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Impact of ATIS on Drivers' Decisions and Route Choice: A Literature Review

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Abstract

This report reviews the recent studies adopted in order to understand the drivers' behavior, and in particular their behavior when influenced by an Advanced Traveler Information System (ATIS). Different approaches were used in these studies: field experiments, route choice surveys, interactive computer simulation games, route choice simulation and/or modeling, and stated preference. These studies are classified according to the main approach used, and the main objective, method, and findings are presented.

The significant results are discussed at the end of the paper. These results indicate the need to understand how drivers choose or change routes in the absence of information systems in order to gain an understanding of route choice behavior in the presence of information. This is the aim of an ongoing research project at the University of California at Davis. Further, the effects of the learning process of drivers when exposed to information need to be investigated, which is the aim of a preliminary experiment utilizing interactive computer simulation, developed also at the University of California at Davis.

I. Background

The purpose of this review is to investigate current literature on the subject of driver behavior when influenced by Advanced Traveler Information Systems (ATIS). The report is part of the first year effort and concentrates on drivers' behavior (which could be extended to carpool drivers), subsequent reports will address the extension of this research to paratransit, rideshare vehicles, and the future smart bus system. This review was performed as part of a larger ongoing investigation to address travel behavior and demand issues with ATIS [15]. A multi-year, multi-disciplinary research effort is being performed under California Partners for Advanced Transit and Highways (PATH) program at the University of California at Davis. The goal of the project is to understand how people will adopt ATIS, learn its use, devise rules for travel planning and how all these relate to travel demand. One primary project focus is on drivers' enroute decision mechanisms with the goal of developing mathematical and predictive models of route choice.

The implementation of **ATIS** technologies into real transportation systems is limited and is still in the early stages of development. Due to the lack of real-world environments in which driver behavior, under the influence of **ATIS,** can be observed, experimental methods of analysis must be developed. The crux of the problem is that **ATIS** technologies will not proliferate until a better understanding of the possible impacts of **ATIS** on the transportation system is reached. Yet, without **ATIS** technologies in place it is very difficult for researchers to study the effects of **ATIS** on driver behavior and define these possible impacts.

Several methods have been utilized to investigate route choice behavior when influenced by **ATIS** and include:

1. Field Experiments
2. Route Choice Surveys
3. Interactive Computer Simulation Games
4. Route Choice Simulation and Modeling
5. Stated Preference Approach

There are several **ATIS** field experiments currently underway in the United States, Europe and Japan. These experiments are using emerging **ATIS** technologies in a real-world traffic environment on a limited scale, and should provide a significant amount of information on the behavior of drivers, which will lead to a better understanding of the impacts of full scale **ATIS** implementation. Traditional revealed-preference surveys have been used in several studies **with** the aim of determining respondents' route choice behavior. The goal of the survey methodology is to try to gain a better understanding of the types of information drivers use, and need in making route choice decisions and what are the best ways of delivering that information in a timely manner. Interactive computer simulation games are used to study the drivers' behavioral responses to either real or simulated **ATIS** technologies. The effects of **ATIS** technologies on network flow are often studied through route choice simulation based on a model of driver behavior. Stated Preference studys driver's behavior in a hypothetical situation, and offers indications of his/her behavior when the hypothetical situation materializes.

These techniques can be implemented individually or collectively, for example, a survey or a simulation may use a stated preference approach, or an experiment could be combined with a survey. This review will summarize these techniques and describe how they have been utilized in the literature and significant **findings** will be discussed.

II. Field Experiments and Their Evaluations.

Field Experiments are the most accurate and representative method to understand the effects of ATIS on drivers' behavior. ATIS experiments facilitate the observation of drivers in the real traffic environment. Data recorded in this manner are an accurate representation of driver behavior because these are real decisions being made in a real traffic environment. However, gaining this accurate representation involves a high cost. In addition, experiments in the transportation field tend to require cooperation and coordination among various agencies, and can be difficult to monitor. The results of an experiment are known either by observing the overall performance, or by surveying the drivers involved. Observations of system performance are difficult due to the size and complexity of the traffic system. Experiments are often limited to a relatively small sample of the driving population and as such will have little effect on the overall system performance. If improvements are observed in the experimental sample performance then it may be possible to make reasonable inferences about overall system improvements due to full implementation of the ATIS technology under investigation.

Many experiments are taking place nationally and internationally. Among them are the Pathfinder in The U.S., Ah-Scout and Autoguide in Europe, and Racs and Amtics in Japan. These experiments test the viability of implementing ATIS technologies on a large scale by analyzing the effects of ATIS on a small group of drivers in a real traffic environment. The major ATIS program currently taking place in the U.S. is the Pathfinder, which is a cooperative project among the Federal Highway Administration, California Department of Transportation and General Motors Corporation. Another project, TravTek, is currently in the early stages of implementation.

Pathfinder is an experimental project for an in-vehicle navigation system aimed at improving traffic flow. The system provides drivers of specially equipped cars with real-time information about accidents, congestion, highway construction, and alternate routes. The Pathfinder system is being tested to see how drivers would benefit by receiving on-board information through a computerized mapping device on a monitor display. A control center manages the communication, detecting traffic density and vehicle speeds and transmitting that information back to the equipped vehicles in the form of an electronic map shown on the display screen. The system helps motorists find the most efficient path of travel to their destination. The Pathfinder experiment is taking place in an area known as the Smart Corridor, a 13-mile stretch along the Santa Monica Freeway. The corridor includes five major parallel arterial roads between Los Angeles and Santa Monica. The experiment uses 25 vehicles equipped with electronic navigation systems.

TravTek is a joint project among General Motors, the American Automobile Association, the Federal Highway Administration, the Florida Department of Transportation and the City of Orlando. TravTek will provide navigation, real time traffic information, route selection, route guidance and motorist information services to a fleet of 100 specially equipped rental cars. The system will cover 1200 square miles surrounding the Orlando area. TravTek is addressing system architecture, communications, travel efficiency, human factors and safety issues of ATIS [12].

Ah-Scout is a dynamic route guidance system with on-board equipment that receives routing information from a centrally located traffic guidance computer. The system receives information when passing infrared communications beacons installed at selected traffic signal lights and other strategic locations. The received information consists of a route tree giving the best routes based on current traffic conditions for traveling from the beacon location toward various destination zones. The on-board equipment selects from the route tree according to the destination input by the driver, and issues route guidance instructions along the way by means of a simplified graphic display and synthesized voice. Navigation between beacon locations is accomplished by dead reckoning with map-matching. Travel times from the participating vehicles are communicated to the beacons to augment the traffic information database of the central traffic guidance computer [8].

The Autoguide system is based on a network of short range beacons connected to a control center. All equipped vehicles passing a beacon at a particular time receive the same set of data via a communications link. The data set is updated every five minutes and is based on actual traffic conditions and includes location, map, and route data. The Ah-Scout is the in-vehicle subsystem of the Autoguide system [8].

The Autoguide in-vehicle unit tracks location using a combination of roadside beacons, dead-reckoning and map-matching. The system derives the details of the most appropriate route for the driver's current destination, and provides the driver with appropriate route instructions. At each junction where a turn is to be made, the driver is informed of the maneuver both on a LCD display and by synthesized voice. Communication with the beacons is two-way. Travel time data from vehicles are transmitted to the beacons and then to the control center, which will enable the center to reallocate routes in near real-time. The system will detect and react immediately to traffic incidents, and will have significant implications for improving traffic control quality based on advanced traffic monitoring.

A demonstration Autoguide system has been operational in London since early 1988. The system consists of five independent beacons covering part of central London and the route to Heathrow Airport. Fifteen vehicles are equipped with Autoguide units. The success of this demonstration led the UK government to introduce legislation to enable the commercial operation of Autoguide.

It is anticipated that within 2 years the implementation phase will begin. The system will cover all of central London and the route to Heathrow airport. It will comprise a network of 350 beacons linked to a central computer by a communications network. After evaluating this phase a progression to the commercial system will follow. The commercial scheme will operate in an area which includes the London orbital motorway. It is expected to comprise at least 1000 beacons and offer route guidance to more than one million users [8].

A full scale trial of Ah-Scout is currently in operation in the LISB (Leit and Information System Berlin) project in Berlin, where there are 250 infrared beacons installed over the western part of Berlin and connected to a control center. When an equipped vehicle first passes a road side beacon, the display changes to "full guidance" mode. From this point on, the minimum time route to the destination is made known to the driver via symbols on a display and audible messages instructing the driver to make the requisite turns at each junction [3].

LISB began giving advice in May 1989 but at that stage the guidance was based only on average traffic conditions for the time of day (static guidance). In January 1990 the system became fully operational such that the guidance was based on LISB's estimates of current traffic conditions derived from a combination of historical data and recent link traverse-time records transmitted by LISB-equipped vehicles which were already on the network (dynamic guidance). By the end of the experiment approximately 700 vehicles were to be equipped.

Bonsall [3] presented results of a survey of drivers equipped with a route guidance system as part of the Berlin LISB trial. Self-completion questionnaires were administered among a subset of about 100 drivers of LISB-equipped cars at three stages; before any guidance was provided, during the static guidance phase, and again during the dynamic guidance phase (one-group pretest post test design). Respondents were asked about their travel patterns, the route they used, the journey conditions they experienced with and without guidance, their assessment of the usefulness of guidance for different types of journeys, and their opinion as to how LISB might be improved.

About 20% of the survey respondents said they had changed their normal route to or from work as a result of the static LISB guidance. Since static guidance depends on average traffic conditions, it is unlikely for a driver to use it more than once, because it does not change from one day to another. Respondents were asked about recent journeys to unfamiliar destinations. LISB had become the most frequently used, and the most useful method of finding unfamiliar destinations, with three quarters of the respondents claiming to use LISB for all such journeys. There was some evidence that the availability of LISB had encouraged respondents to make more journeys of this kind.

After six months of using LISB with dynamic guidance 65% of the respondents had come to expect to save time when using LISB for journeys in unfamiliar areas but only 47% expected to do so on the journey to work. The ratings for dynamic LISB were not markedly more positive than they had been for static LISB. This may reflect the fact that for journeys to unfamiliar locations the dynamic element is not crucial and perhaps that, for more regular journeys, the quality of advice achieved by LISB was still not sufficient to outperform many respondents' unaided route choices.

Another behavioral change evidenced from the survey is an increased readiness to try new routes even without LISB. These tendencies are based on the respondents' own subjective comments, it would be very useful to have more objective data on these aspects.

It could be concluded from the LISB experiment and its related survey that the overall drivers' benefit from LISB was less than expected. Only drivers frequenting unfamiliar areas or drivers with fairly modest ambitions with respect to route optimization could find LISB beneficiary, and it would be viable to target these groups.

Two experiments, focusing on the effect on driver behavior of the introduction of various types of route information, were recently conducted under the European DRIVE Program **[19].** These two experiments were conducted in a real driving environment using members of the general driving public. The first experiment compared two types of route information displays, a paper map and text display on an LCD screen. The second experiment also used two types of route information displays, the graphical, text based, LISB/Ali-Scout and the electronic, map based Bosch Travelpilot, both real route guidance information systems.

The main thrust of this research was to compare the attentional demand requirements imposed on drivers when using either a map-based, self-navigating, information device or a graphical-based, system-directed, navigating device. The findings of this research indicate that the map based navigational information display (paper map or Travelpilot) imposes greater attentional demands on drivers and that the graphical or text based navigational information display (text or LISB/Ali-Scout) is generally less demanding.

In the second experiment when drivers were navigating from a given origin to a specified destination, the routes chosen by drivers using the Travelpilot were significantly different than those taken by drivers using the LISB/Ali-Scout. This is a significant finding relating to route choice behavior under the effects of ATIS. Unfortunately, this research did not investigate the decision rules used by the Travelpilot drivers which resulted in their use of less optimal routes. The drivers using the LISB/Ali-Scout systems are only presented with one route choice, the optimum route as determined by the system. The Travelpilot system with its map display presents drivers with a choice set of alternative routes. The decision rules being applied by the Travelpilot drivers to find optimum routes are significantly different than those used by the LISB/Ali-Scout system. These findings point out the depth of complexity in understanding drivers route choice behavior. Not only is a thorough understanding of driver behavior in the presence of information needed, but also how that behavior may be modified based on various display modes. Even a subtle difference in the way information is presented to drivers may have significant effects on their route choice decisions leading to changes in travel demand in the network.

III. Route Choice Survevs.

The survey approach enables the researcher to analyze the effects of ATIS directly from the reported behavior and perceptions of the individual system users. Unlike a limited experiment, a large scale survey can achieve a sample size that adequately supports quantitative modeling and forecasting. A better representation of the population in a survey can also facilitate better understanding of actual human behavior and decision processes. Very few surveys, however, have addressed the behavior and decision processes related to the route and departure time choices of drivers.

Khattak **[13]** used mail-back questionnaires to evaluate the effect of radio traffic reports on commuters' route and departure time decisions, and also to solicit suggested improvements to the traffic information system. This approach was an attempt to study drivers' behavior related to an existing information system instead of trying to evaluate, by experiment or simulation, a non-existing system or a system that doesn't have enough market penetration. This is a significant approach because radio traffic reports are widely available and many commuters use them.

A different approach, also by Khattak **[14],** was to use a stated preference mail back survey to investigate the effects of incident and recurring congestion, real-time traffic information, driver, roadway, and incident characteristics on commuters' willingness to divert. Both studies used the ordered-response **probit** model to examine ordinal responses to attitudinal questions using likert scales.

It was found that an important improvement of radio traffic reports would be the capability to predict traffic conditions. Near-term prediction of traffic conditions on congested and unreliable routes may be particularly appealing because drivers generally want to know traffic conditions before they reach the road link. Further, those who change departure time may require relatively longer-term prediction of traffic conditions compared with route changers. Prediction of traffic conditions could help drivers make better and more informed departure time decisions because they would know the implications of changing their departure time. The need to predict traffic reports influenced both route and departure time decisions; and near-term prediction can contribute to improved accuracy. It is possible that prediction of traffic conditions may sometimes result in the deterioration of the traffic situation due to redirecting of a large amount of traffic to the same route. Such scenarios need to be researched, yet this should not hamper the development of prediction capabilities when there is an overwhelming need for prediction.

An important finding was that drivers were more willing to divert in response to information received from radio traffic reports than from their own observation of delay. This may be a recognition that by observing congestion drivers do not get a good sense of its extent for supporting a diversion decision. Drivers may perceive that traffic reports give a clearer image

[illegible] completed or partially completed surveys), and a detailed trip diary. The first mailing was to lateness at the work place in excess of five minutes. The average travel time from work to home for the commuters on days with no intervening stops was 23.6 minutes.

The trip chaining behavior addressed in this paper corresponds to the critical evening commute periods. Since only after work paths were considered, all trips begin at work and end at home. These trips may or may not have intermediate stops. Diary information available for each stop includes the location, purpose, arrival time, and departure time.

About 39.3% of evening commuters were found to have one or more stops, where personal business and shopping were the most frequent cause. For each commuter, a stop ratio was calculated by dividing the number of trips with stops by the total number of trips reported. Commuters with high stops ratio (e.g. $\geq$ 0.7) are likely to make the same stop on many trips. Furthermore, trip chaining significantly influenced route and joint (both route and time switch) switching behavior: trips with stops were much more likely to involve switching than trips without stops. The analysis utilized both a "day-to-day" and a "deviation from normal" approach to switching behavior. The day to day definition captured higher frequency of switching than did other defmitions.

In general, commuters tend to change departure times more frequently than routes, possibly a reflection of a limited route choice set in comparison with a broader set of available departure times. Also it was found that travelers with short trips may see no need for altering routes (small absolute time savings), while those with long trips may face too much uncertainty with regard to travel time variability to distinguish one route's superiority over another.

Work place variables such as lateness tolerance and work end time dominate evening departure time, route, and joint switching behavior. Socioeconomic variables such as gender, age and home ownership, display explanatory power, but their effect is not as clear cut. The only socioeconomic attribute found was that commuters between ages 30 and 60 tend to make more frequent joint switches than older or younger trip makers. This reflects more complex activity and work patterns for middle aged commuters, resulting in the need for more joint switching.

It was indicated that the documentation of actual switching habits using trip diaries is subject to fewer problems than a phone or mail survey which involves recall or stated intentions by the respondent.

Surveying commuters to gather information about motorists activities and behaviors, particularly the potential for changing these behaviors through the design and delivery of motorist information, was the goal of research sponsored by the Washington State Department of Transportation (WSDOT) [9, 10, 223.

The purpose of the WSDOT survey was to draw conclusions and make recommendations for the improvement, development and design of Motorist Information Systems. The research utilized a large scale, on-road distribution, mail-back survey which targeted a specific freeway corridor. The motorist information systems investigated by this survey were existing systems, including; Radio Traffic Reports (RTR), Variable Message Signs (VMS), and Highway Advisory Radio (HAR) [9]. In order to gain information on the effects of ATIS technologies, a small follow-up survey was performed which investigated drivers perceptions and preferences for five prototype traffic information screens [10].

Through the use of cluster analysis the researchers were able to identify four commuter subgroups [9]. Cluster analysis is a statistical method that groups subjects into similar groups according to statistical distance measures. The analysis used a set of variables that characterized the effect of traffic information on departure time, route choice, and mode choice. The objective was to partition the group of subjects into mutually exclusive and exhaustive subgroups based on similar characteristics. The cluster analysis separated the subjects into four major driver groups: Route Changers, Non-Changers, Route and Time Changers, and Pre-Trip Changers [9].

Route changers were identified as willing to change route, but were unwilling to change departure time or transportation mode and made up 20.6% of the sample. Non-changers were unwilling to change departure time, route, or transportation mode and made up 23.4% of the sample. Route and time changers were willing to change route and departure time but not transportation mode and made up 40.1% of the sample. Pre-trip changers were willing to change time, route or mode prior to leaving their residence, but were unwilling to change route while driving and made up 15.9% of the sample [9]. The measure of a driver's willingness, or unwillingness, to change their behavior was based on the driver's responses to the following questions:

- When on the freeway, 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?
- Before you drive, how often does traffic information influence your route choice?

If it is assumed that this sample is an adequate representation of all urban area commuters then this finding has great significance for ATIS technologies. It is indicated by this survey that approximately 75% of drivers already are changing or are willing to change their commuting route with 60 % willing to change enroute or at home and 15 % willing to change only prior to leaving home. When exposed to potential ATIS screens 55% of those identified as Non-changers indicated a willingness to change route. This indicates the positive impact that ATIS could have on changing the behavior of those most resistant to change of any kind.

The overall size of this survey was large (3,893 respondents), yet only 100 respondents were specifically questioned on ATIS technologies. There is no intent to belittle the importance of the main survey. This is an indication of the difficulty involved when surveying drivers about new technology. The survey respondent, having no experience with the system, must imagine how the system under investigation would work and how they would use it. The behavioral responses obtained in this manner could be drastically different from the observed behavior once systems are implemented and drivers gain experience using the system. The survey research on driver behavior is scarce and more surveys of this type are necessary if we are to gain a thorough understanding of drivers decision mechanisms. Prior to understanding the effects of ATIS on drivers behavior a basic understanding of driver behavior in the current traffic environment must be established.

The survey research into understanding commuter behavior must continue and be expanded to include other major commuting areas. In this way a significant data base can be assembled which will allow for the comparison of commuter characteristics independent of area-specific variables [9]. To continue to build the knowledge base on the subject of driver behavior, a survey of commuters' route choice behavior is being planned as part of the on-going investigations into the impact of ATIS on travel behavior [15]. The survey will target Los Angeles area commuters and investigate how much information drivers have about their routes, their awareness of alternate routes, and their awareness of traffic information which effects their route choices.

Iv. Interactive Computer Simulation Games.

Perhaps the most widely used technique for studying the effects of **ATIS** technologies is simulation games. In general, simulations are less expensive, require little or no coordination with outside activities, provide for greater control, and are easier to monitor than field experiments or field trials. The simulation methods presented in this section simulate the driving environment and are used to study drivers' behavioral responses **[1** , 2, 5, **20].**

Allen et al. **[2]** present a human factors simulation study of the decision making behavior of drivers attempting to avoid nonrecurring congestion by diverting to alternate routes with the aid of in-vehicle navigation systems. This paper describes the simulation approach and summarizes results on diversion decision behavior and alternate route selection.

The simulation is based on an IBM-PC, in which the computer controls visual and auditory displays simulating travel along a freeway corridor, and recording drivers' decisions to divert or not from the main route to avoid congestion, and in case of diversion, the selection of alternate routes. In this study the computer controlled a sequence of slides that represented a lo-mile stretch along state route 22 in Orange County, California. Slides were presented nominally every 5 seconds showing an out-the-window scene including freeway traffic and guide signs, and a partial instrument panel showing a speedometer, odometer and digital clock. The traffic scenes represented various levels of congestion. At the same time, a computer monitor presented prototype in-vehicle navigation displays which provide various degrees of feedback information to help with route diversion decisions. Based on the above visual and auditory stimuli, the driver's task was to decide when to divert from the freeway to an alternate route in order to minimize trip delay. To motivate these decisions, drivers were given rewards and penalties according to their performance in minimizing delays and estimating traffic congestion levels. The computer kept track of where subjects decided to divert from the freeway, and calculated their reward/penalty payoff. Also, experimental driving scenarios included attributes of traffic incident severity, time constraints, and trip destination.

Four prototype systems were used; static map, dynamic map, advanced experimental system (dynamic map with highlighted alternate route), and a route guidance system (non-map system with graphic symbols for guidance). The objective of the simulation experiment was to compare the effect of the various experimental navigation systems on driver route diversion and alternate route selection.

The majority of the subjects were Southern California Automobile Association employees, with unfamiliar subjects recruited from the Costa Mesa processing center near the freeway route. Additional subjects were recruited from local advertisements and retirement centers to fill out the young and old age categories. Commercial drivers were solicited from airport shuttle services.

It was found that the advanced experimental and route guidance systems caused drivers to divert before reaching the point of heavy congestion while the static map users and the control (no navigation information) drivers experienced heavy or jammed congestion conditions before diverting. The dynamic map, advanced experimental and the route guidance systems allowed drivers to anticipate the congestion conditions and divert from the freeway to alternate routes earlier than static map or control group drivers.

For people that have some facility for using maps, a map based system may be more effective because subsequent to diversion, the map based system provides more information on alternate routes. It is important to mention that of all the subject grouping variables, only age seemed to have any consistent effect on diversion behavior, with older drivers (more than 55 years old) being more hesitant to divert than younger subjects.

Bonsall et al. developed an interactive simulation model **[5].** This model was used to study the influence of route guidance advice on route choice. Unlike the simulation method presented by Allen et al., this model is based on a small hypothetical network.

The computer program recorded diversion decisions made by each driver and also asked each subject a series of personal and stated preference questions. In analyzing this data, two main approaches were pursued; first finding the relationship between the quality of advice and the probability of it being accepted, and secondly, using regression models to determine which variables, or combinations of variables can best explain whether or not advice is accepted.

Bonsall concluded that the possible influence of in-vehicle route guidance and information systems will be very dependent on the way in which it affects drivers' choice of routes.

Evidence as to the complexity of the route choice process has been presented and some behavioral constraints have been discussed. The main findings from analyzing the data set were that the acceptance of advice depend on the drivers' knowledge of the network, previous experience with the information system, and the consistency of the advice with drivers' expectation. It appears also that distance minimizer drivers tend to accept advice more than time minimizers. It was found that as drivers get closer to their destinations they appear more able to discriminate between good and bad advice.

Adler et al. [1] propose a theoretical approach for modeling route choice behavior based on conflict assessment and resolution theories. This modeling approach presumes that a driver's decision to divert or to make a change in travel plans occurs when a threshold of tolerable conflict is exceeded, and the driver perceives that an alternate course of action would reduce the level of conflict below the threshold. This concept of acceptable thresholds related to route choice decisions has been proposed by others as well [23, 24].

To test their modeling approach, Adler et al. [1] have developed an interactive computer-based navigation simulation, "Freeway and Arterial Street Traffic Conflict Arousal and Response Simulator" (FASTCARS). FASTCARS integrates a driver simulation program with the conflict model approach to create a data collection tool for analyzing driver behavior. The data will be used for estimating and calibrating predictive models of driver behavior under conditions of real time traffic information (a draft report has been written). A functional example of how the simulator operates is provided taking a subject from a given origin to a specified destination.

The authors suggest that thresholds of conflict tolerance, motivation improvement index, and value of information directly influence diversion behavior and real time information search and acquisition. The inability to achieve goals or the exceeding of threshold tolerances raises frustration and anxiety levels. Response is obtained when motivation is aroused through perception of significant improvement in goal attainment or ability to reduce conflict is achieved. Further they suggest that perception, experience, knowledge and risk lead to problem solution. Information search and acquisition is applied to improve decision making capabilities when it is necessary.

Polak and Jones [20] have developed a computer simulation of an in-home pre-trip information system to study the effects of pre-trip information on travel behavior. The simulator provided information on expected travel times by bus and car at different times of day. Information was also provided on parking search times and expected bus arrival times at stops. Respondents were able to query the system by inputing a departure time and mode choice or a required destination arrival time and mode choice. The simulator would respond by providing expected travel times, parking times, and either expected arrival or required departure times. The respondents would then rank the travel options displayed by the simulator in order of preference.

The simulator was designed based on information gained from an in-home survey. The survey was used to get information on car travel times, costs, and perceived variability in travel times from respondents based on a recent journey to the city center.

The respondents showed little interest in performing extensive searches, and journey related factors had little effect on the number of enquiries made. The results support the existence of heuristically guided search behavior e.g. if respondents first enquiry showed travel times no worse than they currently experienced then they were more likely to perform only the minimum amount of searching. The results provide evidence that information acquisition is structured according to travel preference.

V. Route Choice Simulation and Modeling.

Because the route choice process in the real traffic environment is so complex and little is understood about the way drivers process information and select their routes, route choice simulation in the most simple and controlled environment, enable the researcher to analyze the effects of various factors (including information) on route choice behavior.

Mahmassani and Shen-Te Chen [17] developed a numerical simulation method to study the effects of enroute and origin based traffic information on the traffic network performance. Different combinations of three loading patterns, five levels of market penetration, and two distinct behavioral rules were used. In an attempt to model drivers behavior, three different behavioral rules were proposed, but only two were used in this study. The first rule is the Myopic Deterministic Choice Rule, which states that from any given node, the user will always select the best path (in terms of least cost or least travel time) from his/her current node to destination. The second rule is a Boundedly Rational model using a satisficing switching rule, that means that the driver will switch from his/her current route to the best alternative only if the improvement in the remaining trip time exceeds a certain limit (indifference band).

System performance for each simulation run (123 runs using different combinations) was evaluated by comparing the average trip time for all commuters in the system to the corresponding value in the base case. The results showed that the existence of benefits as well as the relative effectiveness of origin-based versus enroute information is highly dependent on the initial conditions prevailing in the system as well as the behavioral rules governing path selection. Extreme behavior by users (with frequent switching in myopic response to any gain, no matter how small) could lead to severe performance loss of the system under real-time information from either source. Switching according to a Boundedly Rational model is more likely to lead to meaningful system wide benefits.

The results of the simulation suggested that the need for coordination in the provision of information beyond a certain market level, may be as low as 10 or 20 percent, depending on the loading patterns. The existence of benefits from ATIS obviously depends on the manner in which users respond to the information. Ultimately, it is likely that users themselves will reach their own conclusions about appropriate switching rules, through repeated experience with the facility. The dynamics of the formation of such indifference bands constitute an important subject of additional research, which could benefit from previous work on the day-today dynamics of commuting decisions through the use of laboratory experiments.

Lotan and Koutsopoulos [163 present a new modeling framework for route choice in the presence of information based on concepts from fuzzy set theory, approximate reasoning and fuzzy control. Most modeling studies make simplifying assumptions such as: drivers have complete information, infinite information processing capabilities, are able to make optimal decisions, or that a certain compliance rate to the information is achieved. This framework includes models of drivers perceptions of network attributes, attractiveness of alternative routes as well as models for reaction to information and the route choice mechanism itself.

The two main components of the methodology are drivers' perceptions of attributes of the network and the route choice mechanism. To define the model, a set of base rules is developed and an approximate reasoning scheme is used to derive rules that do not correspond exactly to one of the base rules but that are close to it. This method adds flexibility to the interpretation of the rule by allowing the premise to be partially true and changing the consequence accordingly. In general a given input will have a certain amount of overlap with several rule premises. Every rule whose premise condition overlaps with the input is activated and thus, depending on the inputs, more than one rule may contribute to the **final** decision. The merit of the approach is that given a certain input, several rules are being applied simultaneously, each to a different degree in order to produce a final decision.

It is assumed that the driver has some perception of possible travel times for every link in the network. A fuzzy number is assigned to the perceived travel times on a link and the fuzzy set of all possible travel times on a particular link is used to capture such characteristics as familiarity of the driver with a particular link. It is also assumed that each link in the network could have associated information of various forms. Choice set generation models are used to establish a choice set of reasonable alternative paths for a given origin/destination pair. Each path is composed of links and the perceived travel time on the path is the sum of the fuzzy numbers on all links composing the path.

The decision process is modeled using a set of rules. The rule structure has the form "if A_i then B_i". The left hand side of the rule deals with traffic conditions, traffic information, and other relevant data associated with the alternative paths, expressed as labels of fuzzy sets. The right hand side deals with decisions and choices based on the state of the alternatives described by the left hand side. For a given origin/destination pair with a pre-specified choice set, the model proposes two major groups of rules: rules dealing with perceived travel times (or other attractiveness measures) and rules dealing with current traffic information. The left hand side of these rules characterize a given performance measure according to fuzzy labels. The right hand side of the rules corresponds to aspects of the **final** decision. The right hand side serves as an intermediate step in the decision process and corresponds to the stage in which attractiveness (or utility) of each alternative is evaluated based on the input. The **multi**-dimensionality of the right hand side captures the fact that even if the information on the left hand side of a rule relates to a specific alternative it could also affect perceptions on the attractiveness of another alternative. The degree to which every rule will be triggered is based on the amount of overlap between the input condition and the left hand side of the defining rules. The degree of overlap represents the degree to which the left hand side is fulfilled and the degree at which the right hand side will be fired.

The result of the addition of the right hand side of all the rules that were fired is used to represent the **final** attractiveness of each alternative. Consequently, the attractiveness is composed of results of several rules each contributing to a different aspect of the final decision. The route choice problem is a discrete choice problem, hence even if the output is multi-dimensional, the model should provide a unique output. The model proposes a defuzzification scheme to resolve this issue. The set of alternatives is defuzzified into a set of scalars and then the scalars are compared to obtain a discrete choice. The authors suggest the simplest approach is to choose the alternative such that the corresponding scalar is maximum. More elaborate methods using utility maximization and the logit model are also suggested. A simple example of how such a model might work was presented, but a route choice model based on fuzzy set theory was not fully developed or validated by the authors.

VI. Stated Preferences Approach.

Observed or revealed preferences indicate how drivers behave in real-life situations and represent actual behavior. Stated preferences, on the other hand, indicate how drivers may behave in a hypothetical situation contrived by the researcher and may not be an exact representation of actual behavior. In a stated preference study respondents are presented with a selected set of alternatives and asked to choose which alternative they prefer. The method is typically used in analyzing consumers demand for products or services which either do not exist or consumers have no experience with. Stated preference questions allow for an understanding of the tradeoffs between various factors which influence diversion decisions and could be designed to address issues related to developing ATIS systems [14]. Thus it is a logical method to be used for analyzing new emerging ATIS technologies.

In stated preference investigations of ATIS technology two data collection methods have been used in the literature; stated preference surveys, and stated preference simulations. Khattak [14] used stated preference questionnaires in a mail back survey. He found that drivers perceive that traffic reports give a clearer image of delay and congestion than their own observation, and that they are more willing to divert from their usual route in response to incident congestion probably because their normal route choice decisions may not account for incident-induced congestion. Haselkorn et al. [10] used stated preference survey methods to evaluate potential ATIS screen formats for the development of a real-time dynamic traffic information system. They concluded that exposure to positive examples of new information sources will greatly increase people's desire for those sources.

The use of an interactive computer simulation is in effect a specific type of stated preference survey. Through the simulator, respondents are presented with a series of contrived choice sets which the researcher wishes to evaluate. As the respondent uses the simulator, the individual decisions made for each choice set are automatically recorded. The main advantages of the computer simulation over the paper survey method are the large number of choice sets which can be presented to the respondent in a relatively short amount of time, and the increased level of realism provided by placing the respondent in the environment. Adler et al. [1], Allen et al. [2] and Bonsall [5], utilized interactive computer simulations to analyze route choice behavior. All of these simulations place the driver in a simulated traffic environment and record route choice decisions.

The degree to which drivers stated behavior agrees with their actual behavior may be very dependent on the level of realism involved in the stated preference method used. The simulations of Bonsall and Adler et al. were based on fictitious networks while the work by Allen et al. was based on a real traffic network. The use of real traffic networks, and travel characteristics of the network, integrated into driver simulations will help improve the level of realism experienced by respondents and may yield a more accurate description of driver behavior under the effects of ATIS.

VII. Summary and Conclusions.

Several large scale experiments or field trials studying the effects of ATIS technologies are currently underway around the world. Little has been published from these experiments to date, as some are in early stages and others are still ongoing. In the meantime other investigations of ATIS technology are being carried out using methods of a smaller scale.

Laboratory and small field experiments utilizing ATIS technologies from the larger field trials have been performed by Bonsall [3] and Parkes et al. [19]. Mail surveys have been used by Khattak [13, 143 to investigate the effects of existing information systems on drivers behavior and to investigate the effects of incidents and recurring congestion, real-time traffic information, and driver, roadway, and incident characteristics on drivers diversion propensity. Haselkom et al. [9, 10, 22] have used a large mail-in survey and follow-up in-person surveys, to gather information about motorists activities and behaviors and to investigate drivers information requirements for the design of **ATIS** technology. Allen et al. **[2],** Bonsall et al. **[5],** Adler et al. **[1]** and Polak and Jones **[20]** have developed interactive computer simulations to study the effects of **ATIS** on driver behavior. Mahmassani and Shen-Te Chen **[17]** have developed a numerical simulation method which models driver behavior to study the effects of **enroute** and origin-based traffic information on the traffic network. **Lotan** and Koutsopoulos **[16]** have developed a new modeling framework for route choice in the presence of information based on concepts from fuzzy set theory, approximate reasoning and fuzzy control.

Results from Bonsalls' survey of LISB users indicate that about 20% of the survey respondents had changed their normal route to or from work as a result of the static route guidance information and that 75% of respondents were using static route guidance information for all journeys to unfamiliar destinations. After 6 months of using LISB with dynamic guidance 65 **%** of the respondents had come to expect to save time when using LISB for journeys in unfamiliar areas while 47% expected to do so on the journey to work. It is indicated in the survey by Haselkom et al. **[9]** that approximately 75% of drivers already are or are willing to change their commuting route with 60% willing to change **enroute** or at home and 15% willing to change only prior to leaving home. These results indicate that **enroute ATIS** technologies have the potential to effect a significant percentage of drivers and alter their normal behavior. When exposed to potential **ATIS** screens 55% of those identified as Non-changers indicated a willingness to change route. This indicates the positive impact that **ATIS** could have on changing the behavior of those most resistant to change of any kind.

An important finding from Khattaks' research **[13, 14]** was that drivers were more willing to divert in response to information received from radio traffic reports than from their own observation of delay. Radio traffic reports are generally perceived as being accurate, if this same perception can be developed for **ATIS** then the potential for influencing drivers diversion decisions is increased. Also, drivers were more willing to divert in response to incident related congestion, which implies that **ATIS** should improve the capability to detect incidents and disseminate incident related information in a timely manner. Also, drivers who normally experienced longer travel times were more willing to divert. This finding suggests the possibility of tailoring information to specific types of drivers who are more willing to respond. Haselkom et al. also identified subgroups of drivers which could be supplied with tailored information to effect a desired change in behavior. The approach here would be to design **ATIS** technologies to provide information which has been formatted specifically for targeted subgroups. To improve the overall **traffic** system **ATIS** need only effect the behavior of a certain percentage of all drivers, thus information systems could be designed to impact those drivers of a known behavioral type.

The results of Mahmassanis' simulation [17] suggested that the level of market penetration, beyond which coordination in the provision of information is needed, may be as low as 10 or 20 percent, depending on the loading patterns. The existence of benefits from ATIS obviously depends on the manner in which users respond to the information. Mahmassanis' simulation is based on the assumption that drivers will always choose the optimum route between to points. Results from Parkes et al. [19] showed that the routes chosen by drivers using the Travelpilot were significantly different than those taken by drivers using the LISB/ALI-SCOUT and that the optimum routes were not always chosen by drivers. Ultimately, it is likely that users themselves will reach their own conclusions about appropriate switching and route selection rules, through repeated experience with the facility. The dynamics of the formation of such indifference bands constitute an important subject of additional research.

The investigations into the impact of ATIS on route choice behavior have shown that a significant percentage of drivers are willing to alter their normal driving route given appropriate information, but overall system performance may not be improved depending on the level of market penetration that is achieved by ATIS. If high levels of market penetration are achieved, then some form of information coordination will be required to improve overall system performance. Study results indicate that specific driver types exist which may be predisposed to using certain types of information and could be target groups for tailoring information. A basic understanding of how drivers choose or change routes in the absence of information is still needed in order to gain an understanding of route choice behavior in the presence of information. Also, the effects of the learning processes of drivers when exposed to an information system need to be investigated.

To gain a basic understanding of drivers route choice behavior and to develop predictive models of drivers' enroute diversion choice, a route choice survey of Los Angeles area commuters is being planned as part of an on-going PATH project. The survey will investigate how much information drivers have about their routes, their awareness of alternate routes, and their awareness of traffic information which affects their route choices. In future year investigations, laboratory interviews and surveys will be utilized to build on the initial route choice information and develop a mathematical model system of learning, adoption and decision making with ATIS, or an Artificial Intelligence system. The objective is to model how commuters and household members learn to use **ATIS** and make travel decisions with the information it supplies.

Gaining an understanding of the learning processes of drivers is a second major focus of the ongoing PATH Project at the University of California at Davis **[15].** Understanding drivers' adoption processes of this new technology is a critical element in the evaluation of **ATIS** impact on travel demand. Viewing changes in travel demand as results of learning and adoption processes will allow us to capture the impact of **ATIS** to its full extent. A preliminary learning experiment utilizing an interactive computer simulation was recently completed and data analysis is currently underway.

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REFERENCES

1. Adler, J., **Recker,** W., McNally, M., "A Conflict Model and Interactive Simulator (FASTCARS) for Predicting **Enroute** Assessment and Adjustment Behavior in Response to Real-Time Traffic Condition Information", Presented at the 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

2. Allen, R., Stein, A., Rosenthal, T., Ziedman, D., Torres, J. **&** Halati, A., "A Human Factors Simulation Investigation of Driver Route Diversion and Alternate Route Selection Using In-Vehicle Navigation Systems", Society of Automotive Engineers, Warrendale, PA, **Oct.** 1991, pp. 9-26.

3. Bonsall, P. **&** Joint, M., "Driver Compliance with Route Guidance Advice: The Evidence and Its Implications", Society of Automotive Engineers, Warrendale, PA, **Oct.** 1991, pp. 47-59.

4. Bonsall, Peter., "The Influence of Route Guidance Advice on Route Choice in Urban Networks", Special Issue of **Proc.** of Japanese **Soc.** Civil Eng., Feb. 1991.

5. Bonsall, P. and Parry, T., "A Computer Simulation Game to Determine Drivers' Reactions to Route Guidance Advice", **Proc** 18th PTRC Summer Annual Meeting, London, 1990.

6. Boyce, D., "Route Guidance Systems for Improving Urban Travel and Location Choices", Presented at the 67th Annual Meeting of TRB, Washington D.C., 1988.

7. Catling, I., Harris, R. and **McQueen,** B., "A Review of European Developments in Route Guidance and Navigation Systems", American Society of Civil Engineers, New York, NY, 1991, pp. 358-362.

8. Catling, I. and McQueen, B., "Road Transport Informatics in Europe - Major Programs and Demonstrations", IEEE Vehicular Technology Society, New York, NY, Feb. 1991, pp. 132-140.

9. Haselkorn, M. et. al. (1990) "Improving Motorist Information Systems: Towards a User-Based Motorist Information System for the Puget Sound area", Final Report, Washington **State** Transportation Center **(TRAC),** University of Washington, Seattle, March 1990.

10. Haselkorn, M., Spyridakis, J., Barfield, W., "Surveying Commuters to Obtain Functional Requirements for the Design of a Graphic-Based Traffic Information System", Society of Automotive Engineers, Warrendale, PA, **Oct.** 1991, pp. 1041-1044.

11. **Heywood,** H., "Advanced Traveler Information Systems The Vision Beyond", American Society of Civil Eng., New York, NY, 1991, pp. 468-472.

12. Krage, Mark K., "The **TravTek** Driver Information System", Society of Automotive Engineers, Warrendale,PA, **Oct.** 1991, pp. 739-748.

13. Khattak, **Asad., Schofer,** Joseph. **&** Koppelman, Frank., "Effect of Traffic Reports on Commuters' Route and Departure Time Changes", Society of Automotive Engineers, Warrendale, PA, **Oct.** 1991, pp. 669-679.

14. Khattak, **Asad.,** Koppelman, Frank. **& Schofer,** Joseph., "Stated Preference for Investigating Commuters' Diversion Propensity", Presented at the 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

15. Kitamura, R., Jovanis, P.P., **"ATIS** Impact on Travel Demand", Proposal to PATH, ITS, University of California at Davis, 1991.

16. **Lotan,** Tsippy., Koutsopoulos, Haris N., "Fuzzy control and approximate reasoning models for route choice in the presence of information." Presented at the 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

17. Mahmassani, **Hani.,** and Shen-Te Chen, Peter. **,"Comparative** Assessment of **Origin-**Based and En-Route Real-Time Information Under Alternative User Behavior Rules", Transportation Research Record 1306, Washington D.C., Jan. 1991, pp. 69-81.

18. Hatcher, and Mahmassani, **Hani.,** "Daily Variability of Route and Trip Scheduling Decisions for the Evening Commute", Presented at the 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

19. Parkes, Andrew M., **Ashby,** Martin C., and Fairclough, Steve H., "The effects of different in-vehicle route information displays on driver behavior", Society of Automotive Engineers, Warrendale, PA, **Oct.** 1991, pp. 61-70.

20. Polak J.W. and Jones P.M. (1991) 'A study of the effect of pre-trip information on travel behavior', Transportation studies Unit, University of Oxford., Presented at the 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

21. **Rillings,** J. and **Betsold,** R., "Advanced Driver Information Systems", IEEE Vehicular Technology Society, New York, NY, Feb. 1991, pp. **31-40.**

22. Spyridakis, J., Goble, B., Garner, M., Haselkom, M., Barfield, W., "Designing and Implementing a PC-Based, Graphical, Interactive, Real-Time Advanced Traveler Information System that Meets Commuter Needs", Society of Automotive Engineers, Warrendale, PA, **Oct.** 1991, pp. 1045-1048.

23. Young, William., "The Role of Thresholds in Transport Choice", Behavioral Research for Transport Policy, VNU Science Press, Utrccht, Netherlands, 1986, pp. 153-170.

24. Young, W., Bertram, D., "Attribute Thresholds and Logit Mode-Choice Models", Transportation Research Record No. 1037, Washington D.C., 1985, pp. 81-87.

Appendix A

Annotated Bibliography

REFERENCE: "A Conflict Model and Interactive Simulator (FASTCARS) for Predicting Enroute Assessment and Adjustment Behavior in Response to Real-Time Traffic Condition Information", Adler, J., Recker, W., McNally, M., 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

OBJECTIVE(S): This paper presents a theoretical methodology based on conflict assessment and resolution theories and personal tolerance thresholds for modeling enroute driver behavior choice. A computer based simulator, "Freeway and Arterial Street Traffic Conflict Arousal and Response Simulator" (FASTCARS), is described. FASTCARS integrates a driver simulation program with the conflict model approach presented to create a data collection tool for analyzing enroute driver behavior.

METHODOLOGY: It is argued that a conflict model, combined with an overall goal-oriented approach to travel behavior, can provide the basis for modeling enroute behavioral choice and may be extended to estimate a general model for both static and dynamic driver behavior choice. The changes in enroute driver behavior, either through diversion or goal revision, is a direct reaction to the perception that drivers will be unable to meet their travel goals. The combined processes of becoming alarmed by the increased probability of not achieving one's travel objectives together with the motivated response to adapt one's travel behavior to alleviate the situation comprises enroute travel assessment and adjustment.

Conflict theory is presented as a basis for describing this enroute assessment and adjustment behavior. Conflict theory is based on the idea that humans act either address internal needs or in reaction to external forces. The behavioral response is predicted by stages of conflict arousal and motivation. The main responses available to drivers enroute are diversion to new path and restructuring the objective set. The proposed framework for modeling driver choice is constructed through the relationships between driver behavior, cognitive processing abilities, and components of the decision making process.

It is proposed that trip making is composed of goal specification, conflict arousal and motivation, information acquisition and response. It is assumed that drivers are rational decision makers attempting to optimize the value of trip-making, and that all decisions reflect the goal set and the importance of attaining the specified objectives. The degree of motivation and the level of conflict together determine if drivers adapt travel patterns and what the response will be. It is assumed that all decisions are based on the notion of expected improvements in goal attainment. In addition, it is assumed that drivers seek some optimum value of goal attainment. This level is not the "absolute" maximum or minimum but a degree of satisficing towards which the drivers try to achieve.

CONCLUSIONS: FASTCARS was developed as an interactive computer-based simulator based on the modeling framework proposed. The simulator is used to gather data for estimating and calibrating predictive models of driver behavior under conditions of real-time information. The simulation integrates a model of goal specification and evaluation, a hypothetical traffic network, simulated real-time information technologies, and interactive driver travel choices. The program encompasses the entire driving process from pre-trip planning through arrival at the destination. Subjects are required to make a broad range of travel choices including goal specification, route and lane changes, and whether or not to use available information technologies. Also, system variables, such as network conditions and information content can be altered to represent different driving conditions. **FASTCARS** is equipped to emulate three types of **ATIS** technologies, Variable Message Signs, Highway Advisory Radio, and In-Vehicle Navigation Systems. A scoring and evaluation format, based on weighted additive utility models, provides a basis for analyzing behavior and preference.

This paper does not discuss research findings from data analysis and it is not clear if an experiment has actually been run using the **FASTCARS** simulator. A functional example of how the simulator operates is provided taking a subject from a given origin to a specified destination.

COMMENTS: A significant extension of this work would be to simulate a real traffic network with travel times based on current observed levels of congestion and to sample users of the network. This would provide the test subjects with a simulated environment more representative of what they are actually experiencing under normal driving conditions. Observations of route choice behavior within this environment would be more representative of driver behavior in the real world.

REFERENCE: "A Human Factors Simulation Investigation of Driver Route Diversion and Alternate Route Selection Using In-Vehicle Navigation Systems", Allen, R., Stein, A., Rosenthal, T., Ziedman, D., Torres, J. & Halati, A., Society of Automotive Engineers, PA, Oct. 1991.

OBJECTIVE(S): Investigating how well drivers can perform with in-vehicle navigation systems in diverting from main routes and selecting alternate routes when faced with traffic congestion and trip delays.

METHODOLOGY: Simulating trips using slide representations of the environment and prototypes of various navigation system formats. The computer controlled a sequence of slides that represented a 10 mile trip along State Route 22 in Orange County, California. Slides were presented nominally every 5 seconds showing a speedometer, odometer and digital clock. The traffic scenes represented various amounts of congestion. Auditory feedback of engine, road and wind sounds was generated with a sound synthesis card and was consistent with the displayed speed. At the same time, a computer monitor presented prototypes of in-vehicle navigation displays that provided various degrees of information to help with route diversion decisions. Based on the above visual and auditory stimuli, the driver/subject's task was to decide when to divert from the freeway to an alternate route in order to minimize trip delay. Experimental driving scenarios included attributes of traffic incident severity, time constraints, and trip destination.

Different groups of subjects were assigned to each navigation system condition. Each of the groups was broken down into three age groups for non commercial drivers plus a commercial driving group that included all ages. Drivers were then further categorized according to gender and familiarity with freeway route. Each subject experienced four driving scenarios that represented three congestion conditions (11, 18 and 30 minutes delays).

VARIABLES: The variables of interest were navigation system configurations. Four prototype systems were defined for testing its effect on driver behavior; Static map system, Dynamic map system, Advanced experimental system (dynamic map with highlighted alternate route) and Route guidance system (a non-map based display with arrow symbols for direction instructions).

SAMPLE: The majority of the subjects were Southern California Automobile Association employees, with unfamiliar subjects recruited at the downtown Los Angeles headquarters and familiar subjects recruited from the Costa Mesa processing center.

CONCLUSIONS: Of all the subject grouping variables, only age seemed to have any consistent effect on diversion behavior, with the old age group (>55) being more hesitant to divert than younger subjects. Route familiarity did not seem to have a bearing on route diversion behavior.

Navigation system configuration influenced diversion decisions for all congestion conditions. The Static Map proved to be no better than using no navigation system, because it gave no feedback on traffic congestion. The Advanced Experimental and Route Guidance conditions gave the best results. The Dynamic Map System does give feedback on congestion conditions, but offers no Route Guidance assistance.

For people that have some facility for using maps, a map based system might be better because subsequent to diversion, the map based system could provide further help in route finding.

REFERENCE: "Driver Compliance with Route Guidance Advice: The Evidence and Its Implications", Bonsall, P. & Joint, M., Society of Automotive Engineers, PA, Oct. 1991.

OBJECTIVE(S): Examine the validity of the assumption that drivers equipped with information or guidance will have access to perfect knowledge of the system and will hence select optimal routes.

METHOD: This paper present results from two sources; questionnaires conducted among drivers equipped with route guidance as part of the Berlin LISB trial and analysis of decisions made by users of the interactive route guidance simulator known as IGOR (IGOR is presented in different studies by Bonsall).

LISB provides users with advice on minimum time routes to specified destinations via an in-car display screen and synthesized voice. It began giving advice in May 1989 but at that stage the guidance was based only on average traffic conditions for the time of day (static guidance). In

January 1990 the system became fully operational such that the guidance was based on LISB's estimates of current traffic conditions derived from a combination of historical data and recent link traverse-time records transmitted by LISB-equipped vehicles which were already on the network (dynamic guidance). Self-completion questionnaires were administered among drivers of LISB-equipped cars, respondents were asked about their travel patterns, the route they used and the journey conditions they experienced with and without guidance, their assessment of the usefulness of guidance (relative to what they thought they could achieve without it and what they had expected of it) for different types of journeys, and their opinions as to how LISB might be improved.

IGOR is a PC based program which invites users to choose routes through test networks and which stores information about the choice made such that subsequent analysis can determine the influence of specified parameters on the decisions.

VARIABLE& Drivers of LISB-equipped were surveyed at three stages; before any guidance was provided, during the static guidance phase, and again during the dynamic guidance phase.

Each participant in the IGOR simulation session, made 12 journeys, reflecting the different levels of flow expected at different times of the day.

SAMPLE SIZE; 100 drivers of LISB-equipped cars were surveyed.
350 subjects participated in the experiment using IGOR.

CONCLUSIONS; The most significant result of this study from the authors point of view is that drivers are unlikely to request guidance if they find the effort of doing so out of proportion to their perceptions of the benefits to be gained, and that they are very likely to ignore or reject guidance advice if they do not find it credible.

The following points are among the conclusions drawn from this study:

- Concerning the marketing of current generations of route guidance systems, it is important to target groups who are likely to find the advice credible - e.g. those who do a lot of driving to unfamiliar destinations, and those who are predisposed to accept advice, such as less experienced or less confident drivers with fairly modest ambitions and abilities with respect to route optimization. Also marketing which emphasizes potential savings in journey time on regular journeys may succeed for a while but will itself come to lack credibility.

- The role of roadside variable message signs and queue management (via traffic signals) in conjunction with route guidance is an obvious possibility.

- The questionnaires among LISB and the work with IGOR has yielded some response to one type of guidance system and, for that type of system, there is sufficient data to begin calibrating models. In order that the performance of other types of system (e.g. navigation) can be evaluated it is important that work such as that done with IGOR be conducted for them.

COMMENTS: It is a good idea to conduct surveys to study the effect of a certain system and collect data to calibrate models.
However, it could be more beneficiary to begin with existing traffic information systems, such as Radio Traffic Reports.

REFERENCE:
"A Computer Simulation Game to Determine Drivers' Reactions to Route Guidance Advice", Bonsall, P. and Parry, T., Proc 18th PTRC Summer Annual Meeting, London, 1990.

"The Influence of Route Guidance Advice on Route Choice in Urban Networks", Bonsall, Peter., Special Issue of Proc. of Japanese Soc. Civil Eng., Feb. 1991.

OBJECTIVE(S): Modeling the effect of route guidance advice on route choice in various circumstances and using the developed model to study drivers' route choice and acceptance/rejection of advice. A discussion the possible influence of In-Vehicle Route Guidance and Information (IVRGI) systems on drivers' choice of routes and network performance is provided.

METHODOLOGY: The research team at Leeds University, England, developed an interactive simulation model (IGOR). IGOR runs on a PC and is based on a small hypothetical network (30 two way links, 19 nodes) which represent a typical small town. At each junction the participant is shown a plan of the junction. Drivers are asked to make a series of journeys, from specified origins to specified destinations. The route guidance advice is shown in the form of a flashing arrow in the advised direction, and the driver is free to accept or ignore it. The advice provided to drivers in IGOR is generally based on the minimum time route to the destination given current traffic conditions. To make the system more realistic, deliberately several links were made invisible to the system and a known amount of bad advice was given to the drivers (to test their reaction). In one version of IGOR an engine sound is emitted as the driver moves from one junction to the next. Another sound effect which was considered is an impatient car horn if the driver takes an inordinate time to make a decision.

When the user first logs in, he is interactively asked a series of personal questions (age, sex, home location, car ownership, distance driven per year, whether he drives to work and how adept he considers himself in finding new destinations for the first time). He is also asked whether he has an idea of which route he intends to take. At the end of the last journey the user is presented with six stated preference questions, he has to indicate which of two directions he would take in each of the six specified situations. The circumstances faced, advice received, characteristics and responses for each driver are recorded on a data disk, to analyze the choices made.

VARIABLES: Traffic conditions in the IGOR networks vary from one run to another to reflect the different levels of flow expected at different times of day and the variation in traffic from one day to another. Among other variable information presented at each junction, is the amount of congestion and traffic turning at each exit, and which exit is recommended by the IVRGI system.

SAMPLE SIZE: **350** individuals in UK and France, that count for over 11,000 decisions.

CONCLUSIONS: In analyzing the data, two main approaches are pursued; first finding the relationship between the quality of advice and the probability of it being accepted, and second using regression models to determine which variables, or combinations of variables can best explain whether or not advice is accepted. The following points are the main conclusions derived from the simulation experiment:

- acceptance of an item of advice is very dependent on the quality of that advice (completely accurate time minimizing advice was accepted on about 80% of the occasions),

- drivers' acceptance of advice varies with their knowledge of the network (67% acceptance when familiar vs 80% when unfamiliar).

- drivers are prepared to adhere to an occasional piece of bad advice provided that their previous experience of advice has been good,

- young drivers seem less ready than older drivers to accept advice,

- as drivers get closer to their destinations they appear more able to discriminate between good and bad advice,

- advice that sends the driver in what he perceives to be the correct direction is much more likely to be accepted than advice that conflicts with the drivers' sense of direction,

- non optimal advice is very likely to be followed if it adheres to the sign posted route and if it uses uncongested roads,

- commuters who choose their routes in order to minimize distance seem very prepared to accept advice (distance minimizers accept 71% of non optimal advice whereas time minimizers accept only 48% of non optimal advice).

The mentioned points are leading to a much improved understanding of the circumstances in which drivers will and will not accept guidance, in order to design guidance strategies and prediction of route decisions.

COMMENTS: IGOR allows the researcher to experiment with a range of situations and scenarios which are difficult to observe in the field, drivers' behavior, and the impact of IVRGI on it. The study also presents the complexity of the route choice process. It could have been more beneficiary if studying drivers' familiarity with the network were based on a real network instead of using hypothetical one and supplying the driver with a map.

REFERENCE:
"Improving Motorist Information Systems: Towards a User-Based Motorist Information System for the Puget Sound area", Haselkom, M. et. al. (1990), Final Report, Washington State Transportation Center (TRAC), University of Washington.

"Surveying Commuters to Obtain Functional Requirements for the Design of a Graphic-Based Traffic Information System", Haselkom, M., Spyridakis, J., Barfield, W., Society of Automotive Engineers, PA, Oct. 1991.

"Designing and Implementing a PC-Based, Graphical, Interactive, Real-Time Advanced Traveler Information System that Meets Commuter Needs", Spyridakis, J., Goble, B., Garner, M., Haselkom, M., Barfield, W., Society of Automotive Engineers, PA, Oct. 1991.

OBJECTIVE (S): The purpose of this research is to draw conclusions and make recommendations for the improvement, development and design of Motorist Information Systems, based on the results from a large scale, on road, driver information survey.

METHODOLOGY: The research utilized a large scale, on road, mail-in survey which targeted a specific freeway corridor. From the survey respondents, a sub-sample, in-person, follow up survey was performed as well an in-person analysis of potential motorist information screens. The survey was developed after examination of 12 surveys administered on the issue of motorist behavior conducted between 1963 and 1987.

VARIABLES: The survey resulted in a data set with 62 variables concerning commute characteristics, route choices, interaction levels with motorist information, and demographic data. This report does not provide a listing of all variables in the data set nor does it contain samples of the survey questionnaires.

SAMPLE SIZE: Nearly 10,000 commuters from the selected freeway corridor were surveyed, with a response rate of approximately 40%. 3,893 commuters responded to the survey and 100 of these participated in the follow-up, in-person survey.

CONCLUSIONS: The use of cluster analysis and the discovery of distinct, stable motorist groupings with respect to driving behavior and information needs was stated as the single most significant finding for the purpose of tailoring specific driver information for area commuters. The researchers used cluster analysis to identify four commuter groups: (1) Route Changers (RC) (20.6%); (2) Non-Changers (NC) (23.4%); (3) Route and Time Changers (RTC) (40.1%); and (4) Pre-Trip Changers (PC) (15.9%).

The strategy advocated for the design of ADIS is to 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. By targeting these drivers, a maximum improvement in traffic flow can be achieved at a minimum cost. Significant conclusions put forth by the researchers are listed below:

-The survey methodology used is extremely successful at gathering data on commuter behavior and decision processes.

-The use of cluster analysis is extremely successful at leading to deeper, more inferential analysis of traffic data.

-Distinct, stable sub-groups of commuters can be identified.

-Commuters less flexible about a driving decision are also less likely to be aware of information that could impact that decision.

-Commuters are dramatically split in their departure time flexibility.

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

-Commuters question the credibility of motorist information.

-Having modified their behavior, commuters have little feed back on the correctness of their choice.

-Commuters tend not to be receptive to information delivered on the freeway.

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

RECOMMENDATIONS: Specific recommendations put forth by the researchers for the design, development and improvement of ADIS are listed below.

-Use driver groups to tailor information to the groups most likely to be impacted.

-Place high priority on home delivery of information, particularly related to impacting departure time.

-Include feedback mechanisms in any motorist information system.

-Place a high priority on improving on-road information delivery mechanisms.

-On-road information systems should target commuters who tend to change route while driving.

-Coordinate home and on-road messages for motorists need for feedback and reinforcement.

-Improve on-road message content.

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

These recommendations are being incorporated into a PC-based, graphical, interactive, real-time driver information system called "TRAFFIC REPORTER". The system processes data from detectors in the roadway to estimate travel speeds and travel times on the freeway corridor. The information is graphically displayed as a map of the corridor with four color coded speed ranges displayed. Selected entrance ramp to exit ramp travel times are estimated, and average speeds at a particular location can be displayed. The system can store and play back commute data for statistical analysis.

REFERENCE: "Effect of Traffic Reports on Commuters' Route and Departure Time Changes", Khattak, **Asad., Schofer,** Joseph. **&** Koppelman, Frank., Society of Automotive Engineers, PA, Oct. 1991.

OBJECTIVE(S): Evaluating the effect of traffic reports on route and departure time decisions.

METHODOLOGY: Downtown Chicago automobile commuters were **surveyed during** the AM peak period by giving them mail-back questionnaires. The empirical aspects focused on downtown Chicago automobile commuters because they were most likely to experience congestion, traffic information was available on several major routes and drivers could choose from several available roadways. Drivers first evaluated the overall effect of Radio Traffic Reports **(RTR)** on their trip decisions and then evaluated attributes of the traffic information system.

The authors hypothesized that the decision making process on regular work trips consists of the formation of perceptions regarding system characteristics and the development of feelings for the choice context. Perceptions and feelings together determine driver preferences regarding perceived options. Situational factors along with preferences then determine the observable trip choices.

The effect of attributes of the traffic information system, attributes of the alternatives and the individual and situational factors on decisions to change route and departure time were explored by estimating models using multivariate statistical analysis. The ordered **probit** model was used for estimation, and it provides thresholds which indicate the levels of agreement with the statement.

SAMPLE SIZE: Downtown Chicago automobile commuters were surveyed during the AM peak period. Questionnaires were given to more than **2000** commuters at downtown parking facilities and 700 returned the surveys by mail.

CONCLUSIONS; The findings of this research are reasonable and useful in **evaluating** and improving radio traffic reports, which provide a useful service to travelers. There are opportunities to improve radio traffic reports by predicting traffic conditions. This may result in increased benefits to travelers and a reduction in traffic congestion.
The authors also found the following:

- Automobile commuters used traffic information more en-route compared to when they were planning their trips.

- Drivers were more likely to switch routes if they could get traffic information whenever they needed it, which reflects the dynamic nature of en-route decisions and drivers' need for quick traffic information updates.

- Close to 70% of the respondents indicated that they listen frequently to radio traffic reports. Drivers who listen more often were more likely to take alternate routes.

- Radio traffic reports may be particularly useful for more familiar drivers.

- Traffic reports reduced enroute anxiety and frustration of drivers even if drivers did not modify their trip decisions.

- Drivers are more likely to change their times of departure if they perceived radio traffic reports to be accurate, listened to it frequently and perceived usual route to be congested.

- Among socioeconomic attributes, higher income drivers were more likely to take alternate routes and males were likely to divert compared to females.

COMMENTS: It is important to note that among the findings of this research is that drivers who perceived their usual route to be congested were more likely to change their route decisions, that is why it is essential to understand drivers' perceptions to design the suitable information system.

REFERENCE: "Stated Preference for Investigating Commuters' Diversion Propensity", Khattak, Asad., Koppelman, Frank. & Schofer, Joseph., 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

OBJECTIVE(S): Using a stated preference approach to make a research design, in order to evaluate the effects of real-time traffic information along with driver, roadway, and incident characteristics on drivers' willingness to divert.

METHODOLOGY: To assess drivers' diversion propensity a five point scale ranging from definitely take usual route to definitely take alternate route were used. A total of 16 stated preference questions were in the survey distributed. A descriptive model of diversion propensity was developed. To explore the effects of several variables on diversion propensity two sets of independent variables were used in the models, Dummy Variables and Reported Driver and Trip Attributes. The ordered probit model was used for estimation because the categorical dependent variables have a natural ordering.

VARIABLES; Usual and alternate routes, delay lengths, type of congestion, source of traffic information, time pressure, and drivers' reluctance to take unfamiliar alternate routes.

SAMPLE SIZE; Differed from one question to the other, but the maximum size was 640 drivers. Sample place was downtown Chicago.

CONCLUSIONS: The stated preference results are consistent with the authors' expectations and with the findings of earlier studies. The results showed the following:

- Socioeconomic and trip attributes significantly influenced driver's willingness to divert,

- commuters were more willing to divert if delays on intended route increased, the congestion was incident induced (not recurring), delay information was received from radio traffic reports, trip direction was home to work, the alternate route was safe, familiar and had no traffic stops,

- drivers willingness to divert in response to incident congestion implies that advanced traveler information systems should improve the capability to detect incidents and disseminate incident related information in a timely manner,

- advanced traveler information systems should update travel time information on both current and alternate routes to support diversion advice, and

- drivers may be more willing to divert on being told the cause of delay along with delay length, compared to simply being informed about delay length.

COMMENTS: Stated preference is what people say they would do under particular circumstances, and they tend to be relatively less credible because the scenarios presented to the individual are hypothetical. The respondent may behave differently if faced with similar situation in real life. Further, the respondent may want to please the researcher, particularly if he was asked about a new service.

REFERENCE; "Fuzzy control and approximate reasoning models for route choice in the presence of information." **Lotan,** Tsippy., Koutsopoulos, Haris N., 71st Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1992.

OBJECTIVE(S): This paper presents a framework for modeling route choice behavior under the provision of real time traffic information. The framework includes models for driver's perceptions of network attributes, attractiveness of alterative routes, as well as models for reaction to information, and the route choice mechanism itself. The approach suggested to model driver's behavior in making route choice decisions is based on elements from fuzzy set theory, fuzzy control and approximate reasoning.

PARAMETERS; The models presented assume that travel time is the most important factor in making route choices. The travel time on a particular path was categorized into five fuzzy sets: Very Low, Low, Medium, High, and Very High.

METHODOLOGY; The two main components of the methodology are driver's perceptions of attributes of the network and the route choice mechanism. Fuzzy control consists of three elements: fuzzy rules relating the input of the system to control actions or decisions; approximate reasoning logic used to modify the rules to accommodate actual current conditions; and a mechanism to combine the modified rules into a unique decision. The decision structure in fuzzy control has the form "if A_i then B_i". The A term is the attribute of the network, in this case one of five travel times on a particular path VL, L, M, H, or VH. The B term is the route choice mechanism. The route choice mechanism is modeled by defining five fuzzy sets representing the driver's attitude towards taking an alternative route: Definitely Not, Probably Not, Indifferent, Probably Yes, Definitely Yes.

To define the model a set of base rules is developed and an approximate reasoning scheme is used to derive rules that do not correspond exactly to one of the base rules but that are close to it. This method adds flexibility to the interpretation of the rule by allowing the premise to be partially true and changing the consequence accordingly. In general a given input will have a certain amount of overlap with several rule premises. Every rule whose premise condition overlaps with the input is activated and thus, depending on the inputs, more than one rule may contribute to the final decision. The merit of the approach is that given a certain input, several rules are being applied simultaneously, each to a different degree in order to produce a final decision.

CONCLUSIONS: The modelling framework presented is one of the first attempts at mathematical modelling of the complex problems of driver decisions (route choice) under uncertainty. The use of fuzzy set theory, approximate reasoning and fuzzy control holds great promise in more realistically modeling these complex human oriented decision systems by allowing the use of linguistic descriptors, phrases, hedges and modifiers.

REFERENCE; "Comparative Assessment of Origin-Based and En-Route Real-Time Information Under Alternative User Behavior Rules", Mahmassani, **Hani.** and Shen-Te Chen, Peter., 70th Annual Meeting of Transportation Research Board, Washington D.C., Jan. 1991.

OBJECTIVE(S): Examining the effects of real-time traffic information, supplied at the origin or en-route, on the overall system's performance under alternative behavioral rules governing path selection in the network, as well as exploring the opportunities for system improvement with respect to four principal experimental factors:

- Behavioral Rules
- Sources of Information
- Loading Patterns (initial conditions)
- Market Penetration

METHODOLOGY; Conducting numerical simulation experiments to compare the relative effectiveness of en-route and origin-based real-time information. The simulation experiments are performed for a commuting corridor with three major parallel facilities (freeways), for a morning commute. All three facilities are nine miles long, and each is descretized into nine one mile segments, with crossover links at the end of the third, fourth, fifth, and sixth miles to allow switching from one facility to another. Commuters enter the corridor through ramps feeding into each of the first six one mile segments on each facility, and commute to a single common destination downstream.

Three distinct Behavioral Rules are proposed for en-route path switching; similar constructs can also be used for initial path selection. The first is called Myopic Deterministic Choice Rule, which states that from any given node, the user will always select the best path (in terms of least cost or least travel time) from the current node to his destination. The second is a Boundedly Rational model of path switching, this rule can be operationalized using a satisficing switching rule with an indifference band of trip time saving. A user will switch from his current path to the best alternative only if the improvement in the remaining trip time exceeds this indifference band. The third is a standard random utility discrete choice model (not presented in this paper).

Two Information Sources are considered: home-based information, consulted prior to actually starting the trip, and in-vehicle en-route information. Four levels arc considered for this factor: 1) no information, 2) home-based pre-trip information only, 3) en-route only, and 4) both sources are available.

To capture the effect of the existing network's traffic conditions, three Loading Patterns were used in the simulation experiments. Under the first loading pattern, commuters are split equally among the three highways, departing at a rate of 30 vehicles per minute per sector for each facility. The second loading pattern has departing rates of 40 vehicles per minute for Highway 1, 30 vehicles per minute for Highway 2 and 20 vehicles per minute for Highway 3, for each sector. Under loading pattern 3, 60 vehicles enter Highway 1, 20 vehicles enter Highway 2 and 10 vehicles enter Highway 3, all per minute per sector.

To examine the effect of Market Penetration, five levels of fraction of users with access to real-time information were considered: 0.1 , 0.25 , 0.5 , 0.75 and 1.

VARIABLES: The corridor contains 3 major Highways, the first has the highest free mean speed 55 mph, the second and third have speed of 45 and 35 mph respectively..

SAMPLE SIZE: Using different combinations of the four above mentioned experimental factors, 123 separate simulation runs were performed.

CONCLUSIONS: System performance for each simulation run is evaluated by comparing the average trip time for all commuters in the system to the corresponding value in the base case (the do nothing case).

It was strongly suggested in the results that the overall effectiveness of real time information in a network is highly dependent on the prevailing initial conditions, and the extent to which these offer opportunities for improvement. It appears that the closer the system is to the optimum, the higher the likelihood that information from either source may actually worsen system wide performance.

The relative effectiveness of home based versus en-route information is also highly dependent on initial conditions, and on the manner in which the present system may be suboptimal. For instance, it was seen that when the fastest facilities are under utilized, origin based information could be effective. When the reverse is true, initial switching appears to be **effective** only at very low market penetration levels, and en-route information seems to be much more effective.

The results also suggest the need to carefully consider several important parameters and factors in the ongoing research and development efforts pertaining to **ATIS,** in particular the following four items:

- The importance of initial conditions in determining the potential effectiveness of real-time information strategies. Additional effort should be directed at characterizing present conditions in congested networks, especially in terms of how trip makers actually utilize the components and facilities of these networks.

- The existence of benefits from **ATIS** obviously depends on the manner in which users respond to the information. Ultimately, it is likely that users themselves will reach their own conclusions about appropriate switching rules, through repeated experience with the facility. The dynamics of the formation of such indifference bands constitute an important subject of additional research, which could benefit from previous work on the day to day dynamics of commuting decisions through the use of laboratory experiments.

- The need for coordination in the provision of information beyond a certain market penetration level. The results of the simulation suggested that the level beyond which coordination is needed may be as low as 10 or 20 **%,** depending on initial conditions.

- The nature of the information supplied to the drivers. The strong interrelation among supplied times, user decisions, and traffic conditions makes the prediction problem and the design of information supply strategies rather complex.

<u>COMMENTS:</u> The simulation model used in this study depends on a technique developed by the authors. It is very difficult to model the drivers' behavior. It could have been more realistic if the authors used a survey or experiment to support the simulation model especially in respect to the behavioral rule.

REFERENCE: "The effects of different in-vehicle route information displays on driver behavior", Parkes, Andrew M., **Ashby,** Martin C., and Fairclough, Steve H., Society of Automotive Engineers, PA, Oct. **1991.**

OBJECTIVE(S): This paper briefly reports on two experiments that attempt to study the changes in driver behavior brought about by the use of route information devices. Experiments are performed in a real road environment, and by using a variety of data relevant to each of the important levels of the real world driving task.

METHODOLOGY: Two experiments were carried out focussing on methods for micro-level evaluations of driver behavior. These experiments focus on the effect on driver behavior of the introduction of various types of route information.

The first experiment utilized two methods of route navigation; paper map, and computer text. The paper map was presented on a white card with the intended route highlighted in green. The map was magnetically attached to a plate on the dashboard and allowed for rotation as required. The computer text was presented on a LCD computer screen mounted on a dash board bracket. A set of navigational instructions were programmed and presented as a list which the user could scroll through using up and down keys.

The test subjects participated in both of the experimental conditions. The experimental routes were located in a suburban area, unfamiliar to the subjects. Traffic density was low during the experimental trials. Video recordings were obtained from three cameras giving drivers' eye movements and traffic situations encountered. The subjects heart rate was captured using an electrode belt and receiver unit.

The second experiment also utilized two methods of route navigation; auditory and graphic symbol guidance with the LISB/ALI-SCOUT system, and map-based navigational information from the Bosch Travelpilot system **(Etak).** Subjects drove a test vehicle equipped with both systems. The system displays were mounted on the upper dashboard at steering wheel height.

Video recordings were made of drivers' head and eye movements as well as the road ahead. The experimental task was to drive the car over a given route within urban Berlin, during **off-**peak periods, while using the two information systems.

VARIABLES: Variables for the first experiment included heart rate, eye movements (frequency and duration), time for route completion, and number of errors. Variables for the second experiment were the same as the first except heart rate was not recorded and a subjective **rating** comparing the two systems was used.

SAMPLE SIZE; The first experiment used 20 subjects (10 male, 10 female) with age range of 20 - 60 years and driving experience of l-30 years from the local population in the UK. Subjects were paid 5 pounds per hour for participation.

The second experiment used 24 subjects with 15 under 30 years of age and 9 over 55 years of age. Subjects were drawn form the local Berlin population and were paid for participation but the amount was not specified.

CONCLUSIONS: Experiment number 1. The results showed that the map condition was associated with higher heart rates, slower speeds, more errors, more time away from the forward view, and a greater feeling of workload than the computer text condition. The primacy of the navigation task over the vehicle control task was evident.

Experiment number 2. Drivers judged LISB to be less demanding than the map-based travelpilot. This is to be expected as drivers have to make route decisions for themselves from a complex moving map. With the Travelpilot visual attention to the roadway ahead fell when compared with LISB use. Attention was also increased to the near and offside windows indicating that subjects were matching information on the map to local surroundings.

COMMENTS: The results of enroute map use verses a text or graphical display were similar between the two experiments. No explicit comparison of data was made between the two experiments. Neither experiment utilized a test condition in which no navigational aide was used to establish a normal value for the variables under investigation. This type of comparison would provide information on the changes in driver behavior from "normal" conditions to a condition under the influence of navigational information.

REFERENCE; "A study of the effect of pre-trip information on travel behavior", Polak J.W. and Jones P.M. (1991), Transportation studies Unit, University of Oxford.

OBJECTIVE(S): This paper investigates traveller's requirements for different types of travel information, investigates methods of information enquiry and relates the process of information acquisition to changes in travel behavior.

METHODOLOGY; Utilization of a stated preference (SP) approach, built on the use of a PC based simulation of an "in-home pre-trip information system" offering information on travel times from home to city center, by bus and car, at different times of day. Surveys were undertaken in parallel in Birmingham and Athens allowing comparison between typical southern and northern european settings.

The research utilized surveys performed with the respondents in their homes and were based around a recent journey they had made to the city center by car. The surveys were repeated for different days to obtain more data per interview. Car travel times, costs, and perceived variability in travel times were obtained from respondents. Comparable information for travel by bus was also obtained.

The survey information was used to derive estimates of mean travel times by different modes at different times of day. For the computer model a random element was applied to the mean travel time to reflect day-to-day differences in network travel conditions.

Using the mean travel time information (obtained from the survey) the researchers developed an in home traffic information simulator using a personal computer. The simulator provided information on expected travel times by bus and car at different times of day. Information was also provided on parking search times and expected bus arrival times at stops.

Respondents were able to query the system by inputing a departure time and mode choice or a required destination arrival time and mode choice. The simulator would respond by providing expected travel times, parking times, and either expected arrival or required departure times.

Upon completion of an enquiry exercise the respondent was asked to rank the travel options displayed in order of preference. For non-work trips the additional selections "alternative destination" and "trip abort" were added to the list of options to be ranked.

VARIABLES:
Home Survey: sex, age, socio-economic group, trip purpose, frequency of trip to city center, free parking in the city center?, current trip re-timed to avoid congestion?.

Computer Simulation: enquiry mode (car, bus), enquiry type (departure or arrival oriented), change in departure time.

SAMPLE SIZE: A total of 666 individuals took part, 344 in Birmingham, England, and 322 in Athens, Greece. No indication of the response rate attained was given.

CONCLUSIONS: There was significant differences in the types of information desired by respondents in the two cities. Respondents in Athens had a much higher interest in public transportation, while those in Birmingham showed more interest in trip re-timing. The respondents in both cities showed little interest in performing extensive searches; and journey related factors had little effect on the number of enquiries made. The results support the existence of heuristically guided search behavior i.e. if respondents first enquiry showed travel times no worse than they currently experienced then they were more likely to perform only the minimum amount of searching. The results provide evidence that information acquisition is structured according to travel preference with Birmingham respondents enquiring more about trip timing and Athens respondents enquiring more about mode.