Motorist Behavior and the Design of Motorist Information Systems

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Results are described of an in-person survey of Seattle commuters on the topic of motorist behavior and decision making. Three broad areas were of interest: (a) behavior and decisions of commuters relative to their choice of route before departure; (b) behavior and decisions of commuters while driving; and (c) responses of commuters to manipulations of variable-message sign messages. Results indicated that all commuter groups were familiar with alternative routes, but rarely used them during actual commutes. In addition, commuters who did use alternate routes reported higher levels of stress during their commutes in comparison with traveling primary routes. Changes in primary routes were generally in response to congestion actually observed by commuters rather than to information provided by existing traffic information sources. Further, commuters rarely changed mode of transportation or time of departure on the basis of currently available information received at home before departure. These findings point to specific issues that need to be addressed in the design of future motorist information systems.

As politicians, planners, and engineers in major metropolitan areas have struggled to meet the transportation needs of their citizens, emphasis has been placed on surveying the commuting population to increase the available knowledge of general driving characteristics (*1–7*). These surveys have tended to focus on demographic features of the population, such as age, sex, and income. The critical problem with this general approach is that often the assumption is made that the commuting population can be treated as a homogeneous audience of motorists with respect to driving behaviors, decision processes, and needs for traffic information.

In fact, motorists cannot be treated as a homogeneous population. As demonstrated by more recent approaches to the analysis of commuting behavior (*8,9*), including studies of motorist behavior in the metropolitan Seattle area (*10,11*), stable subgroups of the commuting population can be identified and the identification of these subgroups can be used (among other purposes) to optimize the means of delivering traffic information to members of these subgroups. By basing the design of motorist information systems on knowledge of the behavior of identifiable subgroups of commuters, traffic planners can deliver user-based traffic information with the goal of allowing drivers to make decisions that will result in fewer delays for individual motorists and an overall improvement for commuters in general (*12*).

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Procedures and results of an in-person interview of Seattle commuters on motorist behavior and decision making are described. The survey used a random sample of commuters (n = 96) drawn from a larger sample of motorists (n = 1,697) who participated in an earlier and more general study of motorist behavior and information needs.

BACKGROUND

In September 1988, investigators from the University of Washington's College of Engineering, in cooperation with traffic engineers from the Washington State Department of Transportation (WSDOT), conducted a major study of the commuting population in metropolitan Seattle. The goal was to provide a set of recommendations aimed at improving the design and delivery of traffic information, thereby increasing the likelihood of changing commuters' driving behavior and improving the flow of peak-time traffic. Nearly 4,000 drivers who commute into downtown Seattle on southbound I-5 completed mail-in surveys, allowing the investigators to gather results on 62 variables relevant to motorist behavior and the impact of available motorist information on commuters' route decisions. Motorists commuting from areas north of downtown Seattle were selected for the sample frame because they have access to a range of motorist information sources, including commercial radio, highway advisory radio (HAR), and variable-message signs (VMS).

Using a multivariate statistical procedure termed cluster analysis, the investigators identified four commuter subgroups (clusters) based on commuters' willingness to adjust their driving behavior in response to traffic information (*13*). The four clusters were defined as follows:

1. Route changers (20.6 percent), those willing to change their commuting route on or before entering I-5;
2. Nonchangers (23.4 percent), those unwilling to change departure time, transportation mode, or commuting route;
3. Time and route changers (40.1 percent), those willing to change both departure time and commuting route; and
4. Pretrip changers (15.9 percent), those willing to make time, mode, or route changes before leaving the house but unwilling to change en route.

Route changers often divert to an alternative route on I-5 and report that traffic information often influences their route choice but not their departure time or transportation mode. Nonchangers rarely divert to alternative I-5 routes and rarely or never change their departure time, transportation mode, or commuting route. Time and route changers sometimes divert to an alternative I-5 route, often change their departure time and commuting route, but rarely change their transportation mode. Pretrip changers often alter their departure time and sometimes change their transportation mode, but rarely divert to alternative routes once on I-5.

Whereas the cluster analysis was conducted to identify groups of commuters based on their willingness to adjust their commute in response to traffic information, further analysis was conducted to determine commonalities among commuter responses in the survey. A principal components factor analysis of the correlation matrix from the original data set revealed a five-factor solution across the 62 variables (*11*):

1. Issues affecting route choice;
2. Distance-time information;
3. Traffic information, particularly TV and radio;
4. Traffic information, particularly VMS, HAR, and telephone hot line; and
5. Commute attributes and flexibility.

This initial survey provided an extensive amount of data on commuter behavior. The survey revealed that the commuting population of metropolitan Seattle is diverse and cannot be treated as a homogeneous audience for motorist information, yet it is composed of stable subgroups. However, this initial survey also raised a number of interesting questions, which the in-depth interview was designed specifically to probe. These questions assessed flexibility in departure and arrival time, commuters' specific knowledge of primary and alternative routes, and detailed characteristics of the commute. From the original survey, cluster analysis provided a means of conceptualizing the design of the in-depth survey and principal components factor analysis indicated that additional information was required regarding issues that might affect route choice.

METHOD

Subjects

Subjects were recruited from a portion of the initial survey respondents who indicated a willingness to participate in an in-depth study. Of the 3,893 respondents in the initial survey, 1,697 agreed to the in-depth study. Subjects in the original survey entered I-5 on one of the seven downtown exits.

In order to be included in the original sample frame, motorists had to (a) travel south on some portion of the north I-5 corridor to downtown Seattle during peak morning commute hours (6:30 to 9:00 a.m.), (b) travel this corridor at least once each week, and (c) be the driver of the commuting vehicle. This group of commuters allowed focusing on drivers exposed to a variety of highway information sources and drivers with a variety of end points for their commutes.

Subjects for the in-depth survey were selected at random from each of the four clusters identified in the initial survey, in numbers proportional to the original cluster sizes. Table 1 presents the distribution of subjects according to sex and cluster membership. Of 120 subjects who were recruited, 96 subjects participated, an 80 percent participation rate.

Variables of Interest

The in-depth interview probed three broad areas of interest, on the basis of the analysis of responses to the initial survey:

1. Behavior and decisions of commuters relative to their route choice before departure,
2. Behavior and decisions of commuters while driving, and
3. Responses of commuters to a set of syntactic and semantic manipulations of messages that might be displayed on VMS.

The survey was limited in temporal scope to the time of the inbound commute. This decision was partially based on the initial observation of significant differences in commuters' flexibility in departure on the morning commute with minor differences observed for the afternoon commute. Also, because the literature on survey methods indicates that the total in-person interview time should be less than 1 hr for all aspects of an interview [e.g., see work by Sharp and Frankel (*14*)], probing both inbound and outbound commutes was deemed infeasible.

Behavior and Decisions Before Departure

The first set of questions investigated the behavior of and decisions made by commuters in the period before departing for work. In order to understand the environment in which

TABLE 1 SAMPLE DISTRIBUTION ACCORDING TO SEX AND CLUSTER

Cluster	Males	Females	Total	% of Total
Route changers	14	12	26	21.9 (*20.6*)
Non-changers	10	12	22	22.9 (*23.4*)
Time and route changers	12	15	27	28.1 (*40.1*)
Pre-trip changers	11	10	21	21.9 (*15.9*)
	47	49	96	
	49% (*49%*)	51% (*51%*)		

Note: Numbers in italics indicate percentages each cluster represented in the original survey.

pretrip information is received and used, the amount of time that commuters have before departure was examined along with the number and type of demands experienced by commuters during that time. Commuters were asked to estimate the time they normally awaken and normally leave for work. These estimates were used to calculate the average amount of time that commuters have before departure. Commuters were also asked to estimate the number of significant tasks completed during this period. Significant tasks were defined as any tasks outside of those completed in preparation for departure. Commuters were also asked to give subjective estimates of the amount of stress experienced during the period before departure and the amount of flexibility in determining departure time.

Also included in this first set were questions probing access to and use of traffic information during the period before departure. Commuters were asked to describe how actively they seek traffic information, how frequently they receive traffic information, and how they make decisions on the basis of that information. Commuters also estimated the amount of time between first receiving information and departing. Commuters were then asked about their decisions to alter choice of route, mode, and departure time.

Behavior and Decisions En Route and After Commute

The second set of questions probed commuters' behavior and decisions during the commute between home and work. Commuters were asked to orally describe one primary and two alternative routes (if known and used) and to trace those routes on detailed street maps. Commuters' knowledge of the routes was assessed by counting the number of landmarks, street names, and compass directions used in their descriptions of primary and alternative routes, a method suggested from human factors investigations of route knowledge, navigational skills, and map reading (*15,16*).

Tallies were made of the total number of decision points on primary and alternative routes. Decision points were defined as points where drivers might need to make adjustments to their routes. Commuters were asked to report their reasons for altering routes at each of the decision points and their use of traffic information (including their subjective observations of traffic conditions) in making choices. Additional questions probed sources of information used to either confirm or refute decisions to alter routes. The final items in this set of questions probed commuters' perceptions of flexibility in arrival time, penalties for arriving late, and stress of using alternative routes. Commuters were also asked to estimate the number of times they arrived late for work each month because of traffic conditions.

Syntactic and Semantic Manipulations of Sign Content

The third set of questions probed commuters' responses to syntactic and semantic manipulations of messages that might be displayed on VMS. Two messages that WSDOT typically displays on a VMS located above southbound I-5 just north of downtown Seattle were used as the basis for the two sets of manipulations.

The first set of manipulations involved two variables known to affect task performance—task instruction and message order (*17–19*). Two types of task instruction were presented—specific and generic. Messages that presented specific task instructions suggested a specific alternative route in response to a traffic situation (e.g., Use I-90 Eastbound); messages that presented generic task instructions suggested a general response (e.g., Use Alternate Routes). The order of messages was randomized so that the task instruction (either generic or specific) appeared either before or after the reason (the description of the traffic problem).

The second set of manipulations involved the type of reason presented in the message and the presence or absence of the task (the response to the traffic situation). Two types of reasons were presented, specific and generic. Messages that contained specific reasons presented a specific description of the traffic problem (e.g., Accident at Mercer Street Exit); messages that presented generic reasons gave a more general description (e.g., Accident Ahead). Messages were manipulated to present either a suggested response to the traffic situation or a general statement (e.g., Expect Delays).

Messages were printed in 24-point Helvetica bold on 8½- × 11-in. white paper in landscape orientation using a laser printer. Commuters' interpretation of sign content and indication of a probable response to the message were used as dependent measures rather than recall, following observations by human factors researchers indicating superiority of reaction behaviors to recall in assessing significance of sign content (*20,21*).

Survey Administration

The choice of survey administration method considered a number of issues: demands placed on the subjects, reinforcement of subjects, reliability, response mode, and tone and presentation. The in-person format was selected on the basis of a review of the literature and after considering the issues surrounding the types of questions to be asked. A number of authors have suggested that as demands placed on the respondent are reduced, the quality of responses increases (*14,22*). Babbie (*22*) notes that not only do in-person interviews have higher response rates than other survey methods, but that in-person interviews also allow the interviewer to clarify questions when the respondent is confused. Additionally, in-person interviews allow a wider set of responses to items in the survey.

In-person interviews allow subjects to be positively reinforced for their participation, both at the outset and at the conclusion of the interview, thus increasing subjects' sense of the importance of their contribution to the survey. Sharp and Frankel (*14*) note that if subjects perceive their contributions to be important, responses will be of higher quality.

Although in-person interviews have numerous advantages, threats to internal validity must be controlled. The nature of in-person interviews can create a lack of reliability in response sets caused by inconsistencies among interviewers and among interview sessions conducted by individual interviewers. Two steps were taken to control for these two threats to validity. First, interviewers were trained by one researcher and were required to meet specific criteria before interviewing commuters. Second, interviewers worked from a written questionnaire that specified all interviewer prompts and provided categories for recording commuter responses.

The formal training of interviewers occurred in two parts. The first part of the training consisted of the trainer reading each of the questions aloud, as they should be read to commuters, and discussing the possible responses. During this part of the training, the trainer also discussed timing and preparation for the interview. The second part of the training required the trainee to interview the trainer. The trainer was prepared with a set of difficult or ambiguous responses to a number of the interview questions. The trainee was required to respond to and code the responses correctly two times without error before being considered trained on a specific question. Each interviewer received approximately 3 hr of direct training before interviewing commuters. In addition, each interviewer was required to have partially memorized the scripted portions of the interview before the formal training. Once trained, interviewers were debriefed by the trainer following randomly selected interviews to determine if any retraining was required.

The tone of the interview was intended to be conversational but neutral. Interviewers were to present themselves as interested professionals to enhance commuters' sense of the importance of their responses without encouraging specific response patterns.

Subjects were interviewed individually at the University of Washington. They were informed that participation was voluntary and that they could take a break or terminate the interview at any time.

Data Coding and Analysis

All categorical variables were coded for data entry following completion of the entire set of interviews. A standardized coding protocol was established in advance, assigning numeric codes to the categories of responses in each of the interview questions. Coding of all interviews was completed by two research assistants. Coding accuracy was subsequently checked and all errors were corrected before data entry. All statistical analyses were conducted using the SYSTAT statistical software system.

RESULTS AND DISCUSSION

Data obtained in the in-depth interview were analyzed in a manner similar to the data analysis completed for the first survey. Responses were examined for patterns across the entire sample and were further examined for patterns across clusters and sex. Finally, a principal components factor analysis was conducted to reveal commonalities of responses.

Patterns Across the Entire Sample

Behavior and Decisions Before Departure

Commuters reported that they have approximately 72 min (M = 71.969, SD = 32.391) between the time they wake up and the time they depart for work. During that period, commuters must accomplish at least one significant task (M = 1.063, SD = 1.296) other than preparing themselves to leave, such as preparing breakfast for other members of the household. The majority of commuters reported that they perceive this period to be relatively calm (60.42 percent rated the period as a 1 or 2 on a 5-point scale of hecticness) and relatively stress free (66.67 percent rated the period as a 1 or 2 on a 5-point scale of stress).

The majority of commuters (72.92 percent) receive traffic information of some kind during the period before departure and reported that traffic information is first received soon after awakening. Half of the commuters reported receiving traffic information pertaining to their primary route almost immediately after awakening. An additional 10 percent (for a total of 61.43 percent) reported that they receive their first traffic information more than 1 hr before departure. Commuters reported receiving traffic information at least three times (M = 3.059, SD = 2.143) between awakening and departing. Although commuters reported that they are aware of traffic information, they reported that the information has little impact on their decisions before departure. The majority of commuters reported that they rarely decide to use an alternate route (65.71 percent), that they rarely decide to use an alternate mode (90.00 percent), and that they rarely decide to change their departure time (64.29 percent) on the basis of information received before departure. In an average month, commuters reported that before departure they decide to change their route twice (M = 2.333, SD = 2.666). Although these results might indicate that a large number of Seattle commuters are unresponsive to traffic information delivered before departure, the results also indicate that an important proportion of commuters could be influenced by predeparture traffic information. Indeed, if traffic information could influence one-third of Seattle commuters to change their departure time or route choice or one-tenth to change transportation mode, significant improvements in peak-time traffic conditions could result.

On the whole, commuters are somewhat receptive to traffic information delivered before departure. Commuters reported that the period before departure is not stressful and that they have a relatively small number of tasks to accomplish. The low rate of modification to route, mode, and departure time may indicate that while receiving traffic information, commuters may receive the information passively and may not find it credible. This second inference is supported by comments to this effect received from commuters on the initial survey (*10*). The low rate of route modification may as well be caused by temporal delay between receipt of the information and decision because the majority of commuters reported receiving their first traffic information more than 1 hr before departure.

For purposes of designing an information system, these results reinforce the notion that demonstrating system credibility may be a significant issue. Further, these results indicate that commuters may have time to use an interactive graphical traffic information system, one that would demand some active engagement.

Behavior and Decisions En Route

Commuters indicated a high degree of knowledge about their primary commuting route and their first and second alternative routes. Alternative routes were defined as major deviations from the primary route that could, however, include a small portion of the primary route. Thus, an alternative route could include a portion of I-5. Indications of route knowledge were obtained from counts of the number of landmarks and street names used when commuters described their commuting routes. Results support the intuitive prediction that commuters have a more detailed knowledge of their primary route than of either their first or second alternative routes. For example, when asked to trace their commuting routes, commuters used five times as many street names as they did landmarks in describing their routes. Table 2 presents the means and standard deviations for number of street names and landmarks used by commuters to describe their primary route and their first and second alternatives.

Of commuters who both know and use an alternative route, half reported that their first and second alternative routes avoid I-5 (52.94 percent for the first alternative route, 50.90 percent for the second alternative route). The vast majority of commuters (95.83 percent) reported knowing an alternative to the route that would be used if a large portion of their normal route were inaccessible for some reason. On average, commuters reported knowing between two and three alternative routes (M = 2.880, SD = 1.568). However, only 75.00 percent of those interviewed reported that they actually use one of those alternatives.

Commuters reported that the decision to use an alternative route is based first on traffic information received in the car (33.28 percent for the first alternative route, 35.09 percent for the second alternative route) and second, on observed traffic conditions (23.53 percent for the first alternative route and 21.05 percent for the second alternative route). Interestingly, approximately one-fourth of the commuters who use alternative routes reported that they seek out information about the use of an alternative route while at home, more than 30 min before departing (26.87 percent for the first alternative route, 24.56 percent for the second alternative route).

Commuters reported receiving little feedback regarding their choice to use an alternative route and what feedback they do receive is relatively delayed. Nearly one-third of the commuters indicated that they have no way of telling if their choice to use an alternative route is correct or not (27.94 percent for the first alternative route, 31.58 percent for the second alternative route). The majority of commuters indicated that if they do receive any kind of information confirming or refuting their choice to use an alternative route, they receive this information more than 5 min after making the choice (69.57 percent for the first alternative route, 48.72 percent for the second alternative route). Only a small percentage of commuters (2.94 percent) indicated that they receive this information from radio traffic reports.

Commuters reported making between one and two adjustments to their normal route each day (M = 1.552, SD = 1.897). Adjustments were defined as minor deviations from the primary route that necessarily include a return to the primary route. Primarily, route adjustments are made in response to observed traffic congestion and reports of traffic congestion received in the car (i.e., radio traffic reports). At the first decision point, observed traffic congestion was cited by 39.47 percent of commuters as the reason for adjusting routes, whereas traffic information was cited by 35.71 percent of commuters. At the second decision point, the percentage of commuters who respond to observed traffic conditions as opposed to traffic reports is even greater: 54.76 percent cited observed traffic conditions as the reason for making their second route adjustment, whereas 23.81 percent cited traffic information received in their cars. If they commit to using an alternative route, commuters reported making fewer adjustments to their alternative routes than they do to their primary route (for the first alternative route, M = 0.647, SD = 1.182; for the second alternative route, M = 0.474, SD = 0.928).

On the whole, commuters reported having few tasks (M = 0.611, SD = 0.982) to complete (such as dropping off a family member) on their normal drive into the city. Although the majority of commuters (58.95 percent) reported experiencing low to moderate levels of stress on their primary route, approximately one-third of the commuters (33.68 percent) reported experiencing relatively large amounts of stress on their primary route. If they decide to use an alternative route, 77.78 percent of commuters reported that the level of stress experienced increases. Thus, making the choice to use an alternative route (and, perhaps, the driving conditions that lead to that choice) appears to be perceived as a stressful event.

The patterns observed for all commuters indicate that commuters have a high degree of knowledge of their primary and alternative routes, that a majority do at some time make use of alternative routes, and that nearly half of the alternative routes make use of some portion of I-5 (the primary route used by commuters into downtown). Commuters appear to make a small number of adjustments to their primary route, mainly on the basis of their observations of traffic conditions. However, commuters appear to decide to use an alternative route on the basis of traffic reports received either at home or in the car. Commuters receive little feedback regarding their choice to use an alternative route and, when received, this feedback is delayed. Finally, commuters are not burdened with tasks other than commuting to their workplace, and

TABLE 2 NUMBER OF NAMES AND LANDMARKS IN ROUTE DESCRIPTIONS

		Primary Route	Alternate 1	Alternate 2
Street names	Mean	8.45	5.02	4.26
	SD	6.23	3.70	4.01
Landmarks	Mean	1.67	1.03	0.79
	SD	1.89	1.48	0.90

approximately one-third of all commuters experience high levels of stress, with the perceived level of stress increasing if they use an alternative route.

The implications for design of an information system for commuters en route are somewhat similar to those for an information system designed for commuters before departure. Although commuters do rely on traffic reports, they require that the information be more current and more specific than the information currently available and that the accuracy of information be verified through feedback. These findings parallel results and recommendations reported nearly two decades ago (*23*). Increasing currency and specificity might well increase the probability that commuters would choose an alternative route (as opposed to merely making minor adjustments to the primary route). Incorporating feedback mechanisms into on-road systems for delivering information might also increase their effectiveness in encouraging commuters to choose alternative routes.

Behavior After Commute

Commuters reported that they are late for work because of traffic conditions approximately four times in an average month (M = 4.097, SD = 4.099). When asked to rate their flexibility in arrival times, commuters responded with answers that were distributed evenly across a 5-point scale, indicating no particular pattern. The majority of commuters (82.29 percent) indicated that the penalties for arriving late for work are relatively minor (rating the penalties as either a 1 or 2 on a 5-point scale).

Summary of Implications for the Design of Information Systems

This description of the behavior and decisions of commuters before departure, en route, and after the commute has a number of implications for the design of information systems:

1. Commuters may benefit from two different types of information systems, one used predeparture and one used en route;
2. These two systems should be integrated to provide feedback and confirmation of accuracy; and
3. The information transmitted needs to be current and specific to be used and acted on.

However, these implications are somewhat limited in scope and do not address the need to change commuter behavior under specific conditions. The analyses reported in the following sections (patterns across commuter group and sex and the patterns observed in the factor analysis) provide a more detailed view of commuter responses and underscore the idea that commuters are not a homogeneous population with uniform traffic information needs.

Patterns Across Clusters

Group membership for each commuter participating in the follow-up survey was determined on the basis of cluster analysis performed on the data from the initial survey. The four clusters were defined as (a) route changers (RC), (b) nonchangers (NC), (c) time and route changers (TRC), and (d) prechangers (PC). Responses of the commuters participating in the follow-up survey were examined to determine if there were any significant differences in behavior and decisions attributable to cluster membership. This section reports those analyses that produced results significant at $p \leq 0.05$; results with probability values >0.05 but ≤ 0.10 are reported as trends.

A Kruskal-Wallis test for group differences revealed that clusters differed with respect to flexibility in departure time. Table 3 presents the Kruskal-Wallis statistics, rank values, and probability values for the comparisons reported. As Table 3 indicates, clusters differed significantly in flexibility with regard to departure time—the TRC cluster had the highest

TABLE 3 KRUSKAL-WALLIS COMPARISONS

	Rank Value			
	RC	NC	TRC	PC
Flexibility in departure time, $H = 10.846$, $p \leq 0.013$	1328.0	661.5	1560.5	1106.0
Likelihood of changing route due to information received prior to departure, $H = 10.337$, $p \leq 0.016$	700.5	252.0	866.0	666.5
Knowledge of alternate routes, $H = 7.376$, $p \leq 0.061$, *trend*	1313.0	916.5	1366.0	1060.0
Actively seek information on primary route, $H = 6.863$, $p \leq 0.076$, *trend*	876.5	477.0	617.0	514.5
Seek information prior to departure, $H = 9.757$, $p \leq 0.021$	493.0	209.0	632.0	319.0
Stress on primary route, $H = 7.650$, $p \leq 0.054$	1143.0	902.0	1211.0	1304.0

flexibility, followed by the RC, PC, and NC clusters. Members of the TRC cluster are also significantly more likely to change their route on the basis of information received before departure. The TRC cluster was followed, in terms of decreasing probability of changing route on the basis of information received before departure, by the RC, PC, and NC clusters, a pattern similar to the response to the departure flexibility question.

A one-way analysis of variance (ANOVA) revealed differences between clusters in terms of the number of times cluster members choose an alternative route in an average month, $F(3, 74) = 4.111$, $p \leq 0.009$. A Tukey HSD comparison revealed that although there was no difference between members of the TRC and PC clusters (TRC M = 3.29, PC M = 3.40), members of both clusters select an alternative route more frequently in an average month than members of the NC cluster (M = 1.10), (TRC versus NC, $p \leq 0.0319$; PC versus NC, $p \leq 0.0318$). Finally, a Kruskal-Wallis test for group differences indicated that members of the NC and PC clusters tended to have less route knowledge than members of the RC and TRC clusters ($p \leq 0.061$).

The Kruskal-Wallis test revealed a trend ($p \leq 0.076$) for members of the RC cluster to more actively seek out information regarding traffic conditions on their primary route. The RC cluster was followed by the TRC, PC, and NC clusters. However, members of the TRC cluster seek out information regarding traffic conditions more frequently before departure than (in order) members of the RC, PC, and NC clusters.

An ANOVA analyzing the number of landmarks used to describe the first alternative route revealed significant differences among the clusters, $F(3, 64) = 3.413$, $p \leq 0.023$. A Tukey HSD comparison revealed that members of the NC cluster used more landmarks (M = 2.083) in describing their primary and first alternative routes than members of the other clusters (RC M = 1.143, PC M = 0.6471, TRC M = 0.5556). A heavier use of landmarks as opposed to street names indicates that NC cluster members possess a less detailed knowledge of the route (*15,16*). A trend was also observed for members of the NC cluster to use more landmarks (as opposed to street names) in their descriptions of their primary routes, $F(3, 92) = 2.308$, $p \leq 0.082$.

Although members of the NC cluster appear to have less knowledge of their primary and first alternative routes, they also appear to experience less stress when using their primary route ($H = 7.650$, $p \leq 0.054$). The NC cluster was followed (in terms of increasing stress on the primary route) by the RC, TRC, and PC clusters.

These findings more fully complete the picture of the commuter groups identified in the initial survey and tell more about targeting information for these groups. For example, data from the first survey indicate that NC cluster members found traffic information received at home less preferable and had less positive reactions to messages and media. Results from the in-depth survey indicate that members of the NC cluster are more likely to use landmarks than street names in describing their commuting routes, indicating less knowledge of these routes. Because the majority of available traffic information sources rely heavily on the use of street names in the description of routes, members of this cluster would be less likely to find the information usable. Thus, an information system targeting members of the NC cluster might need to provide more graphic information, including real-time displays of traffic situations, such as live video displays of traffic conditions. The information system might also need to provide greater levels of information regarding alternate routes (perhaps even offering an option that would increase commuters' familiarity with the available routes, in the fashion of a tutorial).

Patterns Across Sex

Only a small number of sex differences were uncovered in the analyses of the responses to the in-depth interview. Women indicated that they have less flexibility in the time of arrival ($\chi^2(5) = 12.599$, $p \leq 0.014$) and that they tend to have less flexibility in the time of departure ($\chi^2(4) = 8.700$, $p \leq 0.069$). Women also tended to rate the period before departure as more hectic than did men ($\chi^2(4) = 9.187$, $p \leq 0.057$).

These findings imply that women, having greater time demands placed on them, need an information system that provides time estimates of traffic delays and commuting routes. In a more general sense, these findings indicate that commuters differ even by sex with regard to aspects of their commute and use of traffic information, thus supporting further the notion that commuters cannot be treated as a single group in terms of traffic information needs.

Results of the Factor Analysis

In the previous discussions, patterns were presented that could be attributed to characteristics of commuters (such as sex) and their commuting tasks (such as miles traveled). As was done for the initial survey, a principal components factor analysis was performed on the responses to the in-depth interview to determine commonalities of responses rather than distinguishing member characteristics. In essence, although cluster membership, sex, and distance traveled allowed commuters to be distinguished, principal components analysis allowed the responses of commuters to be analyzed for common features. The purpose of principal components analysis was to elicit the basic structure of the correlation matrix (*24*). Each resulting factor represents attributes that are highly intercorrelated but not correlated with other attributes.

The five-factor solution obtained (see Table 4) has an interesting degree of conceptual overlap with the five factors obtained for the initial survey (issues affecting route choice, distance-time information, traffic information—TV and radio, traffic information—VMS, HAR, phone, and commuter attributes and flexibility). Because the absolute value rather than the signed value of the loading is of importance, Table 4 presents all loadings with positive values. The matrix of factor loadings was obtained using the VARIMAX rotation; the five-factor solution accounted for 71.82 percent of the total variance in the correlation matrix.

Just as knowledge of the commonalities of the responses of commuters participating in the first survey allowed refinement of the in-depth survey, knowledge of the commonalities of responses in the in-depth interview allows an even finer set of conclusions to be reached regarding traffic information systems. Further, these factors reinforce the importance of not considering commuters as a homogeneous group when designing motorist information systems.

TABLE 4 FACTOR LOADINGS FOR FIVE-FACTOR SOLUTION

Variable	Distance, Time	Personal Chars.	Primary Knowledge	Alternate Knowledge	Stress Response
Mileage	0.831				
Tasks, pre-depart.	0.773				
Time. pre-depart	0.662				
Penalties, late arrival	0.543				
Age of youngest child		0.909			
Age of commuter		0.888			
Flexibility, arrival		0.720			
Times seek info., pre-depart		0.628			
Flexibility. departure		0.590			
Gender of commuter		0.498			
Street names in desc.			0.863		
Landmarks in desc.			0.817		
Actively seek info., pre-depart			0.578		
Stress, pre-depart				0.859	
Seeks info, pre-depart				0.771	
Tasks, primary route				0.647	
Change in stress, alt. routes				0.625	
Number of alt. rtes. known				0.617	
Stress, primary route					0.822
Modifications. primary route					0.759

Thus, designers of effective information systems need to consider the distance traveled by and the time available to commuters, personal characteristics of the commuters, commuters' knowledge of their primary and alternative routes, and commuters' responses to stress. The distance-time factor indicates that, with increasing commuting distance, commuters have less time available before departure and they accomplish fewer significant tasks before departure. The personal characteristics factor indicates positive correlations among age, sex, age of the commuter's youngest child, flexibility of arrival and departure, and times the commuter seeks information before departure. The primary route knowledge factor shows the relationship between the detailed knowledge of street names and landmarks and the time at which commuters first seek out information regarding traffic conditions on their commute. The alternative-route knowledge factor demonstrates the intercorrelations of number of alternative routes known, stress when using an alternative route, stress experienced before departure, how actively commuters seek out their first traffic information, and the number of tasks performed on the commute. Finally, the stress response factor shows the relationship between the number of modifications made to the primary route and the amount of stress experienced on the average commute.

Analysis of Responses to VMS Message Manipulations

As discussed earlier, accuracy of perception and probability of changing route in response to messages given by VMS were also studied. Results were analyzed using repeated-measures ANOVA. Values of the F-statistic and related probabilities are presented in Table 5.

Commuters were 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. Interestingly, a pattern completely in opposition to the pattern just described 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 did not present the task.

Task information appears of secondary importance to commuters. Further, commuters prefer generic reasons. This finding may indicate that commuters wish only to know that a

TABLE 5 RESULTS OF VMS REPEATED MEASURES ANALYSIS

Variable	F	p
Correct response, generic vs. specific task	9.141 (1, 83)	0.003
Correct response, task first vs. reason first	16.719 (1, 83)	0.001
Probability of route change, generic vs. specific task	141.142 (1, 89)	0.001
Probability of route change, task first vs. reason first	66.726 (1, 89)	0.001
Probability of route change, generic vs. specific reason, task present vs. task absent	22.173 (1, 94)	0.001

traffic problem exists and that they wish to tailor their response to their specific commuting goals (*25*). These findings also may be medium dependent in that the observed pattern of commuter responses would not be observed if, for example, the messages were delivered by radio. Further, they can only be generalized to information delivered en route, not to information delivered before departure.

CONCLUSION

The survey and analyses described have produced a picture of an extremely complex commuting population, but one with definable needs that can be grouped parsimoniously, producing important implications for the design of motorist information systems. The method employed has produced information that would not have been available through use of a standard survey and has provided a set of baseline responses that will allow any changes or modifications to existing information systems to be examined for efficacy.

The analyses also raise a set of additional questions for researchers interested in motorist information systems. One question would involve applicability of these findings to other commuting corridors. Work is currently under way at the University of Washington to extend this method to studies of other corridors in the Seattle area. Studies of other major commuting groups using a similar method would allow for comparison of findings and a search for more general principles that could be followed in the design of information systems. A second question would involve the stability of the identified subgroups once they have received tailored motorist information. Thus, the results observed could well serve as a baseline for changes in the behavior of Seattle-area commuters that might be traced to delivery of motorist information.

From the discussion of the analyses, the central premise—that commuters cannot be considered as a homogeneous population—has been supported. The method employed focused on those differences and has identified aspects of commuters' daily tasks that help determine their use of and response to motorist information.

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