Behavioural Team
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Smart Cars for Drivers With Disabilities

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1. PROJECT BACKGROUND

1.1. Introduction and Purposes

The purpose of this report is to outline issues and present recommendations for future development in configuring *Smart Car* or, synonymously, *Intelligent Vehicle-Highway Systems,* to serve individuals towards the ends of Human Factors scales of hearing, vision, mobility, etc. Specifically, issues of interest to people with disabilities or personal conditions arising from advanced age which limit their effectiveness and enjoyment of driving are addressed.

Smart Cars? At this time — summer, 1993 — a great deal of activity is underway in the development of intelligent systems and instantaneous access to information for road vehicles and their drivers, largely through the applications of micro-electronics and communications technologies. This report uses the generic *Smart Cars* or *IVHS* to denote any sort of personal road vehicle which has special systems that improve…

- driver information,
- navigation,
- feedback in vehicle mechanical status,
- interaction with information sources outside the vehicle, and
- other similar kinds of assistance in travel.

These categories are more fully outlined and explored in the report.

Inserted throughout this report are illustrations taken from popular magazines, which reflect current media attention to *Smart Car* topics.

In recent years, the Transportation Development Centre of Transport Canada has been investigating means of assisting drivers with special needs. Of particular importance is the application of micro-electronics to make the task of driving safer or easier.

To further this line of research, a project was funded to take a closer look at the special user by directly speaking with such drivers and to consider the ways in which IVHS developers are accommodating their needs.

What is *not* covered in this report

Some IVHS applications directly affect the control of vehicular motion. For example, "smart" hand steering controls could be devised which average out small amplitude hand or arm tremors while responding to large amplitude steering motions. Headway control or crash avoidance are possible, likewise as aids for drivers with motor or reaction-time limitations.

Such applications may be termed "prosthetic." While of great importance, the configuration and application of prosthetic features is largely self-evident. Thus a person with a missing limb requires a person-borne or vehicle-borne prosthesis or an alternative control system which does not require the same limb input. Therefore, this project was concerned with information and sensory systems rather than with vehicular control systems.

Also "prosthetic" in another sense are tools which simplify driving or reduce the cognitive demands of the activity. Persons with intellectual limitations may be sufficiently aided by IVHS to become licenced drivers. Alternatively, IVHS may increase the intellectual demands of driving beyond the capabilities of some present-day drivers.

Likewise, some people have emotional limitations which interact with the demands of driving. Again, IVHS can reduce or worsen these conditions.

Because these applications are self-evident or quite thoroughly examined in other TDC and Behavioural Team reports, it is not essential to address them in this treatment of IVHS.

This report was prepared by the staff of Behavioural Team. Chapter Three and related appendices were prepared by J. A. Parviainen.

1.1.1. Elements of Human Factors in Driving

A basic analytic framework can be used for present purposes providing a general division of driving into (a) tasks such as control, guidance, and navigation and (b) the driving environment, such as road signs.

"Control" refers to controlling the motion of the vehicle and steering. "Guidance" refers to driving behaviour such as positioning the car in the lane and setting the speed. "Navigation" refers to larger conceptual tasks such as orientation on a route. *Smart Cars* can enhance the information needed for good control and guidance, and of course, can provide navigation information.

Failures with respect to the control of vehicles have been studied for some time. For drivers with disabilities, limitations are ordinarily examined on a person-by-person basis at the time of licencing. But what is the situation for elderly drivers?

In 1992, the famous human factors authority H. McIlvaine Parsons studied the use of VCR remote controls, calculators and joysticks by seniors, mostly females, as an investigation into the area of the control of devices. His conclusions seem to indicate that where elderly humans are concerned, the use of the familiar hand-held small-sized devices maybe the wrong avenue to pursue. Yet many devices in the IVHS family require the use of such input controls.

But a great many accidents also occur because drivers cannot "read" the road and anticipate circumstances by which they are about to be engaged.

Signs

Some of this information is explicit, as presented by direct messages such as "Slow down." But some messages which are meant to be explicit really aren't: "Soft Shoulder," really requires a whole set of inferences between reading the sign, translating the word "shoulder" into a non-anatomical concept, and figuring out what sort of reaction, if any, is needed.

A great deal of re-examination is currently underway (in Ontario for example), for road signs. An example of a potential improvement based on an extension of presently used behaviourally motivated efforts is as follows: if a driver is entering a curve at too great a speed, a roadside sign could flash, "Hey you in the Chevrolet… slow down to 50 kph really quickly." But all things considered, the best potential for more effective messages lies in in-vehicle messaging systems.

Signs and the major engineering activity of setting uniform standards for traffic control and highway messaging can truly blossom with IVHS. This is because IVHS represents a potential change from expensive highways signs; the initial charge to erect a major overhead highway sign can be a hundred thousand dollars. With IVHS, a message is created by software and has only a small marginal cost. Indeed, drivers can get messages on their in-vehicle CRT in the language of their choice and with other parameters of presentation appropriate to their personal circumstances.

Environmental support for perceptions

Most information needed for guidance arises from visual perceptions. But it is a fallacy to think that drivers "see" hazards in the sense that they might see an oil slick on the road surface. For example, a driver may see that he/she is only two metres from the car ahead. Yet it still requires a series of implicit inferences to "see" that one's car is too close to the car ahead. Further, it is yet another psychological step to join (1) the perception of closeness and (2) the motivation to prolong your life in order to (3) perform the *behaviour* of slowing your car so as to increase the space between cars.

It is important to recognize that all driving behaviours are founded on such chains of inferences — the great Helmholtz (1963) called them "unconscious inferences." Veridical mental perceptions are, of course, created from physical stimuli in the environment. As noted above, IVHS *can* provide these cues, although in a manner which is second-order as compared to the natural flow of stimuli from the road and from the driver's body. In practice, this flow of stimuli can be a *just right* accompaniment to natural stimulation or it can be overwhelming like the "hints" mechanism in the Macintosh computing environment which foists on the user an endless flow of hints, comments, and cautions meant to serve as helpful advice to the experience deficient.

Some complex perceptions may be simple or reflex-like inferences from immediate perceptions, as in the headway example above. But some inferences are really quite complex: at night, the horizontal spacing of road edge markings must be interpreted to yield cognitions of road curvature. In turn, behaviour relating to guidance of the vehicle must be initiated.

Smart Cars can help inspire scientists to re-examine the subtle *perceptual* communication from roads and drivers. These are important components of driving although not heretofore much studied. Just as with messages which are now borne by physical signs, by means of IVHS, Human factors specialists can provide a great deal more information and can make explicit much of what today must rely on perceptions.

Implications for drivers with limitations

It is clear that needed signs and environmental supports for perceptions must be provided by traffic engineers. But signs and the veridicality of the perceptions resulting from signs (and *all* road cues) are marginal in many circumstances today, even for drivers of average capabilities. Listening to expert witness testimony from human factors specialists in court will quickly convince anyone of this fact. In so far as some drivers — with or without handicaps — have problems sensing and reacting to the marginal signs on today's roads, IVHS can provide a marked improvement in safety and driving effectiveness.

Licencing of drivers

As mentioned above, drivers with limitations of sensory or motor functions are ordinarily required to have their capability for driving and conditions of driving — for example, necessary assistive devices — reviewed on an individual basis. All the provinces deal with such issues although approaches differ. A great deal of soul-searching is underway at the present time as to the best approach for the re-authorization or renewal of driving privileges for drivers who might be experiencing functional impairments associated with advanced age.

TDC has had an ongoing interest in this issue. In a TDC-funded report, Rutenberg and Atkinson (1990) conducted a telephone survey review of licensing procedures for the provinces of Canada. They found, as applicable to Smart Cars, that evidence of medical fitness is generally required for *older* seniors and persons with obvious disabilities. But the licencing agencies appear to take great care not to discriminate in their application of driver examination procedures. As shown in the recent TDC conference, *On the Road Again,* the current procedures involving a case-by-case review by physicians, rehabilitation agencies and driver educators appears to be generally acceptable to licence administrators for persons with disabilities. But can this approach be applied to far greater numbers of persons who are old?

In Manitoba, Newfoundland and Labrador, the Northwest Territories and the Yukon there are no converted vehicles or simulators available for training purposes. Ontario is the only province to apply age-based re-examination for licences although this is becoming quite common in the U.S.

Some of the recommendations from this report as voiced by the rehabilitation agencies called for the provision of standardized interactive automobile simulators, standardization of evaluation and training programs, and mobile evaluation clinics.

With the introduction of *Smart Car* systems, such simulators will have to simulate the IVHS elements as well as the conventional aspects of the driver's task.

1.2. Human Factors Issues

1.2.1. Drivers and tasks

The broad demands of driving cover a wide gamut of human performance and, likewise, the range of impairments relevant to driving effectiveness is wide too. Therefore, this report does not attempt to identify all such impairments nor to assess in detail the impact of any of them through empirical evaluation. In this chapter, a conceptual overview and discussion is presented.

Drivers have tasks to perform to successfully "achieve" a journey, such as those alluded to in Section 1.0, two such tasks are *steering* and *braking.* But a personal impairment which results in capabilities appreciably below the level needed to accomplish one of the tasks of driving hinders the effective performance of this task. Poor personal capabilities can be in the areas of physical impairment, sensory weakness, compromised states of mind, and others shown in Chapter 2.

The phrase "level needed to accomplish one of the tasks," does not mean that a fixed level is necessary for success. Some driving tasks can rarely be successfully accomplished by anybody! For example, parallel parking is largely a trial and error proposition on the first try because sightliness, visibility of curbs, knowledge of fender positions, and steering mechanisms are not presented to the driver in a manner likely to result in a good parking maneuver on the first try. In other words, the environment — such as the field of view of the driver — in which the driver performs the task can often be much improved.

Some of this improvement is through human factored design of conventional aspects of the driving environment and some through new technology… the object of this report.

1.2.2. **Mapping impairments on drivers' tasks**

The relation of impairments and driving can be examined with the help of the following framework, Fig. 2. First, the *Tasks of the Driver* are identified. Then, *Driver Impairments* that affect the performance of these tasks are identified. The *Performance Shortfalls* arising from the interaction of tasks and impairments are then outlined. These shortfalls have solutions, which can be *Conventional Solutions* or *IVHS Solutions* (although Conventional Solutions are not substantially addressed in this report).

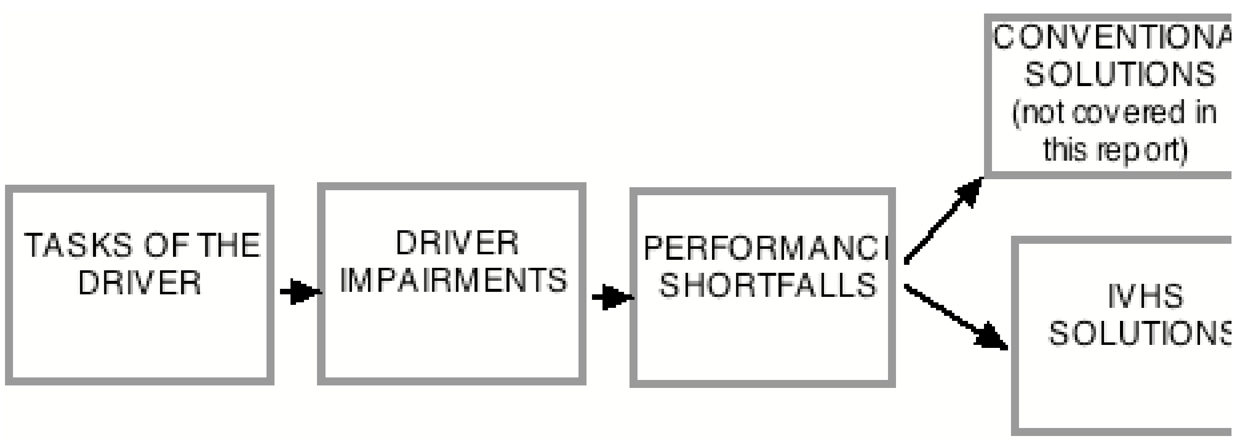

Figure 2. Tasks of the driver and IVHS solutions

Figure 1 compares impairments with the tasks of driving. The framework shown in Figure 2 connects these impairments with solutions. In the matrix, cells are highlighted which represent

"Performance Shortfalls." That is, aspects of performing the task can be compromised through impairments of the type which heads the column. These are discussed in detail below and potential means of ameliorating shortfalls through IVHS solutions are presented one by one.

1.2.3. A matrix of performance shortfalls

In order to establish which aspects of driving may require additional attention, a matrix of shortfalls has been prepared and is elaborated in the next chapter. The rows of the matrix present the various *tasks of driving* as they might be treated in an Ontario high school driving textbook. The columns represent personal impairments as divided into six major categories. The cells with entries in them (E1, E2, MT1, etc.) are the tasks in which there are judged to be performance shortfall or sub-standard levels of skill resulting from the presence of impairments of the indicated category.

For example, persons with hearing impairments have performance shortfalls in addressing problems of breakdowns because of obstacles in spoken communications with road service providers. Or, persons with emotional disabilities may not show good judgment in proceeding into hazardous intersections.

The following capsule descriptions are meant as modal characterizations of the impairments but not as exhaustive descriptions of all conditions which might result in impairments.

Emotion

Inability to inhibit inappropriate or disabling responses such as might arise from agoraphobia, non-specific anxiety, substance abuse, or impulse control problems.

Hearing

Deafness or requiring a hearing aid to follow conversation.

Language

Dyslexia or other conditions resulting in reading ability below grade 3 level.

Limb control

Paraplegia, quadriplegia, or poor control of limbs arising from functional loss of a limb, cerebral palsy, multiple sclerosis, stroke, or arthritis.

Memory and thought disorders

Delay in intellectual development or decline in mental abilities due to old age (including reaction time, complex decision time, and overload due to competing demands).

Vision

Poor acuity or specific blindness of the visual field such as tunnel vision or foveal losses; extreme weakness of colour vision.

1.3. Comments on Contacts with Users with Disabilities

It should be borne in mind that results of any study are constrained by the methods of study. The specifics of these methods are discussed below but for the moment, one general observation should be offered, as follows.

The purpose of this study is to represent the needs of drivers with disabilities — but only vis a vis IVHS-type features. Some effort was made to channel discussion away from systems which control the movement of the vehicle. For many drivers with disabilities, a car which assumes a lot of the control (including detection, decision, effective action, etc.) is the terminal solution for their driving needs.

Thus, owning a computer-driven taxi which responds to voice commands would be the ideal (and the "smartest") of all cars. Therefore, it would simply be begging the question to have the discussions with drivers or the contents of this report extend that broadly. While respondents were always free to introduce their imaginative concepts of hypothetical micro-electronic features, discussion of future vehicle *control* systems was discouraged in favour of vehicle *information* systems.

2. A CONCEPTUAL OVERVIEW

The material in this chapter is revised from material originally appearing in reports by Parviainen, Webster, Levy and Smiley, 1990, and Parviainen Atkinson, and Young, 1991.

2.1. Driver, Vehicle, and Environment Factors

A description of the overall private passenger transport environment - to which advanced sensor, computer and communications technologies are being increasingly applied - must incorporate both driver and other system considerations. The factors (characteristics) by which the driver 'component' of the system can be framed are commonly collated into five categories: physical, perceptual, cognitive, motivational and other.

For the purposes of this study, only the most important factors have been selected within each category - specified at a level that is sufficiently detailed to be meaningful for the designers of in-vehicle systems, but not so detailed as to become unmanageable in the design and testing process. Within the 'perceptual' category, for example, the following vision-related factors have been included:

-acuity (SVA + DVA)

-dynamic visual acuity (DVA), i.e. clarity of vision when observing moving objects

-static visual acuity (SVA), i.e. acuteness or clarity of vision when observing stationary objects

-visual field impairments (i.e.. loss of field vs. compensation by head movement)

-resistance to continuous glare and recovery time from intermittent glare

-colour and contrast sensitivity (particularly with moving objects).

The other components of the overall system are: passengers, vehicle, traffic, road and weather. Passenger characteristics include the passenger's general behaviour (while in the vehicle), conflict level (primarily with the driver), and co-pilot skills (ability to interpret maps, etc.) - which can be good or bad, but also either helpful or disruptive.

For each factor, whether within the driver or the other categories, a range of conditions exists that must be considered in the design, development, testing, implementation, operation and evaluation of Intelligent Vehicle-Highway Systems (IVHS) - or Advanced Transport Telematics (ATT) systems (Parviainen, 1990). Described as the positive and negative boundaries for each factor, these conditions are presented in Appendix C, Exhibit 1. Although the list of factors within each category is not exhaustive, and some of the definitions for the boundary conditions could surely be phrased differently, this set already provides a rather demanding framework for IVHS developers.

Additional behavioural considerations, to be recognized in the development work, include:

-the driver's trip making characteristics (or those of his/her passengers, whose requirements may well control the travel decisions)

-number of trips by purpose

-destination and travel time choices

-propensity to venture out to unfamiliar areas

-distances driven without stopping

-extent of pre-trip planning

-selection of vehicle type and propensity to purchase accessories

-inclination/tendency to study and practice (or not) the use of new devices before venturing on the road

-and finally, for those who already have given up driving, the reasons (as perceived) for giving it up.

Please see Exhibit 1 in Appendix C.

Under unfavourable circumstances, a negative boundary condition in a single factor - such as extreme sensitivity to glare - can result in a collision. Obviously the status of the other factors will even then play a part - i.e. the collision will not be with another vehicle, if there aren't any around. And for the most part, it is in fact negatively reinforcing interactions among factors within one or more of the six categories (driver, passenger, vehicle, traffic, road, weather) which cause abrupt maneuvers, panic control reactions and subsequent collisions. One illustration of these interactions is presented in Appendix C.

It is not uncommon to assume, in the development process, that highly favourable conditions exist - namely, that all system factors are in an optimum state. This is unrealistic and can only result in unsatisfactory systems - with potentially serious implications in terms of road safety.

"While a global negative - i.e. a negative condition for all variables simultaneously - would simply bring the entire ATT-supported transport system to a standstill (vehicles would be safe only if parked), an all-positive condition is just as unrealistic as a basis for design. Identifying combinations of variables for which a negative condition can reasonably be expected to happen simultaneously - and then systematically testing the hardware and software under such system duress - is a prerequisite for good, responsible design." (Parviainen, et al, 1990).

The design/development process must ensure that the in-vehicle devices, and IVHS in general, accommodate or at least somehow account for all types and levels of driver and other factors which affect vehicle-operating skills required for the navigation, maneuvering and control tasks. The designers and developers must research, investigate and experiment to learn about the complex interactions, and negatively reinforcing conditions of the factors within the entire system.

2.2. Countermeasures to Negative Boundary Conditions

The development process must also recognize that the IVHS-based technology responses are (ought to be) preceded by non-technology actions. To assume that IVHS modules will somehow make these low-tech, common sense responses redundant is not rational. In fact, under all negative conditions it should be an immediate priority to ameliorate the situation by appropriate driver and system actions. Carefully designed in-vehicle devices will, through features within their functional modules, guide the user into implementing parallel complementary responses. (Note: the sequence is particularly important when evaluating the cost-effectiveness of various countermeasures - the comparisons must be done 'at the margin', i.e. comparing the incremental gains made for each increment of financial (and other) investment).

The illustrative countermeasures to negative boundary conditions in driver, passengers, vehicle, traffic, road and weather factors that would support elderly and disabled drivers, presented in Exhibit 2, Appendix C, are divided into two response levels: Non-IVHS Actions and IVHS Functional Modules. Together, they are designed to make private automobile travel possible, more convenient and enjoyable, and safer for people with diminished driving skills or other travel impediments.

For example, for a negative physical condition - 'in pain' - the individual non-technology response is, when time so allows, to stop and rest, to adjust seat, mirror, etc. positions to optimal comfort levels - and, where warranted, to take appropriate medicine. IVHS modules which will help in this situation include: access/egress assist systems (with remote control), Smartcard driven power seats and mirrors, close perimeter radar and power steering (for parking), cruise control (to reduce lower-back pain by allowing more comfortable positioning of legs and feet), intelligent cruise (to further lessen required pedal work), and an on-board computer which will ring a chime to alert about times to take medicine.

Vision-related problems call for wearing correct glasses and sun glasses with Polaroid lenses - but also for preparing for each trip (to be able to expect /spot landmarks), increasing visual search and scanning (picking up relevant information, ignoring distractions), avoiding peak-hour travel and night driving. IVHS modules helpful in this situation include: in-vehicle signing, simplified (skeleton) navigation displays, route-by-choice guidance incorporating a voice module (to avoid high-demand routes), intersection presence sensors and beacon transmitters (for increasing alertness, assisting in left turns across busy arterials), forward looking radar (for general alerts), night vision enhancement radar, and intelligent cruise (with gap and lateral assist).

Two primary conditions in the cognitive sphere, low capacity in information processing and slow reactions, call for driving slower (and if not safe, diverting to a slower facility), planning each leg of a trip well, increasing anticipatory driving (increasing the gap to vehicle in front, changing lanes earlier, etc.), and practicing processing and reactions (special driver training, under the duress of driving tasks). IVHS modules include: simplified in-vehicle advance-signing with timely repeats, navigation display (for co-pilot use, if present) and route guidance - and, most importantly, increased 'buffers' (e.g.: 3 second gap, instead of the usual 2 seconds).

Route guidance features may incorporate special algorithms that, at the request of the user, will identify a route to the destination (or a by-pass route for an incident site) which, within reason, will minimize left-hand turns across busy arterials. (Note: disregarding the fact that the oncoming traffic has the right-of-way and misjudging when the oncoming vehicle will be at the intersection are perhaps the most common traffic violations and errors by elderly drivers).

2.3. **Assessment of Effectiveness**

In order to identify priority modules, with which to best ameliorate the road safety and other effects of the negative boundary conditions on E&D drivers, an assessment of their likely effectiveness needs to be made. The results of a first, preliminary assessment, in terms of anticipated direct and indirect influences of a sample set of modules (communications/information modules/comfort/security/on-board computers/vehicle location/autonomous navigation/route guidance/presence sensors/intelligent cruise), are presented in Exhibit 3 in Appendix C.

The fundamental assumption in this representation is that each IVHS functional module has been properly integrated by the designers, and is being properly used by the driver - with priority always given to the driving tasks of navigation, maneuvering and control (hence, 'being used properly' in the exhibit title). Careless use of almost any of these features, such as attempting to read CRT map information while the vehicle is moving in the traffic stream, can result in a close call or a collision. The degree of expected amelioration within each of the main categories is - for illustrative purposes - rated as H(igh), M(edium), L(ow) or nothing and not applicable (represented by a faint period).

Based on this preliminary, subjective assessment, some of the winning features, with across-the-board favourable impacts, are:

-vehicle to/from road side communications

-in-vehicle signing

-route guidance

-intersection assist

-gap-keeping intelligent cruise.

Many other functions are critical as countermeasures for specific driver or system shortcomings - e.g.: ATMS (Advanced Traffic Management Systems) messaging for traffic flow optimization, access/egress assist for physically disabled drivers, 911 for emergencies, OBC (on-board computers) for memory problems, map display for co-pilot efficiency, proximity radar for those with physical and perceptual disabilities to allow parking in tight quarters, etc. The implication is that while a very specialized support unit can help drivers cope, a comprehensive (read expensive, for now) unit clearly provides the breadth of support required for full comfort, ease, safety and security in travel.

The High/Medium/Low ratings, once further refined at brainstorming sessions with expert groups and by other assessment techniques, such as linear scoring functions (LSF) or simulators, can be useful in identifying research and development priorities. A corresponding ‘conflict matrix’ should also be prepared to illustrate the likelihood of the various functional modules being improperly used and conflicting with the driving tasks - and the expected severity of the consequences (the negative Highs, Mediums, Lows). After all, in real circumstances the ideal conditions (of IVHS modules fully compensating for various deficiencies) and correct manner of use may not be all that common; the favourable High/Medium/Low level influences can be diluted or canceled out altogether.

2.4. Alternative Context

Other representations of the non-IVHS and IVHS responses may relate them to specific requirements or weaknesses in driving and other in-vehicle tasks and/or current systems. For example, in order to identify an over-night destination and navigate to get there, one may have to:

- locate an up-to-date accommodations directory (if not available in the vehicle, locate a tourism information centre and obtain one)
- identify the hotel(s) by facilities and rates
- locate a public telephone (and coins), stop and call about availability
- locate and unfold a current road map for the area (if not available in the vehicle, locate a tourism information centre or service station and obtain/purchase one)
- find the vehicle’s and the hotel’s positions on the map
- determine the best route (e.g.: shortest, most scenic, safest)
- follow that route simultaneously on the map and on the road
- re-orient in case of getting lost (or being diverted due to construction or a road incident)
- interpret differences between the map (if not current) and the road network
- find local access to the hotel from the highway system
- refold and store the map.

The device-level responses would then be identified in relation to each of those tasks. Many would not be necessary or would be much less demanding on the driver (particularly in single occupant vehicles), assuming a multi-function in- vehicle unit with a CD-ROM (or similar) map database etc. - e.g.: the vehicle ‘knows’ its location and automatically displays it on the in-vehicle map screen, yellow pages directory can be context sensitive with search and display features (motels with accessible facilities, rate categories, etc.), update transmissions about facilities and availability might be received from a local beacon, route finding including construction by-passes is automated and displayed with direction arrows and voice instructions (based on preference-criteria expressed through controls or in the Smartcard of the user), reservations via a two-way communications link could be automatic with confirmation displayed on the screen and perhaps even being printed on an on-board printer.

Yet another method (Parviainen, 1990) would focus on driver behaviour and accident causation, and relate the countermeasures to the following driver-variables:

visual perception
ability to detect relevant information
ability to detect relevant information in time
ability to attend to relevant information
ability to make correct judgments
ability to implement judgments into actions
ability to estimate safety limits of equipment
motivation to drive safely.

In Europe, the ATT-related work on elderly and disabled persons is being done in France, U.K. and Sweden. Within the DRIVE II program, two research projects - being carried out by international consortiums representing six and four countries respectively - focus specifically on E&D driver needs:

- TELematic Applications for the Integration of Drivers with special needs (TELAID) - which aims to apply a user- centred approach in proposing 'integrated solutions', and to design guidelines and draft regulations for drivers with special needs, utilizing the possibilities of advanced telematics;

- Elderly and Disabled Drivers and Information Telematics (EDDIT) - designed to examine the driving behaviour of elderly people and the type and frequency of their accidents, to review Information Telematics (IT) systems that may ameliorate driver problems and extend safe driving life, and to test these systems, initially by simulation, subsequently by in-vehicle on-road assessments.

2.5. Conceptual Framework for System Development

The IVHS functional modules or capabilities presented in Exhibit 2 in Appendix C - as the countermeasures (to negative boundary conditions) - constitute but a sampling of a broad range of features expected in future advanced, comprehensive systems. An established method of introducing IVHS is to group the modules/features under primary application-based categories.

Because the focus in this study is on travel by private automobile, the following categories and sequence could be used:

Advanced Traveller Information Systems	ATIS
Advanced Mobile Support Systems	AMSS
Advanced Vehicle Control Systems	AVCS
Advanced Traffic Management Systems (corridor/area-wide/special event)	ATMS
Advanced Fleet Management Systems (public transport/emergency/service fleets)	AFMS

The suggested ATTS/IVHS functional modules (their acronyms and definitions), primary features, and sample features to support E&D travellers, are presented in Appendix C for general reference to the Advanced Travel Accessibility System (Alm, 1989). This is the source for many of the IVHS functional modules which have been identified as responses to negative boundary conditions of specific driver and other factors in Exhibit 2 in Appendix C.

A conceptual framework for an Advanced Travel Accessibility System (Alm), with its application areas and functional modules, is also presented in the Appendix for general reference. Illustrated also are the fundamental design factors (on the left and bottom) and the ATAS relationships to advanced fleet and traffic management systems (AFMS & ATMS). Unlike in conventional IVHS units, all functional modules have been specifically tailored to enhance the diminished skills that often make driving and traveling tasks difficult for elderly and disabled persons.

In Appendix A, a preliminary conceptual framework for the development of systems for E&D travellers is presented. The developer of IVHS equipment and services may wish to review this broader context (for E&D IVHS units) before any major investment decisions. Even the functions of a single function or a simple multi-function unit - as opposed to a fully integrated, comprehensive unit - will be part of an overall framework for general IVHS and E&D services.

A further elaboration on functional capabilities specifically tailored to assist elderly and disabled travellers (drivers & passengers) is presented in Exhibit 1 of Appendix C.

2.6. Current Systems

Ever since the advances, during the 1980s, in micro-electronics, sensor and communications technologies, the pace of development in IVHS has been furious - particularly in Europe, Japan and more recently the U.S.A.

The current systems are no more simple AVI (automatic vehicle identification) devices, but incorporate a broad range of features - specifically designed for use in private automobile travel. In Japan, some 300 000 units have already been sold - in many cases, as options at the time of a new vehicle purchase.

A small survey undertaken by the Navigation Working Group of the SAE IVHS Division, covering 27 systems currently on the market, recorded the features in these systems (Exhibit 4 of Appendix C). The features ranged from position/location determination (25), route calculation (21) and voice route guidance (19) to intermodal trip planning (5) and download software update to vehicle (4). Position/location determination is obviously essential before many of the automated features, such as route guidance and interactive yellow pages, can practically be provided in autonomous systems. The survey established the popularity of the following input/output interfaces:

Twenty-one included a graphical display (17 in colour); 19 a voice synthesizer; 2 a heads-up display; 8 included a touchscreen; 5 steering wheel buttons; another 5 voice recognition. For communications, 13 systems had cellular; 12 came with 1- or 2-way radio frequency; 7 with FM sub- carrier/spread spectrum; and 2 with DAB (digital audio broadcast).

Four representative navigation systems - without implying any preference or rating/comparison of available systems worldwide - are as follows:

Travel Pilot… by Blaupunkt Bosch Telecom (Robert Bosch Corp.) & Etak

Telepath… by Delco Electronics (Subsidiary of GM Hughes Electronics)

Soarer Electro Multi Vision… by Toyota Motor Corporation

EURO-SCOUT… by Siemens Aktiengesellschaft.

Discussions with IVHS equipment developers, suppliers and researchers in the Detroit area confirmed that, in general, the diminished vehicle operating skills of both elderly and disabled persons are not specifically addressed in the design/development/testing process. This is somewhat surprising considering the potential importance of this market segment -

its continually increasing size, its likely interest in technologies that can make travel easier and safer, and its inherent purchasing power - and considering that it is commonly acknowledged that devices developed with elderly users in mind are typically easier to learn and use for users of all age groups and skill levels.

The introduction of elderly and disabled users, even beyond their (current) relative shares of the overall driving population, into the groups used for testing and assessments, is strongly indicated. The selection of the boundary conditions for each of the test variables (such as presented in Exhibit 1, Appendix C), and the assumptions on what combinations of simultaneous negative conditions ought to be addressed, should be influenced by the reality that many users - not just elderly or disabled - will have temporary or permanent limitations on their vehicle operating and information processing skills; and that unexpected combinations of environmental and vehicle factors (e.g. mechanical condition) can play havoc on the assumption that the IVHS equipment is being used in some inherently safe conditions, or in an inherently careful and safe manner, with margins to spare.

Although elderly and disabled drivers' needs may not have been specifically addressed, nor representatives of these groups used in the testing process, the form that some of the units reviewed have taken - and the functions that have been made available - do not, in the main, run counter to E&D considerations. For example: one unit has been so developed that the functions that can be accessed while the vehicle is in motion are severely limited - to discourage drivers from diverting their attention from the primary driving tasks to dealing with the equipment and its information; one unit does not display any map at all but provides instructions with directional arrows (and simultaneous voice messages); where there is a beacon-based infrastructure to 'feed' such an in-vehicle unit, the problems associated with attempting to both read and study a map while the vehicle is moving, or stopping at inappropriate locations to get access to a map display are avoided; another in-vehicle navigation/information unit can be removed from the vehicle, and many of its functions operated while at home or in a motel, for example; this facilitates pre-trip planning and route learning so that the trip itself will be less stressful and safer (for all road users); this feature is likely to be particularly attractive to E&D travellers.

Of course, only close scrutiny and en-route testing - trying to operate the vehicle and the various features of the unit in unfamiliar areas and traffic conditions - with subjects representing typical combinations of diminished skills would really establish how practical, helpful and safe these units are for the E&D user groups. Such experiments could prove very valuable and are highly recommended.

The overwhelming impression from the marketplace and the development laboratories is that future systems will become more and more feature laden. Much work is underway, for example, in the development of yellow pages type data bases and the related communications modules to provide integrated reservation and purchasing features. Full colour map displays, heads-up displays and digitized and synthesized voice modules are being provided.

However, little work is underway specifically focusing on the needs of elderly, and particularly those of disabled. This represents an important, indeed, an urgent opportunity for Canadian research, development and demonstration work - leading to manufacturing of both hardware and software for a rapidly expanding and influential niche market.

3. VIEWS OF DRIVERS WITH SPECIAL NEEDS

3.1. Introduction

As indicated in this report, development within the automobile sector is very closely tied to a concept of the size of the market. Thus in 1976, Ford authorities at the Oakville Plant in Ontario indicated to us that Ford management in Michigan was very little motivated to respond to Canadian requirements because of the size of the market here. Other car makers who sell in Canada may work under a similar constraint.

Likewise in 1993, the same point of view was again expressed to researchers on a TDC investigation. Of course, the constraints on customizing cars which were in force in 1976 are much reduced in 1993. Nevertheless, Ford, in its best judgment, adheres to a policy of producing cars to serve only large markets and, presumably, small markets get correspondingly less attention.

If only modest attention has been paid to smaller markets then, it may be inferred, efforts towards addressing problems of drivers who are handicapped by existing cars or who are driving through the benefits of third-party customization would get little attention. This appears to be the case, to this time, in Smart Car development.

For this project, it was determined that a small effort should be made to speak with typical drivers with special needs. Three means of collecting information were pursued. First, a focus group was convened with seven drivers. Second, additional individual interviews were conducted. Third, a small survey was administered to respondents at the group discussion and in the individual interviews. The survey questionnaire appears in Appendix C.

In addition, the following section in this chapter introduces some published data.

3.2. Interview and Survey Results

Because of the small sample, spoken results from the interviews and written reactions from the survey are presented together, each type of data complementing the other. Persons with disabilities are not an homogeneous group. Their needs, special and ordinary, vary as much as those of any other group of drivers.

To assemble a group, voluntary organizations in the Toronto area were contacted. A distribution of disabilities and personal characteristics were sought, in so far as any spread of characteristics is possible for a single small group. The supplementary interview respondents were selected because of their special experience and knowledge of driving and disabilities.

All 10 respondents in the sample are drivers. As employed people with active lives, they reported that they drive quite a bit. They average 29 days a month and the group range is 25 to 31 days of driving. They range in age from 27 to 68 with an average age of 43 years. Two of the respondents were women. Five of the respondents used wheelchairs, with three of them using wheelchairs as a result of trauma. Two members were hard of hearing and used hearing aids, two had intellectual limitations, and one respondent had no serious disability except for diminishing functioning as a result of aging.

The focus group was conducted using a study guide with timings. But as with all such methods, the flow of the discussion influenced the topics and timings.

General concerns

At the most general level, what are these people concerned about? First, drivers look forward to greater safety. Features such as a radio location beacon which is activated automatically in an emergency are valued.

Because driving is mentally and sometimes physically demanding, drivers with disabilities are particularly committed to defensive driving strategies. Furthermore, because the challenge of driving is greater for them in many ways, they find driving a heavy psychological work load. Thus any change in work load is viewed with great interest, either as a threat or as a benefit.

Second, respondents welcome any enhancement in the ease and comfort of driving. All features discussed found strong endorsement among some drivers and nothing seemed trivial to everybody.

Third, they want “friendly” systems that are foolproof to operate, thoroughly trustworthy in their operation, and do not compromise safety in any way. A driver with disabilities may be more dependent on certain systems. Thus they may be more adversely affected than a non-disabled person with a lesser degree of dependence. For example, if a tire slowly loses air, the worst-case situation for an able driver is to change that tire on some deserted stretch of road. A driver who is unable to change his/her own tire depends on an early warning of impending tire failure to avoid the need to change a tire while on the road.

Features that divert one’s attention while driving, for example, are not favoured. Because drivers with disabilities have varying special needs, there was emphasis on configurable systems that adjust to the particular driver. Inserting a personal Smart Card might for example, set a pattern of operation, seat adjustments, interaction timings, and so on, suitable for the bearer of that Smart Card.

Fourth, drivers are quite apprehensive about the introduction of complicated systems that are difficult to understand and to use. As a communication output, drivers favoured speech, with text on a screen as back-up.

Finally, drivers with special needs are keen to see stakeholders like themselves remain influential in the development of IVHS.

Naturally, the emphases on specific features differ between persons with different disabilities. Navigation is a strong priority for drivers who are dyslexic or learning disabled, because they frequently get lost, even in their home towns. But drivers with paraplegia have their "hands full" already and they are resistant about adding to their driving chores.

Some 5-point rating scales were presented in the survey: 7 scales related to what features are of interest and 4 scales related to how such systems should be configured. "5" is a rating of "very important" and "1" is a rating of "very unimportant." Data under each of the two headings below is presented in decreasing order of importance.

Features

Driving aids (snooze alarm, cruise and steering control, and radar) were the favoured features. Please see Figure 3. Conventional dashboard tell-tale lights ("idiot lights") were disparaged because they were often too-little-too-late with information; but the development of an effective tell-tale system was endorsed.

Although it might be analytically more useful to have *each* feature rated, rather than have the features taken together as "drive aids," the scope of the study and its preliminary character did not permit this level of detail.

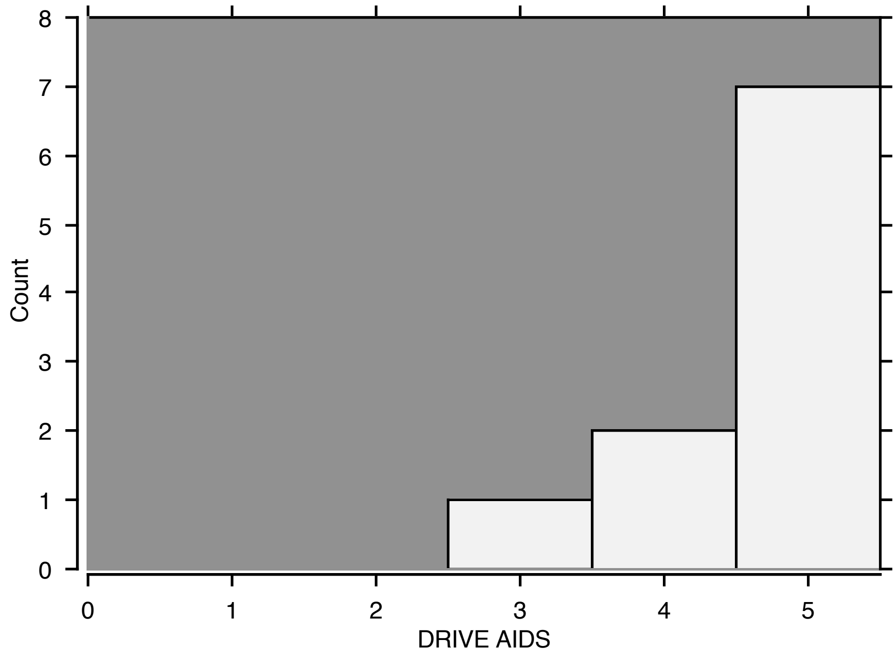

Figure 3. Rating of driving aids

Information to drivers (road, traffic, weather, and driving conditions) was the next most favoured, as shown in Figure 4. The manner of implementation — voice, maps, re-callable instructions, touch-screen, etc. — was deemed of particular concern. This area was not investigated in any greater detail. Drivers who use wheelchairs are particularly bound to their cars. Thus they especially cherish the prospect of being forewarned of road closures.

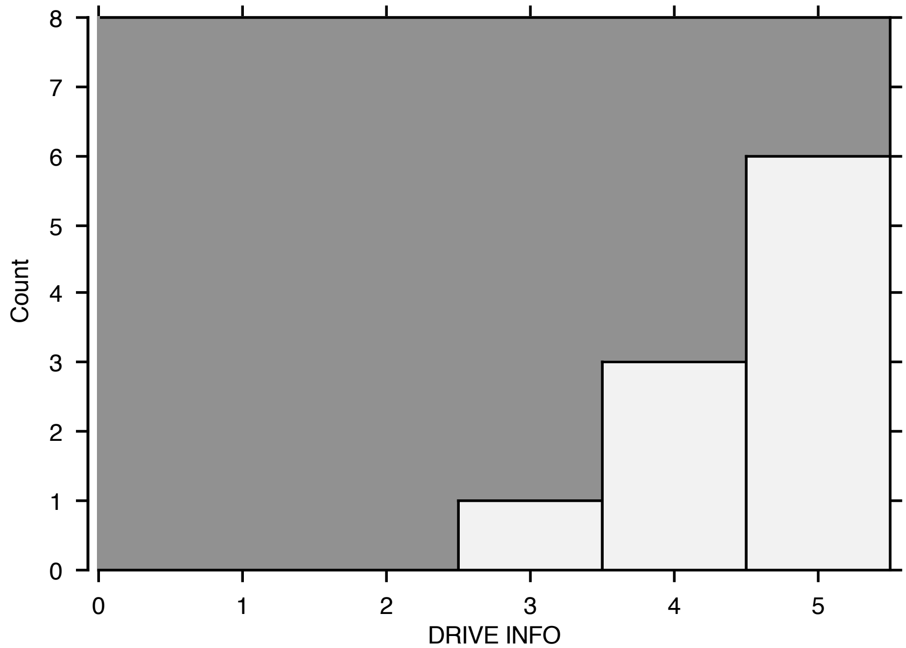

Figure 4. Rating of driving information

Third, drivers wanted aids to operations (such as setting seats or steering for a personal fit) and maintenance (such as expected remaining lifetime of brake pads), as well as information on the condition of the engine and fluids (such as oil volume).

Some knowledge of car maintenance, Figure 5, is considered part of a modern person's repertoire although manufacturers strive to reduce this burden as much as practical. But those with learning disabilities may have trouble keeping track of maintenance schedules and other facts. It should also be appreciated that many disabled persons are too poor to own a car. As a consequence, adults with disabilities may be less familiar than others of the same age with car maintenance. Because maintenance features do not detract from the driver's command role or intrude strongly, they are well liked and are viewed with fewer reservations than other features which are active during driving.

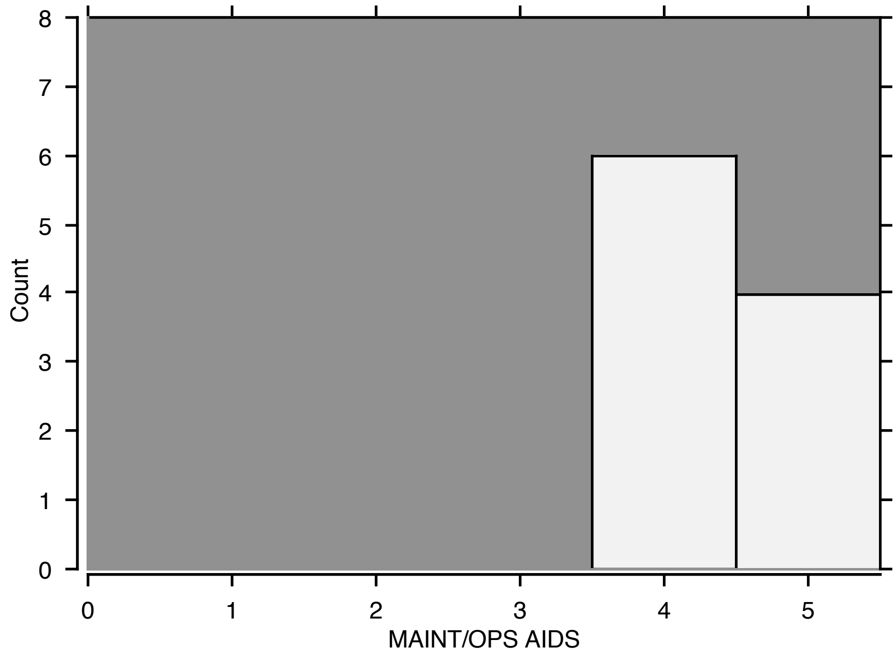

Figure 5. Rating of maintenance and operations aids

Route information, Figure 6, the feature most popularly touted in Smart Car promotion, was next in line. Many drivers with disabilities are compulsive in their trip preparations because the cost of getting lost is high for a person with mobility or communications limitations. Maps, street guides, and tourist kits are frequent companions. Because of this routine preparation, drivers were interested in but not effusive about a dashboard accessory. For example, some drivers favoured a device that could be programmed at home before starting the trip. Some wanted a passively available memory prompter rather than a device resembling a Sergeant Major commanding obedience.

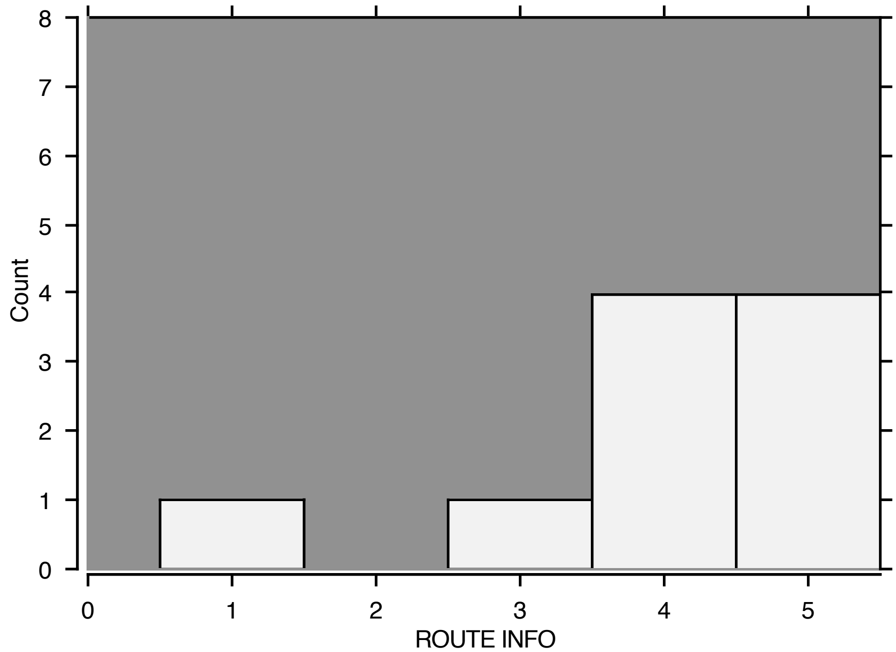

Figure 6. Rating of route information

Traveler information (hotels, entertainment, facts of interest to travelers) came next on the list, as seen in Figure 7.

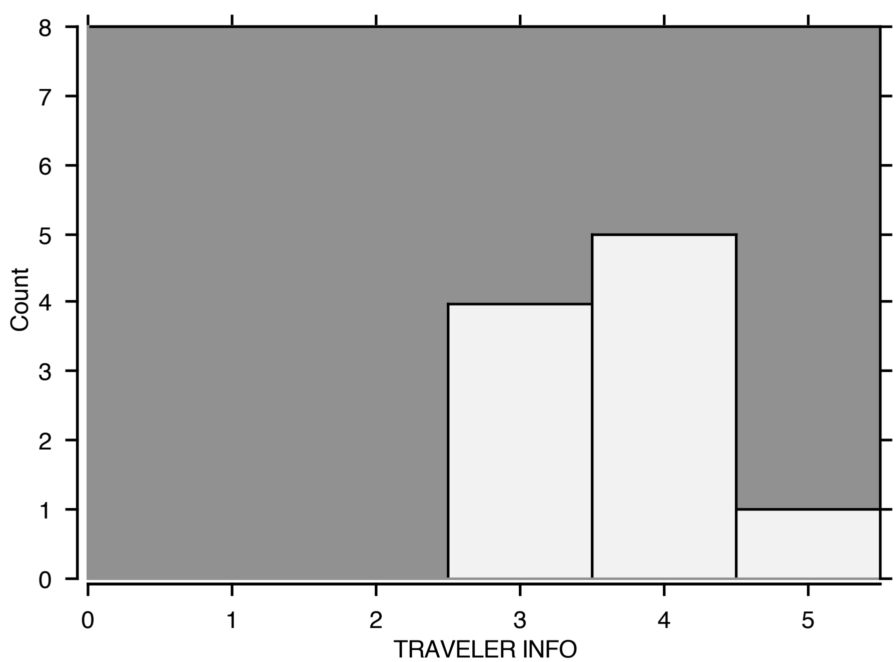

Figure 7. Rating of traveler information

Nearer the bottom of the features list was health-related help that might remind the driver about medication, tell where to find hospitals, or automatically radio medical emergencies, as seen in Figure 8. This item would have had an even lower priority had not many users strongly endorsed the introduction of emergency beacons such as those found on downed airplanes.

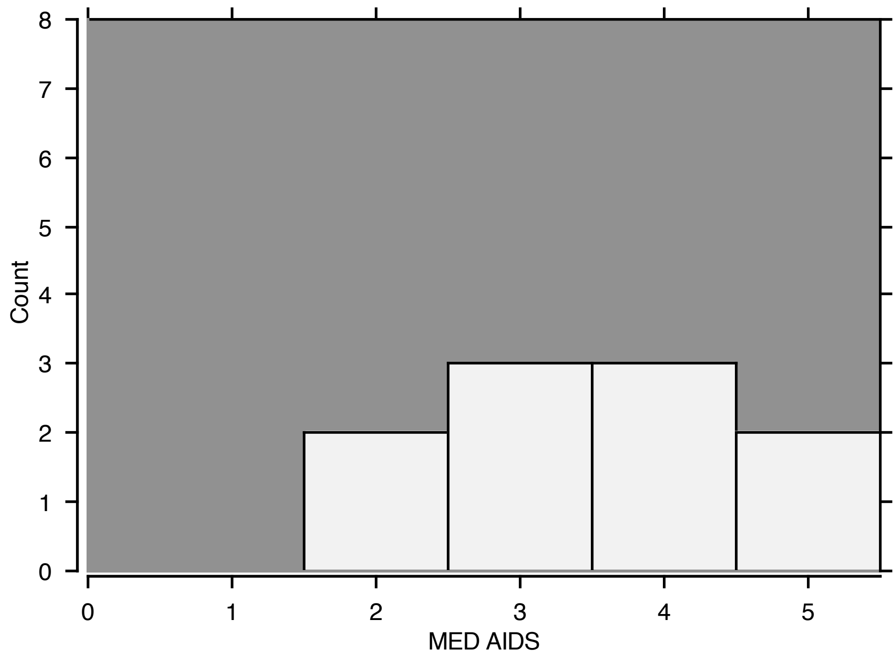

Figure 8. Rating of medical aids

At the bottom of the list was general purpose personal and entertainment computer features, as seen in Figure 9.

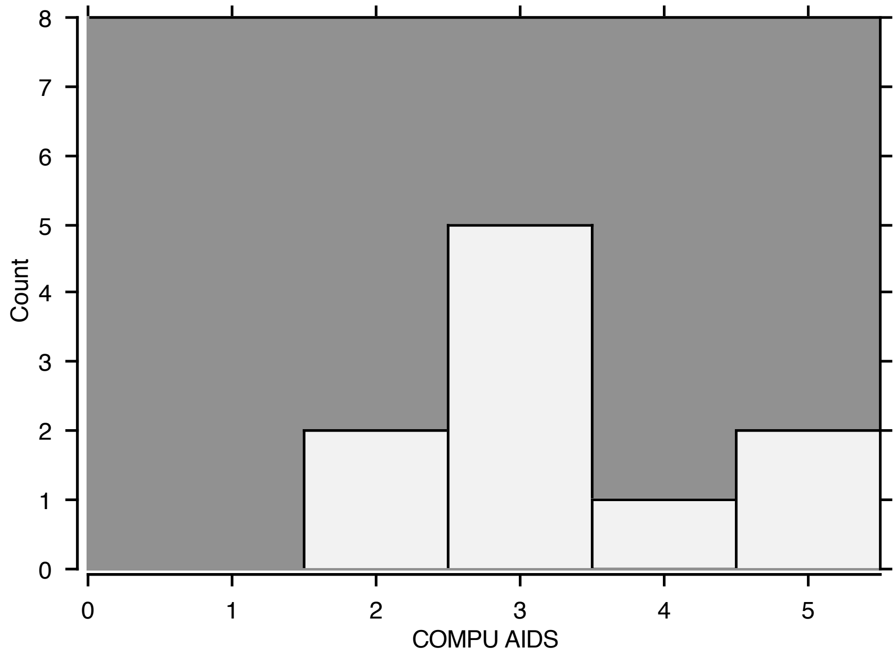

Figure 9. Rating of computer aids

***How* should features be configured…**

As the two main considerations, respondents voted strongly to avoid visual distraction and they did not want intrusive IVHS systems which compromise safety while the car is in motion, as seen in Figure 10.

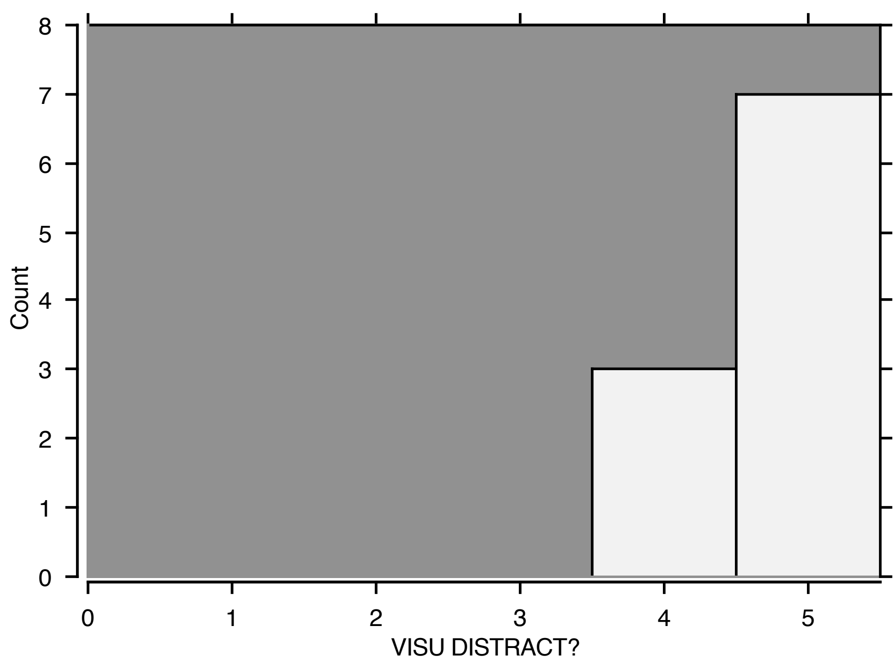

Figure 10. Rating of visual distraction

It was suggested however, by respondents, that, with practice, safe division of attention is possible. Respondents who do a larger amount of driving a month appeared less concerned about visual distraction.

Some designs (using sound) or operations that engage only passengers are feasible, as seen in Figure 11. Drivers considered a heads-up display that presents a virtual image of the information in the line of sight of the driver. Because no one had used such a device, no consensus was possible on its value.

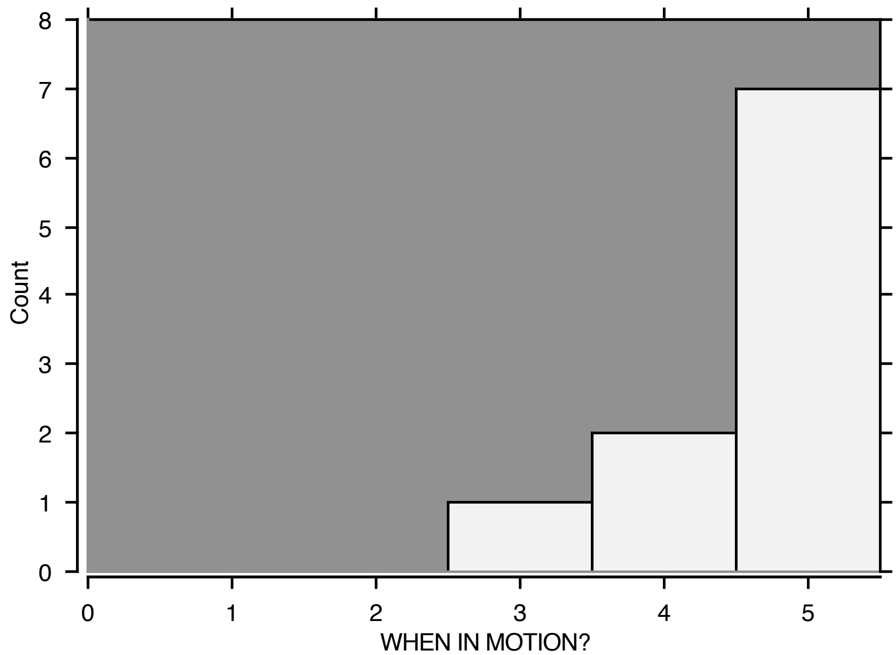

Figure 11. Rating of usefulness when vehicle is in motion

Having two-way or interactive properties — allowing drivers to make hotel reservations while on the road, if not while moving — was considered worthwhile, as seen in Figure 12.

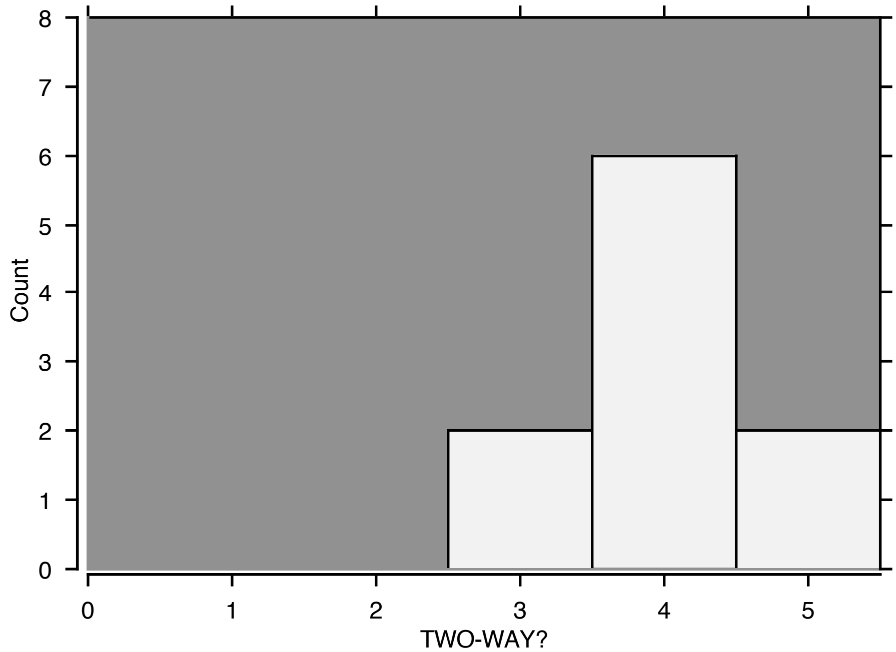

Figure 12. Rating of usefulness two-way communication capability

Lowest on the list of “Hows?” — but still rated “important” — was the ability to tote the system out of the car for use at home or in hotel room, as seen in Figure 13.

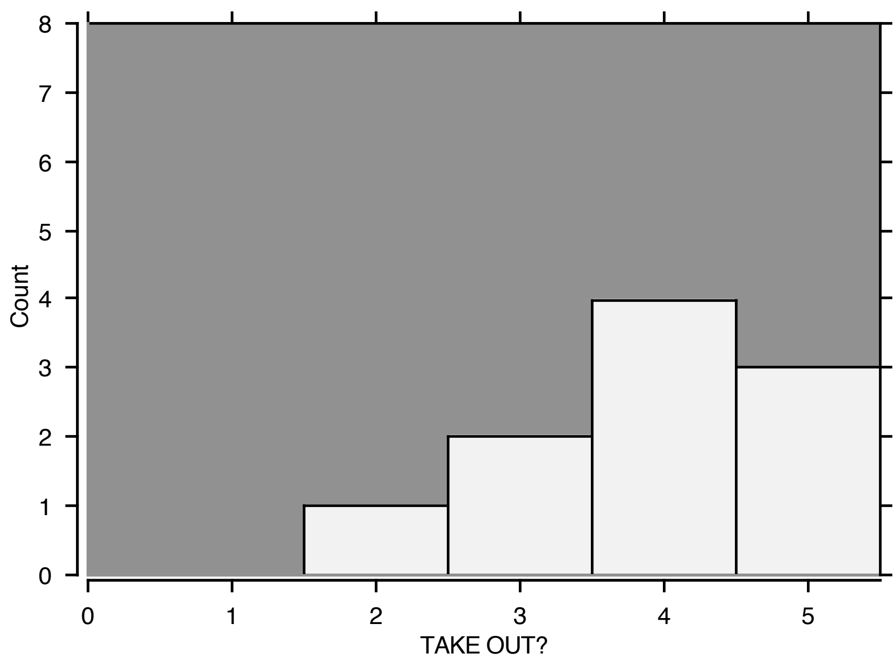

Figure 13. Rating of usefulness of being able to remove device from vehicle

A major systems decision for developers relates to whether the vehicle's system is self-contained or tied interactively to a central traffic computer. In retrospect, drivers favoured maps on CD (which is a self-contained option) over being linked to a central computer. Drivers were not confident that the central computer would stand them in good stead in certain challenging situations, such as unexpected road closures for repairs. Drivers preferred to have good maps to fall back on rather than to trust to a central traffic computer. Self-reliance and heightened sensitivity to system failures are motifs emphasized by these respondents.

Drivers were interested in road conditions. This requires, of course, contact with a central authority. But this kind of contact can be handled in many ways — some as simple as automated dialing recorded phone reports or the reports from traffic observers in helicopters which are broadcast on commercial radio stations.

The group were definitely concerned about commercial interests causing distortions of the accuracy or comprehensiveness of information in Smart Car databases. Drivers felt more comfortable with information in government-controlled systems rather than controlled by for-profit organizations. In addition to outright favouritism and unsavory practices, the cost of a small restaurant enrolling in a commercially-controlled database might be prohibitive.

One respondent brought up the question of privacy, because inevitably a profile of the driver, his/her purposes, etc. will need to be stored in any system using a central computer. Privacy and threats to security are serious issues among the disabled community. A person who is learning disabled with a deficit that is undetectable in most work and social settings may prefer to keep others from needlessly knowing about their disability.

Drivers shared a view that they would "try anything once" and felt receptive to innovative concepts in assistive devices for cars despite showing only medium enthusiasm for efforts in the TravTek family of energetic dashboard-borne visual displays with emphasis on navigation.

A final observation is that driving — and the sense of personal efficacy and independence it brings — plays a bigger role in the psychological world of drivers with disabilities than in that of other drivers. That is because the self-effectiveness of transporting yourself about is a delight which counters the image (and to a degree, the reality) of constraints and inhibitions experienced by persons with disabilities.

Features and approaches ranked

Figure 14 shows both features and the means of implementing them arrayed in a *single* chart for ease of comparison. Overall, Driver Aids and Driver Information are given ratings of high importance. But it is important to note that *caveats* regarding visual intrusion and interference while the vehicle is in motion are given comparable prominence.

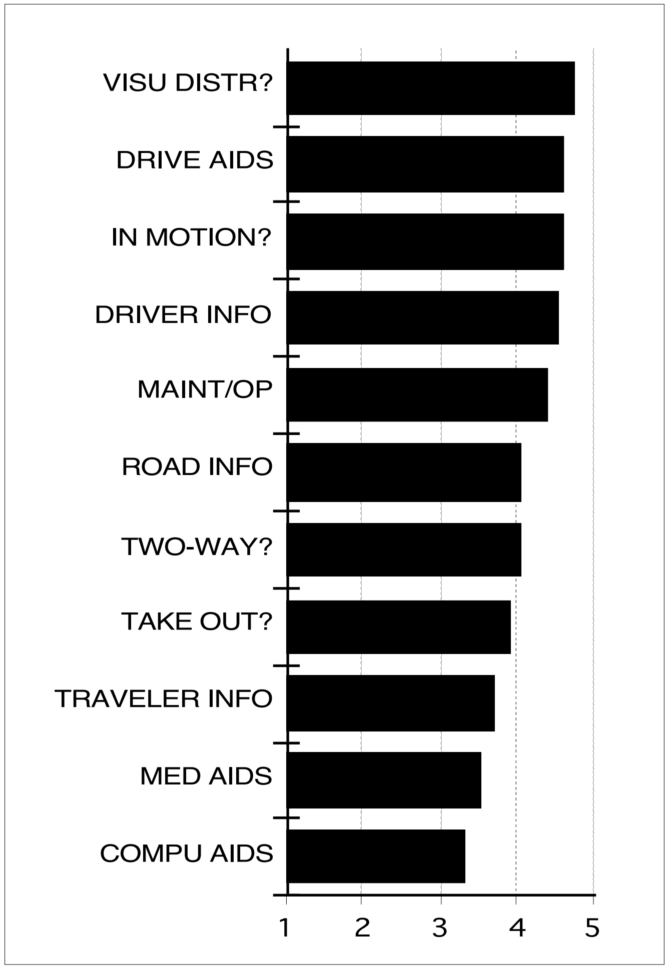

Figure 14. Ratings of all of the features compared

3.3. Some Published Information About Older Drivers

The focus group had representation from persons with disabilities but only one person was over 65. The focus group results therefore relate more to persons with disabilities than to the issues common to aging drivers.

There is some information about the needs of elderly drivers. For example, Simms (1992) has been studying characteristics of drivers who are over 70 years old. Elderly drivers accommodate to their changing capabilities by becoming quite selective about their trips. They accede to their limitations by avoiding bustling, challenging, crowded, or poorly illuminated routes.

They cut down on total travel, averaging about 4 600 miles a year; 42% never go on longer tours, such as over 234 miles. They mainly travel to familiar shopping, banking, and social venues. They take care not to be exposed to the risk of mugging.

The sensible accommodation shown by aging drivers is an intelligent acquiescence to reality. But with the emergence of *Smart Cars,* *reality* will be changed. An effort to write down new routes and to avoid unfamiliar surroundings can be noted in Figure 15 below. With IVHS devices assisting the driver in route finding, old drivers would be able to venture further afield into new territories.

In the study cited, Simms asked her sample of 269 “Which preparations would you make for a long journey?”. Figure 15 below shows the sorts of things elderly drivers consider before starting off.

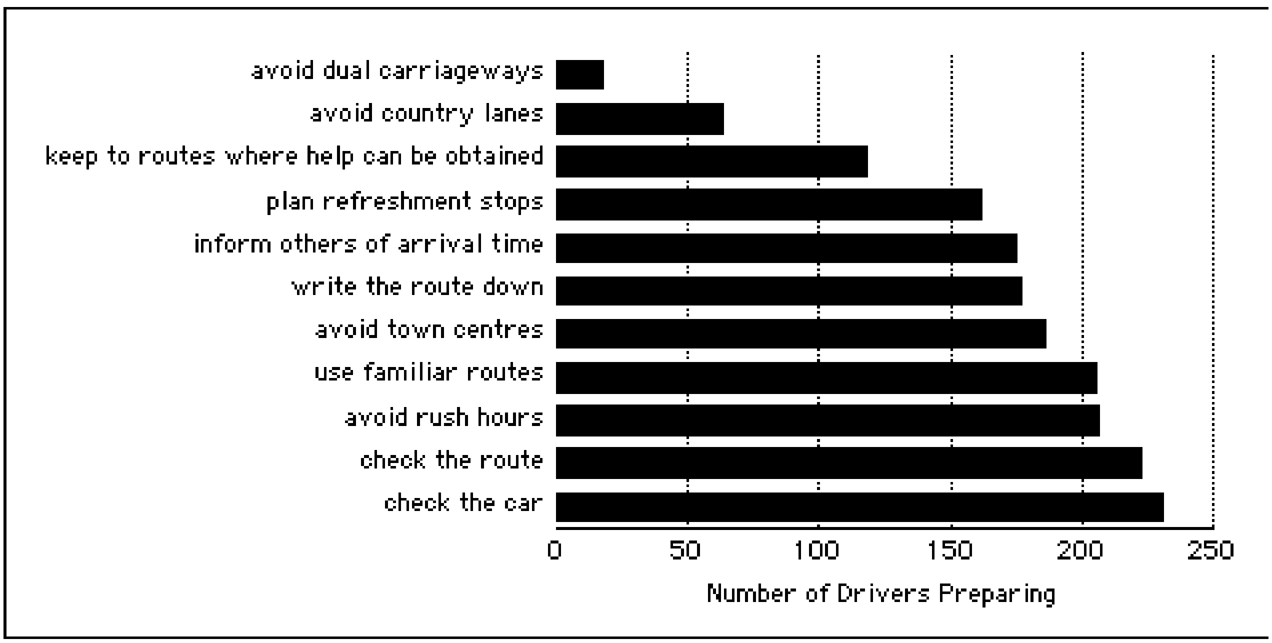

Figure 15. Pre-driving preparation by older drivers

All of these types of preparations have the potential of being enhanced, or at the least, being supported by one or another *Smart Car* system currently in production. The heightened preparation shown by these older drivers resembles the heightened preparation of those in the focus group reported here. However, there may be differences in motivation and, if so, these would be important for manufacturers to recognize.

Of particular interest is the issue of car accidents. Can micro-electronics help elderly people avoid their “favourite” accident site, at intersections? Can micro-electronics help with dazzle from oncoming car headlights at night? If micro-electronics enables elderly drivers to drive more and in riskier circumstances, what behavioural (or micro-electronic) strategies will act to limit increases in accidents?

4. COMMERCIAL DEVELOPMENT

Discussions with IVHS equipment developers, suppliers, and researchers confirmed that, in general, the vehicle operating skills of neither elderly nor disabled persons are specifically addressed in the development process. This is somewhat surprising considering the potential importance of this market segment - its continually increasing size and its likely interest in technologies that can make travel easier and safer - and considering that it is commonly acknowledged that devices developed to meet special needs are easier for everyone to understand and to use.

Effectively accommodating the elderly and disabled driving constituency — or any special market segment — requires the introduction of special users into testing and assessment at an early point in the R&D cycle. The selection of the boundary conditions for each of the test variables (as outlined in Appendix C), and the assumptions on what combinations of simultaneous negative conditions ought to be addressed, should be influenced by the knowledge that many users will have temporary or permanent limitations in skills relevant to driving. Unexpected combinations of environmental and vehicle factors (e.g. mechanical condition) can vastly reduce safety margins, and play havoc with the assumption that the IVHS equipment is being used safely in inherently safe conditions.

Although elderly and disabled drivers' needs might not have been specifically addressed, some units under development are complementary to these needs. For example:

- one unit has been designed so that only certain functions can be accessed while the car is in motion, thus reducing the diversion of attention from the road,

- one unit displays only rudimentary visual guidance information and provides spoken instructions so that the driver does not need to read a complex map,

- another unit can be removed from the car so that it can be used at home or in a hotel, thus transferring activities away from the driving setting.

Of course, only close scrutiny and road testing, with the full range of special drivers, can solidly establish the value of IVHS. Testing needs to be done with a range of users and under various conditions of traffic and route familiarity to determine how practical, safe, and helpful these units are for elderly and disabled user groups. Such experiments could prove very valuable and are highly recommended.

5. WHAT DO PEOPLE WANT?

5.1. Super-ordinate Factors of Features

From the user data collected in this study — primarily from drivers with disabilities — there appear to be three super-ordinate factors or mental dimensions of IVHS for users with disabilities. In decreasing order of prominence, they are:

DRIVER'S AIDS

- driver information related to roads, traffic, and weather
- driver's aids such as radar, cruise control, and steering, and snooze alarm
- medical-related aids such as automatic alarm phone-in and location of treatment centres

- but <u>not</u>… visually distracting

TOOLS

- maintenance and stationary operations aides (the system should be portable)
- the system should also work as a computer stand-in
- two-way interactive

but <u>not</u>… visually distracting

TOURING BENEFITS

- information for travelers about hotels and destination opportunities
- two-way interaction so that reservations can be arranged and information accessed
- a computer stand-in perhaps for help in storing information and providing passenger entertainment while en-route, or an address book

but <u>not</u>… providing route information

This analysis — very preliminary at best — indicates that there are three main factors of IVHS in the minds of users with disabilities. In decreasing order of prominence, they are:

- A DRIVER'S AID system providing enhanced sensory capabilities (radar or visible warnings of sirens), enhanced controls (steering assistance), emergency medical tie-ins (automatic accident radio beacons or information about treatment locations), and, perhaps most desirable of all, the ability to foretell what is happening down the road.

- A TOOLS system that unobtrusively enhances existing dashboard functions (adding such new data as oil level and tire pressure readings) and enhances existing controls (such as automatically adjusting the seats to feel comfortable for a specific individual). Also desirable are new tool functions such as a portable computer and communications link.

- A TOURING BENEFITS PACKAGE system useful while away from home and providing accommodation and entertainment information, the various benefits of having your own computer on hand, and the ability to make reservations from the car; this package does not need to include any information about fastest or most scenic routes.

For the small sample of drivers with disabilities queried in this study and for the superficial introduction they received to IVHS possibilities, route information does not figure positively in any of these factors. It may be that such drivers (as well as old drivers) make it their purpose to be served well by conventional maps and Trip-tiks and are routinely well prepared before they get underway.

5.2. Does the Size of the Market Matter?

There is something self-evident in recognizing that the size of a market "share" should set the commercial development priority of that market group. Belief in this commercial "truth" results in one-size-fits-all products that ignore the needs of specialized or atypical consumers. But is this an immutable commercial truth? The following observations might be brought to bear to counter this "truth."

A firm which can not readily serve any niche markets, despite the availability of automation at every point in manufacturing, selling, and distribution, should re-examine its organizational effectiveness and undertake self-scrutiny.

Users with special needs are by no means a commercially insignificant number of people and TDC maintains an ongoing database of information characterizing such individuals, at least with regard to their transportation lives.

Considerations which apply to special needs drivers are similar in kind to those which apply to many other drivers. For example, poor vision leading to difficulty in reading instructions printed in fine type may be a fact of life for many older drivers. But some impairment of vision is also present for all those who drive without their eyeglasses, for bifocal wearers who are using their distant-vision sunglasses, and for the myriad of people who have not yet gotten the eyeglasses they need for reading. In other words, the needs of special drivers may not be unlike the needs of typical drivers.

It is an ideological trap to believe that modal or average characteristics are actually shared by many members of a group. Sometimes *nobody* is average — there are no families with 2.2 children or commuter cars with 1.2 occupancies! Likewise, it is a trap to believe that any single user who is typical in one aspect will be typical in many aspects; it is not so. Someone may be of average height (50th percentile), but they may of 15th percentile hand size.

Universal access to services is accepted as social policy in all industrialized countries and this social value is unlikely to change as populations rise in average age. No developer should harbour beliefs that the objects of their development can exclude some body of users for long.

6. RECOMMENDATIONS

6.1. Recommendations for IVHS Commercial Development

The research undertaken in this project indicated that very little in the way of human factors effort is taking place among developers. It may be that more work is underway than was revealed. In addition, no instance of special attention to persons with disabilities was apparent.

It would be useful for the IVHS development community to pursue behavioural research and human factors efforts with greater energy and, in particular, to address the market of persons with disabilities. The first step is the mounting of market research into the needs of special populations.

The present study indicated that persons with disabilities are apprehensive about systems which divert their mental and physical resources while the vehicle is in motion. Likewise, they show relatively less interest in route aids and more in driving aids. Persons with skills diminished by advanced age may want a slightly different set of features which would allow them to function more as they did at a younger age and which would free them from the preparation beforehand and the constraints in route choice which they seem to observe.

6.2. Recommendations for TDC R&D

TDC has taken on a variety of roles over the years. In the case of the LRC (light, rapid, comfortable) train, TDC was central to the initiative and provided a focus of development. The IVHS initiative is something of a cross-over technology, involving as much transportation as communication and computation development. Moreover, the roles of human factors and human-computer interaction studies are very significant.

As the R&D branch of Transport Canada, TDC needs to provide a researched underpinning to regulation and control functions. Even if one assumes that the needs of typical drivers will be suitably addressed by manufacturers, one cannot assume that special drivers will be well served, since no attention has been devoted to their interests heretofore.

The role of government is central in relation to the safety aspects of vehicles, the provision of roads, and the control of other IVHS related infrastructure.

Vehicle safety

It is clear that safety is a special issue for E&D drivers in relation to IVHS. While current designs are either neutral with regard to disability (roughly the same side impact standards apply) or are bound by precedent (the character of steering and pedals are enshrined by historical precedent for better or for worse), new IVHS is different. For one thing, these system impinge directly on areas of sensory functioning. For example, deaf persons have an acceptable accommodation with the driving sound environment today, but would be challenged by an IVHS system which uses spoken communications.

A second set of problems arises because of a substantial fear on the part of drivers with disabilities that IVHS systems cut into their margin of safety or "cognitive headroom," to coin a phrase. Any system which demands attentional or manipulation resources leaves less spare capacity for reacting to the demands of driving.

Roads

Except for an experiment which Ontario is thinking about trying with Highway 407, roads are publicly owned and operated. Any accommodation which must take place on the roads for IVHS must be accepted by the public authorities. While there is little discussion of changes to roadways, many systems require that circuits be installed under or near roadways.

Other IVHS infrastructure

For smart car system development to proceed in an orderly and commercially satisfactory manner, government must set in place rules and/or physical infrastructure to mediate IVHS. For example, radio communication channels must be defined. The definition might include frequency bands, modulation patterns, and the assignment of proprietary channels to companies. But to create such a system (one is tempted to joke about a "new information superhighway attached to the old concrete superhighway") a great deal more information is needed about what information should flow on the information channels. How much information? how fast? in colour? including stereo sound? Drivers with special needs should be included in this exercise. Are *their* smart car needs being met?

Few would argue that government should underwrite research in an area of potentially profitable development but, at the least, Transport Canada must ensure that *all* drivers are well served by new systems. TDC needs to develop an independent knowledge base on the needs of all drivers and how drivers would like IVHS to serve them.

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