A USER-BASED APPROACH TO PROVIDING MOTORIST INFORMATION FOR THE PUGET SOUND AREA

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

INTRODUCTION AND RESEARCH APPROACH

Background

As in many larger cities, the traditional solution to traffic congestion in the Puget Sound area has been to build bigger and better roads. Yet despite recent construction, the central Puget Sound region suffers today from the sixth worst traffic congestion in the nation. Currently, no plans exist to construct additional freeways, and congestion is expected to increase dramatically throughout the coming decades. To avoid the high financial and environmental costs of building new freeways, the Washington State Department of Transportation (WSDOT) is pursuing several transportation system management initiatives designed to increase the efficiency of existing facilities. This state-of-the-art review is the first stage of an initiative to combine improved motorist information with new communication technologies so that drivers will use Puget Sound freeways more efficiently.

Problem

One way to alleviate traffic congestion and to use existing roadways more efficiently is to modify commuter behavior. A change in commuter behavior can be brought about by providing motorists with appropriately packaged and delivered, up-to-the-minute information that will allow them to make more effective pre-trip and en route driving decisions (OECD, 1987). An aspect of this approach is to examine human factors, such as personality and vision, which influence how commuters perceive and interpret traffic related information. With improved, user-based content and delivery of freeway traffic information, drivers can make decisions that will result in fewer delays for the individual motorist and an overall improvement in traffic flow.

Significant improvement in traffic flow through motorist information can only be achieved if the mechanisms for delivering that information are developed as an integrated system that is responsive to users' needs and perspectives. In turn, this can only be achieved if we obtain a better understanding of commuters. Thus, current problems to be overcome include not only issues relating to the selection and use of communication technologies and the generation of information, but also issues of audience definition. In addition, we must better understand the relationships between the technologies for information delivery information and the characteristics of the commuter.

Motorists are not a homogeneous group; rather, they are an extremely complex and diverse audience for driver information. Before we can design and implement an effective motorist information system, we must first answer some questions: What groups constitute the users of a particular freeway system? Which of these groups are most susceptible to varous types of motorist information? What travel decisions do these groups make? On what basis do they make them? Where do they make them? How do we best present information to the various motorist groups? What will be the impact on traffic as a whole if a particularly susceptible group is influenced by motorist information? Which types of information are most appropriate for various information systems? Until now, the complex nature of motorists as an audience for information has been an extremely neglected topic.

In addition to the nature of the driving audience, there are problems relating to the various types of motorist information, the appropriate mechanisms for presenting each type, and the appropriate places and times for delivering information. An integrated information system should provide motorists with information that will influence their decisions on mode of travel, departure time, and route choice. Pre-trip information can assist drivers in making mode choice decisions, whether short-term, involving a single trip, or long-term, involving a permanent switch to an alternate mode of transportation. Pre-trip information can also influence motorists' departure times. Ultimately the adjustment of mode choice and departure time will result in a lower peak demand for the roads, easing the congestion of rush hour traffic.

Route choice information, provided both pre-trip and en route, can persuade motorists to choose an alternate route through presentation of information on current delays, incidents on a given route, and traffic flow and description of alternate routes. Once an alternate route has been chosen and the driver is en route, route guidance must provide easily understood directions to guide motorists either to their destination or back to their regular route. The use of alternate routes will lessen the demand on congested roadways, resulting in smoother overall traffic flow.

Although many newly developing technologies are capable of providing information to motorists, our approach is not only to discuss the relative benefits of a number of these technologies, but also to discuss the potential impact of these technologies on the human as a decision-making commuter.

Research Approach

This state-of-the-art review focuses on how to transmit behavior-modifying traffic information to motorists in a manner that best meets the complex needs of the driving population. To implement a successful information system, one must thoroughly understand the population using the system. Therefore the first portion of this review is devoted to an examination of surveys that have been administered to determine drivers' responses to traffic information and other influences on route selection. Methodology as well as results of these surveys will be discussed. Methodology is relevant here because the next stage of this initiative to improve Seattle's motorist information system involves surveying motorists who commute on I-5 between Lynnwood and the central business district of Seattle.

After covering previous relevant surveys, this state-of-the-art review examines the various media that are currently being used, or have the potential for being used, to provide effective traffic information to motorists. Motorists may seek information either prior to or during their journey. Thus, this portion of the report is divided into two sections, one dealing with pre-trip information sources and the other dealing with in-vehicle information sources. Both sections are subdivided so that each information medium is dealt with individually. The section on sources of pre-trip information examines news bulletins, telephone, television (including graphics and teletext), and micro-computers. The section on sources of en-route information examines signs (static and Variable Message), in-vehicle navigation systems, radio (commercial and dedicated systems), and cellular telephones.

The research reported in this review was chosen for its applicability to the traffic information problems in the central Puget Sound region. The amount of detail in each discussion varies with the applicability of the information. In a number of cases, human factors research related to particular information sources is described to provide the reader with additional technical background, and because these issues are central to the creation of an effective, user-based motorist information system.

I. TRAFFIC INFORMATION AND ROUTE SELECTION SURVEYS

This section of the state-of-the-art review focuses on surveys that have investigated either drivers' route choices or drivers' opinions on traffic information dissemination. A selection of surveys spanning the last 25 years is reviewed here; although the findings of the older studies are not always relevant to the problems currently existing on the roads of the Puget Sound region, some of the survey methodology used in the older studies provides useful information for future surveys including our own. Rather than discuss each study separately, we will first present a general discussion of survey methodology, followed by a discussion of survey findings.

Survey Methodology

This discussion of survey methodology examines sample sizes and administration methods, sample characteristics, sample generation, and finally, the statistical techniques used to analyze the data.

Table 1 (following page) overviews the sampling methodology for selected surveys from the United States and Europe. These studies were done by public agencies or universities between 1963 and 1987, in Texas, California, Sweden, and England. All of the studies were administered in urban or densely populated suburban areas and had sample sizes ranging from 25 to 2,971.

Sample Size and Administration Methods

The surveys presented in Table 1 exemplify the breadth of sample size and methods of survey administration. Sample size is directly tied to the type of survey and the survey budget. Because in-depth interviews are costly, sample sizes are frequently small; Stanford Research Institute's 1963 and 1964 personal interviews of 25, 30, and 150 drivers (Anderson, Haney, Katz, and Peterson, 1964; Haney (ed), 1964) and Texas Transportation Institute's 1983 on-the-road interviews of 18 drivers in each of three surveys (Dudek, Huchingson, and Brackett, 1983) are

Table 1. Summary of Survey Methodology

Agencies	Date	Location	Sample Size	Sex; Age; Income Distribution (NG = Not Given)	Sampling Method Generation	Administration
LA City & Co., CA Highway Patrol & DOT	Feb 1987	LA county,CA	400 drivers	58% M, 42% F; Age: 18-20=5%; 21-40=67%; 40<=28%; Income NG*	Random list of computer generated phone numbers	Structured phone interview
TX Trans. Inst., TX A & M	Reported 1983 (3 surveys)	San Antonio, TX	18 drivers each survey	Sex, Age, Income NG*	Not given; naive about freeway system	In-car interview
Trans. Res. Board	1981, but reported 1984	Houston, TX	843 drivers	Sex, Age, Income NG	License-plate survey at 6 sites on 3 freeways	1-page mail-in questionnaire
Transport Studies Unit, Oxford University	1978, but reported 1979	Reading area, England	9 homes; 32 homes	Sex, Age, Income NG	Maximized range of car use, trip purpose, household characteristics; not representative	Unstructured in-depth, home interview
British Dept. of Trans.	1976, but reported 1977	Gloucestershire and Avon, England	508 (?)	Sex, Age, Income NG	Volunteers at destination sites	Not given
Lund Inst. of Technol., Dept. of T Pl & Eng.	Reported 1975	Malmo & Lund, Sweden	691 homes 830 drivers	Sex, Age, Income NG Sex, Age, Income NG	Not given Not given	Home interview mail questionnaire
UCLA, Inst. of Trans. Traffic Eng.	Reported 1971	LA Auto Club and DMV, CA	304, half at each	76% M, 24% F; Mean age 37; Income NG	Volunteers at sites	On-site interview
UCLA, Inst. of Trans. Traffic Eng.	Reported 1971	LA Preview House, CA	2971 drivers	48% M, 52 % F; Age: > 35 = 61%, 35-49 = 24%, ≥ 50 =16%; Income NG*	CA driver's license, recruited to represent pop.	Questionnaire
TX Trans Inst., TX A & M	Reported 1971	Houston & Dallas, TX	505 drivers	68% M, 32% F; Age NG*; Income given	Employees of 17 groups; 329 in H, 176 in D	On-site interview
Stanford Res. Inst.	1963	Palo Alto, CA	30 drivers	19 M, 11 F; Age, Income NG	Employees from S. Palo Alto	Unstr. interview
Stanford Res. Inst.	Reported 1964	Palo Alto, CA	25 drivers	Sex, Age, Income NG	Employees from S. Palo Alto	Struct. interview
Stanford Res. Inst.	Reported 1964	Palo Alto, CA	150 drivers	All male; Age, Income given	Residence in a given block	St. home interview

NG* = Not given but researcher claims sample represents population examples of in-depth interviews. Both of these institutions used relatively small sample sizes, because of the high cost of individual, in-depth interview methodology.

Other surveys have used sample sizes in a mid-range, from 304 to 830 drivers. Such surveys have included both interviews (at destination sites, at home, or by telephone) and mailed questionnaires. The largest in-person interview sample (371 participants) in the United States was used in another of the 1971 UCLA studies, with half of the sample interviewed at the Auto Club and half at the DMV (Case et al., 1971). The interview section of this survey appears to have been driver classification questions only; the remainder of the survey consisted of drivers' reactions to various traffic information messages. Sample sizes for written questionnaires have ranged from 505 drivers in a 1971 Houston and Dallas survey (Dudek, Friebele, and Loutzenheiser, 1971a; Dudek, Messer, and Jones, 1971b) to 843 drivers in a 1984 Houston survey (Huchingson, Whaley, and Huddleston, 1984). The Houston survey was limited to a one-page questionnaire, perhaps because of the large response expected.

One of UCLA's 1971 surveys used a large sample size of 2,971; groups of 250 drivers were interviewed (Case, Hulbert, and Beers, 1971). The drivers observed Variable Message Sign (VMS) messages and audio messages superimposed on a film clip showing a length of the Santa Monica Freeway. Data were collected in three ways: (1) audience reactions were monitored electronically through Basal Skin Resistance, representing a physiological response to the VMS messages and "driving speed", (2) questionnaires were administered, and (3) in-depth group discussions were held.

Sample size may also be affected by methods of statistical analysis. A 1987 Los Angeles survey of 400 drivers used a structured interview conducted by telephone. Rather than being based on administration methods, the sample size was selected to permit a worst case sampling error of $\pm 5\%$ with 95% confidence (Shirazi, Anderson, and Stresney, 1988). Most important for our upcoming survey, past studies indicate that a sample size of approximately 500 will provide findings that accurately represent the driving population of a given highway corridor (in terms of small enough standard errors), provided that the sample is selected to be truly representative of that population (Conquest, 1988).

As the preceding review indicates, the choice of sample size involves tradeoffs. Given limited resources, a small sample size allows for more extensive questioning and a broader range of administration methods than can be used with larger sample sizes. However, a larger sample size, which may restrict the amount of information that can be sought and the administration method, can lead to generalizabilty of results to the population of interest.

Other Sample Characteristics

Except for sample size, the traffic survey literature is inconsistent in its presentation of information on the characteristics of samples. Characteristics such as age, gender, and income distribution are typically used to classify, or group, the respondents. Table 1 lists the information provided on age, gender, and income distribution for the studies cited.. Additionally, driver characteristics such as visual deficiencies, education level, occupation, driving training, years of driving experience, and experience with freeway driving or a particular section of freeway have been used in some of these studies to classify respondents.

In a traffic information survey, classification questions should identify groups of commuters which can be targeted as likely candidates for motorist information. For example, questions which group drivers by the preferred form of information (e.g., verbal vs graphic) , the preferred medium (e.g., visual vs auditory), or the preferred location for receiving information (e.g., home/work place vs. at entrance ramps vs. on freeways) would have implications for the design of an integrated motorist information systems.

Sample Generation

The method used to generate the sample frame is related to the characteristics of the sample group, including the sample size, and to the method that will be used to administer the survey. For example, the 1987 Los Angeles survey interviewed 400 drivers by telephone. To generate that response, the study team developed a list of 2,000 valid telephone numbers through a random list of computer generated numbers for a given set of area codes (Shirazi et al., 1988). In contrast, the 1981 Houston survey sampled drivers who used specific freeway sections. In this license plate study, respondents were observed driving on one of three Houston freeways (both directions of travel were observed); then selected drivers were contacted by mail and respondents were sent a one-page mail-in questionnaire (Huchingson et al., 1984).

As shown in Table 1, not all of the survey sample frames appear to have been as carefully generated as these examples. However, if the survey's sample frame is to accurately reflect the driving population in question, the sample must be generated in a manner that represents that driving population. In the case of a motorist information survey, the complex nature of the driver information audience means that survey samples must accurately represent drivers of the specific transportation corridors to be served by the integrated motorist information system.

Statistical Analysis

Once the data have been collected, investigators usually conduct some type of statistical analysis, be it descriptive (describing the characteristics of the population), inferential (allowing the researcher to infer to the population of interest), or both. In most of the studies cited here few inferential statistics have been used, often because the type of data collected did not lead to an inferential analysis. Unstructured interviews with open-ended questions create varied responses that are difficult to quantify. The studies relying on such data-gathering methods often present findings as lists of numbers or per cents of responses; the 1978 Oxford study is an excellent example (Carpenter, 1979). Additionally, many of the responses in unstructured and structured interviews and in written questionnaires represent nominal or ordinal (i.e., categorical) data that do not lend themselves to inferential statistics. Thus, most of the structured interviews and written questionnaires listed in Table 1 reported only percent of responses and occasionally correlations or Chi square analyses (Anderson et al., 1964; Case et al., 1971).

Descriptive statistics are appropriate for answering certain questions, but other questions require inferential methods. Researchers in Europe have shown that inferential statistics can successfully be used with traffic survey data. For example, the Lund University study included a factor analysis of 14 variables (such characteristics as route selected and driver preferences) that generated 5 factors; the analysis proved to be fairly stable in dividing the sample. A regression of the factors on route characteristics also gave consistent results (Hansson, 1975). The Lund University researchers did not describe the nature of the variables in the report of their study, so the basis for their factor analysis is unclear.

Survey Findings

This subsection examines the major findings of the studies presented in Table 1. Table 2 (following page) presents the findings in summary form. The three main categories of findings reveal drivers' attitudes about:

- Travel time, delay, congestion, and the use of alternate routes.
- The accuracy of the traffic information being provided.
- The content of the traffic message and the manner in which content is presented.

These categories form the basis for the following discussion.

Table 2. Summary of Survey Findings

Location	Date	Findings: Time/Delay/Congestion/Alternate Route	Findings: Accurate info.	Findings: Message by Radio/VMS/Other
Los Angeles, CA	1987	Average delay is 18 min; Will divert for stop and go traffic; 71% know alternate route(s).	70% would divert with accurate info & shorter route.	Radio reports cause most route changes; 68% want continuous reports; 53% want traffic phone #.
San Antonio,TX	1983	--- --- --- ---	--- --- --- ---	Terse message style most effective.
Houston, TX	1984	"Major delay"≥23 min; "Minor delay"≤8 min; Drivers divert to service road at delay of 5-6 min.	--- --- --- ---	--- --- --- ---
Reading, England	1979	Drivers try to minimize time & distance but weigh other factors. Drivers use perceived fastest, most direct route. Drivers will increase distance to decrease time. Congestion is a major factor in route choice.	Drivers find British traffic info not timely enough.	Drivers condense route info from map or other into a list; radio/signs should use list format.
Lund, Sweden	1975	--- --- --- ---	--- --- --- ---	Correlations exist between route choice & preferences, & trip characteristics.
Los Angeles, CA	1971	Drivers want guidance for diversion route & option to divert or not.	--- --- --- ---	Simple VMS message without travel time preferred.
Los Angeles, CA Preview House	1971	--- --- --- ---	Lane naming confusing, except Right" & "Left." Radio viewed as more up-to-date than VMS.	Content of VMS messages: simple, short, actionable; Order: lane blocked, distance ahead, reason for delay, location by ramp or interchange name. Drivers don't understand complex audio messages. VMS more understandable than radio, less distracting, improves driving, eases driver frustration; VMS preferred.
Houston & Dallas	1971	Drivers more apt to divert before entering freeway than when on free way;prefer traffic info before entering freeway. Apt to divert if have prior knowledge of unusual condition and if a suitable alternative is available. Apt to divert when pressed for time.	85% would frequently use accurate real-time info for trip planning; 95% would allot major portion of traffic budget to provide real-time traffic info.	62% of radio users who would benefit from freeway info currently use radio info to plan trip. 45% prefer real-time info via radio; 45% prefer real-time info via VMS; 5% prefer telephone; 5% prefer television. Those who prefer info before trip & on major streets prefer radio; those who prefer info on streets & freeway ramps prefer VMS.
Palo Alto, CA	1964	Time is most important factor in route choice for commuting; safety is 2nd, ease & comfort 3rd, distance 4th, scenery 5th, operating cost 6th.	--- --- --- ---	--- --- --- ---
Palo Alto, CA	1964	On a scale of 1(least)-5(most), time is 4.3, congestion is 4.0, distance is 3.5, and scenery is 1.9.	--- --- --- ---	--- --- --- ---

Time, Delay, Congestion, and Alternate Routes

The findings in Table 2 on travel time, delay, traffic congestion, and use of alternate routes result from studies done both a long time span and a wide geographical and cultural span. However, certain similarity of results from surveys conducted across time and country provide insights about concerns that Puget Sound area drivers may be expected to express. Cocern with amount of delay, congestion, and time spent travelling appear throughout these studies.

Drivers' attitudes about time appear markedly similar throughout the studies. In the 1964 Palo Alto study, drivers said that time was the most important factor in their choice of a route to work. Safety, congestion, distance, and ease and comfort of the drive were all considered less important factors in the choice of a route to work; interviewers also asked about scenery and operating cost, but found that neither was considered of much importance to commuters (Anderson et al., 1964).

Similarly, in the 1971 Houston study, drivers stated that they were apt to divert from a chosen route if they knew about congestion on the route and if a suitable alternative was available, but were even more apt to divert if pressed for time (Dudek, Messer, and Jones, 1971). Time, rather than distance, was the deciding factor. In 1979 in Reading and Oxford, England, drivers indicated that, although they attempted to minimize both time and distance, they would increase the distance they traveled in order to decrease the travel time (Carpenter, 1979). Time, again, was the more important factor. In addition to time and distance, other factors such as congestion, ease of driving, and number of intersections entered into the route decisions of these drivers. The drivers used routes that they perceived to be the fastest and most direct to their destinations; some indicated that they went through town to save time, while others indicated that they stayed on the motorways to save time.

Based on findings in the 1960s and 1970s regarding the value drivers place on time, investigators in the 1980s have assumed that time is important to drivers, and have further investigated time issues. In the 1984 Houston study, drivers, on average, defined a "major delay" as being 23 minutes or more, while a "minor delay" was defined as 8 minutes or less (Huchingson et al., 1984). Houston drivers said they would divert from a freeway to an alternate convenient service road if they were delayed 5 to 6 minutes. Apparently even a minor delay required more time than drivers were willing to spend. The 1987 Los Angeles study did not query drivers as to the length of delay that would cause them to divert; however, the average delay drivers reported was 18 minutes. Furthermore, Los Angeles drivers indicated that they would divert from the freeway for stop and go traffic. Additionally, 71% of the drivers knew of an alternate route to take (Shirazi et al., 1988).

Time and route diversion questions in Los Angeles revealed information about drivers' desire for guidance; when Los Angeles drivers needed to divert from the freeway, they wanted guidance that showed them an alternate route, and they wanted the option as to whether or not they should take that alternate route (Case et al., 1971; Shirazi et al., 1988). This desire for guidance on an alternate route leads to the next group of findings on drivers' attitudes about the accuracy of the traffic information they receive.

Accuracy of Traffic Information

Numerous studies have indicated that drivers have little confidence in the accuracy of the traffic information they receive. For example in 1987, Los Angeles drivers stated that if they were provided with accurate information and a shorter route to their destination, they would be more likely to divert from the freeway (Shirazi et al., 1988). Drivers' opinions about the accuracy of information provided by any particular medium was not tested in the 1987 study. However in a 1971 Los Angeles study, drivers viewed radio broadcasts as more up-to-date than VMS (Case et al., 1971). The 1979 study in Reading and Oxford, England, found that drivers were of the opinion that British radio information was not timely enough to be accurate. Drivers indicated that they would prefer a system of local broadcasts similar to those used in Germany (Carpenter, 1979).

Continuing with survey results related to the traffic information problem, the final group of findings concern both the content of traffic messages and the media used to present them.

Media and Content

Several studies concerned with traffic information have concentrated on radio and VMS media, with inconsistent results. The majority of respondents to the 1971 Los Angeles study preferred VMS to radio as a medium for presenting traffic information: VMS messages were seen as more easily understood, causing less distraction, improving driving, and easing driver frustration (Case et al., 1971). In contrast to the 1971 findings, the 1987 Los Angeles study found that radio broadcasts cause more route changes than any other medium (Shirazi et al., 1988). Of the surveyed drivers, 68% wanted continuous radio reports. When asked about telephone use, 53% said they would like to have a traffic information telephone number.

The 1971 Houston and Dallas survey results may shed light on the apparent attitude shift over time in Los Angeles. The findings indicated that 45% of the drivers preferred real-time information via radio and 45% preferred real-time information via VMS (Dudek et al., 1971a; 1971b). Although equal numbers of drivers preferred radio and VMS, there was a significant correlation between drivers' preferred medium, preferred location, and preferred time for receiving traffic information. Interestingly, those who preferred radio preferred to receive information before they began their trip or on the major streets before entering the freeway. Those who preferred VMS information preferred receiving their information on the major streets and at freeway entrance ramps. (Note that there was no preference for information on the freeway.)

Beyond examining drivers' preferences about media, studies have also examined drivers' understanding of traffic messages. Interestingly, drivers' beliefs about the clarity of the messages may not always coincide with actual understanding. The 1971 Los Angeles study found that, although drivers thought they understood complex radio messages, they actually did not (Case et al, 1971). However, the 1983 San Antonio study found that drivers could follow complex radio messages if the messages were structured properly (Huchingson et al., 1984).

Many studies have also examined message structure and style. The 1983 San Antonio studies found that a terse, complete sentence, message style was most effective in radio broadcasts. Neither a staccato style, with incomplete sentences, or a conversational style, with extra information, was as effective. Instructions were further improved by including information such as landmarks and the number of traffic lights between turns (Huchingson et al., 1984).

The 1971 Los Angeles study reinforces some of the 1983 Texas findings, though for a different medium. The Los Angeles study (Case et al., 1971) found that the content of VMS messages should be simple and short, and should provide information the driver may act on. The content order should be as follows: the identification of the blocked lane(s); the distance ahead to the blockage; the reason for the delay; and the location of the blockage by ramp or interchange name. The 1979 Oxford and Reading Study found that drivers condense route information into lists, even information from maps; the study recommended that radio messages and signs should format route information as a list (Carpenter, 1979).

Summary: Traffic Information and Route Selection Surveys

As the preceding discussion indicates, survey methodology has a major impact upon the type of data collected and thus upon survey findings. For example, the choice of sample size involves tradeoffs: a small sample size allows extensive questioning that cannot be done with larger sample sizes; in contrast, a larger sample size, while restricting the amount and time of information that can be sought, produces information that can be generalized. Choice of sample size thus impacts the type and extent of questions to be included in the survey. Sample size and other sample characteristics are related to the method used to generate the sample and to the method that will be used to administer the survey. If the survey sample is to accurately reflect the driving population in question, the sample must be generated and administered in a manner that creates a sample representative of that driving population. The data collected can only be as valid as the sample from which that data are collected.

The findings reviewed here provide indications of the topics to be addressed in a survey of motorist behavior and attitudes. Time is a major concern of commuters. Surveys should examine the relationship of time to the drivers' tolerance for delay and congestion, and to the drivers' willingness to take an alternate route. Secondary concerns of commuters should not be neglected, however. A survey should contain questions that solicit commuters' opinions about accurate, real-time information, as well as preferences for message content, location and timing of message delivery, and preferences for the media used to present the message.

Until now, statistical analysis of traffic survey data has been limited to descriptive analyses by the categorical nature of the data assessed. However, our understanding of drivers and the driving experience can be increased through the use of inferential statistics, as well. Given the complex nature of the audience for traffic information, it is important that we use all the tools at our disposal to understand that nature. This understanding will lead to more effective designs for motorist information systems.

II. MOTORIST INFORMATION SYSTEMS: PRE-TRIP INFORMATION SOURCES

This section of the state-of-the-art review and the following section, "Motorist Information systems: En Route Information Sources," explore the media that may be used to deliver information to drivers. Pre-trip information can enable motorists to make effective decisions about the mode of transportation they will use and the time they will depart.

Even with the relatively ad hoc information systems that have evolved, motorists have a number of media available to assist them in planning driving strategies before they begin a trip. The discussion in this section of the report covers media that either currently provide pre-trip strategic information, or have the potential for augmenting current systems as a source of pre-trip strategic planning information. The focus here is on newspaper, radio, and television news bulletins; telephone information services; and teletext and graphic presentations on television.

News Bulletins

The news media are a fairly effective means of transmitting certain types of traffic information. Newspaper, radio, and television news bulletins disseminate information which can help motorists prepare driving plans. The audience for this type of information is very broad, and therefore the information provided is fairly general in nature. This method of transmitting information is especially useful for events with advance warning, such as construction projects, weather related problems, or special events. For example, local Seattle area newspapers regularly cover construction projects and their impacts on the traffic system. The Seattle Times periodically displays a picture of the downtown freeway system and highlights the construction projects underway.

Morning radio and TV reports tend to focus on trouble spots, warning drivers to avoid these and occasionally recommending alternate routes. Known problem areas (e.g., I-90, SR 520, I-405 S-curves) are given regular coverage, but receiving information on other areas is a haphazard proposition. Presentation on radio tends to be far superior to that on TV, especially considering the potential of television for visual presentation of traffic information. Morning KING TV traffic reports, for example, are essentially a radio report with a standard, static picture of I-5 and the reporter's face in the corner of the screen. For this reason, a considerable portion of this section is devoted to enhancement of graphic presentation of traffic information.

Television and Screen Display of Traffic Information

Televised traffic information can be delivered in the form of text, graphics, or pictures, or as a combination of all three. Effectively combining text, graphics, and pictures is challenging, and few systems have attempted this combined format. Most state-of-the-art systems are a compilation of computerized traffic congestion data translated to a graphic display map. This real-time, graphic approach allows volumes of congestion information to be processed and displayed in a manner understandable to most viewers. The system's advantage is its ability to change the display with each new bit of information; thus, the information is easily updated to keep pace with changing conditions. Because such systems usually cover a large area, however, the information is generally limited to major roads and is difficult to personalize. In the future, more sophisticated screen displays will be needed to meet this and other difficulties.

To be televised, this type of system requires two major steps: first, computers must receive data from sensors on the road and translate the data into a meaningful display; second, the computer-generated display must be projected onto a television screen. This section focuses on the second of these steps, particularly issues related to screen display.

Teletext systems are one option. These systems combine text and graphics by scrolling text over graphic displays. Teletext could be used to display and transmit traffic information by several methods. At the simplest level, text could be scrolled across the screen, reporting volume build-ups and average traveling times. At a more complex level, an integrated system could be used to display maps with color codes for levels of congestion, scroll text describing average time and speed, transmit video of actual roadways, and allow user interaction with the system. Currently, no such integrated system exists.

Within the United States, Teletext in television has been exclusively provided by Zenith Corporation. However, in the near future both Panasonic and Sony plan to offer teletext capability with their television sets. This medium of information delivery has already been successfully employed within the United States for close captioned programs.

Until recently, screen display of traffic information had been thought of primarily in terms of providing motorists with pre-trip, route planning information. Now, consideration is being given not only to providing terminals at strategic points in the highway system, permitting the user to update information while en route, but also to providing in-car terminals that provide route guidance in response to changing conditions while drivers are on the road.

The remainder of this section discusses topics relating to pre-trip information in greater detail by examining existing and potential delivery systems. The discussion covers implementation for drivers, as well as for traffic systems management centers, and includes adaptations of weather reporting methodology.

Graphics and Teletext for Drivers

Locally, Kirkemo (Kirkemo, 1987) studied the feasibility of implementing a graphic display system to deliver traffic information to drivers in the Puget Sound region via local access cable TV.

The potential impact on drivers' commuting behavior as well as potential benefits resulting from changes in commuting behavior were also analyzed. Kirkemo proposes both a cable only and a cable/microwave option, and examines the costs and benefits associated with each option.

Kirkemo used computer simulation, putting a graphic map with text messages at the bottom of the television screen. Such a system was shown to have potential for reducing traffic delays. The necessary hardware for screen generation is in place, and cost effective methods to provide the transmissions to the cable companies exist. The report concluded that "individual [transportation system management strategies] may only have a marginal impact on the ability of the system to deliver an acceptable level of service. The development of a number of coordinated programs could have a synergistic impact" (Kirkemo, 1987, p. 58). The evaluation of graphic display options proceeds with that goal in mind.

For the past year in Seattle, Metro Traffic Control, a traffic information company based in Houston, Texas, has been operating a traffic reporting service. In conjunction with KIRO-TV, Metro Traffic Control will expand their services to television with their proprietary system, TELETRAC, late in the summer of 1988. TELETRAC uses a graphic map display of the local freeways and features a reporter giving a vocal traffic report at the same time. The station will display a map provided on a video disc by TELETRAC. The traffic reporter, based at the Columbia Center, will report live to the station over a high quality telephone line from information obtained from both eye-in-the-sky reporters and ground-based vehicles. Initially, the station will give three reports during the afternoon rush-hour news shows; expansion will be based on public reception (Perry, 1988).

A TELETRAC-type system is used in Houston and elsewhere in the country but is only a partial solution to the pre-trip information problem. While this type of system does provide a picture of traffic problems that is easily understood, it is basically static, has little potential for interaction, and is not based on individual users' needs. In fact, the display is simply a picture of the relevant section of the traffic system with a voice report and an arrow which points at the particular trouble spot being described. The system's best use will probably be as a bridge between current Puget Sound traffic information systems and the more dynamic, interactive, user-based information system the region needs in the future.

Beyond the local area, teletext will be tested in connection with the Smart Street project in Los Angeles, beginning October 1988. A teletext traffic message will be broadcast either by satellite or by local television stations to homes within a suburb of Los Angeles. The effect of the broadcast upon the commuting public will be determined by a survey.

Another southern California traffic reporting service, called MONICA, is operated by the Automobile Club of Southern California in San Diego. This teletext service, one of the best currently in operation, includes graphic display of current traffic information that is provided to local televisions stations and used in morning and evening news slots. The screen consists both of a map of the local freeways and text lines at the bottom which give the current average speeds for each highway. The map is color coded to show how traffic is flowing and where trouble spots are located.

The information in MONICA is downloaded by the Auto Club every thirty seconds from CALTRANS mainframes to a microcomputer. The Auto Club must then enter by hand the information to update the color codes and time averages. The time lag from occurrence to television report is 2 to 5 minutes.

The color coded map and bottom line text reinforce each other. The text provides viewers with specific information about particular arteries; the color coding provides viewers with general system information they can understand quickly and easily. The code uses green to represent a traffic flow of 40 mph and above, yellow for 20 to 40 mph, and red for 0 to 20 mph. Although this system is dynamic and changes with new information, the end user still has no control over the content or display of information (Taylor, 1988).

On the international level, two examples of teletext systems are CEEFAX in Great Britain and ANTIOPE in France. ANTIOPE's service includes a map display of conditions on major roads.

Televised Graphic Display of Weather Information

There is considerable untapped potential for televised display of real-time traffic information, probably because this is still a relatively new field. There is, however, much to be learned from efforts in related fields to provide dynamic, graphic information to the public. Television weather graphics, for example, are more sophisticated and have a longer history than televised traffic information, and may provide some insight for future traffic displays. Over the past forty years, television has successfully brought the complex science of meteorology to the general public in a text/graphic format that is easily understood. People now use this information in planning their daily activities. There is no reason why the same cannot be accomplished with traffic information.

Television weather reports have changed greatly from the first hand-drawn weather map displayed in the United Kingdom in 1936. Today, satellites beam accurate pictures to earth every few hours; those pictures are compiled and displayed in sequence, like a short movie, to show weather pattern changes over a quarter of the earth's surface. In addition, system operators have control of the display options, including cloud pattern sequences, charts with friendly icons, and weather statistics. This evolution from a static, non-interactive, one-dimensional system to a dynamic, interactive, multi-dimensional system provides the base for today's rapidly evolving technology, and provides a possible model for future developments in the graphic display of traffic information.

As weather reporting has changed, so has the public's perceptions and expectations. The main users of early weather graphics were forecasters, aviators, and sailors. These users needed detailed and accurate information; thus, the early graphics included much numerical data. As television technology improved and television use spread, televised weather reports switched from expert audiences to the general public, and the graphic images changed to respond to the needs of these new viewers. The data gave way to simple one or two word descriptions and easily understood symbols. General descriptions replaced details because the public was more interested in deciding how comfortable their day would be rather than in what the cloud patterns and wind directions would be.

Major changes are once again occurring; the driving forces again are technology, and the public's perceptions and needs. The latest computer technology allows for real-time display of information in many forms. In addition, communication technology is moving from a focus on massive audiences towards smaller, specific audiences. At the same time, the public is demanding information tailored to such specific users as agricultural, recreational, and travel groups. Because computer technology allows the information to be shaped to specific uses, this customization can work successfully. These new changes are built on the visual literacy currently held by the general public, and can therefore be easily initiated.

Several problems with televised weather information relate to televised traffic information. One common problem is the tendency in both areas to overwhelm the public with information. The World Meteorological Organization (WMO) reports that ". . . the amount of information that can be recalled from a weather forecast by the recipient is independent of the length of the message. Therefore, no matter how much information is presented by the forecaster, there is a limit beyond which no additional information can be assimilated" (WMO, 1987, p. 25). WMO also reports that the public is likely to remember certain items more than others. The public's ability to absorb and distinguish information must be considered in the design and implementation of the graphic system used.

Another common issue is the competition for television news time. Television time is a valuable commodity that is allotted carefully. Consequently, weather reports have become very concise yet very vivid and even entertaining. They make use of verbal and visual means of transmitting information at the same time. Traffic reports do not yet meet the same standards.

Beyond these general problems, both areas must do further work to study the requirements of end users and to design displays that take these requirements into account. The World Meteorological Organization has recommended the following presentation design guidelines. These ten common sense recommendations are as applicable to delivery of traffic information as they are to weather reporting:

- Understand the needs of users.
- Tailor (broadcasts) to meet the users' needs.
- Select the proper medium to reach the users.
- Use language familiar to the users.
- Resist the temptation to add information the users do not need.
- Stress that advanced technology is being used in observation, prediction, or communication whenever possible.
- Use graphic presentations when possible.
- Present information with enthusiasm and good humor.
- Encourage user response to (broadcasts).
- Modify presentations as indicated by users' reactions.

Graphics and Teletext for the Traffic Systems Management Center

The previous discussion focused on the use of graphics and teletext to present information directly to the general public. Various transportation and traffic centers are also using teletext and graphic systems to manage freeways and to provide information to traffic specialists who in turn pass this information on to the media for public use. The Seattle area Traffic Systems Management Center is one example of such a system.

From Seattle's Traffic Systems Management Center, WSDOT operates the Surveillance, Control and Driver Information System as part of its overall FLOW system. The Surveillance, Control and Driver Information System combines radio communication, electronic metering, computer generated graphic displays, and closed circuit television to gather a real-time picture of the Seattle freeway traffic situation. This information is then passed on to local media for broadcast. Presently, radio and television traffic reporters call in to receive a detailed report from WSDOT system operators.

Since the current dissemination of information depends on phone conversations between expert intermediaries and local media and then on subsequent radio or TV reports, the system is neither as timely or as responsive to driver needs as might be desired. There is, however, considerable potential for more technologically sophisticated and user oriented transmissions of this real-time traffic information.

Two subsets of the Surveillance, Control and Driver Information System offer options for presenting information more directly and interactively to the commuting public: the computer-based Graphic Display System and the Closed Circuit Television (CCTV) system.

Graphic Display System

The Graphic Display System presents a graphic representation of traffic on the freeway system in the Seattle area, including I-5, I-90, I-405, and SR 520. Traffic is monitored by strategically placed loop counter stations which transmit their data to a mainframe computer. From this data, the computer generates a color coded map of the freeways. The level of congestion per mile is depicted by the color of the roadway section; green indicates no congestion (occupancy 0-15%), yellow indicates the onset of some congestion (occupancy 15-22%), red indicates moderate congestion (occupancy 22-35%), and flashing red indicates severe congestion (occupancy above 35%).

In addition to the color coded display of the entire freeway system, two additional displays are available. The first illustrates conditions within any given one-mile section. The location of each loop counter station is shown graphically within the one-mile section and the congestion level at each station is depicted using the color codes stated above. The volumes and occupancy values per minute are shown for each station, as well as volumes per minute on all on and off ramps within the one-mile section. Finally, a second display shows the operation on any one ramp in the system. The metering rate and mode are shown numerically, and the status of the ramp signal in real time is depicted, as well as the occupied/not occupied status of all on-ramp loops.

The information retrieved from the screen is used in at least two ways. As previously mentioned, information is passed on to traffic reporters who in turn pass it on to the public. In addition, operators are able to monitor components of the Electronic Surveillance and Ramp Metering subsystems to determine equipment performance. Operators do this monitoring by comparing the road conditions reported on the display screen with other sources (CCTV, patrol vehicles, time of day) to verify that the reports received are correct. If operators suspect a malfunction or a discrepancy, they can display, on a separate computer terminal, the section or station involved to examine the data more closely. If a problem is discovered, specific information about the road station as well as system information is available to help correct the problem.

As an example of this maintenance function of the system, suppose that the graphic display shows a one-mile section of I-5 severely congested (blinking red),while all other sections around it indicate no congestion (green). The time is 9:20 A.M.--after rush hour. The operator can check the section via CCTV if it is in the range, or check the log of calls from the highway patrol to see if an accident condition exists. If neither of these sources provide any information, the operator can check the status of the loop indicator for the one mile section. This check might reveal that the only station in this section currently functioning is the one displaying 99% occupancy. The operator could then switch the display to that particular station and might discover a stalled vehicle on one station creating false readings. Having confirmed that no general traffic congestion exists, the operator could refer the problem section to a maintenance crew.

Closed Circuit Television System

The Closed Circuit Television System (CCTV) is used primarily for incident verification and for reporting traffic conditions to commercial radio stations. Presently, 26 camera stations cover the freeways listed earlier. As of early June 1988, ten were functional, covering both I-5 from the Kingdome north to Northgate and the Mercer Island floating bridge.

The CCTV System is composed of three components: the cameras, the touch screen control, and the program monitors. The cameras are mounted throughout the system on utility poles and are connected to the main system by coaxial cables (I-5) or microwave (I-90). The touch screen control allows the operators to interact and control the entire system from one location. The screen includes a freeway map showing all camera locations, a program monitor section, and a camera movement control section. The two program monitors display the video selected from the control screen. The monitors can be programmed to display different camera views in a sequence that allows the operators to monitor the traffic without continually changing camera selections.

The Camera Control Center makes the system unique. All cameras are controlled by a microcomputer through a touch screen system that features a graphic interface similar to the Graphic Display System. Operators need only touch the screen area that they wish to operate and the controls for that instrument are activated.

Three problems surfaced when this system was observed in action. First, the video monitor for the graphic display is a standard television monitor and the resolution of the image is marginal; the resolution would not meet existing standards for televising the information directly to the public. Second, the human-machine interface is clumsy. A trained technician is needed to operate the system, and the control is designed in a way that makes no intuitive sense. Before this system could be used for direct delivery via personal computer (see next section), the interface would have to be changed. Finally, the touch screen technology controlling the CCTV system malfunctions intermittently, interrupting operation of the system.

Ideally, the Graphic Display and the CCTV systems would be integrated, placing them under one easily operated control. What is currently in place is adequate for current uses, but this integration would give the system an added dimension that would enhance its ability to serve the general public, either as a source for displaying traffic information on network or cable television, or delivered directly via home or office computers.

Micro-Computers

Since visual traffic information like that presented in the Graphic Display is computer based, microcomputers connected via modems to traffic information systems are an exciting future possibility for transmitting traffic information directly to drivers. This option would allow individual interaction with the information system, allowing drivers to tailor the information to personal needs. Appropriate microcomputers already exist in growing numbers in homes and offices, and are likely to become a standard option in cars of the future. Most small computers can display graphics and text, though video reception is an expensive option that probably is not viable at this point in time.

It is difficult to gauge the present practicality of this kind of system since no real-time motorist information system in this country currently uses microcomputers at the receiving end. Therefore, it is worthwhile considering microcomputer applications that use interactive graphics in other transportation areas. Microcomputers have been connected through modems to information services in such areas as vehicle route scheduling and transportation planning. There are several products, in the United States and internationally, with a range of interactive capabilities available in each field.

United States Systems

Vehicle routing software is used to plan trips for fleets of vehicles to make the best use of time and distance (Klien, 1987). Using a map display, the operator can key-in starting locations, delivery points, and pick up sites for back hauling. The software then compiles the information and displays a route to use. The best systems allow "what-if" manipulations to test new conditions. They also make use of such variables as natural barriers, speed zones, and travel standards.

A motorist information system could use these characteristics and plug in real-time congestion information to complete the system. Of the packages available, Roadshow from Routing Technology Software, Inc., offers all of these capabilities plus "geocoding." Geocoding is "a computer based routing method that matches an address with specific map latitude/longitude coordinates. . . It allows for natural barriers and travel over streets/highways, calculating true distances, not straight line distances" (Klien, 1987, p. 12). This feature is essential for a system designed with the general public as the end user.

There are several packages in transportation planning that have features desirable for traffic reporting (U.S.D.O.T., 1987). NEDS from the Center for Urban Analysis uses zooming capabilities to work with a whole network or just part of one. Quick Response Systems II from AJH Associates allows for importing data defined for other applications. This feature is useful for working with existing technology. CARS from Rodger Creighton Associates displays simulations of traffic flows. This simulation suggests the use of simple animations for displaying congestion problems. MicroTRIPS from MVA Systematica displays volumes of traffic by varying the bandwidth of the road. This simple component is a powerful visual attribute. In addition to all of these individual features, Horowitz and Pithavidian (1987) state that the best systems relate map display to the real roadway systems in a fashion that is easily understood. Using highway identification symbols would be an appropriate example of this relationship for a traffic information display.

International Systems

Interactive Videotext, exemplified by TELETEL-ROUTE in France, ROUTE-TEL in Great Britain, and ARCS in Australia, requires a remote terminal and a phone connection. Subscribers have access to a huge data-base of intersections and road segments, and to computer algorithms capable of calculating the quickest, shortest, or cheapest route from one point to another. Videotext output takes the form of a series of directions similar to what you would give a friend you were directing to your house.

One current disadvantage of videotext is the difficulty in updating the data-base in response to changing road conditions. However, the current system can be adjusted for extended conditions, such as ongoing construction, and current research is aimed toward developing updating capability.

Route Tel System developed by TRRL in the United Kingdom provides customized routing information to the user via mainframe terminal. The system is currently used to provide route information; application of a real-time traffic information system would be an extension. The cost of such systems is prohibitively high, but, with declining computing costs and the growing computing power of microcomputers, solutions like these will become more feasible in the future.

Telephone

Perhaps because it is such a common communication medium, telephones are rarely considered as a means of delivering real-time traffic information. However, special telephone numbers within the Seattle metropolitan area already provide timely information to the inhabitants, though this information is only marginally traffic-related. These messages are either pre-recorded or interactive in nature. Interactive phone messages require the user to punch numeric codes on a touch-tone telephone to retrieve specific information. Systems that exist today provide information on weather, sports, or the stock market. The most relevant service is a comprehensive telephone information system which SEA-TAC Airport has implemented to provide parking and flight information. Oracle Communications, the supplier of SEA-TAC's system, has discussed with WSDOT their plan for supplying Seattle drivers with interactive, real-time traffic information via telephone.

Similarly, a state-of-the-art, phone-based trip planning system is being developed by the Media Lab at Massachusetts Institute of Technology (Davis, 1987). The system, called Direction Assistance, uses techniques from artificial intelligence and natural language processing. Direction Assistance will provide information to assist travel within the Boston area. The project translates 11 square miles of the Boston area into a program that communicates with naive users over the telephone through a natural language interface. The transmission of information has been divided into three categories: obtaining the driver's origination and destination, finding the direct route, and describing the suggested route in such a manner that the user is able to obtain the information necessary to reach the destination. The system does not, however, provide traffic information other than route guidance.

The literature does not indicate that a system similar to Direction Assistance has yet been developed to provide real-time traffic information. However, such a system is feasible and, with an increased number of cars with cellular phones, could help alleviate traffic problems by providing not only pre-trip information, but en route information as well.

III. MOTORIST INFORMATION SYSTEMS: EN ROUTE INFORMATION FOR MOTORISTS

In addition to information received before trips are begun, motorists need information about traffic on their route while they are traveling. This tactical information should enable drivers to (a) make effective route choices, (b) travel routes with which they are previously unfamiliar, and (c) respond quickly and appropriately to unforeseen incidents that occur en route. The means of conveying tactical traffic information to drivers en route can be divided into two categories: information delivered outside the vehicle and information delivered inside the vehicle. Information delivered outside the vehicle is visual and is delivered by various types of traffic signs. Information delivered inside the vehicle may be visual, delivered by an in-vehicle navigation system, or it may be verbal, delivered by commercial or dedicated radio, or by cellular telephone. The following subsections of this report examine all of these systems.

Visual Information Outside the Vehicle

Information delivered to motorists outside their vehicles is communicated by means of visual signs. Static signs have been most commonly used for various traffic control, route guidance, and diversionary purposes. Variable Message Signs (VMS) are newer, and are capable of being electronically adjusted to inform motorists of prevailing conditions. VMS can convey real-time traffic information to drivers, enabling them to make appropriate decisions at key decision points during their trip.

A well designed sign system should ensure that all the information the signs convey can be read and understood by motorists within the time period that they view the sign. In addition, motorists must be willing and able to respond to the sign while the appropriate response is still possible. Since most of a driver's stimulus input is visual, an understanding of the visual abilities of drivers is essential in the design and placement of effective traffic signs.

One of the characteristics which influence the perception of signs, be they roadway or VMS, is a personality characteristic referred to as field-dependence/field-independence. Basically, field-dependent people are better than are field-dependent people at distinguishing relevant from irrelevant cues in their environment. Various psychometric tests measure field dependence. Goodenough (1976) has reviewed the literature on these tests and has summarized several experiments and field studies in the area as follows: as compared to field-independent drivers, field-dependent drivers are slower to recognize developing hazards and to respond to embedded road signs (those surrounded by other stimuli), have greater difficulty in learning to control a skidding vehicle, and are more likely to fail to drive defensively in high-speed traffic. Other evidence (Shinar et al., 1983), indicates a relationship between field-dependence and eye movement behavior. Thus more field-dependent drivers have longer eye-fixation duration and therefore take longer to pick out relevant information.

These results indicate that personality or perceptual styles of drivers, such as field-dependence, are important variables to consider in the design of motorist information systems and in the design of surveys which desire to isolate these groups in the sample population. To clarify the factors involved in the design and placement of effective signs, the following subsections include further review of recent relevant human factors research.

Effectiveness of Sign Content

A study on the effect of freeway diversionary sign content and motorist behavior found that, despite instructions to exit the freeway, one-third of 360 subjects continued on the freeway (Mast and Ballas, 1976). The severity of the message had a direct effect on the number of people choosing an alternate route. A message in the imperative mood had the greatest influence; signs that explicitly stated a message such as "USE I-XX BYPASS NEXT EXIT" were interpreted as commands. The same study also concluded that motorists prefer time-delay information over incident information. A Finnish study found that as motorist's motivation increased, their reaction time when faced with highway signs decreased (Summala and Hietamaki, 1984). These and other findings indicate that the content of diversionary signs should be tied to a motorist's motivation for choosing an alternate route.

Other studies have found that age has a significant impact on recall of sign content, with younger drivers recalling the signs better than older drivers (Milosevic and Gajic, 1986; Evans and Ginsburg, 1985). With the average age of the driving population increasing, an attempt will have to be made to determine the appropriate message content and its effect on various age segments of the population.

A fair amount of controversy exists on the relationship between recall of signs and professional status of the driver. Milosevic and Gajic (1986) found that the professional status of the motorist does affect the recall of signs; professional drivers have higher recall than non-professional drivers. In contrast, Hakkinen (1965) found that non-professional motorists had better recall of signs than professional motorists. To further complicate matters, Johannson and Rumar (1966) found that professional status had no effect on recall of signs. These studies were all performed in different countries; Milosevic and Gajic's study was performed in Yugoslavia, the Hakkinen study was done in Finland, and Johannson and Rumar's study was done in Sweden. Perhaps the geographic location of the study affected the results. In any case, further research is needed to gauge the effects of different driver types on the recall of signs.

A study to measure the effect of "close following" signs was done at the Transportation and Road Research Laboratory (TRRL) in England (Helliar-Symons and Ray, 1986). Its purpose was to measure the effectiveness of warning signs on the behavior of motorists on major motorways. Findings indicated that females responded to signs more than males. The study also revealed that the response to signs increased with age. The same study also concluded that drivers of passenger cars responded more to signs than drivers of heavy or light goods vehicles. Generally, in the TRRL study, professional drivers responded less to the signs than non-professional drivers.

Research examining methods of conveying the content of traffic signs agrees that symbolic sign messages have a number of advantages over word sign messages. Symbolic sign messages are identifiable at greater distances and are more legible at a quick glance than are verbal messages (Elks and Dower, 1979; Whitaker and Stacey, 1981; King, 1985). The meaning of symbolic traffic signs is generally understood more quickly than that of the corresponding signs with verbal messages. Furthermore, symbolic messages can be recognized more easily under degraded conditions, such as rain, fog, or snow (Ells and Dewar, 1981).

These studies only begin to address the many questions about message content that must be answered before a truly effective motorist sign system can be developed.

<u>Sign Placement</u>

According to Mourant and Rockwell (Mourant and Rockwell, 1970), peripheral vision is used for monitoring lane position, other vehicles, and road signs so that the eye's center of focus may be directed where a clearer examination is needed. Since peripheral vision, with its poor visual acuity, is used to monitor the road edge, easily detected lines and conspicuous road signs are particularly important. In freeway driving, the search and scan pattern of drivers becomes more compact; as drivers become more familiar with their route the center of the pattern shifts down and to the left. The center of the final visual scan pattern is located above the right road edge marker and slightly higher than the horizon (Mourant and Rockwell, 1976). This pattern indicates that traffic and road signs should be placed on the right side of the road (in the direction of travel) and should have the sign board at an elevation slightly higher than the horizon.

On curved roads the visual fixation patterns of drivers follows the road geometry, whereas on straight roads the search behavior is less active; most of the fixations are close to the point, straight ahead of the driver, where objects appear stationary in the moving visual field. In driving through curves, drivers direct their eye's center of focus to lateral placement cues rather than relying on peripheral vision (McDowell and Rockwell, 1977). The process of curve scanning begins in the section of road prior to the curve itself. Search and scan patterns on right and left curves are not symmetrical: eye movements to the right on right curves are greater than eye movements to the left on left curves. The studies on curves suggest that the optimal placement for advisory curve signs may be just prior to the section of road before the curve, so that drivers are warned to switch their visual search strategy and maximize their curve scanning time prior to entering the curve. This placement is especially critical for roads designed for high speeds.

Eye fixation patterns also differ when drivers travel at different speeds. Drivers looked further ahead when traveling at high speed (80 km/hr. or more). As driving stress (rated subjectively) increases, the frequency of short eye fixations increases, the frequency of long fixations decreases, and eye movement distances become shorter (Whalen et al., 1977).

Sign Visibility

Conspicuity is the property that causes an object to attract attention or to be readily located by search. A study by Cole and Hughes (1984) concluded that the angle of eccentricity of an object (deviation from the stationary point in the driver's straight-ahead field of vision) to the observers line of sight is an important factor in determining conspicuity. This finding implies that, to achieve conspicuity, traffic signs should be located so that the sign has a small eccentricity to the observer's line of sight. Small angles of eccentricity are afforded by minimizing the distance the sign is set off to the side, and by ensuring a long observation distance. A larger sign at a greater angle of eccentricity is not as effective as a smaller sign at a lesser angle. The study found that conspicuity was not strongly dependent on either the object's size or the amount of light the object reflects. This conclusion contradicts the results of an earlier study conducted by Cole and Jenkins (Australian Road Research, 1982) which found that size is an important determinant of conspicuity.

Age has been related to the visual perception of traffic signs (Sturgis and Osgood, 1982). Visual acuity decreases significantly with both increasing age and decreasing background luminance (luminance is the amount of light leaving a surface, whether reflected or emitted). Threshold target luminance increases significantly with age. Glare has a multiplicative effect on threshold target luminance that is independent of age. Older persons (on the average) do have significantly greater target luminance requirements in the presence and absence of glare. A similar study carried out by Evans and Ginsburg (1985) supports these findings.

Visual tracking of a sign is affected considerably when the vertical distance between signs in an array was 18 degrees of visual angle or greater (Noble and Sanders, 1980). This study also found that tracking is best when color provided a perfect cue. These findings indicate that highly distinctive colors should be used for signs. In addition, symbolic cuing lightens the cognitive load in a divided attention context (Chechile and Sadoski, 1983); verbal cuing did not reduce the cognitive load, since it still requires attention to read the verbal message. Together, these studies suggest that traffic signs should have highly distinctive background colors, coupled with symbolic messages that minimize the human information processing task. The optimal design would incorporate high conspicuity and contain a message that is legible and understandable.

Under conditions of degraded visibility (fog, heavy rain, and darkness), the overall degradation in visibility does not lower the drivers perception of all driving-related cues. Rather, it shifts the driver's attention towards warning signs that contain the preview information that is not directly visible in their view of the road ahead (Shinar and Drory, 1983). Shinar and Drory also found that at night, when the view of the road ahead is severely restricted, drivers' recall of signs is higher than during the day, when drivers can obtain most of their information directly from the view of the road ahead. Olson and Bernstein (1979) found that in darkness, more highly reflective sign backgrounds create better legibility at greater distances. This study also concluded that reflective backgrounds reduce the adverse effects of degraded viewing conditions. Luminance contrast requirements were found to be lowest for highly reflective backgrounds and increase as background reflectivity increased.

The greater Seattle area is known for its rainy conditions. Unfortunately, there have been few studies of the legibility of highway signs and the visual load they demand in rainy situations. A study by Bhise, Meldrum, Forbes, Rockwell, and McDowell (1981) concluded that diver's visual acuity, including the ability to read signs and to see at a distance, decreases with increasing rain intensity. More study and research in this area needs to be done to understand the factors involved in traffic sign design to accommodate the effects of darkness and rain.

Overall, human factors considerations are a crucial component in the content, placement, and design of highway signs. Considerable research is yet to be done, particularly on the human factors issues related to VMS and other new sign technologies.

In-Vehicle Navigation Systems

With the reduced cost, increased compactness, and improved capabilities of sophisticated communication equipment, externally linked route guidance has become a topic of interest among traffic planners. In its most sophisticated form, this guidance consists of an in-vehicle navigation system that communicates with transmitters and receivers along the roadway or on satellites, providing the motorist with information about location, alternate routes, best route to destination, existing road conditions, and other vehicles.

United States Systems

ETAK Inc. has developed an online navigational display system for automobiles. The ETAK Navigator consists of a Cathode Ray Tube (CRT) display screen located on the vehicles dashboard. The display is a map similar to the screens discussed in previous sections on television and microcomputers, with one primary difference: instead of a large overview of a freeway system, the system offers a point-of-view map geared toward the destination of the driver (Honey and Zavoli, 1986). The direction the car is traveling always faces the top of the screen; the display rotates to accommodate any change. The map gives the driver the advantage of knowing what route options are available from the car's current position.

An on-line navigational display system, using ETAK, is currently being tested in the Los Angeles area as part of the traffic management system called Smart Streets. A three year research project, called Pathfinder, is testing the feasibility of electronically linking traffic condition information for in-vehicle navigation systems. The project, conducted by CALTRANS, uses 25 specially equipped cars donated by GM. Each car has an electronic map of Los Angeles streets displayed on a console screen fitted to the dashboard. During the project, the system will be refined to receive real-time traffic and accident information from CALTRANS' traffic operation center. The users of the four inch ETAK computer screen will program in their present location and destination and select one of eight different scale sizes in which to view the map. The selections will be transmitted and received over FM radio or cellular phone. The central computer will transmit graphic or textual traffic information on the screen. The visual information will be complemented by audio transmissions. Preliminary results from this study are expected by mid 1991.

International Systems

Internationally, a number of approaches to in-vehicle route guidance systems have been studied. As early as the 1960s an American system, Electronic Route Guidance System (ERGS), was tested. ERGS linked automobile and information units on the roadway by radio. A West German

System, ALI (Destination Guidance System), gathered information from induction loops in the road and recommended optimum routes to individual motorists. Both of these projects were discontinued because of the prohibitive cost of modifying the roadway.

Currently, a number of intermediate route guidance systems are being developed. The CARIN system from the Netherlands provides a prototype digital map on which the motorist and the proposed route can be located. An in-vehicle computer then keeps track of the vehicle's direction and speed, and gives a dead reckoning location of the vehicle. The ROESY system from Great Britain takes an innovative approach, allowing the motorist to create a digital map of only relevant roads and intersections. The computer then uses that map to plot an optimum route. Cost is still high for any version of this technology: an in-vehicle CARIN system would cost approximately $1300. As systems are refined and production volume increases, costs are expected to drop and the capability of the systems is expected to increase.

Effectiveness of In-Vehicle Navigation Systems

A navigational display in an automobile poses a unique set of human behavior problems. Virginia Polytechnic Institute has completed a series of human factor studies to evaluate the use of an in-vehicle navigational system for route guidance (Dingus, Antin, Hulse, and Wierwille, 1986; Wierwille, Hulse, Fischer, and Dingus, 1987). These studies, using the ETAK Navigator described earlier, found that ETAK is as effective a means of route guidance as road maps; the difference in performance between the two was found to be statistically insignificant. The dependent measures included eye scanning and dwell time, task completion, and quality of driving.

The automotive industry has already incorporated various forms of electronic displays in automobiles. Ford Motor Company has funded extensive research on electronic and digital displays, and concluded that subjects using digital displays of numeric information such as vehicle speed could more accurately determine actual speed than subjects using dials or meters. However, 38% of the 100 subjects found digital displays to be the very distracting (Baines and Simmonds, 1980).

An alternative to CRT or digital displays is the Heads Up Display (HUD) used in aircraft. In a HUD, information is presented to the user by displaying altitude and pitch information on the windshield. Thus the display information is superimposed on the real world view, enabling a user to scan the forward view without loss of information. (Harding, 1980). Nissan Motor Company will be introducing a HUD in its latest automobile models to provide information that has previously been conventionally displayed on the dashboard.

Human Factors Issues for In-Vehicle Navigation

When people are required to do more than one task at the same time, referred to as divided attention or timesharing, performance on at least one of the tasks usually declines. The driving task requires timesharing; the driver has to respond to visual stimuli while using motor skills to control the vehicle. For the driver, controlling the vehicle is the primary task. Studies have been conducted to determine how driving affects performance on a secondary task such as reading randomized digits from a digital counter mounted above the console (Wierwille and Gutmann, 1978).

Performance on single and multiple tasks, such as operating navigational instruments while driving, has been found to be related to personality type. For example, type A personalities who are competitive, achievement oriented, and have an extreme sense of time urgency, perform better when doing two tasks simultaneously (Damos, 1986). In addition to personality, there is a strong correlation between self-assessed and objective measures of navigational capabilities (Streeter and Vitello, 1986).

Human factors specialists are examining the design of the CRT displays used in the 1986 Buick Rivera (Zwahlen, Adams, and DeBald, 1987). Traditional knobs make use of motorists' tactile senses, whereas the CRT type panels require the driver to visually scan the instrument. By measuring lane drift, the study concluded that operating a CRT type apparatus is detrimental to driving. In a related study, Noy (1987) found a direct correlation between the complexity of the visual task and poor driving quality. This correlation is attributed to the heavier cognitive load that drivers experience while performing the visual task. These findings suggest that in-vehicle navigation and route guidance systems require further research before implementation.

Studies done at Virginia Polytechnic Institute also concluded that navigational systems demand more attention than common road maps (Dingus, Antin, Hulse, and Wierwille 1986; Wierwille, Hulse, Fischer, Dingus, 1987). The 1986 study compared the attention required to read a speedometer (low attentional demand) or tune a radio (high attentional demand) to the attention required to navigate using a display or a map. The 1987 study investigated the adaptability of users' visual scan patterns. The experiment involved two kinds of changes in the visual scene: changes the drivers anticipated (advance notification, e.g., driving down a winding road), and changes the drivers did not anticipate (no advance notification, e.g., an oncoming vehicle turning left). The studies concluded that motorists can, and do, adapt to new technology in vehicles and to information overload. Although motorists do adapt, the researchers caution designers to work on reducing the attentional demands of the navigational instruments.

The following design rules for CRT displays in vehicles have been suggested by various human factors specialists (Zwahlen et al., 1987; Streeter and Vitello 1986):

- A maximum of 3 consecutive looks should be required to operate a CRT touch panel control system.

- The acceptable time range for interrupting the driver's scanning of the road to operate a CRT panel is 2 to 4 seconds (although we recommend much shorter ranges).

- HUD (Heads up Display), used in fighter aircraft to display information directly on the windshield, may be an alternate method for displaying information.

- The placement of the navigational instrument display should maximize the driver's use of near peripheral vision, so that driving tasks may be performed while attending to the instrument.

- Although computer generated pictures are effective and can be transmitted to an in-vehicle computer, navigational information should be presented vocally.

This last point brings us to an alternative or adjunct to in-vehicle displays--in-vehicle voice instructions.

In-Vehicle Voice Instructions

Primarily through radio broadcasts, voice instructions are an effective means of transmitting traffic information to motorists, and their application could be significantly extended. Research funded by the federal government has concentrated on the aircraft environment; however, the general principles are applicable to automobiles. Some research has indicated that voice warning systems result in quicker response than tonal or visual displays, particularly in high stress situations.

Developments in radio broadcasting are aimed at solving two fundamental problems: first, delivering to the individual motorist the information needed to follow a specific route, and second, immediately informing motorists of an incident or a change of conditions. There are currently two modes of transmitting audio information to the motorist: a multi-purpose system, designed to meet many needs, including the delivery of necessary traffic information (i.e., commercial radio); or a dedicated system designed for traffic information only. The following subsections will examine both modes.

Commercial Radio

One of the most widely used means of transmitting traffic information is through commercial radio stations. There are several radio stations within the Puget Sound area that attempt to broadcast up-to-the-minute traffic information, using either information from the DOT center or information from their own traffic reporters, often in helicopters. The service is often inefficient: the information may be delayed, may not be broadcast when needed, may not be heard when broadcast, and, when heard, may be irrelevant to an individual driver's journey. Some of these problems are addressed by dedicated radio systems.

Dedicated Radio Systems

Dedicated audio instruction systems can provide 24 hour, up-to-the-minute traffic information and route guidance to automobiles in transit. ARI, "motorist's broadcast information," the West German system developed by Blaupunkt, has met with some success and acceptance from motorists. ARI is made up of over 40 broadcasting stations separated into 12 zones. The broadcast signal is modulated in such a way that stations within zones can be distinguished; another special modulation indicates when a station is broadcasting.

The ARI system requires a special receiver capable of interpreting these modulations; these receivers come in various levels of sophistication. The simplest and least expensive ($15 to $30) informs the motorist with an indicator light, when the radio is tuned to the local information station. The top-of-the-line receiver (cost unavailable) automatically detects the broadcast, tunes the radio to the appropriate information station, and either plays or stores the message, at the motorist's discretion.

ARI is currently in operation, and an estimated 80% of West German motorists have some form of ARI receiver. Other systems are in experimental and prototype stages. For example CARFAX, an English system not yet implemented, depends on transmitters rather than receivers to prevent interference. A computer operated system would inhibit transmitters in the same range from broadcasting at the same time. A receiver for this system costs the motorist approximately the same as the cheapest ARI receiver. CARFAX is currently being delayed by a lack of available, appropriate broadcast frequencies.

Radio Data System (RDS) avoids the broadcast frequency problem by piggybacking a digital code onto a standard FM signal. Again, the motorist must have a special receiver and decoder. One of the strongest features of RDS is that the digital signal can be interpreted into any language, verbal or symbolic. In addition, the message can be easily stored in its digital form and called up at the motorist's convenience.

Traffic Incident Information System (TIIS) in Japan has a different design; the TIIS transmission overrides any other broadcast. The special receiver for this system automatically tunes to TIIS whenever TIIS is transmitting. If the driver does not wish to hear the message, he or she can manually tune the radio to another station.

Highway Advisory Radio (HAR) is already in place in many parts of the United States. HAR is relatively unsophisticated. By flashing lights on a highway sign, it signals motorists that a short-range, dedicated radio station is currently broadcasting potentially useful information . The motorist must then manually find the station while driving. Generally, HAR is not used for real-time traffic reports. Despite its current lack of technical sophistication, HAR might serve as the infrastructure for a more advanced system.

Effectiveness Of Voice Instructions

If dedicated voice systems are to be truly effective in the future, as much attention must be paid to the effectiveness of this media, as well as to other human factors issues related to voice commands and instructions, as is currently being paid to technological issues of transmission and reception.

A New Jersey study compared the effectiveness of route information disbursed by two media: audio tape instructions and maps (Streeter, Vitello, and Wonsiewicz, 1985). Subjects given the audio information performed better (drove fewer miles) than subjects given maps. In addition, the map group made 67% more errors than the tape group.

A survey conducted in 1971 by the Texas Transportation Institute (Dudek et al., 1971a) revealed that 62% of the survey participants could benefit from radio reports. The same survey revealed that, among the 4 modes of communication (radio, signs, tv and telephone), radio was the most preferred mode.

Additional Human Factors Research

Traditionally, auditory information within automobiles has taken the form of buzzers and bells. However, recent developments in computer and speech technology have resulted in incorporating synthesized or natural voices for such purposes as warning messages about using seat belts or leaving headlights on. Public acceptance of such messages has been mixed. The success of "talking products" for traffic information, including natural or synthesized voices, will depend upon the application of human factors principles.

The following general issues have been cited as crucial in the design of audio message systems (Michaelis, 1980; Schwab, Nusbaum, and Pisoni, 1985):

- Vocabulary: Vocabulary for the use of route guidance and information should incorporate various psychological considerations. Drivers should not be alienated through the use of unfamiliar words.

- Intonation and Inflection: Synthesized speech does not sufficiently allow the designer to vary the intonation or inflection of words and, as a result, can be fatiguing or annoying. Studies varying the length of time between words to provide hints of inflection have reduced the annoyance factor.

- Cues: Several non-verbal cues are also important when relaying information. The speaker should be perceived as sincere, helpful, and friendly rather than condescending or threatening.

- Training: Driver's perception of synthetic speech can be improved with a moderate amount of training by exposure to synthetic speech, even of lower quality. Thus drivers exposed to synthetic speech over a period of time should improve their performance of route-following tasks. The effects of training can be retained over a long intervening period.

The following recommendations have been provided as guidelines for developing an effective Highway Advisory Radio message (Dudek et al., 1983):

- Lengthy dialogs should be avoided when route information is delivered. Subjects in the study performed better with a terse message style.

- The capacity of a driver to remember an unfamiliar route is limited to 4 turns and 4 names. This phenomenon could be related to short term memory capacity of 7 ± 2 (Miller, 1957).

- Repetition of the diversion route improves retention of the route information among motorists. This could be accomplished through external or internal redundancy.

- Prominent landmarks can help guide the unfamiliar motorist. Using the number of traffic lights between turns as a landmark should be done with care. Traffic lights as landmarks should be avoided when flashing lights are involved.

- Motorists familiar with a route, such as commuters, do not need as detailed a description of route change as unfamiliar drivers.

- Researchers felt the instruction "you have come too far," was helpful for drivers who inadvertently left the route, although one study indicated that subjects disliked the information (Streeter et al., 1985).

Cellular Telephones

With the widespread use of cellular telephones in automobiles, it is now feasible to consider the telephone as an in-vehicle means of incident information and route guidance. However, use of cellular telephones for this purpose poses problems. Relatively few of the total number of cars on the freeway system currently have cellular telephones. The proposed survey for this project will reveal some quantitative and qualitative data on the population using cellular telephones within the I-5 corridor.

Safety is a concern in the use of cellular telephones. A study presented at the 21st Annual Workshop on Human Factors in Transportation (Zwahlen, Adams, and Schwartz, 1987) measured the deviations of automobiles from the centerline while drivers were using cellular telephones. The study, using two different automobiles and two different mounting positions for the digital cellular telephone, concluded that the drivers' lateral deviations from the centerline were too high during the use of cellular telephones. Thus use of in-vehicle cellular telephone systems for traffic information (like use of visual dashboard displays) may compromise vehicle safety, and such systems should be assessed carefully before they are implemented.

CONCLUSIONS

Previously, the media discussed in this state-of-the-art review have been studied mainly as information sources that are independent of each other and of motorists' needs. In evaluating the usefulness of these media for supplying traffic information to freeway motorists in the Seattle area, the various information channels must be viewed as part of an integrated system consisting of technology and humans that is specifically designed to meet the complex requirements of the Seattle area freeway drivers. The information gained from the motorist surveys discussed in this report, and from the upcoming motorist survey which is the next phase of this project, should help us design a traffic information system that will enable drivers to become more efficient users of the freeway system. Information about Seattle commuters should serve as a basis for determining what media will be used in the integrated traffic information system for the Seattle area and, along with technical considerations based on information contained in this report and elsewhere, should determine the placement of the media and the content of the messages delivered by those media.

Further, this review has isolated a number of important "human" factors issues which must be considered in the design of motorist information systems. Variables such as age, visual acuity, personality type, eye scanning patterns, and mental workload, for example, all interact to determine how commuters perceive, understand, and act on information. Clearly if factors such as these are not considered in the design of information systems, the result may be a costly new piece of technology which has little impact on the behavior of Seattle commuters. The survey which will temporally follow this review is designed to answer some, but not all, of the issues reviewed here. Future extensions of this project are necessary to provide a clearer and broader description of the Seattle commuter and to determine the most effective means of providing motorist information to commuters.

Use of the sophisticated technologies described in this report will require compatibility between the various systems; thus standardization is an issue that must be considered in designing an integrated traffic system. Any system, regardless of the forms in which it currently presents information, should be compatible with emerging technologies so that the system does not become obsolete.

Ultimately, however, motorist information systems must be user-based. The designer of an effective system must first know who the drivers are, what decisions they make, where and on what basis these decisions are made, and what predispositions drivers have towards the delivery of information about these decisions. This state of the art review is only the first step towards answering these questions.

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