Improving Motorist Information Systems

Towards a User-Based Motorist Information System for the Puget Sound Area

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16. ABSTRACT

This report documents new knowledge of Puget Sound freeway commuter behavior and information needs, relevant to the design and development of a motorist information system for the Seattle area. Methodological innovations resulted in a larger, more relevant sample; more complex and varied data; and a finer grain of analysis than previous efforts to survey motorist behavior. Findings are relevant not only to driver information systems in particular, but also to transportation management in general. Commuters were found not to be a single, homogeneous audience for motorist information, but rather to consist of four subgroups, which we labeled: (1) **route changers**, (2) **non-changers**, (3) **route and time changers**, and (4) **pre-trip changers**. Commuters were more receptive to motorist information delivered at home than to information delivered on the freeway. Most commuters were inflexible about changing transportation mode, but *pre-trip changers* were somewhat flexible and more likely to change mode than to change route while on the freeway. The most flexible driving decision was the departure time of *route and time changers* and *pre-trip changers*, yet the least flexible driving decision was the departure time of *route changers* and *non-changers*. Commuters were fairly flexible to on-road route changes, but less flexible than to changing pre-trip routes based on traffic information received prior to departure. Commercial radio was the preferred medium for on-road traffic information, while HAR and VMS were either not used or not generally perceived as helpful. Whatever the delivery medium, commuters questioned the credibility of motorist information.

The report describes how the identification, analysis, and targeting of susceptible driver groups can improve the design of motorist information systems. Recommendatios are also presented to improve commuter response to and use of HAR and VMS.

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Research Project GC 8286, Task 26
Motorist Information Systems

IMPROVING MOTORIST INFORMATION SYSTEMS:

TOWARDS A USER-BASED MOTORIST INFORMATION SYSTEM FOR THE PUGET SOUND AREA

by

Mark Haselkorn
Principal Investigator

Woodrow Barfield
Co-Principal Investigator

Jan Spyridakis
Investigator

Loveday Conquest
Consultant

Washington State Transportation Center (TRAC)
University of Washington, JE-10
The Corbet Building, Suite 204
4507 University Way N.E.
Seattle, Washington 98105

Washington State Department of Transportation
Technical Monitor
Kim Henry
I-90 Traffic Engineer

Prepared for

Washington State Transportation Commission
Department of Transportation
and in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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DISCLAIMER

Additional details of this work can be found in the expanded technical report of this project.

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EXECUTIVE SUMMARY

Advanced Driver Information Systems (ADIS) are a promising approach to relieving problems related to urban traffic congestion. However, the output of an ADIS must not only be thought of as a message or display, but also as the ability of that message or display to impact drivers. The design of a motorist information system should therefore be based not only on the capabilities of communication technology, but even more importantly on an awareness of driver behavior and information needs.

This project surveyed Puget Sound freeway commuters in order to determine their driving behavior and information needs relevant to the design and development of a motorist information system for the greater Seattle area. Building on previous efforts in driver analysis by transportation researchers, our methodology proved extremely successful, resulting in a larger sample, more complex and varied data, and a finer grain of analysis than previous efforts to survey motorist behavior. Analysis of our extensive data set has lead to important findings and conclusions not only for the design of motorist information systems in particular, but also for transportation management in general.

Particularly significant was our use of *cluster analysis* and other inferential techniques to discover, confirm, and explore commuter sub-groups. Commuters are not a single, homogeneous audience for motorist information. We found four commuter groups, and labeled them: (1) **route changers** (RC), willing to change routes before or during their commute but unwilling to change departure time or transportation mode (20.6%); (2) **non-changers** (NC), unwilling to change departure time, route, or transportation mode (23.4%); (3) **route and time changers** (RTC), willing to change route and departure time, but not transportation mode (40.1%); and (4) **pre-trip changers** (PC), those unwilling to change route while driving, but willing to change time, route, or even mode prior to leaving their residence (15.9%). Not only are certain commuters more flexible about a given driving behavior than others, but those commuters who are less flexible are also less likely to be aware of available information that could impact that decision.

The identification of driver groups and driver decisions is central to the design of motorist information systems. The goal of these systems is to improve traffic flow, not to be equally useful to all drivers at all times. This improvement in traffic flow can be achieved by affecting the behavior of relatively small percentages of commuters. An ADIS should deliver motorist information targeted to impact particular driving decisions and tailored to those groups most likely to be impacted.

Pre-trip delivery of motorist information is a complex but particularly promising area. Commuters were far more receptive to motorist information delivered at home than they were to information delivered on the freeway, and (except for the NC) were flexible about changing routes based on traffic information received prior to departure. Most commuters were inflexible about changing transportation mode, though one commuter type (PC) was somewhat flexible and should be targeted for information relating to mode choice (in fact, pre-trip changers were more likely to change mode than they were to change route while on the freeway).

Perhaps most promising of the pre-trip decisions is departure time. Commuters were dramatically split in their departure time flexibility. The single most flexible driving decision was the departure time of the RTC and PC groups, yet the single least flexible driving decision was the departure time of the RC and NC groups. By tailoring pre-trip information to those commuters identified as susceptible to altering departure time, we should be able to spread out the commute and reduce peak congestion.

While commuters were not generally receptive to traffic information delivered on the freeway, they were fairly flexible to on-road route changes (though less so than pre-trip route changes). Commercial radio was far and away the preferred medium for delivery of on-road traffic information, while Highway Advisory Radio (HAR) and Variable Message Signs (VMS) were either not used or not generally perceived as helpful. However, the follow-up survey showed that exposure to positive examples leads to a marked improvement in commuter response to new mediums. HAR and VMS can be improved by (1) targeting those commuters who tend to change route while driving, (2) integrating and coordinating HAR and VMS with home delivery systems to provide feedback as well as updated information, (3) improving message content, (4) keeping messages relevant to particular driver decisions, or to feedback and reinforcement of those decisions, (5) incorporating an indication of timeliness into messages, and (6) integrating HAR and VMS more closely with real-time gathering of traffic data.

Whatever the delivery medium, commuters questioned the credibility of motorist information. In addition, when they did modify their behavior, commuters did not know whether or not they had made the correct decision. Having decided to use an alternate route, commuter stress increased, rather than decreased. If we are to reinforce commuter modification of driving behavior, it is necessary to include a feedback mechanism in any motorist information system.

For future implementation, we propose (1) extending our survey to include east/west and southern Seattle commuters; (2) sharing our expanded analysis of commuter behavior with state agencies, lawmakers, and public groups to help shape state transportation policy; (3) developing a front end/interface to the current system for gathering and displaying real-time traffic data, capable of converting traffic data into information tailored to impact susceptible commuter groups as to their choice of route, mode, and time of commute; (4) selecting and developing home delivery mechanisms for the information produced by this front end, (5) integrating on-road and home delivery of motorist information to provide feedback and confirmation of system reliability; (6) developing and implementing state-wide guidelines for HAR and VMS; and (7) performing additional research on motorist response to traffic message content.

CONCLUSIONS AND RECOMMENDATIONS

The following are related conclusions and recommendations derived from our work.

THE SURVEY

Conclusion #1

The survey methodology developed for this project is extremely successful at gathering data on commuter behavior and decision processes.

Previous studies have surveyed general population [8] or Central Business District workers [10] or households [11], but ours focused directly on the population in question--commuters traveling a selected corridor, contacted near the end of their trip while still in their cars. This resulted in a high response rate; an extremely large, relevant subject pool; and an extensive, complex data set.

Conclusion #2

The analytical methods applied to the data, particularly *cluster analysis*, are extremely successful at leading us beyond descriptive results to deeper, more inferential analysis of traffic management data.

Our analysis expanded that of previous studies, providing a rich picture of motorist behavior. For example, a previous study [11] found that "departure time decisions are... much more flexible than are mode choices." While our study confirmed this general conclusion, cluster analysis allowed us to take it much further. Actually, there are two types of commuters for whom both departure decisions and mode choice are extremely inflexible, a third type for whom departure time is extremely flexible and mode choice extremely inflexible, and a fourth type for whom departure time is extremely flexible and mode choice is somewhat flexible (in fact this fourth type is more likely to change mode than they are to change route while on the freeway). Cluster analysis enabled us to define and explore previously unknown commuter types.

Recommendation #1

Apply the methodology and analytical methods of this survey to other corridors, locations, and situations.

Only by building up a body of comparable data for numerous corridors, locations, and situations can we distinguish generally applicable commuter characteristics from those which are dependent on geography, date, and other local variables. This knowledge is essential to efficient development of traffic management strategies.

COMMUTER TYPES

Conclusion #3

Commuters are not a single, homogeneous audience for motorist information.

Rather, commuters are a complex audience with differing information requirements related to differing geography, socio-economic status, driving tendencies, stress levels, personality types, etc. At any given moment, a particular message can be "right" for one commuter, "wrong" for another, and meaningless to a third.

Conclusion #4

Distinct, stable sub-groups of commuters can be identified, based on driving behavior, decision-making, and information needs.

As described above, we identified four commuter groups, each of which is more or less likely to be influenced by motorist information, depending upon the type of driving behavior to be modified. These groups remained stable for related findings not used in the cluster analysis, as well as for in-depth survey findings.

Conclusion #5

Commuters who are less flexible about a given driving decision are also less likely to be aware of available motorist information that could impact that decision.

While this conclusion holds for all commuter types, it is most evident in the *non-changer* group, which not only is least likely to modify their driving behavior, but also is most likely to claim they have never received relevant traffic information.

Recommendation #2

Use the identification of driver groups to tailor motorist information to those groups most likely to be impacted.

The goal of a motorist information system is to improve traffic flow, not to be equally useful to all drivers at all times. This improvement can be achieved by affecting a targeted subset of commuters. To efficiently achieve this improvement, designers of motorist information systems should guide complex design decisions such as what to say, how to say it, and how and where to deliver it, by targeting those commuter sub-groups who are most susceptible to the information.

PRE-TRIP INFORMATION

Conclusion #6

Commuters are dramatically split in their departure time flexibility.

Conclusion #7

The single most flexible driving decision is the departure time of the *route and time changer* and *pre-trip changer* groups.

Nearly all of the commuters from these two groups (99.6%; N=2018) reported that they frequently or sometimes change the time they leave based on traffic information received at home.

Conclusion #8

The single least flexible driving decision is the departure time of the *route changer* and *non-changer* groups.

Nearly all of the commuters from these two groups (99.3%; N=1588) reported that they either rarely change the time they leave or never receive information relevant to this decision at home.

Conclusion #9

Most commuters are flexible about changing routes based on traffic information received prior to departure.

In three of the four commuter groups (*route changer*, *route and time changer* and *pre-trip changer*), 80% of the commuters reported that they frequently or sometimes change their route based on traffic information received at home.

Conclusion #10

Commuters are receptive to traffic information delivered at home.

The initial survey found that most commuters prefer their motorist information at home. The in-depth survey found that commuters have the time and inclination to seek motorist information an average of three times before leaving the house.

> ### Recommendation #3
>
> **Place a high priority on home delivery of motorist information, particularly related to impacting departure time.**
>
> ### Recommendation #4
>
> **Target home delivered motorist information for specific types of commuters, based on the driving decision to be impacted.**
>
> For example, by impacting those commuters identified as susceptible to altering departure time, we could spread out the commute and reduce peak congestion.

RELIABILITY OF MOTORIST INFORMATION

Conclusion #11
Commuters question the credibility of motorist information.

This was a prevalent theme of survey comments which was supported by subsequent findings indicating that commuters generally do not find existing messages credible.

Conclusion #12
Having modified their behavior, commuters do not know whether or not they have made the correct decision.

Having decided to use an alternate route, commuter stress increases, rather than decreases. In addition, nearly one-third of the commuters indicated that they had no way of telling if their choice to use an alternate route was correct or incorrect , with the remainder indicating that if they did receive information confirming or refuting their choice to use an alternate route, they received it too late to be of use.

> ### Recommendation #5
> **Include a feedback mechanism in any motorist information system.**
>
> Commuters require verification that information is reliable and timely. Without feedback, for example, a driver cannot know whether or not a congested alternate route was actually an improvement over the abandoned primary route. Informing commuters of the benefits of their decisions reinforces those decisions and builds needed commuter confidence in the system. This is especially true for on-road delivery mechanisms such as HAR and VMS.

ON-ROAD INFORMATION

Conclusion #13
On-road route changers are fairly flexible, but less flexible than pre-trip changers.

Seventy percent of the commuters in the *route changer* and *route and time changer* groups said they frequently or sometimes change their route based on traffic information received while on the freeway.

Conclusion #14
Commuters tend not to be receptive to information delivered on the freeway.

Less than 3% of the commuters in the *route changer* and *route and time changer* groups prefer to receive their traffic information while on I-5. Even though these two groups tend to alter their route while driving, 58% prefer to receive traffic information at home.

Conclusion #15
Commercial radio is the preferred medium for delivery of on-road traffic information.

Ninety four percent of commuters in the *route changer* and *route and time changer* groups report that they are helped by traffic information delivered via commercial radio. Only 1% claim never to have used commercial radio to receive on-road traffic information.

Conclusion #16
HAR and VMS are not generally perceived as helpful.

Only 37% of commuters in the *route changer* and *route and time changer* groups report that they are helped by traffic information delivered via VMS, and only 31% by traffic information delivered via HAR. Furthermore, 44% of the commuters from these route changing groups claim never to have used VMS and 53% never to have used HAR. During the in-depth survey, common complaints were that VMS were poorly located, did not give sufficient warning prior to actual congestion, and that message content was not relevant or up-to-date. Common problems cited about HAR were that commuters did not know it existed, had never tried using it, had difficulty receiving it, or found better information from commercial radio stations.

Recommendation #6
Place high priority on improving on-road information delivery mechanisms.

On-road delivery mechanisms are crucial both as feedback mechanisms and as a means of encouraging route changes following an incident. While HAR and VMS were not seen as effective (and even commercial radio was most popular among those least likely to change routes), the in-depth survey showed that through exposure to positive examples, commuters response to delivery media can be markedly improved.

Recommendation #7
When designing and delivering on-road motorist information, target those commuters who tend to change route while driving.

Overall, commuter receptivity to on-road information is far less positive than that for pre-trip information. This makes it even more important to target those commuters most likely to be impacted in order to design and deliver effective on-road traffic information.

Recommendation #8

Through the use of an *integrated* information system, coordinate home and on-road messages, taking into account delivery location and motorists' need for feedback and reinforcement.

Motorist messages are both dynamic and interrelated. This means that constantly changing conditions require drivers to continually update and confirm their concept of traffic conditions through access of related messages from multiple media at various locations and times. On-road messages should be tied to the motorist decisions made at the location where they are delivered, and new locations should be developed both at key decision points and at locations where feedback is sought. Thus, messages should be seen not only as isolated events, but also as one of a series of communications that a motorist can receive during a single trip.

Recommendation #9

Improve on-road message content.

In particular, balance the trade-offs between generality and specificity of the message, and between reason vs. task information. More research is needed in this area.

Recommendation #10

Keep on-road messages relevant to impacting particular driver decisions, or to feedback and reinforcement of those decisions.

Motorists need to be convinced of the relevance and usefulness of on-road traffic information. If no information is available that is intended to impact or reinforce a specific driving decision, avoid "filler" messages such as "Buckle up."

Recommendation #11

Incorporate an indication of the timeliness of the message into on-road motorist information.

Recommendation #12

Integrate on-road delivery mechanisms more closely with real-time gathering of traffic data.

Recommendations #8, #9, #10, and #11 will only be effective in improving on-road information systems if on-road messages are developed through a rapid yet effective conversion of existing real-time traffic data into useful motorist information.

BACKGROUND

The rapid growth in the number of cars commuting on U.S. highways has generated numerous economic and public policy problems. Some of the most pressing problems can be traced directly to the significant increase in urban traffic, both on freeways and arterials. For example, in a recent survey of more than 4,000 businesses in the greater Seattle area, nearly one in five indicated that traffic is forcing them to consider relocation. And this, of course, is only one of the economic and social problems that increased traffic has brought to U.S. cities. Other traffic related problems include: increasing noise and air pollution; loss of productivity due to decreased worker performance; and multi-billion dollar costs for construction and road maintenance, as well as for potential high cost alternative forms of transportation.

A number of major new efforts to alleviate urban traffic congestion center around motorist information. Foreign development efforts in the areas of motorist information and navigation systems are already well underway in West Germany, Great Britain, France, and Japan; in Germany these efforts are already to the point of public testing. In the U.S., recent initiatives in this area have been spurred by the Federal Highway Administration's announcement of a High Priority National Program Area in "Advanced Motorist Information Systems for Improved Traffic Operations." The single largest U.S. effort at this time is a cooperative project between FHWA, California Department of Transportation, and General Motors known as "Pathfinder." Pathfinder, as its name implies, focuses on the assessment of communications technology for route guidance and in-car navigation in response to incidents and traffic congestion.

The Advanced Motorist Information System (ADIS) approach assumes that by providing motorists with timely and appropriately designed traffic information, coupled with route guidance to encourage alternatives, driver decision-making and behavior can be modified to both improve short-term motorist response to incidents and peak hour congestion, and to modify long-term behavior of commuters. This would result in more efficient use of existing transportation resources, which in turn would lessen the need for costly new roadway construction or alternative transportation facilities like light rail.

Of course providing motorists with timely, accurate, and effective information is only one of many possible approaches to reducing urban congestion, and it is highly unlikely that any single solution will produce a quick fix. There are, however, a number of important advantages of information-based solutions. These include:

Economic: Motorist information systems are relatively inexpensive. Even considering the full range of ADIS development issues (e.g. understanding commuter behavior and decision-making, gathering real-time traffic data, converting that data into effective driver information, and delivering that information at appropriate decision points), the cost of an effective motorist information system is still a fraction of construction and maintenance costs for either additional roadways or alternative transportation systems.

Social: Motorist information systems have less potential negative impact on major social areas such as land use, environmental impact, and population dispersion, than do either alternative transportation systems or new roadway construction.

Political: Motorist information systems fit well into the American political philosophy since they represent a consumer-based, free choice approach to traffic congestion. ADIS provide drivers with the best possible information available and leave them to make their own decisions based on that information. This is in contrast to the development of controlled guidance systems or the many possible "enforced" solutions such as requiring a minimum number of drivers in cars during peak hours.

While motorist information systems are theoretically attractive, their practical design raises a number of considerations and problems.

PROBLEM STATEMENT

Generally, past efforts to address traffic problems have focused on additional resources to meet high cost, high technology solutions. While additional resources are often needed, the application of technological solutions to human-based problems first requires a thorough understanding of the intended users of that technology. Thus, engineering solutions to transportation problems should be developed within the context of a thorough understanding of motorist behavior. Otherwise, we cannot be confident that these "solutions" will produce the desired effects.

This is particularly true in the case of solutions based on motorist information. No matter how rapidly and accurately it reflects the current state of the transportation system, information alone is not enough to improve the situation. People must respond to that information, and it is this response which actually improves the environment in which the information system operates. The output of a motorist information system, therefore, must not only be thought of as a message or display, but also as the ability of that message or display to impact drivers.

Many factors determine the impact of motorist information on motorists. Some are characteristics of the communication itself, such as timeliness, content, delivery point, medium, and clarity. Others are characteristics of the receiver of the communication, such as driving routines, willingness to change, decision procedures, awareness of alternatives, and flexibility. These may also be affected by the time of day that they are delivered. The design of a motorist information system must be based not only on the capabilities of communication technology, but even more importantly on an awareness of driver behavior and information needs.

Further complicating matters is the fact that motorists are not a homogeneous audience for traffic information. Rather, they are a complex mixture of driver types, differing in personality, geography, travel demands, social situations, economic status, etc. A single message cannot identically impact all motorists, nor would we generally want it to. A designer of motorist information must understand the complex driver audience, particularly if he or she wishes to target specific sub-groups to increase the effectiveness of particular messages.

Much information about commuters, particularly demographic data, already exists. No existing studies, however, describe motorist behavior patterns and decision-making processes with sufficient detail or focus to be useful for information system design. In particular, extremely little is known about Puget Sound commuters, and obtaining this information was the first step towards developing an effective, user-based motorist information system for the Puget Sound area.

RESEARCH APPROACH AND METHODOLOGY

To improve and develop driver information systems in the Puget Sound area, we first needed to understand more about motorist activities and behaviors, particularly the potential for changing these behaviors through the design and delivery of motorist information. Therefore, we first needed to conduct a "Motorist Information Survey" designed to gather data about motorist activities and behaviors, as well as to help us analyze the potential for changing these behaviors through the design and delivery of motorist information.

For many years, transportation specialists have used survey results to guide highway design decisions; the most recent focus has been on motorist behavior, specifically from the framework of activity based driver analysis [4]. In the past, an understanding of motorist behavior has often been obtained through household based trip surveys or general driver population surveys. However, we desired a more direct approach. Therefore, we targeted commuters who use a specific freeway corridor and administered to them: (1) a large sample mail-in survey, distributed on-road, (2) a sub-sample, in-person, follow-up survey, and (3) a sub-sample, in-person analysis or response to potential motorist information screens.

We began designing our surveys by examining previous relevant research. A search to identify recent surveys administered on the issue of motorist behavior led us to focus on the methodology of 12 surveys conducted by public agencies or universities between 1963 and 1987, in Texas, California, Sweden, and England. All of the studies were administered in urban areas and had sample sizes ranging from 25 to 2,971. Our examination of these surveys helped us to identify important aspects of motorist survey methodology. (See Technical Report, Appendix I, Table 1.)

Given the great diversity in the designs and methods used in previous motorist surveys, numerous complex decisions had to be made during the survey design phase of our project. The state-of-the-art-review (Technical Report, Appendix I) examines issues related to these decisions which are not frequently discussed in the existing literature on motorist surveys. For example, our review of previous relevant research revealed that past statistical efforts have often been limited to descriptive analyses. However, statistically more powerful techniques are often required to achieve the goals of a motorist survey, and innovative application of these techniques can both enhance the internal validity of the design and increase the generalizability of the findings. Conclusions like this one were the major guides in our survey design.

The considerable effort put into survey design paid off. Nearly 10,000 commuters from a selected freeway corridor were surveyed, with approximately 40% responding. This resulted in a data set based upon 3,893 commuters with 62 variables concerning commute characteristics, route choices, interaction with various types of motorist information, and demographic data. One-hundred of these respondents took part in follow-up in-depth interviews which further explored their commutes, use of motorist information, and preferences for information design.

In fact, one outcome of our work is the development of a successful survey methodology for studying motorist behavior and information needs. Considerable benefits could be obtained by applying this methodology to other situations. Certainly it would be advisable to extend our survey of commuter behavior and traffic information beyond the north I-5 corridor of Seattle to the rest of the Puget Sound area. By studying the two remaining freeway corridors, the Seattle inbound commuters on the southern I-5 corridor, and the east/west commuters on the I-90 and SR520 corridors, and by using the survey methodology and instrument developed in our initial work so as to assure comparable data, we could produce a complete analysis of Seattle metropolitan commuter behavior and design requirements for a comprehensive Puget Sound motorist information system.

FINDINGS

Following are selected findings in three areas: (1) results from the initial survey, excluding cluster analysis; (2) results from the cluster analysis; and (3) results from the in-depth, follow-up survey.

INITIAL SURVEY RESULTS (EXCLUDING CLUSTER ANALYSIS)

Demographic Information

The sample was 51% male and 49% female. The majority (61%) were under 41. Females in the sample are younger than males. The majority of motorists live in households with earnings between $50,000 and $59,999 per year. Females live in lower income households than males.

Of the 1,698 motorists willing to participate in a follow-up interview, slightly more males (45%) were willing than females (43%).

Situational Aspects of the Commute

Most motorists surveyed (67%) commute to work 5 days per week with the next highest number being 6 days per week (9%). Males and females commute a similar number of days per week. Most motorists (75%) travel alone in their cars; however, 19% of motorists travel with one other person in their car.

Commuters use I-5 (southbound and northbound) for an average of 8.5 miles of their commute. The reported northbound and southbound distances are quite similar and significantly correlate with each other. On this freeway corridor, commuters average distance between home and work is 14.9 miles. This distance is traveled during the morning commute in about 31 minutes and during the evening commute in about 35 minutes. The distance between home and work significantly correlates with traveling time between home and work, and with traveling time between work and home. As expected, traveling time between work and home and between home and work significantly correlated with each other.

Females' homes are located significantly closer to work than males. This finding agrees with that of other traffic surveys. Interestingly, while males travel a greater distance to work than do females, no significant difference exists in the time that both genders require to travel their respective distances. This suggests that females drive slower than males, less aggressively, or in greater congestion.

Motorists' Commute Attributes

Commuters have more flexibility in their departure time from work to home, than from home to work, and in both cases, males have more flexible departure times than females. Twice as many motorists (29%) reported a lot of flexibility in departure time from work to home than reported a lot of flexibility in departure time from home to work. Most motorists experience stress during their commute (59% some, 15% a lot); 26% say they experience very little stress. Females experience more stress during their commute than males. This increased stress may relate to the lower flexibility that females report they have in departure time.

Most commuters (67%) believe that saving commute time is very important; half believe that increasing commuting safety is very important; roughly a third believe that increasing commute enjoyment is very important. Commuters place the least importance on reducing commuting distance. Those motorists who value commute safety also value commute enjoyment. Females place more importance on all four commuting qualities than males.

In summary, motorists have greater flexibility as to the time they leave work for home than the time they leave home for work; in addition, males have greater flexibility in the time they leave either home or work than females. Most motorists experience some stress during their commute, with females experiencing greater stress than males. Motorists place the greatest value on saving commute time, with females valuing commute qualities (time saved, increased safety, increased enjoyment, and reduced distance) more than males.

Route Choices

Most motorists (62%) believe they are very familiar with alternate routes. Males claim to be more familiar with alternate routes than females. (See Table 1.)

Table 1. Familiarity with Northbound and Southbound Alternatives to I-5

	Very	Somewhat	Not at all
Both	62.4%	32.8%	4.8%
Female	53.4%	40.2%	6.4%
Male	71.3%	25.5%	3.2%

Motorists modify their routes from home to work less frequently than they modify their routes from work to home: 63% of motorists rarely change routes between home and work, as opposed to only 42% who rarely change routes between work and home. Responses to these two issues positively correlate. Males are more likely to modify their route between home and work than are females.

When asked what length of delay would cause motorists to divert from I-5, the average commuter response was 16.3 minutes to routes they know, and 25.5 minutes to routes they do not know. As expected, length of delay causing diversion to known versus unknown routes significantly correlate. The amount of delay that causes motorists to switch to a known or unknown alternate route inversely correlates with the likelihood of changing route between work and home. Motorists most willing to change routes will do so with shorter traffic delays than motorists less willing to change. Males will divert to both known and unknown routes sooner than females.

Thirty-four percent of respondents chose their commuting route while still at home or work; 23% chose on city streets, 26% chose near entrance ramps, while only 16% chose after entering I-5. About one fourth of the motorists reported that traffic messages, traffic congestion, and time of day frequently influence their route choices while only 12% reported that time pressures have an influence and only 8% that weather conditions influence their choice of commuting routes. Other surveys [5,6] have found that traffic congestion influences drivers' decisions; however, while only 12% of this survey's motorists stated that time pressures influence their commuting routes, other surveys [5,7] have reported a strong effect of time pressure . Females route choices are more frequently influenced by time pressures and weather conditions than are males.

The influence of traffic information correlates most strongly with congestion, congestion correlates most strongly with time of day, time of day correlates strongly with weather and time pressure, and weather also correlates strongly with time pressure.

In summary, motorists are more likely to change their routes from work to home than from home to work, with males being more likely to change than females. Route changes are most influenced by traffic information, congestion, and time of day. Motorists will divert to known routes sooner than to unknown routes, and males will divert sooner than females.

Location and Timing of Traffic Information

More than half of the motorists (56%) prefer to receive traffic information before driving. About 40% prefer to receive traffic information after beginning their commute, but before entering I-5 (23% preferred "city streets," 17% preferred "near entrance ramps"). Motorists least prefer to receive traffic information after entering I-5 (only 4% said they preferred receiving information on I-5). A 1971 Texas survey [7] also found that drivers prefer to receive traffic information before entering the freeway.

Depending on the driving decision, between 2% and 14% of motorists stated they are <u>frequently</u> influenced by traffic information before they drive. The data suggest that route choice and time for leaving are more influenceable than transportation mode; additionally, the influence of traffic information on pre-trip route choice and departure time significantly correlates. Further, motorists who said that their route choice was influenced before driving also responded on an earlier question that their route choice was influenced by traffic information in general. The reported influence of traffic information on departure time also correlates with the influence on transportation mode. Traffic information influences females pre-trip decisions about departure time, transportation mode and route choice more than males.

Females appear to have a greater pre-trip flexibility than males. We believe that females reluctance to alter routes while driving is due to a greater pre-trip attention to commuter choices, and therefore a greater commitment to the selected route.

Different Media for Traffic Information

Almost all motorists (98%) have received motorist information from commercial radio either before driving, during driving, or both, followed by VMS (53%), HAR (44%), TV reports (29%), phone (8%), and CB radios (3.9%). Motorists who use VMS also use HAR, and motorists who use HAR also get traffic information over the phone. Motorists who use TV to obtain traffic information also use HAR and commercial radio stations. Females are more likely than males to receive traffic information from TV, VMS, and commercial radio stations, while males were more likely than females to receive traffic information from CB radios.

Traffic information received from commercial radio stations was considered very helpful by 55% of the motorists surveyed, as compared to 7% who thought that VMS were very helpful, 5% for HAR, 3% for TV, and 1% for telephone highway construction hot lines. Motorists who found VMS helpful also found HAR helpful; motorists who found traffic information delivered by commercial radio station helpful also stated that traffic information frequently causes them to divert to alternate routes. Finally, motorists who found commercial radio station information helpful state that they would use an up-to-the-minute traffic information phone line if it were available, perhaps suggesting that a specific group of motorists prefer to receive information in an auditory mode as opposed to a visual mode. Females, more than males, find both TV and electronic message signs helpful, perhaps implying that females find visual media more helpful than males.

When asked about proposed up-to-the-minute traffic information sources, most motorists (92%) stated they would use a radio station dedicated to traffic information, if available. Other studies have identified the preference for up-to-the-minute traffic information and specifically that provided by radio [7]. When asked if they would use a phone hot line, a cable TV station dedicated to traffic information, or a computer delivery system, only 34%, 25%, and 15% of commuters, respectively, answered yes. (A California study [1] found that far more of their sample (53%) desired a phone hot line, however that study was conducted by telephone.) Females, more than males, would use either a phone hot line or a dedicated cable TV station.

Most motorists (86%) preferred to see the development of a radio station dedicated to traffic information, then a phone hot line (7%), a dedicated cable TV station (4%), and a computer delivery system (1%).

Remarks

While our most significant discoveries in terms of information system design were to come through the cluster analysis described below, the statistical analyses described thus far were also useful. In addition, these analyses added considerable data to previous efforts which distinguished gender differences in driving behavior. Previous studies have indicated males are more flexible than females in terms of altering route while driving. This study replicated these findings, but went beyond them by indicating that females are more flexible and attentive to available information in terms of pre-trip choices. Thus, females may put more effort into pre-trip route selection, making them less likely to abandon that choice.

In terms of preference for traffic information, a large percentage of all groups preferred commercial radio as the medium. They also expressed a preference for development of a radio station dedicated to traffic information exclusively. Subsequent testing during the follow-up survey indicated, however, that increased familiarity with a graphical medium lead to a greater acceptance of and desire for motorist information delivered via that medium. It is crucial, therefore, to distinguish those results which represent an interesting slice of commuters at a particular time and place, from those results which will prove to be generally applicable.

RESULTS FROM THE CLUSTER ANALYSIS

This section describes how we separated commuters into groups of drivers with similar characteristics on certain variables. Of all the data generated during this project, the discovery through cluster analysis of distinct, stable motorist groupings with respect to driving behavior and information needs was the single most significant finding for the purpose of tailoring specific driver information for Puget Sound area commuters.

Cluster analysis is a statistical method that uncovers an underlying structure in a data set by grouping the cases or subjects into similar groups according to statistical distance measures. We used it to cluster commuters into previously unknown groups. The analysis concentrated on a particular set of variables that characterized the influence of traffic information on drivers with respect to departure time, route choice, and mode of transportation. The variables were elicited from the following questions:

* When you are on I-5, how often does traffic information cause you to divert to an alternate route?
* Before you drive, how often does traffic information influence the time you leave?
* Before you drive, how often does traffic information influence your means of transportation (e.g., car, bus)?
* Before you drive, how often does traffic information influence your route choice?

The overall objective was to partition the entire group of subjects into mutually exclusive and exhaustive subgroups based upon similar responses to these questions. The groups were then further investigated to uncover similar characteristics with respect to other variables not used in the original cluster analysis. Four driver groups proved to be stable both over other variables not used in the original cluster analysis and through subsequent in-person interviews of group members chosen at random.

Descriptions of the Driver Groups

Route changers (RC) often divert to an alternate route on I-5, and pre-trip traffic information often influences their route choice, but not the time they leave nor their means of transportation (20.6%). *Non-changers* (NC) rarely divert to alternate I-5 routes, and rarely or never change the time they leave, transportation mode, or route choice (23.4%). *Route and time changers* (RTC) sometimes divert to an alternate I-5 route, often change the time they leave or pre-trip route choice, but not the mode of transportation (40.1%). *Pre-trip changers* (PC) often alter the time they leave and pre-trip route choice, but rarely divert to alternate routes on I-5 (15.9%). PC are also the only group to show a tendency to change transportation mode in response to motorist information.

Drivers' Commutes and Route Choices

The RC group had the shortest commute, which may contribute to their freeway route flexibility. The NC group had the highest percentage of car-poolers (6%), which may in part account for the general inflexibility of that group. The PC group had the highest percentage of "couples" in the car (25%), which, if residents in the same household, may account for the higher likelihood to make commuting decisions before leaving the house.

With regard to *perceived stress*, people who change the time they leave (RTC and PC) experience more stress than those who do not (RC and NC). The RTC and PC groups also care more in general about their commute with respect to saving time, reducing commute distance, increasing commute safety, and increasing commute enjoyment. The concern and pre-trip flexibility of these two groups makes them prime candidates for home delivered motorist information.

The RC group is highest (73%) in terms of *familiarity* with north-south routes as alternatives to I-5 (the other three groups average around 60%). The RC and RTC groups had the highest responses (7%) in terms of frequently modifying or changing their route from home to work. As for modifying their route from work to home, as expected, the NC group scores the lowest on "frequently" and the highest on "rarely."

Effects of Various Factors on Route Choice

The RC group sometimes or frequently makes changes according to the following factors: actual congestion (89%), traffic reports/messages (86%), and time of day (65%). This group responds less so to time pressures (44%) or weather conditions (35%). The RTC and PC groups sometimes or frequently make route changes according to: traffic reports/messages (84%), traffic congestion (81%), time of day (66%), and, unlike the RC group, time pressures (57%). The NC group consistently responded highest on "rarely" and lowest on "frequently" for all factors.

Length of Delay Before Diverting to Known or Unknown Alternate Routes

The NC and PC groups had the highest means (around 17.5 minutes), the RC group the lowest (13.5 minutes) in changing to a known alternate route when stopped by congestion. The NC and PC groups had the highest means (27.4 minutes) while the RC group had the lowest (22.1 minutes) with respect to changing to an unknown alternate route.

Media from which Information Is Received

The majority of the RC, RTC, and PC groups never receive traffic information via television (65%-70%) with an even higher percentage of the NC group (83%) never receiving information from television. Around one-half of all groups, though more non-changers, claimed never to have received information from electronic message signs over I-5 (RC, RTC, and PC, 43%-45%; NC, 54%). One-half of the "changers" had never received information from HAR (52%-54%); 65% of the non-changers had never received such information.

From 78%-85% of all the groups preferred commercial radio as the medium for traffic information both prior to leaving and while driving. Television was the second choice prior to leaving home (12%-14%) and VMS was the second choice while driving (10%-12%).

Help from Traffic Information Delivered by Various Sources

Twenty-eight percent of the PC group found TV somewhat or very helpful as compared to 23% of RTC, 14% of RC, and only 7% of the NC group. This ordering of groups (PC, RTC, RC, NC) finding various media somewhat or very helpful followed for all cases, with VMS ranging between 40% (PC) and 28% (NC), HAR ranging between 39% (PC) and 19% (NC), and commercial radio ranging between 95% (PC) and 75% (NC). This ordering of groups is a significant pattern and occurs again for other variables.

Point of Preference for Receiving Traffic Information and Choosing Commuting Route

The PC group has the highest response (77%) preferring to receive information before driving. Pre-trip changers are also most likely of the groups (47%) to choose their commuting route at home or work, and the least likely (11%) to make a change en route. The RTC group has the second highest percentage (64%) preferring to receive information before driving; a lower percentage (35%) actually choose the route at home or at work, while half choose the route on city streets or near entrance ramps. The majority of the RC group are most likely to choose their commuting route on city streets or near entrance ramps. However, almost half prefer to receive traffic information at home or at work. About 10% of the NC group prefer to receive traffic information on I-5 as opposed to only 5%-3% for the other driver groups.

Use of Proposed Up-to-the-Minute Traffic Information

Ninety-three to ninety-six percent of the RC, RTC, and PC groups would use a dedicated radio station to access up-to-the-minute traffic information if such a medium were available, with the NC group at 84%. For using a proposed phone hot line, the three "changer" groups ranged from 30%-42% responding "Yes," the NC group was low with 23%. Use of traffic information delivered by computer elicited a large negative response (81%-85%). For a proposed cable TV station dedicated to traffic information, the PC and RTC groups averaged 32% "Yes", followed by the RC group (20%) and the NC group (16%).

Demographics for the Four Driver Groups

Gender of respondents: In terms of percentage of male respondents, the four driver groups were 61% (NC), 57% (RC), 46% (RTC), and 42% (PC).

Age of respondents: The RC and NC groups had the highest average age; the RTC and PC groups had a lower average age.

Income: The RC and NC groups displayed the highest household incomes.

RESULTS FROM THE IN-DEPTH, FOLLOW-UP SURVEY

Patterns Across the Entire Sample

Behavior and Decisions Prior to Departure

Commuters from the follow-up survey average approximately 70 minutes between the time they wake up and the time they depart for work. During that period they must accomplish at least one significant task other than preparing themselves to leave.

The majority of commuters surveyed (73%) receive traffic information of some kind at least three times during the period prior to their departure and half of the commuters report that they first receive traffic information pertaining to their primary route almost immediately after awakening.

While commuters receive traffic information, this information has less impact on their decisions prior to departure than one might expect. The majority of commuters in the follow-up survey rarely decide to use an alternate route (35%), rarely decide to use an alternate mode (10%), and rarely decide to change their time of departure (36%) based on information received at home. In an average month they change their route twice prior to departure.

Behavior and Decisions En Route

When asked to trace their commuting routes, commuters used five times as many street names as they did landmarks in describing their routes.

The overwhelming majority of the sample (98%) use I-5 as their primary route into the city. Of commuters who both knew of (95%) and used (75%) an alternate route, half reported that both their first and second alternate routes avoided I-5. Commuters on average reported knowing of between two and three routes that would serve as alternate routes.

The majority of commuters (59%) reported that they experienced low to moderate levels of stress on their primary route. If they decided to use an alternate route, 81% of commuters experienced a change in their level of stress, with 78% reporting increased stress.

While their choice of route was relatively stable, commuters reported making between one and two adjustments to their normal route each day, due to observed traffic congestion and reports of traffic congestion received in the car. Commuters made fewer adjustments to their alternate routes than to their primary route. The decision to use an alternate route was based first on traffic information received in the car and second on observed traffic conditions. Approximately one-quarter of the commuters who used alternate routes sought out information about the use of an alternate route while at home, more than 30 minutes before departing.

Commuters received little feedback regarding their choice to use an alternate route and what feedback they did receive was delayed. Nearly one-third of the commuters had no way of telling if their choice to use an alternate route was correct or incorrect. The majority of commuters indicated that if they did receive any kind of information confirming or refuting their choice to use an alternate route, they received it more than five minutes after making the choice. Only a small percentage of commuters (3%) indicated that they got this information from radio traffic reports.

Behavior Post-Commute

Commuters reported being late for work due to traffic conditions about four times in an average month. The majority of commuters (82%) indicated that the penalties for arriving late for work were relatively minor.

Patterns Across Commuter Groups

Members of the NC group indicated more frequently than members of the other groups that they did not know of any alternate routes to their primary routes. Members of the NC group also had lower levels of knowledge regarding their primary and first alternate routes than members of the other groups. The NC group tended to use more landmarks (as opposed to street names) in their descriptions of their primary routes. The NC group also used significantly more landmarks in their descriptions of their first alternate routes.

The RC group more actively seeks out information regarding traffic conditions on their primary route than the RTC, PC, and NC groups. However, members of the PC group seek out information regarding traffic conditions more frequently prior to departure.

The NC group indicated the least stress while on their primary route, followed (in order of increasing stress) by the RC, RTC, and PC groups. However, when using an alternate route, members of the RC group reported that their level of stress was likely to decrease, while members of the NC, RTC, and PC groups reported that their level of stress was likely to increase.

Patterns Across Gender

Females tended to have less flexibility in their departure time as well as less flexibility in their arrival time. Females also rated the period prior to departure as more hectic than males. Finally, females were more likely than males to be living alone.

Patterns Based on Commute Geography

Commuters entering southbound I-5 from SR520 and commuters entering between 110th and Alderwood tended to most actively seek out information regarding conditions on their primary route prior to departure. Commuters entering southbound I-5 between Alderwood and Everett tended to be least likely to actively seek out traffic information prior to departure.

Commuters entering southbound I-5 from SR-520 and commuters entering between 110th and Alderwood reported that their first alternate route tended to return at some point to the path of their primary route. Commuters entering southbound I-5 at Northgate reported that their first alternate route tended not to return to the path of their primary route.

Commuters entering southbound I-5 between SR-520 and 522 (Lake City Way) tended to use observations of traffic congestion and information from traffic reports to confirm or refute the advisability of their decision to use their first alternate route. Commuters entering southbound I-5 from between Alderwood and Everett lacked traffic information which could be used to confirm or refute the advisability of their alternate route decision.

Analysis of Responses to VMS Message Manipulations

The only significant difference in reaction time was observed for the comparison of specific versus generic tasks. When commuters were presented with a specific task (i.e., Accident Ahead, Use Roanoke), they responded faster than when presented with a generic task (i.e. Accident Ahead, Use Alternate Route). Commuters were also more likely to correctly interpret the message when presented with a specific task rather than a generic task; further, they were more likely to correctly interpret the message when the reason was presented before the task (i.e. Accident Ahead, Use Roanoke, rather than Use Roanoke, Accident Ahead).

A pattern in opposition to the pattern just discussed was observed for the probability of commuters changing route in response to the message. Commuters indicated that they would be more likely to change their route when the message presented a generic (rather than specific) task and when the task (rather than the reason) was presented first. Finally, commuters indicated that they would be most likely to change their route in response to a message if the message presented a generic reason and the task were absent.

Response to Graphical Display of Motorist Information

In response to graphical displays of congested traffic, the NC group indicated they would divert to another route the least often, followed (in increasing order) by the PC, RC and RTC groups. Subjects were most affected by screens which provided time estimates to their destination. Subjects also preferred text messages to actual pictures of traffic.

Time estimates, with a mean rank value of 1.8, (1 being most helpful and 5 being least helpful), were clearly preferred most by subjects. Text messages ranked second with a mean of 2.3 across all groups except the non-changers, who ranked text a close third. Photographs ranked third with a mean of 2.9, maps fourth with 3.2 and bar-graphs a distant fifth with 4.5. Bar graphs were chosen as least helpful by all groups.

The maps presented in screens were oriented in either vertical (North up), or horizontal (North to the right) positions. Approximately 87% of the subjects selected the vertical orientation. There was a distinct difference in preference across groups. The route and time changers as well as the pre-trip changers selected the horizontal orientation approximately 20% of the time, while route changers and non-changers selected it only about 4% of the time.

When subjects were asked if they would use a TV-based information service that provided screens similar to the ones they had just seen, approximately 81% answered yes. This response was quite uniform across groups: 86%, 82%, 81%, and 76% for PC, RTC, RC, and NC respectively. This was in marked contrast to the 25% who said they would use a dedicated cable TV traffic station in the first survey. Clearly, exposure to examples of graphically displayed traffic information increased subject receptivity. It is likely that positive exposure to traffic information delivered via any medium will increase public acceptance of that medium.

DISCUSSION

As has already been indicated, the findings reported above can be applied to solve practical design problems central to the development of an Advanced Driver Information System (ADIS) for the Puget Sound area.

There are two major ADIS development thrusts: (1) the collection, design, and delivery of real-time traffic information; and (2) the storage, display, and delivery of dynamic route guidance and vehicle navigation information. The effective delivery of both real-time traffic conditions and route guidance information together should contribute to the achievement of two goals: (1) improved short-term motorist response to incidents and peak hour congestion; and (2) long-term modification of commuter behavior for more efficient use of existing transportation resources.

Presently, WSDOT's Traffic Systems Management Center (TSMC) gathers traffic data via freeway sensors, closed circuit television, and police and bus reports. This helps DOT personnel to know almost immediately when and where a backup occurs and gives them a comprehensive picture of freeway traffic flow. However, this picture as currently put together and displayed is not in a form likely to impact commuter behavior, no matter how timely it is delivered. In particular, on-road traffic data from sensors needs to be converted into useful, effective motorist information before being delivered to drivers at appropriate decision points. On one hand, this conversion and delivery must be rapid enough so that the traffic conditions which generate the data are still in effect when drivers receive the information. On the other hand, the conversion must be sophisticated enough so that it produces information capable of impacting the behavior of sufficient numbers of drivers to improve the current state-of-affairs. Our survey findings suggest a number of design strategies for a conversion and delivery that will achieve both of these goals.

RESPONSE TIME, REAL-TIME, AND EFFECTIVE-TIME

It is difficult to describe the precise characteristics which qualify a system as "real-time," and while ADIS are often referred to as "real-time" systems, they differ in many respects from fully automated control systems. "Real-time" relates to a system's *response time*, the time it takes for the system to react to a stimulus from its environment. Some stimuli call for an "instantaneous" response. In practice, however, an "instantaneous" response is often neither necessary nor possible. Instead, "real time" requirements for a complex system depend upon the goals of the system and the conditions under which it must operate. Thus, a system to control a power-station boiler may require response to a temperature change in thirty minutes, while a missile control system must respond to a course change in milliseconds [8]. What ultimately matters is whether or not the system is able to improve the environment in which it is operating. For more complex systems, it may be more helpful to think in terms of *effective-time* rather than real-time.

The ADIS situation is extremely complex, making it difficult to determine its effective-time requirements (the response time required to effectively impact the operating environment). For an ADIS, the operating environment is the current traffic conditions of a given transportation system; the environmental stimuli consist of data about incidents, congestion, and traffic flow; and the system response, at least in one sense, is a broadcast or communication. The effective time of that communication--the length of time after which that communication will no longer be appropriate for the state-of-affairs which produced the stimuli--varies with the nature of the particular traffic problem, ranging from a few minutes to many hours. In addition to response time, an ADIS designer must be concerned with the issue of effective broadcast time, that is, the length of time over which a given message can be transmitted and still be effective. The shorter the response time of an ADIS, the longer the effective broadcast time. The longer the effective broadcast time of an ADIS, the greater should be the system's impact on existing traffic conditions.

The ADIS situation is further complicated by the fact that it is not a fully automated control system, particularly in the response mechanism. If the system response is viewed as a broadcast or message, as we have done thus far, then that response alone is insufficient to affect the operating environment. People are a crucial part of the "system response" since traffic conditions are ultimately affected only through the decisions of drivers to modify their behavior. Thus, in terms of actual impact of the operating environment, *human* response is a key component of ADIS response time.

From this perspective, it is probably not appropriate to think of an ADIS as operating in "real-time" at all. This does not mean, however, that an ADIS cannot operate in "effective-time." To accomplish this, algorithms for rapidly converting traffic data into motorist information must be established, and these algorithms must be based on a thorough awareness of motorist behavior and decision-making processes. This takes us from concerns about system response time to concerns about types of driver behavior to be modified, willingness of drivers to alter that behavior, possible alternatives, and the decision processes of commuters. In short, it takes us from concerns about data to concerns about information and communication.

It is precisely these concerns that our work has addressed, and converting traffic data to driver information is one area in which our findings can be immediately applied.

TRAFFIC DATA VS. DRIVER INFORMATION

No matter how sophisticated the communication technology used to construct an ADIS, it will be ineffective if the information delivered is inappropriate for the driver's situation. An ADIS must rapidly convert on-road traffic data into driver information, yet the design of this driver information must be driven by an understanding of motorist behavior, alternatives, decision processes, and information needs. Within this basic orientation, our work has identified and defined a number of distinctions which must be carefully considered when designing an ADIS. First, there are the types of decisions to be impacted. Assuming that an ADIS will deliver information both at home and on the road, there are four types of commuter choices that we are likely to affect: (1) selection of departure time, (2) selection of transportation mode (buses, trains, car pools, etc.), (3) pre-trip route choice, and (4) on-road route choice.

In addition to types of choices, there are also types of drivers. Motorists are not a single homogeneous audience for traffic information, but rather are a mix of complex sub-groups. Our work has identified four sub-groups of commuters, based on their willingness to adjust traffic behavior in response to motorist information.

A formal process for converting traffic data into driver information that meets the complex informational needs of these driver groups, and does it all in effective time, sounds like a formidable if not impossible goal. Fortunately, ADIS designers have a major advantage over most designers of technical information systems--it is neither necessary nor desirable to impact every driver who receives a given message. The primary goal of an ADIS is to improve system flow. Mass communications such as public relations messages and general information are at best secondary and at worst detrimental to the system. A practical emphasis on traffic flow, combined with an understanding of the distinct behavioral and decision-making driver types, points to an efficient and effective general strategy for converting traffic data into driver information--isolate the particular type of behavior we are trying to modify and then focus on those drivers who are most likely to alter that behavior.

At first glance, this strategy may appear limited because it seems to ignore large numbers of motorists who are unlikely to be affected by particular types of motorist information. However, the driver audience is extremely complex and diverse. Given the constraints of dynamic, effective-time information, there is insufficient time for creating motorist information designed to impact the full range of motorists with their diverse personalities, geography, travel needs, social situations, economic status, etc. More importantly, there is no need to do so. Significant improvement in freeway through-put can be achieved by impacting a relatively small percentage of drivers, while an identical change in too high a percentage would simply move the problem to another portion of the transportation system.

In addition to producing the desired impact, designing motorist information to meet the needs of targeted sub-groups of drivers is cost-effective as well. For each driving decision, there is a significant percentage of drivers who are not only unlikely to change, but are also less likely than other groups to *receive* relevant messages. At first glance, a traffic manager might see the 40% of non-changers who claim never to have received information relevant to their pre-trip route selection as an untapped audience to be targeted for motorist information efforts. One might argue "The information is there, the other commuter groups are receiving it, so if we can just make these non-changers aware of its existence, we might move them into another, more flexible group."

This argument to direct our energies towards re-educating driver groups would be valid if the primary goal of an ADIS was to impact as many drivers as possible. The primary goal, however, is to improve system through-put, and this can most efficiently be done by impacting a relatively small group of receptive motorists. The educational and communication efforts required to both reach and impact a group which is not only unlikely to modify driving behavior, but claims actually to never have received available information, far outweighs the benefits. This is especially true considering that our work has identified significant groups of commuters who are not only willing to modify driving behavior, but are also eagerly seeking information to help them do so. By targeting these flexible, highly motivated drivers, we can achieve a maximum improvement in traffic flow at a minimum cost in development effort and dollars.

The general strategy advocated here does not mean that the same group will always be targeted for all types of motorist information in all types of driving situations. Our research has shown that, except for the non-changers, different driver groups are most flexible and motivated relative to different driving decisions. Thus despite this focused approach, a single successful motorist information system will meet the needs of a wide range of motorists under varying conditions and stages of travel. This strategy does mean, however, that a single integrated motorist information system will consist of carefully designed information modules, delivered through the appropriate media and targeted to address particular commuting decisions of carefully studied and defined subgroups of receptive commuters.

DESIGNING FOR TARGET AUDIENCES

The general issue of how to design motorist information to impact a target audience is closely tied to the type of motorist information at our disposal and our understanding of the behavior and decision-making factors of the target commuters. Differences in commuter behavior are not the only issue. Other factors such as geographic location and timeliness of information also play important roles in the delivery of effective traffic information to commuters. However, commuter characteristics are crucial.

Some susceptible commuter groups are quite distinct. Table 2 reemphasizes the startling split in Seattle commuters' willingness to alter the time they begin their commute. Less than 1% of *RC* and *NC* (11 of 1,588) indicate a willingness (*frequently* or *sometimes*) to adjust the time they leave for work based on traffic information, as opposed to over 99% of *RTC* and *PC* groups (2,010 of 2,018).

Table 2. How traffic information influences departure time

	Frequently	Sometimes	Rarely	Never Receive
RC	0	0	691 (92.9%)	53 (7.1%)
NC	1(0.1%)	10 (1.2%)	471 (55.8%)	362 (42.9%)
RTC	296 (20.5%)	1145 (79.2%)	5 (0.3%)	0
PC	177 (30.9%)	392 (68.6%)	3 (0.5%)	0
All	474 (13.2%)	1547 (42.9%)	1170 (32.4%)	415 (11.5%)

If we look at the combined data for all surveyed commuters, there appears only to be an extreme diversity in commuters' willingness to alter departure time based on traffic information received at home. Based on our awareness of commuter types, however, we can identify a sub-set of commuters and study those factors which influence their departure time. Then, if we can deliver information that speaks to these factors, we can be confident of a high degree of success in influencing when they begin their commute.

We have identified the RTC and PC groups as highly susceptible audiences for home delivery of motorist information that will alter their departure time. How does this actually help in creating algorithms for converting real-time traffic data into effective motorist information? Based on our survey of Seattle commuter behavior and decision-making, we know a number of ways in which the RTC and PC groups tend to differ from the other two commuter groups. From these and other survey results, we can come to some conclusions about these motorists who are most likely to alter the time that they begin their commute. These conclusions then become the basis for converting traffic data into motorist information.

There are essentially two ways that people can alter their departure time. If their arrival time is flexible, they can delay their departure until after congestion has died down. If their arrival time is rigid, they can judge if there are unusual delays due to incidents or congestion and leave earlier so as to meet their arrival deadline. Time changers (RTC and PC) who commute to Seattle from the north are clearly of the latter variety. They tend to be female; have lower household incomes; have longer, more complex commutes; care more about commute time, distance, safety, and enjoyment; and experience higher levels of stress during their commute. They are people with less control over their working environment and for whom the daily commute is a major component of their day. They worry about arriving on time, and after deciding to change route and departure time their stress increases, not decreases.

Information like this leads to a picture of a significant group of commuters who are under stress to complete their commute at a set time. These people want their information at home. Their commute begins as soon as they get up and they start gathering information through TV (the PC group is the highest percentage users of TV information) and radio in an effort to determine if they have to alter their usual pattern of commute. Over a third of the PC group is even willing to change mode if necessary, the only group of the four with a significant willingness to make this effort. In fact, time changers care more about *everything* related to motorist information. They also are more likely to receive relevant information at home and to find it helpful.

This picture of the two groups willing to alter departure time tell us how to speak to them and what they need to know. They are under pressure to complete a complex commute on a rigid schedule, and we need to speak to that need. Most importantly, they need to know commute time information. Ideally, they need to be told what time they would arrive if they left right now under current conditions following their primary route. They also need to know time estimates for alternate routes and alternate modes of transportation, and they need feedback to reduce stress and reinforce modifications to their usual travel routines. Spoken to appropriately, the PC and RTC groups are flexible before leaving the house, and they will change departure times, routes, and even modes of travel (PC) if it is necessary to arrive on time.

To impact different driver decisions, we need to employ different information design and delivery strategies. If the goal is to spread out the time over which a given volume of commuters uses a particular freeway corridor, then the primary target audience will be commuters who use that corridor and are particularly susceptible to changing departure time. However, if the goal is to divert traffic off a stretch of a freeway, then the primary target audience will be commuters approaching that stretch of freeway who are particularly susceptible to altering route while driving.

Non-time changers (NC and RC) versus time changers (RTC and PC) is one way that commuters can be grouped when designing information to impact departure time, but it is not an appropriate grouping for all motorist behavior. "En route changers" (RC and RTC) compared to "non-en route changers" (NC and PC) is another interesting grouping which becomes important when we are considering how to design motorist information to impact on-road route modifications in response to incidents and congestion. As we know more and more about commuter groups, we discover more and better ways to design efficient motorist information systems that meets their needs.

CONCLUSION

The process of converting traffic data to motorist information can be simplified and made more effective by targeting those sub-groups of drivers who are most likely to be impacted. Our findings about commuter groups and their informational needs have significantly contributed to the application of this strategy.

Given these findings, it becomes clear that the creation of a mechanism for gathering real-time traffic data is only the first step in the creation of an ADIS. Subsequent steps must be directed towards (1) isolating the particular driver decision to be affected by each message; (2) identifying those drivers who are highly flexible and motivated on that issue; (3) determining on what basis their decision is made; (4) creating an algorithm for converting on-road data to information that addresses this decision process; (5) determining where the decision is made; (6) delivering prior to that point, at a time when it can be used, information designed to meet the decision-making needs of the targeted drivers; and (7) delivering after that point feedback that reinforces driver decisions by telling them the consequences of their decision.

IMPLEMENTATION

1. We should extend our survey of commuter behavior and traffic information beyond the north I-5 corridor of Seattle to the rest of the Puget Sound area. By studying two additional corridors, the Seattle in-bound commuters on the southern I-5 corridor and the east/west commuters on the I-90 and SR520 corridors, and by using the survey methodology and instrument developed in our initial work to assure comparable data, we would produce a complete analysis of Seattle freeway commuter behavior and decision-making. In addition, because this information has applicability beyond the development of motorist information systems, it should be analyzed and shared with state agencies, lawmakers, and public groups, to help shape state transportation policy.

2. We should develop a front end interface to the TSMC's system for gathering and displaying real-time traffic data. This front end should be PC based, and should be capable of converting existing traffic data into information tailored to impact various commuter groups and their choice of route, mode, and time of commute. Throughout development, formal usability testing should occur to assure that the user interface displays motorist information in a form capable of impacting the specific driving decision of a targeted commuter group.

3. We should select and develop home delivery mechanisms (e.g. dedicated cable TV, teletext, dedicated radio, home networked computer services, telephone system) for delivering the information produced by the system front end.

4. We should link and coordinate the mechanisms by which we deliver driver information both on-road and at home. In particular, we should provide feedback to confirm the reliability of motorist information and to reinforce driver decisions based on that information.

5. We should develop and implement state-wide guidelines for HAR and VMS.

6. We should conduct additional research on motorist response to traffic messages, varying not only message types, but media as well.

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