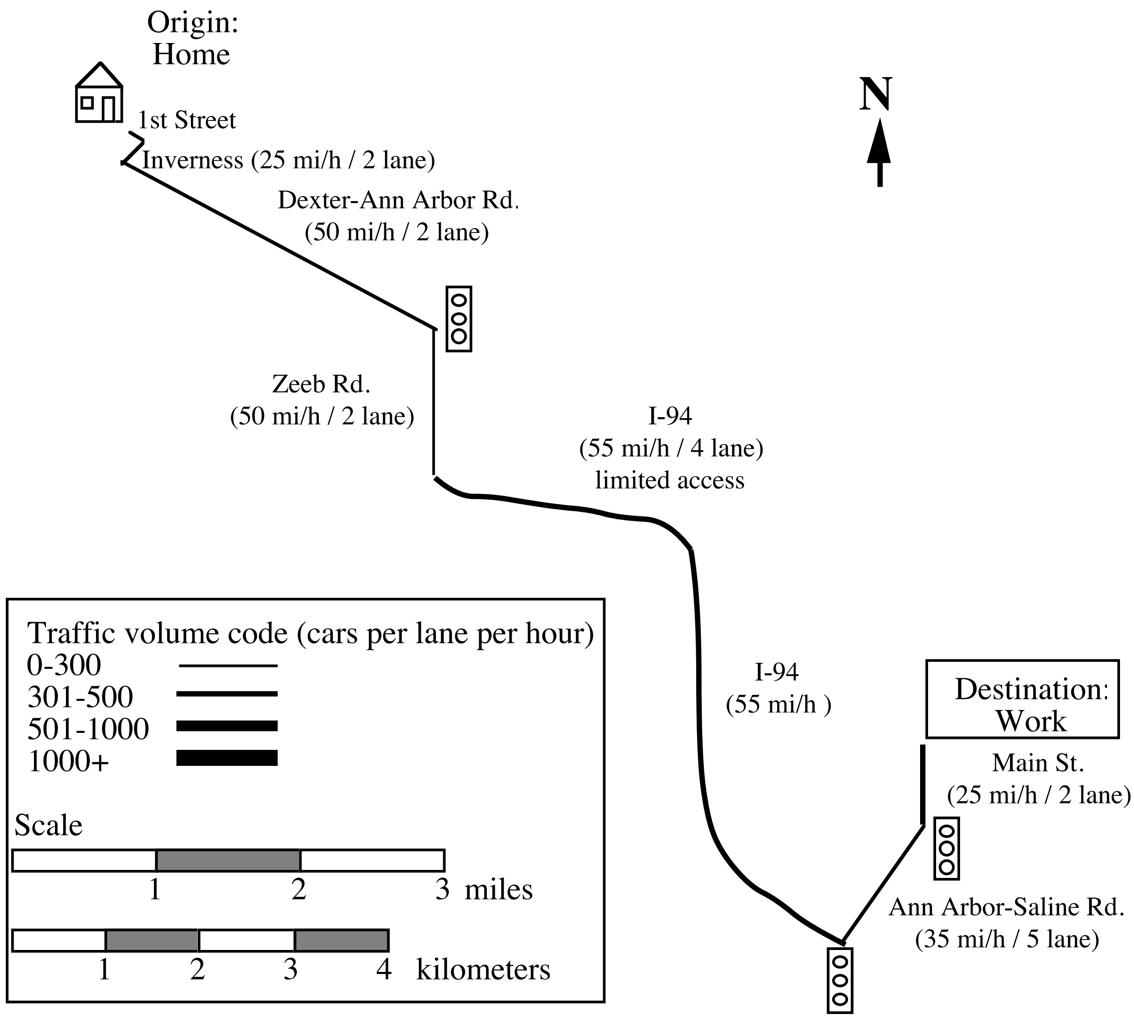


Figure 5. Route for earning a living trip in Ann Arbor.

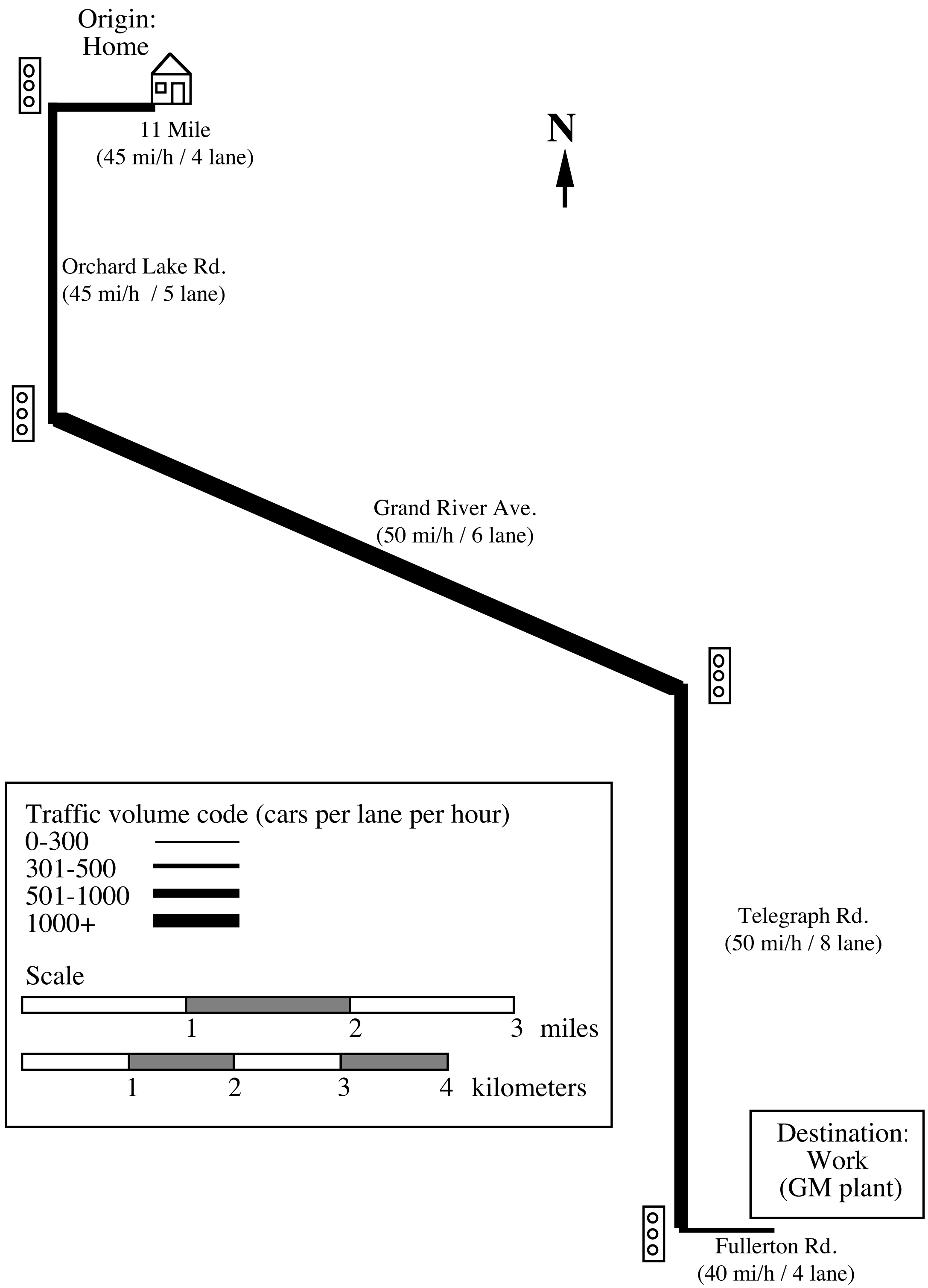
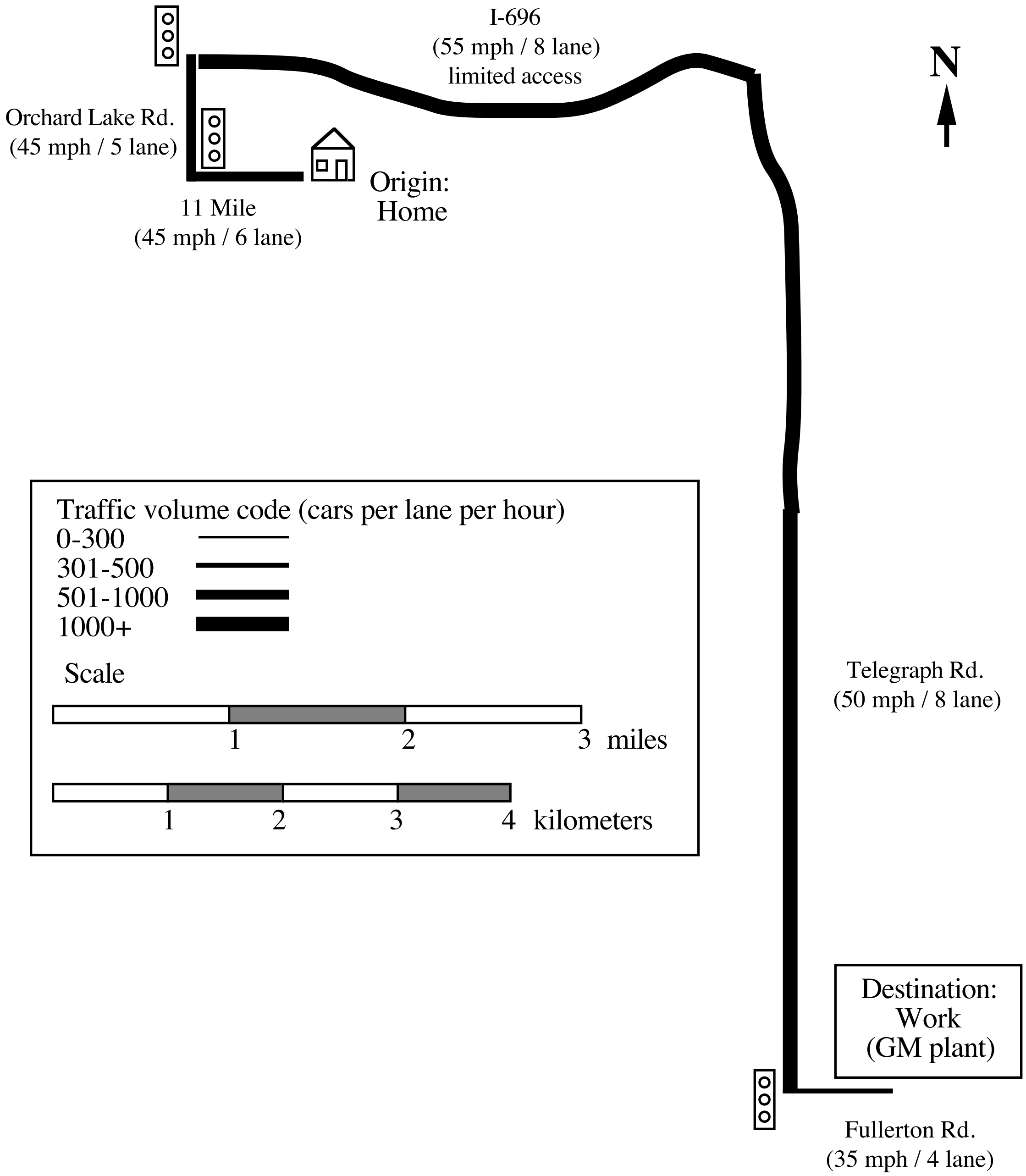


Figure 6. Route for earning a living trip in Detroit.



I-696
(55 mph / 8 lane)
limited access
N
Orchard Lake Rd.
(45 mph / 5 lane)
Origin:
Home
11 Mile
(45 mph / 6 lane)
Traffic volume code (cars per lane per hour)
0-300
301-500
501-1000
1000+
Scale
1
2
3 miles
1
2
3
4 kilometers
Telegraph Rd.
(50 mph / 8 lane)
Destination:
Work
(GM plant)
Fullerton Rd.
(35 mph / 4 lane)

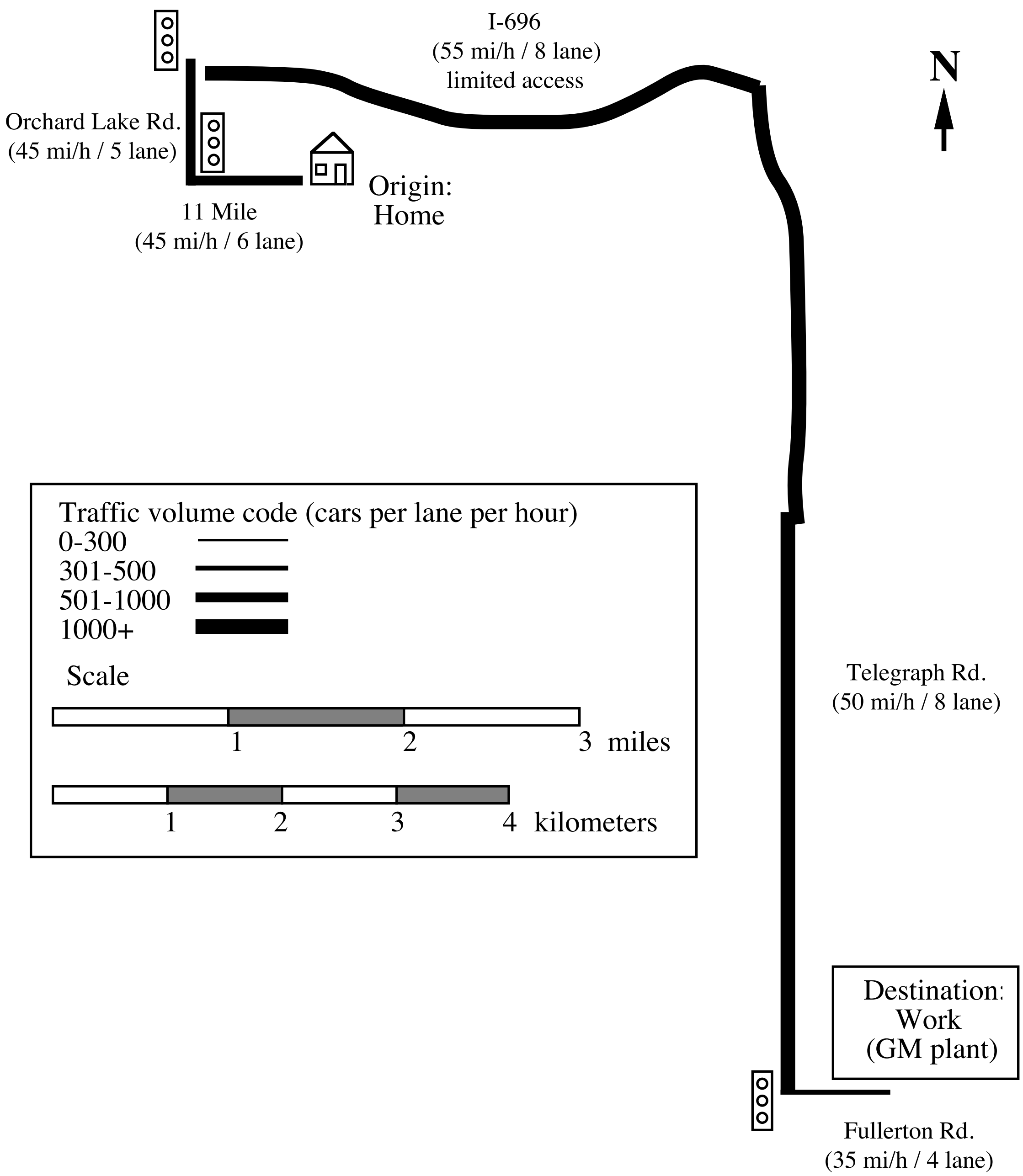


Figure 7. Optional route for earning a living trip in Detroit.

Summary

Categories for driver needs are listed in table 19. The wants dimension is based on drivers' views expressed in the Brand (1990) focus group study. The needs/convenience dimension is based on the three most common trip scenarios: (1) family and personal business, (2) social and recreational, and (3) earning a living.

Table 19. Categories for driver needs.

Wants	Focus Groups
Needs/Convenience	Driving Scenarios Family/personal business Social/recreational Earning a living

The specific scenarios referred to for scoring are given in table 20. In addition to the specific routes, other factors were considered that were not necessarily factored into the scenarios. For the personal business scenario, it was assumed that drivers may stop along the way, that they may be under a time constraint (e.g., doctor appointment), and that they may not be familiar with the route. For the social/recreational scenario, drivers may stop along the way, may know the route, may be using directions to reach their destination, and are probably not under a time constraint. For the work-related scenario, driving to meetings or scheduled appointments were not considered in the scenario but may be a significant portion of a worker's activities on a regular basis. In addition, it was assumed that the driver is familiar with the route, probably knows alternative routes, and is under a time constraint (needs to be to work or appointment on time).

Table 20. Three trip scenarios.

	Purpose	Origin	Destination	Trip Length (miles)	Type of Roads
1	family/personal business (shopping) (figure 2)	home	shopping mall	6.3	residential highway commercial
2	social/recreational (figure 3)	sailing club	country club	13.3	rural
3	earn living (to or from work) (figure 5)	home	work	10.2	residential city highway

STEP 3. FEATURE SCORING AND PRIORITIZATION

Scoring

The features of the systems were scored according to their contribution to the reduction of accidents, benefits to traffic operations, and driver needs. Each feature was assigned a score of 2 through — 2 depending upon how beneficial or detrimental it was with respect to the dimensional categories. The scoring scheme is given below:

2=Highly Beneficial
1=Beneficial
0=No Effect
-1=Detrimental
-2=Highly Detrimental
NA=Not Applicable
?=Unknown

A "0" was assigned if the feature would not substantially benefit or detract from the category or if benefits and detriments were identified but canceled each other out. "0" was also assigned if benefits or detriments were identified for driving cases classified as special cases or with extremely low probabilities of occurrence. A score of "NA" was assigned if the feature did not relate to the dimensional category and a "?" indicated that the effect of the feature on the dimensional category could not be determined.

In some of the early discussions among the authors, initial evaluations were made on a three-point scale. A number of cases arose in which there were clear differences among features in the minds of the authors that were not differentiated by a three-point scale, so the five-point scale was selected. There was some discussion of use of a seven-point scale, but the data did not provide support for such fine distinctions.

The assignment of scores was a matter of discussion among the authors. All are well versed in human factors issues pertaining to the design and evaluation of automobile controls and displays. They include an engineering professor, two engineering graduate students, and an electrical engineer. (See table 21.) In addition to their research, they have been involved with professional societies (Human Factors Society, Society of Automotive Engineers, etc.), other professional activities (such as running the University of Michigan Human Factors Short Course), and activities specific to IVHS.

In most cases two people developed the initial scores that were circulated to the others for review. When there were differences in opinion about scoring, they were debated. Readers should not be too concerned about the score of an individual cell in the matrix. There is some uncertainty about the scores; 10 to 15 percent of the cells are debatable. The change of a single value (out of 792 total values) will have only minor effects on the final ranking of features and functions.

Table 21. Backgrounds of the scorers.

Position	Education	Automotive HF Experience (yrs)
Scientist/Professor	Ph.D. (Ind. Eng. & Psych.) M.S. (Industrial Engineering) M.A. (Psychology) B.S. (Mechanical Engineering)	>15
Ph.D. Student	M.S. (Industrial Engineering) B.S. (Psychology)	2
Graduate Student	B.S. (Industrial Engineering)	2.5
Electrical Engineer	B.S. (Electrical Engineering)	1

When scoring the individual features, it was assumed that the function/feature was a typical system produced by industry. Also, the scorers considered the frequency of encountering a situation where the feature will be needed. The following factors were not taken into account: (1) market penetration, (2) potential frequency of use, and (3) the desired use of the function/feature (will people slow down if they know the road ahead is icy?).

Matrix for Reduction of Accidents

Table 22 shows the criticality scores of the features for the reduction of accidents dimension. The categories across the top of the matrix represent common causes of accidents cited in Treat et al. (1979) (e.g., improper lookout). For clarification, specific examples for each of the categories are shown in table 23. The rows of the matrices consist of the features identified for each of the nine systems (e.g., engine/power). The assigned scores with respect to the categories are contained within the cells of the matrix. Also shown in the matrix are weights associated with the categories, in this case the common causes of accidents, and summary scores. The definition and function of the weights, as well as the calculation of summary scores, will be elaborated upon in following sections.

Table 22. Matrix for reduction of accidents.

Table 23. Causes of accidents and examples (Treat et al., 1979).

Accident Cause		Example/Condition
Driver	Improper Lookout	Pulling out from parking place Entering travel lane from intersecting street, alley, intersection Prior to changing lanes or passing
	Excessive Speed	For road features (type, geometry) For traffic, pedestrians, etc. For weather conditions Combinations of above
	Inattention	To traffic stopped or slowing ahead To position of car on road To road features (curves, lane narrowing, etc.) To road signs/signals To cross-flowing traffic (merging, intersections)
	Improper Evasive Action	Fail to attempt an appropriate evasive action Negate the effect of an evasive steer by over-braking and locking the wheels
Environmental	View Obstruction	Road surface features (hillcrests, dips,etc.) Roadside embankments, escarpments, etc. Roadside structures and growth Stopped and parked traffic
	Slick Roads	Wet, snow, ice-covered roads Gravel/sand on paved roads Traffic-polished roads Gravel roads
Vehicular	Tires	Inflation (under, over, pressure distribution) Inadequate tread depth
	Brakes	Gross brake failure Brake imbalances

Driver Improper Lookout

The improper lookout and inattention causes were easily confused. Accidents caused from improper lookout result when drivers are pulling out from an intersection or a parking place, or are changing lanes or passing. Half of the time, drivers look but fail to see the oncoming traffic, and half the time they fail entirely to check for traffic. Accidents due to inattention involve drivers that fail to recognize slowed or stopped traffic, road features (curves or narrowing lanes), merging traffic, and signals or signs. Hence, the distinction is that accidents due to improper lookout occur when drivers are turning or making another type of driving maneuver that requires them to first check for traffic, while accidents due to inattention occur when drivers fail to notice that the driving situation requires slowing down or stopping.

For driver improper lookout (the second column in the matrix), Communication systems (cellular phone or CB radio) may increase accidents due to improper lookout (scores=-1) because drivers may be distracted from the driving environment. A radar detector will probably not affect such accidents (score=0) .

Two Navigation/Route Guidance systems were believed to have a negative effect on accidents caused by improper lookout. Features such as guidance (score=-1) and orientation (score=-1) may actually contribute to improper lookout accidents.

Most Office features will have a negative effect (scores=-1) on improper lookout accidents as well. The only feature believed not to contribute to such a hazard is dictation (score=0) since the driver will be speaking and not necessarily diverting his eyes from the road.

Excessive Speed

For Communication, cellular phones and CB's will have no overall effect on accidents due to excessive speed (scores=0). However, radar detectors encourage excessive speeds and, therefore, have an extremely negative effect on accidents of this nature (score=-2).

In-Car Signing could help prevent accidents due to excessive speed by making drivers more aware of speed limits, stop signs, and traffic signals (traffic control score=1).

Several of the IVSAWS features (compounding hazards, construction, and crash site) would be beneficial in reducing accidents due to excessive speed (score=1) by warning drivers of circumstances that may require quick stops or maneuvers, thus requiring slower speeds.

It was felt that Navigation/Route Guidance systems were not applicable to accidents involving excessive speed (scores=NA).

Some of the features of Traffic Information systems could help reduce accidents due to excessive speed. Information regarding congestion (score=1), construction (score=1), traffic rules (score=1), and weather (score=1) would alert drivers of conditions that may require slower speeds. However, freeway management, parking, and vehicle access were believed to have no effect (scores=0) on such accidents.

Inattention

The Communication system, cellular phone, was deemed hazardous for accidents due to inattention (scores=-1). The features of Entertainment also posed threats as distractions (scores=-1), especially television (score=-2). The In-Car Signing feature, traffic control, will help prevent accidents due to inattention by alerting drivers of an upcoming stop sign or traffic signal (score=2).

All of the features of IVSAWS may help avoid accidents due to inattention. Notifying drivers of compounding hazards on the road, emergency vehicles, railroad crossings, school buses (and other special vehicles), and new stop signs (supplemental traffic control) will draw their attention to the situation, reducing the chance of an accident (scores=1, except railroad crossings=2 because of the high speed of trains). Information regarding construction (score=1) and crash sites (score=2) will alert drivers to situations causing stopped or slowed traffic. This should help drivers realize that traffic is stopped before it is too late to avoid an accident. IVSAWS is even more important for crash sites since this will be the only warning drivers have, as opposed to construction where signs may be posted along the side of the road.

All Motorist Services features may divert the driver's attention from the driving environment to the information display (scores=-1). The Navigation/Route Guidance feature, orientation, may distract drivers' attention, making them more prone to this type of accident (scores=-1).

Extreme distractions were found among some of the Office features, such as computing (score=-2) and fax (score=-2). Other Office features (calculator, dictation, electronic calendar, and electronic directory) were believed to be hazardous as well (scores=-1).

Finally, some features of Traffic Information (congestion, construction, freeway management, and traffic rules) may also help prevent accidents due to inattention. Congestion (score=1) and construction (score=1) information, similar to IVSAWS construction, will alert drivers to stopped or slowed traffic. Providing the driver with freeway management information (score=1) and traffic rules (score=1) will help to alert drivers to special conditions on roads.

Improper Evasive Action

The functions of Communication, Entertainment, IVSAWS, Motorist Services, Navigation/Route Guidance, and Office were all believed to be not applicable (scores=NA) to accidents caused by improper evasive actions. In-Car Signing, Traffic Information, and Vehicle Monitoring were determined to have no effect on accidents due to improper evasive action.

Alcohol Impairment

None of the functions examined would be applicable to preventing alcohol-related accidents (scores=NA).

View Obstructions

The only function that is applicable to accidents caused by environmental obstructions (trees and other view blockers) is IVSAWS. Within IVSAWS, the railroad crossing feature would be beneficial to drivers coming upon a railroad crossing with a partially obstructed view of the track (score=1). However, the remaining features would probably not have an effect (score=0), except for construction and crash site which are not applicable (scores=NA).

Slick Roads

IVSAWS will be extremely helpful with its compounding hazards feature (score=2) since this gives direct information concerning the problem of accidents caused by slick roads. The construction feature will have no effect on accidents due to slick roads (score=0) while the other features of IVSAWS were determined to be not applicable (scores=NA).

Weather information, provided through the Traffic Information function and the radio (Entertainment), should help reduce accidents due to slick roads (scores=1), since drivers will be more alert to hazardous conditions. All other features of Traffic Information were believed to have no effect (scores=0).

The path control feature of a Vehicle Monitoring system should help avoid accidents due to slick roads by informing drivers of low tire pressure or bad brakes, situations that increase the risk of accidents due to slick roads (score=2). All of the other features were deemed not applicable (scores=NA), except for drivetrain (score=0).

The functions of Communication, Entertainment (cassette/CD player), In-Car Signing (destination assistance and street signs), Motorist Services, Navigation/Route Guidance, and Office were not applicable (scores=NA) to accidents caused by slick roads.

Vehicular Causes

The only IVSAWS feature affecting accidents due to inadequate tires would be the compounding hazards warning (score=1), since this would make drivers more aware of situations in which their tires would be inadequate. The Vehicle Monitoring feature that warns of poor tire condition, path control, would also be extremely helpful (score=2). All other features of IVSAWS and Vehicle Monitoring, as well as the other functions, were not applicable to tire-related accidents (scores=NA).

Similarly, accidents due to brake failure would be considerably reduced by the path control feature of Vehicle Monitoring (score=2), while the compounding hazards feature of IVSAWS was determined to have no effect (score=0). All other IVSAWS and Vehicle Monitoring features, as well as the other functions, were not applicable to brake-related accidents (scores=NA).

Matrix for Benefits to Traffic Operations

Scoring of the features for the dimension, benefits to traffic operations, is given in table 24. The benefits listed across the top of the matrix are the traffic program goals that could possibly be helped by driver information systems.

Mode Choice

Communication (cellular phone) and Office systems (computing and fax) that allow people to be productive in their vehicles could have a negative effect on carpooling and public transportation (scores=-1) since drivers will want to ride in their own vehicles if they have these systems. Cellular phones in vehicles would especially deter drivers from taking public transportation (score=-2). Not much thought has been given to supporting such functions on public transportation even though there are instances where it could be quite beneficial (e.g., to people who commute long distances).

A television (Entertainment) placed in a vehicle so that it is visible to drivers might discourage drivers from taking public transportation (score=-1). It could also dissuade drivers from carpooling, but may actually encourage other passengers to ride in the vehicle for carpooling purposes. Thus, television under carpooling was determined to have no effect (score=0).

For Motorist Services, transportation can provide information on bus and train schedules that will make it easier for drivers to take alternate modes of transportation (score=1). However, providing the driver with destination assistance and yellow pages information would detract from carpooling and public transportation (scores=-1)

Navigation/Route Guidance features, guidance, orientation, and trip planning, will provide drivers with powerful trip planning systems that may entice them to drive their own cars more often (scores=-1).

Other functions and features were determined to have no effect (scores=0) or to be not applicable (scores=NA).

Route Choice

Only two features were determined to be detrimental to traffic flow on corridors and surface streets—radar detector (Communication) (scores=-1) and television (Entertainment) (scores=-1). Drivers who use radar detectors tend to travel at high speeds and thus, may interfere with traffic flow. Further, watching television while driving may divert attention from the road and cause drivers to slow down.

Table 24. Matrix for benefits to traffic operations.

Providing the driver with optimum travel speeds (In-Car Signing—traffic control) and street signs would help maintain optimum traffic flow on corridors and surface streets (scores=1). Street sign information on surface streets will be even more informative to drivers (score=2). Warning drivers of lane blockages ahead due to construction (IVSAWS) would help divert traffic from the corridor and help maintain the new lower maximum traffic density (score=1 for corridors, score=2 for surface streets because diversion is easier). Informing drivers of crash sites would even by more beneficial since they generally have no advanced warning of a problem (scores=2). Providing drivers with information on school buses or other vehicles that may slow them down on surface streets will allow them to divert to other roads or to slow down, thus stabilizing traffic flow (score=1).

Motorist Services (destination assistance) would provide drivers with the location and hours of operation of commonly used services, reducing unnecessary driving on surface streets (score=1). Guidance and trip planning features of Navigation/Route Guidance would be extremely helpful in reducing unnecessary driving on corridors and surface streets (scores=2), in addition to orientation information (Navigation/Route Guidance) on surface streets (score=1).

Diversion of traffic from problem corridors and surface streets could also be initiated by providing the driver with congestion (scores=2) and construction (scores=1) information. Freeway management (Traffic Information) combines a number of the corridor diversion features into a freeway-specialized feature that would greatly benefit traffic flow on corridors (score=2). Parking information (Traffic Information) would reduce the number of vehicles driving on surface streets in search of parking (score=1). Traffic rules (Traffic Information) on surface streets may encourage drivers to stay within the posted limits (score=1), increasing the efficiency of signal timing and traffic flow.

Finally, providing drivers with Vehicle Monitoring information about their engine or tires and brakes (path control) may help to reduce the number of breakdowns on corridors and surface streets and, therefore, the congestion associated with these situations (scores=1). The Vehicle Monitoring features—climate, ingress/egress, and safety—were not applicable (scores=NA) to route choice, nor were compounding hazards, railroad crossing, and supplemental traffic control (IVSAWS) for corridors.

Traffic Flow

The Communication features, cellular phone and CB radio, will speed the notification of the authorities in the event of an accident or stalled vehicle and, thus, will ultimately reduce clean-up time (scores=2). Providing congestion information over the radio (Entertainment) will allow drivers to divert to other roads, thus reducing rush hour traffic and clean-up time (scores=1).

IVSAWS warnings for crash site, emergency vehicle, and school buses or other special vehicles will allow drivers to adjust their speed or divert from the road, thus reducing accident/breakdown clean-up time (scores=1). Trip planning information (Navigation/Route Guidance) may reduce rush hour peak spread by providing the driver with alternate routes (score=1).

Providing the driver with Traffic Information such as congestion, construction, and parking may alter departure times for future trips away from peak travel times and, thus, help reduce rush hour traffic (scores=1). Congestion and freeway management information (Traffic Information) may also help to reduce clean-up time (scores=1).

A number of functions were not applicable (scores=NA) to the reduction of rush hour peak spread (In-Car Signing, IVSAWS, Office, and Vehicle Monitoring) or to the reduction of accident/breakdown clean-up time (In-Car Signing, Motorist Services, Navigation/Route Guidance, Office, and Vehicle Monitoring).

Matrix for Driver Wants

The scores for the want matrix are based on drivers' views that were obtained in the focus group study (Brand, 1990). (See table 25.) The scoring system for this matrix is slightly different from the scoring for the other matrices; the descriptors range from highly desirable (score=2) to highly undesirable (score=-2) rather than highly beneficial and highly detrimental. This captures how drivers from the focus groups felt about the features, rather than how beneficial or detrimental the features were thought to be.

Many of the high technology functions and features proposed for future vehicles were not discussed in the focus group sessions. By their nature, focus groups tend to be free flowing and it is difficult to get comprehensive coverage of a topic. Thus, these features received a score of "?." Further, unlike the other matrices where features rather than functions were scored, two functions (Vehicle Monitoring and Navigation/Route Guidance) were discussed in general and, thus, were also scored.

For the most part, drivers want Vehicle Monitoring systems that will warn them of a potential failure (score=1). The following Traffic Information features were also of high interest to the drivers: congestion (score=2), construction (score=1), freeway management (score=1), and weather (score=1). In particular, they want more specific information than is currently provided in traffic reports, such as where congestion begins and ends as well as alternate travel routes.

There were mixed views of Navigation systems (scores=1), trip computers (score=0), and cellular phones (score=1). Participants in the focus groups thought that they would rarely use Navigation systems for general area driving, but might rely on them more for long trips (e.g., vacations and business trips). Trip computers were viewed as 'toys' by people who did not rely on their cars to a great extent, while those who spend much more time in their cars like them. Cellular phones were viewed as safety devices by women (they could call for help if necessary) and as great advances in technology by those who could continue to work by making calls while driving. Others viewed them as an imposition on their private time. Finally, many thought that they would rarely use a yellow page system (score=-1).

Matrix for Driver Needs/Convenience

Needs/convenience scoring is based on the three trip scenarios (family and personal business, social and recreational, and earning a living) that account for the majority of person trips. (See table 25.) Structured walk-throughs of the scenarios were performed in order to score the need and convenience of the features while driving. The Random House Dictionary (1967, p. 319) defines convenience as "agreeable to needs or purpose; well-suited with respect to facility or ease of use; favorable, easy, or comfortable for use." Similarly, need was defined as "a lack of something wanted or deemed necessary" (Random House Dictionary, 1967, p. 956).

A majority of the features were determined to be beneficial (score=1) for drivers on the three trip scenarios. However, some were deemed as highly beneficial (score=2) or as having no effect (score=0). None of the features were perceived as being detrimental (scores=-1 or -2) with regard to driver need or convenience. In some cases there were differences in the ratings depending on the driving scenario.

Table 25. Matrix for driver wants and needs/convenience.

For Communication systems, cellular phones are needed by drivers on work trips (score=2) more than by drivers on other trips (scores=1). Similarly, drivers on their way to/from work are usually under stricter time constraints than other drivers and, thus, may tend to use radar detectors (score=2).

For Entertainment, while television is not necessary for drivers (score=0), radios and cassette decks are necessary/convenient for drivers on any trip (scores=2).

In-Car Signing (street signs and traffic control) will benefit drivers on personal business, social/recreational, or work-related trips (scores=1). Street sign information, however, may not be quite as beneficial for work trips since drivers generally travel on the same roads to and from work and, thus, know their names (score=0). Destination assistance will be beneficial to drivers on personal business (score=1) and especially social/recreational outings (score=2) when they may be traveling to unfamiliar destinations.

For IVSAWS, because drivers on work-related trips will be familiar with characteristics of the roads (sharp curve) on their route, they do not necessarily need to be warned about compounding hazards (slick) on these roads (score=0). Further, providing drivers on work-related trips with information about crashes ahead can be especially helpful since these drivers are under time constraints (score=2). Drivers on social/recreational trips will benefit more from warnings of approaching trains since they may be traveling on more rural roads than drivers in other scenarios (score=2).

Motorist services, for the most part, will have no effect on drivers' needs. For drivers on personal business trips, features that would be convenient or helpful include banking (score=1) and yellow pages (score=1). Destination assistance would be helpful for drivers on personal business (score=2) and social/recreational trips (score=2), but not necessary for drivers on their way to work since they know where they are going (score=0). Finally, transportation information may be especially helpful for drivers on work-related trips (score=2) who need information on other modes of transportation.

Orientation information for the Navigation/Route Guidance function is convenient for all drivers regardless of the purpose of the trip (scores=2). While drivers on social/recreational and work-related trips would find guidance and trip planning information necessary since they may be traveling on unfamiliar roads or may need to find an alternative route, respectively (scores=2), drivers on personal business trips would not need it as much since it is likely that they run errands on familiar roads in their neighborhoods (scores=1).

Office features are only beneficial for drivers on work-related trips (scores=1), except for more general features such as calculator, electronic calendar, and electronic directory that will be used by drivers regardless of the purpose of the trip (scores=1).

For Traffic Information, a majority of features (congestion, construction, freeway management, parking, and weather) will be highly beneficial for drivers on their way to work (scores=2). For drivers on personal business trips, knowing about congestion, construction, and parking is highly beneficial (scores=2) while the other Traffic

Information features are of a secondary nature (scores=1). For those on social/recreational trips, it would be important to know the weather conditions (especially for outdoor events) (score=2).

For the Vehicle Monitoring function, engine/power and path control received higher ratings (scores=2) than the other features since this strongly influences a driver's trip and knowing this information is convenient for the driver. Information on safety systems will not have much of an effect on drivers' convenience (scores=0). Finally, status and repair information on the doors and trunk (ingress/egress) is more important for drivers on personal business and social/recreational trips who may be loading/unloading children and parcels into/out of the car (scores=1) than for drivers on work-related outings (score=0).

Determination of Category Weights

Weights for the dimensional categories were determined in order to prioritize the features based on the reduction of accidents, benefits to traffic operations, and driver needs. This was necessary so that the relative importance of each category was represented in the prioritization. For example, accidents due to tire problems represent a small percentage of accident causes (4 percent) and should not be weighted the same as accidents due to driver improper lookout (23 percent of accidents). Weights were assigned to the categories based on information in the literature and the authors' judgment (for benefits to traffic operations).

Reduction of Accidents

For the reduction of accidents dimension, a majority of the weights were based on the results of Indiana University's tri-level study (Treat et al., 1979). The weight for alcohol impairment, however, was an approximate weighted average based on numerous sources of accident data (FARS, 1989; NASS, 1989; National Safety Council, 1989). The nine leading causes of accidents and their percentages are given in table 26. The weights were determined by normalizing the percent accidents so that they totaled to 1.000 (100 percent). Readers should recall that most accidents were attributed to multiple causes.

Table 26. Weights for matrix on reduction of accidents.

Accident Cause	%Accidents	Weight
Driver		
Improper Lookout	23	0.211
Excess Speed	17	0.156
Inattention	15	0.138
Improper Evasive Action	13	0.119
Alcohol Impairment	10	0.092
Environmental		
View Obstruction	12	0.110
Slick Roads	10	0.092

Vehicular		
Tires	4	0.037
Brakes	5	0.046
Total	109	1.001

Benefits to Traffic Operations

The six categories of the dimension, benefits to traffic operations, were weighted equally (weight=0.167) since there were no literature or statistics to base the weights on. Weights could have been arbitrarily assigned to the categories. In fact, this method was experimented with and it was found that the ranking of the features did not substantially change. An example of two sets of weightings and the outcomes are given in the next section where prioritization is addressed.

Driver Needs

Driver wants are based on the focus group work (Brand, 1990) and, thus, were assigned a weight of one. For the driver needs/convenience matrix, the weight assigned to each scenario is a normalized weight based on the percentage of trips accounted for by that purpose. The weights are indicated in table 27.

Table 27. Weights for driver needs/convenience matrix.

Driving Scenario	Person Trips (%)	Weight
Personal Business	36	0.414
Social/Recreational	28	0.322
Earning a Living	23	0.264
Total	87	1.000

Prioritization

After the criticality weights were determined, features were prioritized according to how beneficial they were with respect to the dimensions. The first step in doing this was to assign a normalized summary score to each feature within each dimension (matrix). Secondly, these normalized scores for the three dimensions were placed in one matrix and an overall total score was assigned to each feature. The features were then prioritized according to how beneficial they were determined to be. This process is described in more detail below.

Summary Scores

The matrices for reduction of accidents, benefits to traffic operations, and driver wants and needs/convenience are shown in tables 22, 24, and 25, respectively. The last two columns of the matrices entitled "Summary Scores" list the raw and normalized summary scores for the features. The raw summary score for each feature was defined as the sum of the scores multiplied by their respective category weights.

For the benefits to traffic operations matrix (table 24), an example using the feature, orientation, for the Navigation/Route Guidance function is shown below:

Orientation Raw Score: $-0.17 = -1(0.167) + (-1)(0.167) + 1(0.167)$

The raw scores were then normalized. This was done by dividing each raw score by the highest raw score that was calculated within the matrix. The rationale for doing this was to force the range of summary scores to be between 1 and -1. Continuing with the example above, the calculation for the normalized score is shown below:

Orientation Normalized Score: $-0.17 = -0.17/1.00$
(1.00=the raw score for Traffic Information—congestion)

Summary scores for the driver wants matrix are slightly different from those of the other matrices. In the wants matrix (table 25), the raw score was extrapolated from the survey score in the following manner: (1) a question mark (?) was assigned a score of "0", (2) when the entire function was scored (Vehicle Monitoring), features that were not individually scored were assigned the overall score, and (3) numeric scores (-2, -1, 0, 1, 2) were directly translated to the summary score. The raw scores were then normalized in the same manner as for the other matrices.

A comparison matrix for benefits to traffic operations was formulated with a second set of arbitrary category weights to determine to what degree the ranking was influenced by the weights. The categories were assigned the following ratios: Route Choice categories, corridors (6) and surface streets (5), were weighted more than Generic Traffic Flow (rush hour peak spread--2 and reduce accident/breakdown clean-up time--2). Lower weights were assigned to Mode Choice categories, public transportation (1.25) and carpool (1). This resulted in normalized weights of 0.349, 0.291, 0.116, 0.116, 0.072, and 0.058 respectively. The normalized scores using these weights were calculated and prioritized. Table 28 shows the original and alternative rankings of the features.

Comparison of the alternative and original rankings reveals that the differences in weights did not substantially alter the ranking of the top ten features. Traffic Information--congestion, IVSAWS--crash site, and Navigation/Route guidance--trip planning remained the top three features. Only two features moved out of the top ten, Entertainment--radio (from 4 to 12) and Communication--CB radio (from 9 to 16). The ranking of the other features remained relatively stable.

Feature Ranking

The features with their respective summary scores for the three dimensions were combined into one matrix. In order to prioritize the features, each of the three dimensions (reduction of accidents, benefits to traffic operations, and driver wants and needs/convenience) was assigned a weight based on the emphasis it should have with respect to the other dimensions.

The accident weight was based on the annual cost of accidents. This was estimated to be approximately $90.3 billion--$70 billion in lost wages and direct costs and $20.3 billion for the public's valuation of pain and suffering (Mobility 2000, 1990). For benefits to traffic operations, the cost of traffic congestion was estimated to be $60 billion annually. This amount was derived from the Mobility 2000 report (1990) that estimated an annual cost of $41 billion for congestion in 39 large U.S. cities, combined with experts' (Robert Ervin and David Andrea, colleagues at UMTRI) estimates of $20 billion for the rest of the U.S. The weight for driver wants and needs/convenience was based on an estimate by the authors of the annual dollars that would be spent if every new car purchased was equipped with several advanced driver information systems. This estimate was $2 billion, based on annual U.S. car sales of 10 million times $2,000 for information systems in these cars.

The three dimensions and their associated annual costs are presented in table 29. The weights for the dimensions are respective fractions of the total cost. Driver needs/convenience was weighted approximately 50 percent more heavily than wants because the authors were more confident in these scores that were based on the scenarios than the want scores from the focus group studies. The focus groups provided valuable information but it was often incomplete since they did not talk about many of the functions.

Table 28. Comparison of original and alternative rankings for benefits to traffic operations.

Ranking Original	Ranking Alternative	Feature
1	1	TI* congestion
2	2	IVSAWS crash site
3	3	N/RG trip planning
4	12	ENTR radio
5	5	IC street signs
6	6	IVSAWS construction
7	8	TI construction
8	7	TI freeway management
9	16	COM CB radio
10	9	IC traffic control
11	19	MS transportation
12	4	N/RG guidance
13	13	IVSAWS school bus/other special vehicles
14	14	TI parking
15	10	VM engine/power
16	11	VM path control (tires,brakes)
17	20	IVSAWS emergency vehicle
18	15	TI traffic rules
19	22	ENTR cassette/CD player
20	23	IC destination assistance
21	24	MS banking
22	25	MS customs information
23	26	N/RG trip computer
24	27	OFF calculator
25	28	OFF dictation
26	29	OFF electronic calendar
27	30	OFF electronic directory
28	31	IVSAWS compounding hazards
29	32	IVSAWS railroad crossing
30	33	IVSAWS supplemental traffic control
31	34	TI vehicle access
32	35	TI weather
33	36	VM climate
34	37	VM drivetrain
35	38	VM ingress/egress (doors,trunk)
36	39	VM safety restraints
37	21	COM cellular phone
38	17	MS destination assistance
39	18	N/RG orientation
40	43	COM radar detector
41	40	MS yellow pages/commercial
42	41	OFF computing
43	42	OFF fax
44	44	ENTR television

*Key:
COM=Communication
ENTR=Entertainment
IC=In-Car Signing
IVSAWS=In-Vehicle Safety Advisory and Warning System
MS=Motorist Services
N/RG=Navigation/ Route Guidance
OFF=Office
TI=Traffic Information
VM=Vehicle Monitoring

Table 29. Weights for the three dimensions used for scoring.

Dimension	Cost (dollars)	Weight
Reduction of Accidents	$90.3 billion	0.593
Benefits to Traffic Operations	$60.0 billion	0.394
Driver Wants Driver Needs/Convenience	$2.0 billion	0.005 0.008
Total	$152.3 billion	1.000

A matrix with the prioritized features is shown in table 30. A total score for each feature was calculated based on the normalized scores. (See the last column in table 30.) This total score was obtained by summing the products of the normalized scores and their respective dimensional weights. An example calculation of the total score for the orientation feature is given below:

$$\text{Orientation Total Score:} \quad -0.44 = 0.593(-0.65) + (0.394)(-0.17) + (0.005)(0) + (0.008)(1.00)$$

A high ranking indicates that the feature could potentially reduce accidents, improve traffic operations, and may be wanted and/or needed by drivers. On the contrary, a low ranking is indicative of a feature that could potentially increase accidents, degrade traffic operations, and is not necessary or wanted by drivers. A closer look at the specific score for a feature in table 30 will reveal the contribution of each dimension to the total score.

The top ten features include four of the seven IVSAWS features (ranked 1, 4, 7, and 8), four Traffic Information features (ranked 3, 5, 9, and 10), In-Car Signing—traffic control (ranked 2), and Vehicle Monitoring—path control (ranked 6). Traffic control (In-Car Signing), compounding hazards (IVSAWS), and railroad crossing (IVSAWS) had particularly high scores in the reduction of accidents matrix. The other functions and features (IVSAWS—construction and crash site, Traffic Information—congestion, construction, freeway management, and traffic rules, and Vehicle Monitoring—path control) scored relatively high on both the dimensions of reduction of accidents and benefits to traffic operations. Scores for the driver needs dimension were not major contributors to the overall scores due to the low weights for this dimension.

Features with low rankings (negative scores) were from the Office, Communication, Motorist Services, and Navigation/Route Guidance functions. The low overall scores resulted from negative scores for both the reduction of accidents dimension (Driver—improper lookout, excess speed, and/or inattention) and the benefits to traffic operations dimension (Mode Choice—carpool, public transportation, and/or Route Choice—corridor optimum traffic density flow).

Table 27. Overall summary matrix with ranked features.

STEP 4. SELECTION OF FIVE FUNCTIONS FOR FURTHER DESIGN AND EVALUATION

According to the requirements of the government contract, the next task was to select five functions or systems for further analysis. The overall summary matrix with ranked features was used for the purpose of selection. As shown in table 30, the top five functions (and features) ranked were:

1. IVSAWS (crash site, compounding hazards, construction, and railroad crossing).
2. In-Car Signing (traffic control).
3. Traffic Information (congestion, construction, traffic rules, and freeway management).
4. Vehicle Monitoring (path control).
5. Navigation/Route Guidance (trip planning).

Three functions required by the contract were IVSAWS, Vehicle Monitoring, and Navigation/Route Guidance. Because Traffic Information and In-Car Signing had high rankings after criticality scoring, this would make them prime candidates for selection and further implementation and, thus, Traffic Information was selected. Implementation of In-Car Signing would be very similar to IVSAWS and, thus, does not need to be tested as a separate system. For the remaining function, Entertainment (radio) would be a logical choice since it was the highest ranked function after the four already chosen (and In-Car Signing). However, attention was turned to the low ranking features, in particular, cellular phones. It was clear from the literature that of the new systems being considered, cellular phones would have the greatest early market penetration, and there continues to be discussion if they are safe to use while driving. Further, the phone requires a level and type of interaction not found in other features, an interaction that needs to be examined so that the Integrated Driver/Vehicle Model, a model being developed through this project, will be complete. Thus, Communication (cellular phone) was selected as a function/feature to investigate.

In summary, the five functions and their features selected for further evaluation are given in table 31. The features, guidance, orientation, and trip planning, were selected for Navigation/Route Guidance because they were determined to require complex interactions on the part of the driver and their design has not been studied extensively.

Table 31. Functions and features selected for further evaluation.

Function	Feature
Communication	Cellular phone
IVSAWS (road hazards)	Compounding hazards Construction Crash site Emergency vehicle Railroad crossing School bus/other special vehicles Supplemental traffic control
Navigation/Route Guidance	Guidance Orientation Trip planning
Traffic Information	Congestion Construction
Vehicle Monitoring	Climate Drivetrain Engine/power Ingress/egress Path control Safety restraints

STEP 5. IDENTIFICATION OF INFORMATION ELEMENTS

Evaluation of the five selected functions and their features was undertaken to identify the individual elements (information elements) that the driver will interact with when using the features. Information elements for the selected features are provided below.

Cellular Phone

Information elements for the cellular phone were identified by reviewing cellular phone displays and features (Motorola and Visorphone). Scenario walk-throughs were also made to determine the type of information drivers need when using a cellular phone. The information elements identified are shown in Table 32. On a cellular phone, the Roam indicator is provided to inform the driver that service from a different cellular system provider is trying to be obtained. Other information elements that readers may not be familiar with are Lock (prohibits unauthorized use of the phone) and Name (stores/recalls alpha names to/from memory locations).

Table 32. Information elements for cellular phone.

Feature	Information Element
Cellular phone	Brightness Power
	Display number Display status Input number to dia
	In use indicator No service indicato Power indicator Roam indicator
	Handset volume Ringer volume Speaker volume
	Clear End Send Store
	Function Lock Menu Mute Name Recall

IVSAWS

A majority of the information elements for this system were determined from descriptions of possible features in the Streff et al. (1991) report. Others were determined by the authors after consideration of the features and the capabilities of the system. Table 33 shows the information elements for IVSAWS.

Table 33. Information elements for IVSAWS.

Feature	Information Element
Compounding Hazards	Curve (excessive speed) Curve (fog, slippery) Grade (fog, slippery)
Construction	Construction ahead Distance to construction Lane shifts Lanes closed/open Speed limit
Crash Site	Accident ahead Directions affected Lanes closed/open
Emergency Vehicle	Ambulance--at scene Ambulance--on run Fire truck--at scene Fire truck--on run Police--at scene Police--in chase/pursuit Police--on run
Railroad Crossing	Number of tracks Train approaching/crossing
School Bus/Other Special Vehicles	Construction equipment Farm vehicle Funeral procession Horse drawn vehicle Mail delivery Plow/gravel truck Public utility vehicle Refuse removal truck School bus--loading/unloading Slow moving vehicle Tow truck--at scene Wide load
Supplemental Traffic Control	Disabled traffic signal New signal light New stop sign New yield sign

Navigation/Route Guidance

Information elements for orientation and guidance/trip planning were determined through review of existing navigation systems (ETAK, Ali-Scout, and Travtek) and consideration of what drivers need to know when planning a trip or trying to find their way in unfamiliar surroundings. Elements for a Navigation/Route Guidance system are shown in table 34.

Table 31. Information elements for a Navigation/Route Guidance system.

Feature	Information Element
General	Brightness Power Volume
Orientation	Compass Display city or suburb Display current street Display travel direction Distance from last turn Distance from previous cross street Distance to nearest landmark Distance to next cross street Distance traveled Nearest landmark Next cross street Previous cross street Time traveled
Route Guidance	Appropriate lane Current legal speed limit Display next instruction(s) In-vehicle signing Input finished with current instruction(s)
Trip Planning	Display destination Display distance to destination Display route choices Display time(s) of arrival Input current location Input destination Input route choice

Traffic Information

Information elements for Traffic Information were determined by reviewing sources from the literature on congestion (Albert, McCasland, and Levine, 1989; Dudek, 1978;

Frank, 1989; Masters, Blamey, O'Brien, and Kerr, 1989; Parviainen, Case, and Saboughi, 1989) and by listening to traffic broadcasts on local radio stations. Additional elements were also determined by simply thinking about how the driver would interact with the system.

Dudek (1978) cites several studies where driver preferences for traffic congestion descriptors were obtained (Beers, 1974; Case, Hulbert, and Beers, 1971; Dudek, Messer, and Jones, 1971; Heathington, Worrall, and Hoff, 1970). These descriptors are ranked in table 35. Three of the studies (Beers, 1974; Case et al., 1971; Heathington et al., 1970) were performed on freeways using changeable message signs while Dudek et al. (1971) obtained driver preferences through a questionnaire. Drivers wanted the following information about congestion (rank-ordered): congestion level, cause, freeway length affected, length of congestion, location of congestion, lane blockage, travel speed, delay time, and travel time.

Table 35. Rank ordering of traffic descriptors for four studies (Dudek, 1978).

Heathington et al. (1970)	Dudek et al. (1971)	Case et al. (1971)	Beers (1974)
1. Cause Congestion level Freeway length affected	1. Location Length of congestion	1. Lane blockage	1. Distance to blockage
		2. Distance to problem	2. Lane blockage
	2. Congestion level	3. Delay time	3. Location
2. Speed Freeway length affected	3. Cause of congestion	4. Reason for delay	4. Delay time
	4. Speed	5. Location	5. Reason for delay
3. Congestion level Freeway length affected	5. Travel time		6. Travel time
4. Stop and go Freeway length affected			
5. Delay time Freeway length affected			
6. Travel time Freeway length affected			
7. Blank sign			

Other information that can be given about congestion is the location where speed of traffic dramatically decreases (Masters et al., 1989), the occurrence of incidents on other freeways (Albert et al., 1989), and a recommended alternate route. Parviainen et al. (1989) and Frank (1989) identify other traffic information elements. Information elements for Traffic Information (congestion and construction combined) are included in table 36.

Vehicle Monitoring

To a limited extent, vehicle monitoring systems are provided in production vehicles at the present time (low fuel indicator, low oil pressure light, etc.). Systems of the future, however, have the potential to provide drivers with much more detailed information about the status of the vehicles they are driving. More detailed information would benefit the driver since it has been discovered that drivers underestimate the risks from substandard performance of vehicle systems that provide indirect failure feedback to drivers (MacGregor and Slovic, 1989). For purposes of this project, the main concern is with the "health" of the vehicle rather than systems that monitor the driver, the road, or other traffic.

The national office of the American Automobile Association was contacted in an attempt to determine the causes of vehicle breakdowns. Information on the reasons for emergency service calls was obtained and is presented in table 37. Almost half of all emergency calls (41 percent) were due to not being able to start a vehicle and a substantial number of calls (28 percent) were for towing. Tire service, out of fuel, and locked out were causes of 18.1 percent of the calls. While more detailed data on breakdowns could be useful in deciding what to warn drivers about, it does not exist in the open literature and industry contacts were unable to obtain it or to release the associated warranty data.

Table 36. Information elements for traffic information.

Feature	Information Element
Congestion/Construction	Brightness Power Volume
	Input direction of interest Input location of interest
	Cause of congestion Congestion level Location of congestion Location where speed decreases
	Distance to blockage Road length affected (construct.) Lane blockage Length/area of congestion
	Delay time Estimated time of clearup Travel speed (through problems) Travel time
	Alternate route

Table 37. Causes of emergency service calls to AAA (nationwide).

Cause	Calls (%)
Car will not start	41.0
Towing	28.0
Tire service	8.5
Locked out	8.0
Out of Fuel	1.6
Other	4.5
Unknown	8.4
Total	100.0

A recent issue of The Power Report on Automotive Marketing (Power and Associates, April 1991) showed the results of the 1991 J.D. Power and Associates Vehicle Dependability Study. They reported problems with the most impact on vehicle satisfaction. The top ten mentioned problems (in unspecified order as shown in Power and Associates, April 1991) are shown in table 38. A majority of the problems were related to engine trouble, while others had to do with the transmission or interior problems (door and seat).

Table 38. Top ten problems mentioned with the most impact on vehicle satisfaction (cited in unspecified order in Power and Associates, April 1991).

Transmission Fluid Leaks
Engine Stalls
Engine Failed/Died/Would Not Restart
Other Steering and Handling Troubles
Unusual Engine Noises
Interior Door Lock Troubles
Seat Hard to Adjust, Loose in Track
Engine Idles Rough/Too Fast
Vehicle Would Not Start
Automatic Transmission Shifts Roughly

A list of features and warnings that could be displayed to drivers was developed through a review of the literature (Aono, date unknown; Paulsen, 1989) and a brainstorming session with Dave Andrea and Dick Doyle of the UMTRI Office for the Study of Automotive Transportation (OSAT). A small number of information elements that require scheduled maintenance (30,000 mile inspection, tire rotation, engine oil change) were identified by looking through a maintenance schedule for a Ford car.

To determine how likely it is that various features/information elements will be implemented in cars, a survey was designed and distributed to several people (5 to 10) in the automotive industry and in academia who have a sense of future automotive products. This survey is included in appendix A. It consists of a cover page and a matrix in which items that could be monitored are provided along the left column and warnings that could be displayed to drivers are listed across the top. Respondents were asked to fill in the boxes with the year when the item-warning combination may appear in production vehicles. A summary matrix is attached to the end of this appendix. The numbers in the cells represent the number of respondents that selected that item-warning combination and also indicate whether or not the implementation of the warning was thought feasible by the year 2000.

The authors want to emphasize that the survey was not a rigorous attempt to obtain *specific quantitative* predictions about when warning systems might appear in future cars (if at all), but rather to get *a sense* of when they might appear. The survey was designed without extensive effort since it was distributed to only a handful of people and they could call for clarifications. Respondents commented that it was extremely difficult to complete the survey, in part because they were very unsure when implementation would occur. In spite of considerable effort by the industrial liaisons and promises of confidentiality, it was extremely difficult to find people in a position to respond to the survey. Typically, respondents might know about some aspects of technology (e.g., drivetrain design), but it was rare for them to have a comprehensive view of new technology. This was not true of our colleagues in the Office for the Study of Automotive Transportation at UMTRI.

The information elements listed in table 39 include those identified by the UMTRI project team and the survey respondents. Only those warnings thought to be implementable by the year 2000 were included in the list. Along with the information elements are modifiers that describe the status level of the problem (scheduled or unscheduled maintenance and status display, non-maintenance) and the urgency of the repair (requires immediate action or driver serviceable). It should be noted that several elements were not determined until after the survey was sent out and appear only in the table below, not in the survey in the appendix.

Information elements for Communication and Entertainment systems were also determined through a survey of existing systems. These elements are listed in appendix B.

Table 39. Information elements for vehicle monitoring system.

Feature	Information Element
Drivetrain	30,000-mi (48279-km) inspection (SM*) Antilock brake maint (UM) Brake failure (!,UM) Brake fluid level low (UM,D) Brake fluid slow leak (UM) Brake maint (pads worn, slow fluid leak) (UM) Steering maint (UM) Steering, power fluid level low (UM) Suspension maint (UM) Tire pressure low (UM) Tire rotation needed (SM) Tire wear (UM) Transmission repair (fluid quality, fluid level) (UM)
Engine/Power	Alternator maint (UM) Battery current low or high (UM,Stat) Battery voltage low or high (UM,Stat) Catalytic converter maint (UM) Drive belt slack adjustment (UM) Engine coolant level low (UM,D) Engine coolant quality (UM) Engine coolant slow leak (UM) Engine fire (!,UM) Engine temperature getting high (UM,Stat) Engine temperature high (!,UM) Engine timing (UM) Exhaust leak (UM) Fuel leak, danger of fire/explosion (!,UM) Fuel low warning (Stat,D) Fuel pump shutoff (UM,Stat,D) Fuel quality (Stat,D) Fuel slow leak (UM) Fuse status (UM) Oil pressure low or high (!,UM) Oil pump failing (pressure dropping) (UM) Oil, engine, change (SM) Oil, engine, change (UM) Oil, engine, level low or high (!,UM,D) Oxygen sensor repair (UM)

Ingress/Egress	Doors open (Stat,D) Hood open (Stat,D) Trunk/Hatch open (Stat,D)
Path Control	Brake lamps (UM) Bright head lamps (UM) Fog lamps (UM) Head lamps (UM) Tail lamps (UM) Turn signal lamps (UM) Washer fluid level (UM,D)
Safety Systems	Air bag maint (SM) Air bag maint (UM) Seat belt maint (UM)

*Key:

SM=Scheduled Maintenance
UM=Unscheduled Maintenance
D=Driver Serviceable
Stat=Status Display, Non-Maintenance
!=Requires Immediate Action

STEP 6. INFORMATION ELEMENT SCORING AND PRIORITIZATION

For each feature, the information elements were scored on the three criticality dimensions (reduction of accidents, benefits to traffic operations, and driver needs) using a similar scale to that of feature scoring. The scoring scheme was the following:

2.0=Highly Beneficial
1-1/2
1.0=Beneficial
0.5
0.0=No Effect
-1/2
-1.0=Detrimental
-1-1/2
-2.0=Highly Detrimental
NA=Not Applicable
? =Unknown

Four scores (1.5, 0.5, -0.5, and -1.5) were added in order to allow for greater differentiation among the information elements because clear distinctions among elements were not differentiated by the five-point scale.

The category weights were the same as those used in the previous scoring of the functions. For each feature, normalized scores were calculated for the information elements in a similar manner as for the features. However, normal scores for the information elements were determined by dividing raw scores by the highest raw score obtained in the *dimension* matrix, rather than dividing by the highest raw score in the *information element* matrix. The reason for this was to allow for comparison between features and information elements within dimensions and to make judgments between dimensions independent. An example calculation of the normalized score follows for the information element, display city or suburb, in the reduction of accidents matrix:

Display City or Suburb Normalized Score: -0.13 = -0.07/0.54
(where 0.54 equals the highest raw score in the reduction of accidents matrix)

Then, the information elements were prioritized based on each the three dimensions and their weights (reduction of accidents: weight=0.593; benefits to traffic operations: weight=0.394; driver needs: weight=0.013). It should be noted that the driver wants category is not included as a part of this scoring since information elements were not discussed in the focus group study. Therefore, the dimension of driver needs has a weight of 0.013, the combination of the driver wants weight (0.005) and the needs/convenience weight (0.008).

Matrices of the prioritized information elements for the features of interest are given in appendix C.

Cellular Phone

For the Phone rankings, four fundamental elements (power, send, end, and brightness) were ranked the highest, followed by three indicator displays (power, in use, and no service) vital for status information. Information elements that fell to the bottom of the list were those that give the operator options (mute, recall, menu, function, and name), but are not necessary for regular operation. All of these elements except for mute had negative scores. The most pertinent element for the phone function, input number to dial, fell last in the ranking. This reflects a negative score due to inattention and slight but substantial negatives with respect to driver needs/convenience since it is inconvenient for a driver to enter a number while driving.

IVSAWS

The top ten ranked information elements include all from the Compounding hazards feature (curve—excessive speed, fog/slippery and grade—fog/slippery), two each from Crash Site (accident ahead and lanes closed/open) and Construction (speed limit and construction ahead), School Bus/Other Special Vehicles (school bus—loading/unloading), and Emergency (police—on run). Elements at the lower end of the ranking were from the Special Vehicle and Emergency Vehicles features. Lower total scores were obtained for these elements due to their small contribution to the reduction of accidents and neutrality on the other two dimensions. While none of the information elements received negative scores, two elements, number of tracks and funeral procession, had total scores of zero. Neither of these elements represent a serious hazard.

Navigation/Route Guidance

Prioritization of the information elements for Orientation reveals that elements related to the immediate vicinity of travel (next cross street, display travel direction, display current street, and distance to next cross street) ranked high in the matrix. Compass, an element that would probably be presented all of the time, also ranked high. Many of the information elements with negative scores (nearest landmark, distance to nearest landmark, and display city or suburb) present information that is helpful but not as important as other orientation features, such as cross street and travel direction.

For Route Guidance and Trip Planning, information elements that were ranked highest include those that provide information to the driver about a particular destination (in-vehicle signing, current legal speed limit, appropriate lane, display time of arrival, display distance to destination, and display route choices). Basic display parameters were ranked next (power, brightness, and volume) with three Trip Planning elements (input route choice, input current location, and input destination) ranked the lowest due to negative scores. These negative scores from accidents and needs/convenience lead to the conclusion that trip planning while driving is neither safe nor convenient.

Traffic Information

Top ranking information elements include distance to blockage, location of congestion, location where speed decreases, congestion level, and travel speed through problem. Thus, information that should be provided to the driver includes where the problem is and its effect on traffic.

Two elements, input direction and location of interest, had overall detrimental scores
(-0.073 and -0.148, respectively). It is also interesting to note that power, brightness, and volume, three elements that will be provided regardless of their ranking, were so low in the prioritization.

Vehicle Monitoring

The top ten information elements for Vehicle Monitoring include four from the Path Control feature (turn signal lamps, brake lamps, tail lamps, and head lamps), four from Drivetrain (tire wear, tire pressure low, antilock brake maintenance, and brake maintenance), and two from Engine/Power (engine coolant level low and engine temperature getting high). At the lower end of the rankings a majority of the elements were from the Engine/Power feature. These elements are necessary because they provide status and maintenance information but do not cause accidents and will not influence traffic operations. Again, no information elements had negative total scores.

SUMMARY AND CONCLUSIONS

Summary

In summary, the intent of this report was to describe an approach used to identify future information systems that will benefit drivers. Systems were identified and described in great detail in terms of the features and information elements that can be provided. Table 40 shows the functions and features that were identified.

A unique scoring system was used to prioritize the features and information elements based on their contribution to the reduction of accidents, benefits to traffic operations, and driver needs. Based on a variety of sources (research reports, national accident data, experts in the field, a focus group study, personal travel data, and walk-throughs of driving scenarios), categories and their respective weights for criticality scoring were determined. Table 41 shows the categories and weights for the three dimensions. The weights for the three dimensions were determined based on estimates of the annual cost of accidents and traffic congestion, as well as the amount of money spent annually if every new car was equipped with several advanced driver information systems.

Table 40. Functions and features identified for future driver information systems.

FUNCTION	FEATURE
Communication	CB radio Cellular phone Radar detector
Entertainment	Cassette/CD player Radio Television
In-Car Signing	Destination assistance Street signs Traffic control
IVSAWS (Road Hazard)	Compounding hazards Construction Crash site Emergency vehicle Railroad crossing School bus/other special vehicles Supplemental traffic control
Motorist Services	Banking Customs information Destination assistance Transportation Yellow pages/commercial
Navigation/Route Guidance	Guidance Orientation Trip computer Trip planning
Office	Calculator Computing Dictation Electronic calendar Electronic directory Fax
Traffic Information	Congestion Construction Freeway management Parking Traffic rules (one-way, no left turn) Vehicle access (toll roads, size and weight restrictions) Weather
Vehicle Monitoring	Climate Drivetrain Engine/Power Ingress/Egress (doors, trunk) Path control (tires, brakes) Safety systems (air bag, seat belts)

Table 41. Categories and weights for criticality scoring.

Categories		Weights	
Reduction of Accidents		**0.593**	
Driver	Improper lookout		0.211
	Excess speed		0.156
	Inattention		0.138
	Improper evasive action		0.119
	Alcohol impairment		0.092
Environmental	View obstruction		0.110
	Slick roads		0.092
Vehicular	Tires		0.037
	Brakes		0.046
			1.000
Benefits to Traffic Operations		**0.394**	
Mode Choice	Carpool		0.167
	Public transportation		0.167
Route Choice	Corridors		0.167
	Surface streets		0.167
Traffic Flow	Reduce rush hour peak spread		0.167
	Reduce accident/breakdown clean-up time		0.167
			1.000
Driver Needs			
Wants	Focus groups	**0.005**	
Needs/Convenience	Driving scenarios	**0.008**	
	Family/personal business		0.414
	Social/recreational		0.322
	Earning a living		0.264
			1.000
Total		**1.000**	

The scoring method involved obtaining summary scores for the features on the three dimensions—reduction of accidents, benefits to traffic operations, and driver needs. Raw scores were calculated by summing the products of the weights and the scores (2 through -2) in the cells. Normal scores were then obtained by dividing the raw score by the highest score in the matrix. Finally, rankings of the features and information elements were determined based on total scores. Partial matrices for these dimensions are shown in figures 8, 9, and 10. An example of the scoring method for one of the features selected, cellular phone, is shown below.

	DRIVER			..		SUMMARY SCORES	
	improper lookout	excess speed	inattention	..	brakes		
	0.211	0.156	0.138	..	0.046	Raw	Normal
FUNCTIONS & FEATURES				..			
COMMUNICATION (COM)				..			
COM CB radio	-1	0	0	..	NA	-0.21	-0.39
COM cellular phone	*-1*	*0*	*-1*	..	*NA*	*-0.35*	*-0.65*
COM radar detector	0	-2	0	..	NA	-0.31	-0.58
..	..	..	..	..	..	..	..

Figure 8. Partial matrix for reduction of accidents.

For reduction of accidents, the equation for obtaining the raw summary score is:

-0.35 = -1(0.211) + 0(0.156) + (-1)(0.138) + 0(0.119) + 0(0.092) + 0(0.110) + 0(0.092) + 0(0.037) + 0(0.046)

For reduction of accidents, the normalized summary score is:

-0.65 = -0.35/0.54 (0.54=highest raw score in matrix for reduction of accidents)

	MODE CHOICE		..		SUMMARY SCORES	
	carpool	public transp.	..	reduce acc./brkdwn. clean-up time		
	0.167	0.167	..	0.167	Raw	Normal
FUNCTIONS & FEATURES			..			
COMMUNICATION (COM)			..			
COM CB radio	0	0	..	2	0.33	0.33
COM cellular phone	*-1*	*-2*	..	*2*	*-0.17*	*-0.17*
COM radar detector	0	0	..	NA	-0.33	-0.33
..	..	..	..	..	..	..

Figure 9. Partial matrix for benefits to traffic operations.

For benefits to traffic operations, the equation for obtaining the raw summary score is:

-0.17 = -1(0.167) + (-2)(0.167) + 0(0.167) + 0(0.167) + 0(0.167) + 2(0.167)

For benefits to traffic operations, the normalized summary score is:

-0.17 = -0.17/1.00 (1.00=highest raw score in matrix for benefits to traffic operations)

	DRIVER WANTS			. .	. . . NEEDS		
	Survey	SUMMARY SCORES		. .	work	SUMMARY SCORES	
	1	Raw	Normal	. .	0.264	Raw	Normal
FUNCTIONS & FEATURES				. .			
COMMUNICATION (COM)				. .			
COM CB radio	?	0	0	. .	1	1.00	0.50
COM cellular phone	*1*	*1*	*0.5*	. .	*2*	*1.26*	*0.63*
COM radar detector	?	0	0	. .	2	1.26	0.63
. .	. .	. .	. .	. .	. .	. .	. .

Figure 10. Partial matrix for driver wants and needs/convenience.

For driver wants, the normalized summary score is:

0.5 = 1/2 (2=highest raw score in matrix for driver wants)

For driver needs/convenience, the raw summary score is:

1.26 = 1(0.414) + 1(0.322) + 2(0.264)

For driver needs/convenience, the normalized summary score is:

0.63 = 1.26/2.00 (2.00=highest raw score in matrix for driver needs/convenience)

Based on the normalized summary scores, a total score was obtained using weights that were derived from estimates of the annual cost of accidents, traffic congestion, and amount of money spent if every new automobile purchased was equipped with several advanced driver information systems. Referring to figure 11, the total score for cellular phone was calculated in the following manner:

$$-0.44 = -0.65(0.593) + (-0.17)(0.394) + 0.5(0.005) + 0.63(0.008)$$

		DIMENSION				
			TRAFFIC	DRIVER		TOTAL
		ACCIDENTS	OPERATIONS	WANTS	NEEDS	SCORE
		0.593	0.394	0.005	0.008	1.000
RANK	**FUNCTIONS & FEATURES**					
1	IVSAWS crash site	0.80	0.83	0.0	0.63	0.81
2	IC traffic control	1.00	0.33	0.0	0.50	0.73
3	TI congestion	0.54	1.00	1.0	0.84	0.73
	..	..	..	..	..	..
39	N/RG orientation	-0.65	-0.17	0.5	1.00	-0.44
40	*COM cellular phone*	*-0.65*	*-0.17*	*0.5*	*0.63*	*-0.44*
41	COM radar detector	-0.58	-0.33	0.0	0.63	-0.47
42	ENTR television	-0.51	-0.50	0.0	0.00	-0.50
43	OFF computing	-0.90	-0.33	0.0	0.13	-0.67
44	OFF fax	-0.90	-0.33	0.0	0.13	-0.67

Figure 11. Partial overall summary matrix with ranked features.

Based on the total scores, the top ten features include four of the seven IVSAWS features (ranked 1, 4, 7, and 8), four Traffic Information features, (ranked 3, 5, 9, and 10), In-Car Signing-traffic control (ranked 2), and Vehicle Monitoring--path control (ranked 6). Features with low rankings (negative scores) were from the Office, Communication, and Motorist Services categories.

According to the government contract, five functions needed to be selected for further analysis. The functions and features selected included the following:

Function	Feature
Communication	Cellular phone
IVSAWS (road hazards)	Compounding hazards
	Construction
	Crash site
	Emergency vehicle
	Railroad crossing
	School bus/other special vehicles
	Supplemental traffic control
Navigation/Route Guidance	Guidance
	Orientation
	Trip planning
Traffic Information	Congestion
	Construction
Vehicle Monitoring	Climate
	Drivetrain
	Engine power
	Ingress/egress (doors, trunk)
	Path control (tires, brakes)
	Safety systems

Three functions, IVSAWS, Navigation/Route Guidance, and Vehicle Monitoring, were required by the government. Traffic Information was selected because of its high ranking. Cellular phone, although not at the top of the ranking, was selected for a number of reasons: (1) its early market penetration, (2) safety implications while driving, and (3) its incorporation into the Integrated Driver/Vehicle Model, a model being developed through this project.

Finally, information elements for these five functions/features were identified, scored, and prioritized.

Conclusions

This report describes the information elements that should be provided by advanced driver information systems in cars of the future, and a rational for selecting them. Accordingly, the most beneficial features were IVSAWS - crash site, In-car signing - traffic control, Traffic Information - congestion, IVSAWS - compounding hazards, Traffic Information - construction, Vehicle Monitoring - path control, IVSAWS - construction, IVSAWS - railroad crossing, Traffic Information - traffic rules, and Traffic Information - freeway management.

The systems engineering approach that was taken provided a method for determining which features to select for further analysis and which information elements comprise those features. While some may disagree with the features and information elements selected, the authors believe the method is sound; those with other views should feel free to add dimensions and adjust the weights to suit their perspective. The authors are particularly interested in such ideas.

The next steps of the project involve prototyping the systems, evaluating them, and developing human factors design guidelines and test protocols.

REFERENCES

1. Albert, S., McCasland, W., and Levine, S. (1989). "Proposed Real-Time Motorist Information System for Major Activity Center in Houston, Texas." In *Vehicle Navigation & Information Systems Conference (VNIS '89)*, pp. 424-426. New York: Institute of Electrical and Electronics Engineers.

2. Aono, S. (undated). "Technology for the Intelligent Car of the Future."

3. Beers, J. (1974). *User Acceptance Study of Freeway Motorists Advisory Systems*. (Technical Report UCLA-ENG-7436). Los Angeles, CA: Institute of Transportation and Traffic Engineering, UCLA.

4. Brand, J.E. (May 1990). *Attitudes Towards Advanced Automotive Display Systems: Feedback from Focus Group Discussions* (Technical Report UMTRI-90-22). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

5. Burger, W.J., Smith, R.L., and Ziedman, K. (1989). *Supplemental In-Cab Truck Displays: An Inventory of Devices and Approaches to Their Evaluation* (Technical Report DOT HS 807 410). Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration.

6. Case, H.W., Hulbert, S.F., and Beers, J. (1971). *Research Development of Changeable Messages for Freeway Traffic Control*.. Los Angeles, CA: Institute of Transportation and Traffic Engineering, UCLA.

7. Dudek, C.L. (1978). *Human Factors Requirements for Real-Time Motorist Information Displays,* Volume 2 (Technical Report FHWA-RD-78-6). Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

8. Dudek, C.L., Messer, C.J., and Jones, H.B. (1971). "Study of Design Considerations for Real-Time Freeway Information Systems." *Highway Research Record*, No. 363, pp.1-10.

9. Esterberg, M.A., Sussman, E.D., and Walter, R.A. (1986). *Automotive Displays and Controls - Existing Technology and Future Trends* (Report PM-45-U-NHT-86-11). Washington, DC: U.S. Department of Transportation, National Highway Traffic Safety Administration.

10. Frank, D.L. (1989). “Information systems: an integral part of future vehicles.” In *Vehicle Navigation & Information Systems Conference (VNIS '89),* pp. 85-88. New York: Institute of Electrical and Electronics Engineers.

11. Gardes, Y. and May, A.D. (1990). *Traffic Modeling to Evaluate Potential Benefits of Advanced Traffic Management and In-Vehicle Information Systems in a Freeway/Arterial Corridor* (Technical Report UCB-ITS-PRR-90-3). Berkeley, CA: Institute of Transportation Studies.

12. Green, P., Boreczky, J., Serafin, C., Paelke, G., Williams, M., Finnegan, P., Levison, W., and Pew, R. (June 1990). *Workplan: contract DTFH61-89-C-00044, Assessment of Effect of In-Vehicle Display System on Driver Performance*. Ann Arbor, MI: The University of Michigan Transportation Research Institute.

13. Harris, W.J. and Bridges, G.S. (1989). *Proceedings of a Workshop on Intelligent Vehicle/Highway Systems by Mobility 2000*. College Station, TX: Texas Transportation Institute, Texas A & M University.

14. Heathington, K.W., Worrall, R.D., and Hoff, G.C. (1970). "An Analysis of Driver Preferences for Alternative Visual Information Displays." *Highway Research Record*, (303), pp. 1-16.

15. Klinger, D. and Kuzmyak, J.R. (August 1986). *Personal Travel in the United States, Volume I: Nationwide Personal Transportation Study 1983-1984*, Wheaton, MD: COMSIS Corp.

16. MacGregor, D.G. and Slovic, P. (1989). "Perception of Risk in Automotive Systems." *Human Factors*, 31(4), pp. 377-389.

17. Masters, P.H., Blamey, C., O'Brien, W.B., and Kerr, J.A. (1989). "An Approach to Provision of Real-Time Driver Information Through Changeable Message Signs." In *Vehicle Navigation & Information Systems Conference (VNIS '89),* pp. 413-423. New York: Institute of Electrical and Electronics Engineers.

18. Meyer, J.R., Reaser, J.M., Keller, R., Wilson, R.A., and Vadeboncoeur, J.R. (1982). *Feasibility and Concept Selection of a Safety Hazard Advance Warning System (SHAWS)-Volume II-Technical Report* (Technical Report FHWA/RD-81/124). Washington, DC: U.S. Department of Transportation, Federal Highway Administration.

19. Mobility 2000. (March 1990). *Final Report of the Working Group on Operational Benefits.* Dallas, Texas.

20. National Safety Council (1989). *Accident Facts*, Chicago, IL: National Safety Council.

21. Parviainen, J.A., Case, R.E., and Sabounghi, L. (1989). "Future Mobile Information Systems: Potential Applications and Systems Features." In *Vehicle Navigation & Information Systems Conference (VNIS '89),* pp. A36-A43. New York: Institute of Electrical and Electronics Engineers.

22. Parviainen, J.A., French, R.L., and Zwahlen, H.T. (August 1988). *Mobile Information Systems Impact Study*. (Technical Report TP 9360E). Ontario, Canada: J.A. Parviainen & Associates.

23. Paulsen, J.J. (1989). "The State of Automotive Electronics in the Year 2000: A Perspective of the North American Marketplace. In *Proceedings of the Institution of Mechanical Engineers*, pp. 1-15. Suffolk: Mechanical Engineering Publications LTD.

24. Peterson, D.D. and Boyer, D.S. (1975). *Feasibility Study of In-Vehicle Warning Systems* (Technical Report DOT-HS-801-569). Washington, DC: U.S. Department of Transportation.

25. Power, J.D. and Associates. (April). *The Power Report on Automotive Marketing,* 13(4).

26. *Random House Dictionary* (1967). New York: Random House, Inc.

27. Ribbens, W.B. and Cole, D.E. (1989). *Automotive Electronics Delphi*. Ann Arbor, MI: The University of Michigan Transportation Research Institute, Office for the Study of Automotive Transportation.

28. Schiffman, J. (May 1988). *Apparatus for Promoting the Vigilance of a Motor Vehicle Operator*. United States Patent No. 4,742,389.

29. Stafford, F.P. (1990). "Social Benefits of IVHS Systems." *Automated Highway/Intelligent Vehicle Systems: Technology and Socioeconomic Aspects*. (SAE 901506). Warrendale, PA: Society of Automotive Engineers, Inc.

30. Streff, F.M., Ervin, R.D., and Blower, D.F. (1991). *In-Vehicle Safety Advisory and Warning System (IVSAWS), Final Report* (Technical Report UMTRI-91-33). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

31. Treat, J.R., Tumbas, N.S., McDonald, S.T., Shinar, D., Hume, R. D., Mayer, R.E., Stansifer R.L., and Castellan, N.J. (May 1979). *Tri-Level Study of the Causes of Traffic Accidents: Final Report. Executive Summary* (Technical Report DOT/HS 805 099). Bloomington, Indiana: Institute for Research in Public Safety.

32. Tsugawa, S., Kitoh, K., Fujii, H., Koide, K., Harada, T., Miura, K., Yasunobu, S., and Wakabayashi, Y. (1991). *Info-mobility: A Concept for Advanced Automotive Functions Toward the 21st Century* (SAE 910112). Warrendale, PA: Society of Automotive Engineers, Inc.

33. Underwood, S.E. (1990). "Social and Institutional Considerations in Intelligent Vehicle-Highway Systems. *Automated Highway/Intelligent Vehicle Systems: Technology and Socioeconomic Aspects*. (SAE 901505). Warrendale, PA: Society of Automotive Engineers, Inc.

34. Underwood, S.E., Chen, K., and Ervin, R.D. (November 1989). *The Future of Intelligent Vehicle Highway Systems*, Ann Arbor, MI: The University of Michigan, College of Engineering.

35. The University of Michigan Transportation Research Institute, Transportation Data Center. (1989). *Fatal Accident Reporting System 1988 Codebook*. Ann Arbor, MI: The University of Michigan Transportation Research Institute.

36. The University of Michigan Transportation Research Institute, Transportation Data Center. (1989). *National Accident Sampling System 1988 Codebook.* Ann Arbor, MI: The University of Michigan Transportation Research Institute.

37. The University of Michigan Transportation Research Institute, Transportation Data Center. (June 1990). *National Accident Sampling System 1988 Codebook - Version 032490* (Technical Report UMTRI-90-7). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

38. Washtenaw County Road Commission. (December 1989). *Traffic Flow Map & Transportation Profile 1988 - 1989*. Ann Arbor, MI: Ann Arbor - Ypsilanti Urban Area Transportation Study Committee.

APPENDIX A. VEHICLE MONITORING SYSTEMS SURVEY

This appendix contains the Vehicle Monitoring Systems Survey that was distributed to colleagues in industry and academia. Its purpose was to help determine how likely it is that various features will be implemented in vehicles in the future. While only the one page matrix (photo reduced to 60 percent) is included with the cover page, additional pages of an enlarged version of the matrix were included when the survey was distributed.

The responses to the survey are shown in figure 12. The numbers in the cells in the matrix indicate the number of respondents that selected each item-warning combination. A plain number in a cell (without parentheses) indicates the number of respondents who thought the warning would be present by the year 2000, while a number in parentheses indicates the number of respondents who thought that the warning would eventually be implemented after the year 2000. Four people responded to the survey.

VEHICLE MONITORING SYSTEMS SURVEY

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The purpose of this informal survey is to determine the likelihood that various monitoring features will be provided in vehicles of the future. For this survey, vehicle monitoring features are defined as those concerned with the health of the vehicle. They do not include items that monitor the driver (alertness systems), the road (e.g., for ice), or information relating to traffic or navigation.

Because time is short, this survey is being distributed to just a few people (probably between 5 and 10) in industry and academia who have a sense of future automotive products. Those asked to respond should do so immediately by fax (313 936 1081). Respondents may wish to circulate this to others for product planning. It may be useful for guiding research, engineering, and product design as well as to those involved in sensor development, human factors, and business planning. These questions, in a revised form, will probably appear in the next Michigan Delphi survey.

The survey is five pages long. The first page shows what the next four pages would be like if they were pasted together. Use those following four pages for your responses.

I would like you to mark in each cell what you personally think the earliest date will be when each item (e.g., engine - electrical)-warning (schedule maintenance) combination will appear in production cars (e.g., "95," "99," "03," "never," "now"). Notice that warnings might be provided for both systems (e.g., engine-electrical) and specific components (electrical system-drive belt slack). Ignore the item-aspect combinations that don't make sense (e.g., engine-electrical-pressure high/low). I know this could be a great deal clearer, but there is no time to mess with it. If you are still confused, call me (313 763-3795) or send me email on Internet (Paul_Green@ub.cc.umich.edu). If you can think of anything that is missing, please add it.

APPENDIX B. INFORMATION ELEMENTS FOR ENTERTAINMENT AND COMMUNICATION SYSTEMS

This appendix contains information elements for entertainment and communication systems.

INFORMATION ELEMENTS FOR ENTERTAINMENT AND COMMUNICATION SYSTEMS

A survey of information elements provided on entertainment and communication systems currently implemented in vehicles was undertaken by obtaining brochures from local retailers. Entertainment systems of interest included cassette decks, compact disc players, graphic equalizers, and radios. Product brand names of entertainment systems included Alpine, Blaupunkt, Kenwood, and Radio Shack. Coustic, a brand name of compact disc players and radios, was also included in the survey.

Communication systems which were investigated include CB radios, radar detectors, and television sets. These systems marketed by Radio Shack were investigated. Bel-tronics Ltd., a brand name of radar detectors, was included in the survey as well.

Entertainment Systems

Cassette Deck

The cassette deck is almost always included with the tuner (radio). (See table 42 for cassette deck information elements.) Decks that host many options (e.g. tape advance, high/lo position, etc.) typically integrate the cassette controls with the radio presets. For auto reverse, some systems require pressing the fast forward and rewind buttons simultaneously, while others have an independent pushbutton for auto reverse. Also, some auto reverse mechanisms adjust the program direction as well, so that fast forward and rewind are oriented for both sides of the tape. Less advanced systems acknowledge fast forward and rewind only for one side of the tape (REW rewinds, but fast forwards when auto reverse is employed).

Table 42. Cassette deck information elements.

Cassette Deck Information Element	Definition
Eject	
Rewind	
Fast Forward	
Tape Advance	Forwards tape to next song
Dolby NR (B or C)	Activates Dolby noise reduction (B or C type)
High/Lo position	High (metal) or low (normal) position tapes
Auto Reverse	Changes direction of tape play
Index Scan	Scans through tape and stops at beginning of next song
Tuner Call in FF/REW	Enables tuner while FF or REW tape

Compact Disc Player

Most compact disc players that are independent of the auto manufacturer are combined with a tuner, but not a cassette player. Some models provide two buttons (up/down) for track selection, while others provide 10 individual buttons labelled with the digits 0 - 9. The feature of manually scanning within a track (to find specific pieces of a song) is found much less often in auto CD players than in home units. Many of the CD controls are integrated with the tuner. In particular, tuner presets serve as CD controls when the CD player is active. Some manufacturer installed CD players are an exception, as they provide separate units for the CD player, tuner, and cassette player (for instance, the Chrysler Corporation Eagle Talon). Although the use of such systems is more specifically defined, they require a large amount of in-vehicle space. Information elements for compact disc players are shown in table 43.

Table 43. Compact disc player information elements.

Information Element	Compact Disc Player Definition
Eject	
Play	
Track Forward/Backward	Advances to proceeding or preceeding track
Random Play	Plays tracks in random order
Music Scan Up/Down	Advances forward or backward within track
Repeat	Repeats track
Pause	Pauses play
Carousel attachment	Holds multiple discs (6) for programmable play
Preferred Track Memory	Plays throughout designated tracks
Omitted Track Memory	Omits designated tracks

Graphic Equalizer

There are three main types of graphic equalizers—standard, electronic, and parametric. Memory presets and the spectrum analyzer are most likely to be found in electronic equalizers. The parametric frequency control is found only in parametric equalizers. Some equalizer units also contain amplifiers.

Standard and parametric equalizers often have lighted sliders (one for each band) for adjusting the level of the band. Most other controls are push buttons, with the exception of the parametric frequency control which is often a knob. Electronic equalizers have an LCD for displaying the output levels of each band, as well as buttons for selecting which band to adjust (left, right) and for adjusting the level of the band (increase, decrease). These displays may also have a control to switch the LCD from green to amber. Information elements for graphic equalizers are shown in table 44.

Radio

Table 45 shows information elements for radios. It was found that most radio tuners in newer vehicles have digital displays. Analog displays, however, are also in use. The analog displays are tuned using continuous controls (knobs or thumbwheels) whereas digital displays require discrete controls enabling either knobs or pushbuttons for tuning. Presets are found on nearly all systems. Some preset buttons house two stations (push once for one station, twice for another station). Some models have controls which can be lit by activating an illumination control.

Table 44. Graphic equalizer information elements.

Graphic Equalizer	
Information Element	Definition
Band Equalizers	Allows manual adjustment of given frequency range +12dB to -12dB per band
5 bands	50, 200, 800, 3.2k, 12.8k
7 bands	45, 125, 250, 1k, 3k, 8k, 16k
9 bands	40, 120, 250, 500, 1k, 2k, 4k, 8k, 16k
11 bands	31.5, 63, 125, 190, 250, 500, 1k, 2.2k, 4.5k, 9k, 18k
Fader	Adjusts gain between front and rear speakers
Built-in Presets	Equalizer settings optimized for certain kinds of listening (e.g., vocal boost, acoustic flat response)
Programmable Presets	Allows user to enter current settings into memory for recall later
Subwoofer	
on/off	Activates and de-activates signal to additional low frequency speakers
gain control	Adjusts output from negative infinity to 15dB
cutoff frequency selector	Adjusts highest frequency sent to subwoofer from 30Hz to 150Hz
stereo/mono	Switches subwoofers from stereo to mono
Spectrum Analyzer	Allows viewing of frequency output of current sound
Parametric Equalizer	Allows for independent band control for front and rear of vehicle (e.g., 9 bands for rear; 2 bands for front)
frequency control	lo (30-800 Hz), hi (800 Hz - 16 kHz)

Table 45. Radio information elements.

Radio	
Information Element	Definition
Tuner	
Volume	
FM/AM	
Presets	Returns tuner to specified station
Seek (up or up/down)	Finds nearest station and stops
Scan	Finds station, plays briefly, then continues to next
Preset Station Scan/Seek	Scans or seeks station presets
Stereo/Mono	Designates FM as stereo or mono
LO/DX	Reduces interference in congested areas
Bass/Treble	
Fader	Adjusts between rear and front speakers
Loudness	Amplifies bass
Illumination (on or off)	Illuminates controls on applicable models
Clock (display and set)	Tuner also serves as a clock

Communication Systems

CB Radio

Information elements for CB radios are shown in table 46. All of the CB radios have seven-segment LED or back-lit LCD displays. Most have continuous control knobs to adjust volume, gain, and squelch. Channels are adjusted by up/down fingertip buttons, although one model had a numberpad.

Table 46. CB radio information elements

CB Radio	
Information Element	Definition
Volume (includes OFF)	
Squelch	Cuts background noise
RF Gain	Boosts signal strength
Automatic Noise Limiter (ANL)	Cuts pulse type noise
Channel 9	Automatically accesses emergency channel
Noise Blanker (NB)	Cuts pulse type noise
PA	For PA broadcast (jacks for speakers also)

Radar Detector

The radar detectors marketed by BEL-TRONICS contain discrete on/off pushbuttons, except for volume, and LED light displays. The information elements are shown in table 47.

Table 47. Radar detector information elements.

Radar Detector	
Information Element	Definition
Power (PWR)	Power On/Off
False Signal Recognition (FSR)	Minimizes alerts from X band sources
Audio (AUD)	Activates automatic muting for X, K, or Ka band alerts
Dark (DRK)	Makes all LEDs dark except green power light
Volume Control	Adjusts the audio levels of X, K, or Ka band alerts

Television Set

The televisions have a standard set of controls, operable by up/down fingertip buttons. Table 48 shows the information elements.

Table 48. Television set information elements.

Television Set	
Information Element	Definition
Power	
Volume (up/down)	Increase or decrease volume

Channel (up/down)	Increment or decrement channel selection
Mute	Disables volume
Hue (color)	Adjusts color
Horizontal	Adjusts horizontal alignment