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An On-the-Road Comparison of In-Vehicle Navigation Assistance Systems: The FAST-TRAC Troika Study

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16. Abstract

The FAST-TRAC project is a multi year implementation and evaluation of an Intelligent Transportation System (ITS) in Southeastern Michigan and has two main components: An advanced traffic-management system and two distinct in-vehicle advanced traveler information systems (ATIS), Ali-Scout and TetraStar. The purpose of the User Perceptions and Behaviors element of FAST-TRAC is to understand how people use and what they think about the ATIS component of FAST-TRAC. The purpose of the present investigation was to compare not only how people use and what they think about these two specific systems and a third system using Written Instructions, but also to compare performance and what people think about three distinct types of in-vehicle navigation-assistance systems when the systems are used concurrently under identical conditions on the road. Identical conditions were achieved by having triplets, or troikas, of people driving similar vehicles at the same time to the same destinations, while tracking all vehicles through satellite positioning. One person in the troika used Ali-Scout, one used TetraStar, and one used Written Instructions. Driver familarity with area and traffic conditions were also investigated.

Overall, we found that Ali-Scout users got lost more frequently, had more difficulty finding routes and destinations, made more wrong turns, and drove longer routes than did users of the other two systems. When trips in which the driver got lost were removed and drivers had experience with the systems, we found that users of both Ali-Scout and TetraStar had significantly shorter trip durations (5 percent overall) than users of Written Instructions. Analysis of trip duration by traffic conditions and of time spent at zero velocity showed no benefit of Ali-Scout's dynamic route guidance over the static guidance of TetraStar. Other driving behavior and questionnaire data are also reported.

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FAST-TRAC, ATIS, ITS, Navigation, Evaluation, Ali-Scout, TetraStar, Way Finding	Unlimited

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INTRODUCTION

The FAST-TRAC project is a multi year implementation and evaluation of an Intelligent Transportation System (ITS) in Southeastern Michigan. The FAST-TRAC system has two main components: An advanced traffic-management system (ATMS) called SCATS which adjusts signal timings based on real-time traffic conditions and two distinct in-vehicle advanced traveler information systems (ATIS), Ali-Scout and TetraStar. The purpose of the User Perceptions and Behaviors element of FAST-TRAC is to understand how people use and what they think about the ATIS component of FAST-TRAC. In particular, we wanted to know whether the systems helped drivers navigate and reduced their travel times, whether the systems were safe, driver opinions of the systems, whether they would consider purchasing the systems, and, if so, what they would be willing to pay for them. Towards this end, we have conducted four studies. In three of the studies, the Natural Use Studies, people drove vehicles with either Ali-Scout or TetraStar installed and reported use and perception information. The fourth study, the Troika Study reported here, is an on-the-road comparison of Ali-Scout, TetraStar, and Written Instructions when these systems are used under identical circumstances.

While the Troika Study compares specific systems, it can also be considered a test of conceptually distinct types of in-vehicle navigation assistance systems (INAS). In recent years, many different INASs have been developed and these systems vary greatly in their appearance and features. However, all of these systems can be classified according to the scheme shown in Table 1. As shown in this table, certain INAS determine the "best" route between some origin and destination without taking into account traffic conditions that may be encountered during the trip (called static route guidance). Other systems have the ability to use information about potential or real-time traffic conditions to decide the "best" route (called dynamic route guidance). Because there is little agreement on the definition of dynamic route guidance, we define the phrase broadly as route guidance that includes *any* traffic congestion information, including predictions of recurrent traffic congestion (sometimes called predictive route guidance) and real-time information that could detect both recurrent and nonrecurrent traffic congestion. Further, some systems have information about the vehicle's location (e.g., through satellite positioning or dead-reckoning) and can guide a person as he or she drives by giving turn-by-turn instructions during the trip (as-you-drive). Other systems show the entire route or set of instructions to the driver in advance with no additional guidance information being given during the trip (all-in-advance). Listed in Table 1 are the representative systems we tested in this study and their classifications. There is no system listed in the dynamic, all-in-advance cell of this table because this type of system was not tested in the present study.

<table>
<tr><th colspan="4">Table 1: Classifications for In-Vehicle Navigation Assistance Systems and the Example Systems Tested in this Study.</th></tr>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Type of Guidance</th></tr>
<tr><th>Static</th><th>Dynamic</th></tr>
<tr><th rowspan="2">Presentation of Guidance Information</th><th>As-You-Drive</th><td>TetraStar</td><td>Ali-Scout</td></tr>
<tr><th>All-in-Advance</th><td>Written Instructions</td><td>N/A</td></tr>
</table>

The purpose of the present investigation was to compare not only how people use and what they think about three specific systems, but also to compare performance and what people think about three distinct types of INAS when the systems are used concurrently under identical conditions on the road. Identical conditions were achieved by having triplets, or troikas, of people drive similar vehicles at the same time to the same destinations. One person in the troika used Ali-Scout, one used TetraStar, and one used Written Instructions.

METHODS

Subjects

Three-hundred sixty subjects volunteered and were paid for their participation. Subjects were recruited through advertisements running in local and nonlocal newspapers. All subjects who responded were asked whether they had a valid driver's license and their date of birth. Volunteers not in possession of a valid license or under the age of 19 were excluded from participation. The study area was described to volunteers and they were asked whether they had either lived or worked in this area, and whether they thought that they were very familiar, familiar, somewhat unfamiliar, unfamiliar, or very unfamiliar with the study area. Subjects that indicated they had either lived or worked in the study area or were either familiar or very familiar with the study area were designated as "familiar" subjects and were scheduled to participate in the familiar condition of the study. The remaining volunteers were considered "unfamiliar" subjects and were scheduled for participation in that condition of the study.

Of the 360 people who participated, 51.9 percent were male. The ages ranged from 19 to 80 years old with a mean age of 37.4 years (*sd*=15.3 years of age). Table 2 shows the distribution of self-reported education level and Table 3 shows the distribution of self-reported household income.

Table 2: Distribution of Self-Reported Education Level of Troika Study Participants

Response Category	Frequency	Percent
Less than a High School Diploma	2	0.6
High School Diploma	33	9.2
Some College	168	46.9
Bachelor of Arts or Science	72	20.1
Some Graduate School	36	10.1
Graduate Degree	47	13.1

Table 3: Distribution of Self-Reported Household Income of Troika Study Participants		
Response Category	**Frequency**	**Percent**
Less than $15,000	79	22.8
$15,000 - $24,999	53	15.3
$25,000 - $34,999	47	13.5
$35,000 - $44,999	46	13.3
$45,000 - $54,999	40	11.5
$55,000 - $64,999	27	7.8
$65,000 - $79,999	28	8.1
$80,000 - $99,999	24	6.9
$100,000 or More	3	0.9

The participants' travel patterns were varied, as their education and income levels would suggest. When asked how many out-of-town vacations they had taken in the past twelve months 11.0 percent indicated zero, 14.7 percent indicated one, 21.8 percent indicated two, 17.8 percent indicated three, and 34.7 percent indicated that they had taken at least four vacations in the past year. When asked how many out-of-town business trips they had taken in the past 12 months, 65.3 percent indicated zero, 10.6 percent indicated one, 9.1 percent indicated two, 4.6 percent indicated three, and 10.3 percent indicated that they had taken at least four business trip in the past year. Those subjects who had taken one or more out-of-town vacations or business trips in the last year were also asked about their routing preferences between locations on out-of-town vacations and business trips. Table 4 shows the percentage and frequency of respondents who indicated routing preferences. Subjects could indicate more than one preference. Note that the majority of respondents reported preferences for routes that are fastest and shortest for both vacation and business trips.

Table 4: Percentage and Frequency of Troika Study Participant Routing Preferences for Vacations and Out-of-Town Business Trips		
Route Type	**Vacation Trips (n=326)**	**Business Trips (n=164)**
Fastest	80.7 (263)	86.6 (142)
Shortest	55.2 (180)	50.6 (83)
Most Scenic	40.2 (131)	7.9 (13)
Safest	37.1 (121)	34.8 (57)
Avoids/Utilizes Certain Areas	20.2 (66)	15.2 (25)
Avoids Freeways	3.1 (10)	0.0 (0)
Avoids Congestion	0.9 (3)	1.2 (2)
Other	3.7 (12)	1.8 (3)

More than one-half of the study participants (57.2 percent) indicated that when they drove in urban areas they generally listened to traffic reports, and nearly all participants (98.1 percent) indicated that they were willing to divert from a driving route that they normally used in order to avoid traffic congestion. Roughly one-half of the participants reported that they were not confident in their ability to navigate in unfamiliar areas. Finally, subjects were asked about frequency of road map use and 12.8 percent reported "at least once a week," 22.8 percent reported "1-3 times per month," 39.2 percent reported "once every 2-6 months," 11.4 percent reported "once a year," and 1.1 percent reported map use "less than once a year." Analyses of all demographic factors showed that subject characteristics were evenly distributed over the study variables.

The In-Vehicle Navigation-Assistance Systems (INAS)

Ali-Scout: This INAS, developed by Siemens Corporation, determined the fastest route between the vehicle's current position and a user-supplied destination. With Ali-Scout, the fastest route can be determined by using road classification only (static route guidance) or by using this information combined with information about recurrent traffic congestion (dynamic route guidance). Nonrecurrent traffic congestion, or real-time, information was not used by this system. Ali-Scout was operating in its dynamic guidance mode for the entire Troika study. Route information and link travel times were transmitted between the vehicle and roadside beacons with an infrared signal. The uploaded link travel times were used to update the network travel-time data base. To ensure that the link travel times in the area of the Troika Study were reliable and current, the research team drove hundreds of circuits through the network during the two weeks prior to the start of the study. Routes were calculated and link travel times were compiled on a central computer located at a traffic operations center run by the Road Commission for Oakland County (RCOC) Michigan. Communication between the central computer and beacons was through telephone links. Ali-Scout determined the vehicle's location through a dead-reckoning calculation between roadside beacons and provided turn-by-turn instructions to a driver as he or she drove using both visual and voice commands.

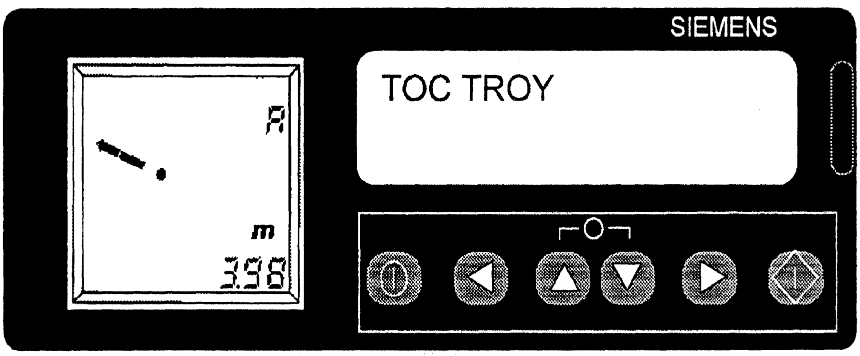


Figure 1: Illustration of Ali-Scout unit in "autonomous mode" showing distance and direction to destination (TOC TROY).

For every trip taken with the Ali-Scout INAS, two conceptually distinct kinds of guidance are used. After a destination is entered into the Ali-Scout unit, guidance begins in what Siemens Corporation calls "autonomous mode." In this mode, only real-time distance and direction-to-the-destination information is displayed (i.e., "as the crow flies" information) without any turns being recommended. Figure 1 shows an example autonomous mode guidance display. As the driver proceeds towards his or her destination, he or she eventually passes a roadside beacon where a communication takes place and a calculated route is downloaded by Ali-Scout. The system then changes to "guided mode," where the driver is given turn-by-turn instructions as he or she drives. An example driving maneuver icon for Ali-Scout is shown in Figure 2. As the turn-by-turn instructions are followed, eventually the driver nears the destination. When the vehicle is within about one-half mile of the destination, Ali-Scout reverts back to autonomous mode guidance and the driver must look for the exact destination. Ali-Scout will also revert to autonomous mode guidance if the driver does not make a recommended maneuver or communication at a beacon is disrupted (e.g., the beacon is not functioning or the infrared signal was blocked). When this occurs, Ali-Scout will remain in autonomous mode until another beacon is passed.

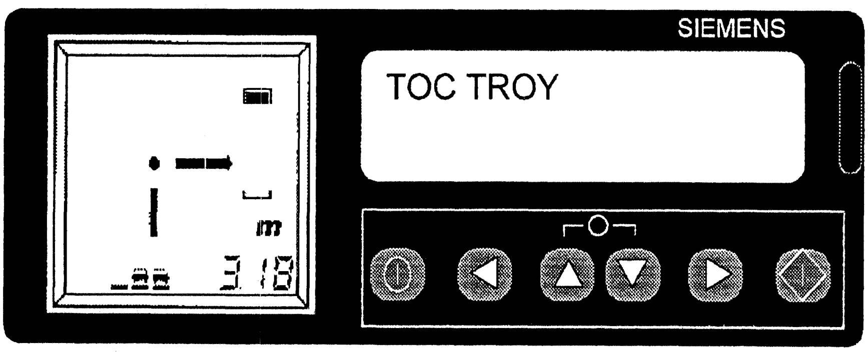


Figure 2: Illustration of Ali-Scout unit showing a right-turn maneuver icon, recommended lanes, distance, and countdown bar showing relative distance to the maneuver.

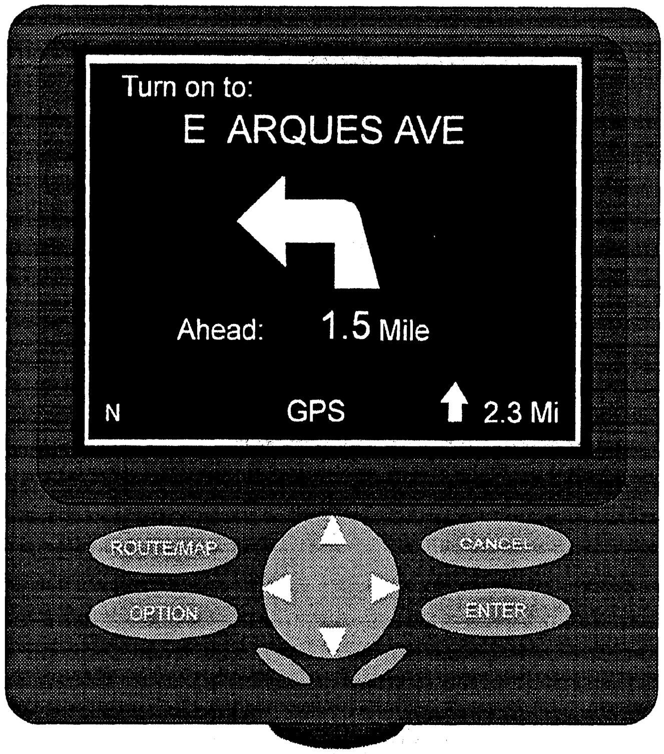


Figure 3: Illustration of TetraStar unit showing a left turn maneuver icon, the name of the road to turn on to, the distance to the maneuver, the compass direction the vehicle is traveling (N), and the distance and direction to the destination.

TetraStar: This INAS, marketed by Siemens Corporation, was similar to other commercially available products such as GuideStar or PathMaster. TetraStar provided static route guidance only; that is, it determined the fastest route between some origin and destination without taking into account current traffic conditions. TetraStar determined the vehicle's location through an on-board global positioning system (GPS) and provided visual and voice, turn-by-turn navigation assistance to the driver. The visual guidance instructions consisted of an electronic map, in which a highlighted route to the user-supplied destination and the vehicle's current location were shown, and driving-maneuver icons.

As a trip started, TetraStar showed the map display, with a highlighted route, and both verbally and visually tells the driver to "please proceed to the highlighted route," usually a few hundred yards from the vehicle's current location. Once on the route, TetraStar begins displaying turn-by-turn instructions by showing the next required maneuver, its distance away, and the name of the street where the maneuver will occur. The driver can switch between the maneuver icons and the map display by pressing a toggle button. Figure 3 depicts the TetraStar display showing a driving maneuver icon. Once the destination is within a few hundred yards, TetraStar reverts to the map display showing the highlighted route to the destination. If a driver fails to make a recommended turn, TetraStar stops giving directions and prompts the user to press the *enter* button to calculate a new route.

Written Instructions: This "system" represents a type of navigation assistance that most people have used and it is the system that electronic INAS must outperform if they are to be considered an improvement over the current technology. For this study, the written instructions were simply turn-by-turn instructions type written onto an 8.5 by 11-inch sheet of paper and were accompanied by a black-and-white map depicting the study area, with an origin and destination indicated. The maps and sets of instructions for each origin-destination (O-D) pair can be found in Appendix A.

So that no *a priori* knowledge about traffic conditions on certain roadways was used in route selection, the routes between the O-D pairs were determined randomly. Because the road network was a grid pattern and because the O-D pairs were diagonal across the grid (southeast to northwest and vice versa) there were several routes that were equally direct. The north-south roads were determined by the locations of the origins and destinations. We selected randomly an east-west road for use in all O-D pairs. Once the route between an O-D pair was determined, all subjects driving that O-D pair were given the same instructions. Only one route for each O-D pair was selected, regardless of the direction of travel.

Design

There were four independent variables in the study: In-Vehicle Navigation Assistance System (Ali-Scout, TetraStar, Written Instructions), Driver Familiarity with Area (Familiar, Unfamiliar), Traffic Conditions (Peak, Nonpeak), and Trip Number (First Trip, Second Trip). Driver familiarity was determined by self-report on a questionnaire completed at recruitment, as described earlier. The study was run on normal weekdays (i.e., Monday through Friday). No trials were conducted on weekends or holidays. Traffic conditions were varied by running the experiment during different times of day. Peak traffic conditions were defined as 7:00 a.m. to 9:00 a.m. and 4:00 p.m. to 6:00 p.m. Nonpeak traffic conditions were defined as 9:00 a.m. to 11:30 a.m. and 1:00 p.m. to 3:00 p.m. Each participant in the study drove two trips. The first trip was from a specific origin to a specific destination. The second trip was to drive the O-D pair in the opposite direction. The subject was not told about the destination for the second trip until the first trip was completed.

Procedure

The study was conducted during May, June, and July 1996 by a team of four research assistants housed in a field office located in the study area. The field office was equipped with phone lines, standard office equipment, and a conference room. The study was conducted every weekday except for holidays and days where severe weather watches or warnings were in effect for the study area. Depending upon scheduling and experimental conditions, several sessions were conducted each day.

An experimental session proceeded as follows. Subjects were run in sets of three (i.e., troikas). If three subjects were not available, the session was not conducted. In order to increase our chances of getting three subjects at the correct time, for every three subjects scheduled an alternate subject was also scheduled. All subjects were contacted the day before participation to remind them of the study time and that they needed to bring their driver's license. If all four subjects arrived on time, the alternate was paid and rescheduled for another day as a primary subject. Upon arriving at the field office, the three subjects were taken to the conference room, assigned randomly to a navigation system condition, asked to sign an informed consent form, and the validity of their license was verified. Subjects were then given a brief orientation on the administrative and procedural aspects of the study. All subjects were told that their task would be to drive between a given origin and destination "as quickly and as safely as possible." They were told not to break any traffic laws and that they could take any route they chose but would be provided with a recommended route. They were also instructed that at the first destination they would be met by an experimenter who would give them a new O-D to drive. This second trip was to drive back from this location to the place where they started. No subject was told about the second destination until the first destination was reached. The administrative overview ended with a tutorial on how to use the cellular phones in the test vehicles they would be driving. These phones were programmed so that only four locations could be called: Emergency services (911), the Research Assistant in the field office, the Research Assistant at the first destination, and the Research Assistant at the second destination. Subjects were instructed to use the phones only if they had an emergency (crash, ticket, etc.) or became lost and to pull to the side of the road before initiating a call. No subjects reported a vehicle break-down, crash, or traffic violation during the study. Subjects were also told that if the phone rang they should answer it. Subjects taking longer than 25 minutes to complete a trip were contacted to find out if they needed assistance. Of all trips taken in the study, less than one percent required a call from us.

After the administrative overview, the three subjects were separated and given training that was specific to the INAS they were assigned. For the Ali-Scout and TetraStar subjects, function and presentation of navigation assistance information was conveyed through the use of a model car, a schematic road network, and a series of printed graphics. The latter for Ali-Scout and TetraStar can be found in Appendix B. The subject assigned to the Written Instructions INAS was simply asked to wait in a comfortable reception area.

Once the training sessions were completed, subjects were brought to the test-vehicles (white 1995 Mercury Sables) and seated in the vehicle containing the INAS they were assigned. All subjects were told about the basic features of the vehicle (e.g., location of controls for lights, wipers, and defrost), asked to adjust the seat and mirrors, and asked to buckle up their safety belts. Subjects were shown the cellular phone and again told how to use it. All vehicle radios were disabled. Finally, subjects were shown the INAS and given a paper map that showed the O-D they were requested to drive (Appendix A). At this time the Written Instructions subject was given the printed instructions (Appendix A). The

Ali-Scout and TetraStar INASs were already programmed with the proper destination by the researcher. Subjects were instructed to not touch the INASs. The TetraStar subject was allowed to press the enter button in response to the question about recalculating the route. Three O-D pairs were used in the study, with a single pair (randomly selected from the set of three) used each day. Each O-D pair was matched on several variables including length (approximately 7.3 miles). The procedures used for selecting and matching the O-D pairs can be found in Appendix C. When the subject was ready, he or she began driving. The experimenter ensured that subjects departed with at least a five-minute delay between subjects to avoid subjects following each other to the destination.

The subjects were met at the first destination by an experimenter. In order to facilitate the visibility of the destination, the researcher's car was marked with a large University of Michigan Transportation Research Institute placard and had a bright-green bicycle flag attached to a six-foot mast. The experimenter at the first destination recorded data on an in-vehicle data sheet (shown in Appendix D), reset the data collection equipment, entered a new destination (for Ali-Scout and TetraStar), showed the subject on a printed map where the next destination was located, gave the Written Instructions subject the printed directions, and let the subject begin driving. Again, a five-minute delay was maintained between subjects.

At the completion of the second trip, another experimenter recorded data, shut off the data collection equipment, and gave the subject a brief questionnaire (Appendix F). When finished, the subject was paid and given a debriefing sheet that described the experiment they had just participated in. The debriefing text can be found in Appendix E.

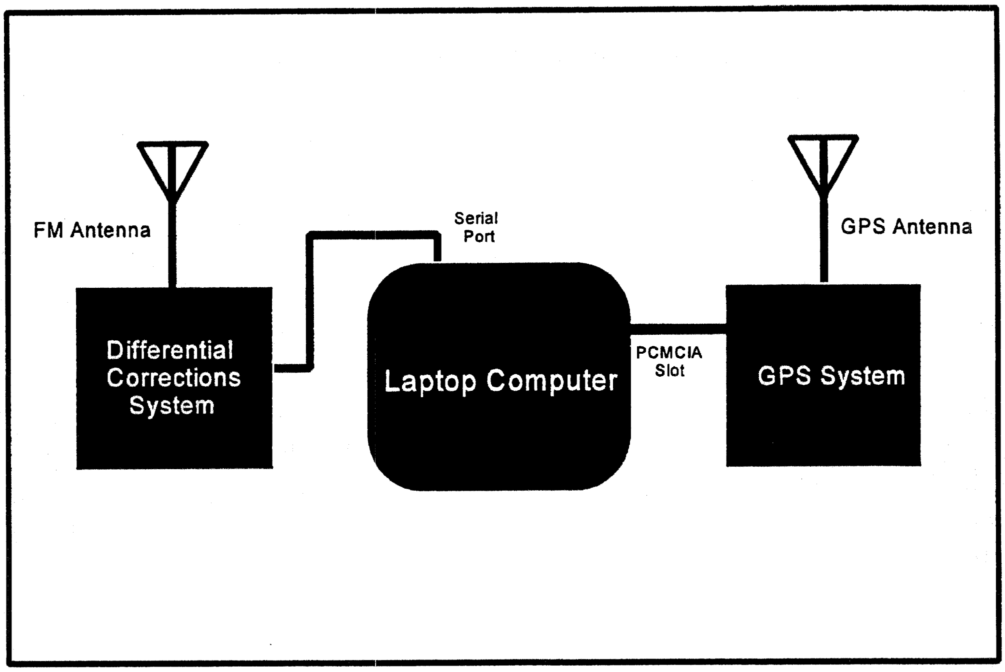


Figure 4: Diagram showing the automated data collection instruments and how they were related.

Data Collection

Automated GPS-Based: Each vehicle was equipped with a laptop computer placed on the floor in the back seating area of the vehicle. Plugged into the PCMCIA slot of the laptop was a Trimble GPS system. The GPS-antenna was routed out the back door and placed on top of the vehicle. Also attached to each computer through a serial port was a Differential Corrections Incorporated (DCI) differential corrections receiver. The DCI system received differential corrections through an FM subcarrier signal broadcast in the study area. A schematic of the various components is shown in Figure 4. The GPS information and differential corrections were integrated with Trimble software and read into a mapping program called City Streets, designed to work with the Trimble GPS hardware. City Streets allowed us to track and record the exact time, position (latitude and longitude), speed, and heading of the entire trip on a second-by-second basis. We called these trip-records *GPS logs.* The program also allowed us to "play back" the GPS logs so that we could peruse each trip at whatever rate we chose. The following measures were determined from the GPS logs

✱*Problem finding initial route?* This was a yes/no measure. If the subject left the origin and immediately turned in the wrong direction this was designated as having difficulty finding the initial route. This measure was included because both Ali-Scout and TetraStar require the driver to first find a route before turn-by-turn instructions are given. This measure is distinct from getting lost because a driver may have difficulty finding the initial route but then may drive directly to the destination. In this case, the trip was defined as one in which there was difficulty finding the initial route but not getting lost.

✱ *Problem finding destination?* This was a yes/no measure. If the subjects were near the destination but either passed it or turned around before reaching it, they were designated as having difficulty finding the destination. In all three INAS, the subjects are given directions to the destination, but then must spot it for themselves. As in the previous measure, this measure was distinct from getting lost because a driver may drive directly to the destination but then have difficulty finding it. In this case, the trip was defined as one in which there was difficulty finding the initial destination but not getting lost.

✱ *Did the subject get lost?* This was a yes/no measure. Those trips in which subjects made consistent maneuvers that took them away from the destination and trips in which subjects' vehicles remained stationary for more than three minutes were considered recorded as the subject getting lost.

✱*The number of turns.* This measure was taken from the GPS log and was a tally of all turns taken by the subject and did not include turns taken in the parking areas of the origins and destinations. U-turns were counted as a single turn.

✱*The number of wrong turns.* This measure was taken from the GPS log and was a tally of all wrong turns taken by the subject and did not include turns taken in the parking areas of the origins and destinations. A wrong turn was defined as a turn that took the driver away from the destination or failing to make a turn that should have been made such as turning into a destination.

✱ *Time spent at zero velocity.* This measure was taken from the GPS log. It was the total amount of time during a trip in which the vehicle remained stationary. This dependent variable was included as a way of measuring the amount of congestion encountered during a trip.

✱ *Trip distance.* The exact distance in miles was taken from the in-vehicle trip odometer which was reset to zero by an experimenter prior to each trip. The GPS log was used as a backup, in case the trip odometer was reset by the subject or did not function on a trip.

✱ *Trip duration.* This measure was taken from the GPS log. It was the time between when the vehicle actually begins to move to the point where it stops at the destination.

Because we monitored each automated data collection system for proper function several times a day, two complete systems were available for backup, and a backup system could be swaped with a malfunctioning system in a few minutes, we experienced data collection problems on only 5.4 percent of trips. For these trips, data for the first six measures described could not be obtained. Trip distance was obtained from the in-vehicle odometer and trip duration was collected from a stopwatch left in the vehicle and operated by the researchers for backup purposes.

Questionnaire: At the completion of the study, all subjects were asked to complete a questionnaire. The questionnaire asked the subject to record on a map the routes that they drove, how they used and what they thought about the INAS, whether they got lost, and their willingness to pay for the INAS. The complete questionnaire can be found in Appendix F.

RESULTS

Automated GPS-based Data

Finding the Initial Route: Percentages of trips in which the driver had difficulty finding the initial route as a function of the experimental variables are shown in Table 5. A three (navigation assistance system) x two (familiarity) x two (traffic conditions) x two (trip number) analysis of variance (four-way ANOVA) showed several significant effects. First, there was a significant main effect of navigation system ($F_{2, 656}$=9.71; p<.001). When averaged across all conditions, drivers had the most difficulty finding the initial route when Ali-Scout was in use (13.0 percent of the trips), followed by TetraStar (8.2 percent), and Written Instructions (2.6 percent). As expected, there was a significant main effect of driver familiarity ($F_{1, 656}$=4.65; p<.05), where familiar drivers had less difficulty finding the initial route (5.6 percent) than unfamiliar drivers (10.1 percent).

Table 5: Percentage of Trips in Which a Driver had Difficulty Finding the Initial Route as a Function of Driver Familiarity, Traffic Conditions, Trip Number, and Navigation System

	Unfamiliar				Familiar			
	Nonpeak		Peak		Nonpeak		Peak	
	Trip 1	Trip 2	Trip 1	Trip 2	Trip 1	Trip 2	Trip 1	Trip 2
Ali-Scout	13.8	6.9	34.5	6.9	14.3	0.0	27.6	0.0
TetraStar	32.1	0.0	19.2	0.0	3.3	0.0	11.1	0.0
Written Instructions	3.6	0.0	3.3	0.0	10.0	0.0	3.6	0.0

Also as expected, the analysis showed a significant main effect of trip number ($F_{1, 656}$=48.30; p<.0001). Drivers on their second trip had little difficulty finding the initial route (1.2 percent) as compared with the first trip (14.6 percent). There were also significant interactions between navigation system and trip number ($F_{2, 656}$=4.89; p<.01) and a three-way interaction between navigation system, driver familiarity, and trip number ($F_{2, 656}$=3.47;

$p<.05$). These interactions showed that on the second trip, some drivers who were unfamiliar with the area were still having difficulty finding the initial route when using Ali-Scout. All other effects were nonsignificant.

Finding the Destination: Percentages of trips in which the driver had difficulty finding the destination as a function of the experimental variables are shown in Table 6. A four-way ANOVA revealed two significant effects. First, there was significant main effect of navigation system ($F_{2, 657}=6.36$; $p<.005$). Averaging across all of the variables, except navigation system, showed that drivers using the Ali-Scout system had the most difficulty finding destinations (11.3 percent of trips), followed by TetraStar (5.9 percent of trips) and Written Instructions (2.6 percent of trips). There was also a significant main effect of trip number ($F_{1, 657}=17.35$; $p<.0001$). As expected since the second destination was familiar to all drivers, subjects had much greater difficulty finding the first destination (10.5 percent of trips) than the second destination (2.7 percent of trips).

Table 6: Percentage of Trips in Which a Driver had Difficulty Finding the Destination as a Function of Driver Familiarity, Traffic Conditions, Trip Number, and Navigation System

	Unfamiliar				Familiar			
	Nonpeak		Peak		Nonpeak		Peak	
	Trip 1	Trip 2	Trip 1	Trip 2	Trip 1	Trip 2	Trip 1	Trip 2
Ali-Scout	20.7	3.4	20.7	6.9	10.7	7.1	13.8	6.9
TetraStar	10.7	0.0	3.8	3.8	6.7	0.0	7.4	0.0
Written Instructions	14.3	0.0	6.7	0.0	6.7	3.3	3.6	0.0

Getting Lost: Overall, people got lost on only 25 of the 681 trips taken (3.67 percent) in which valid GPS data was obtained. Sixteen people got lost on the first trip. The percentage of trips in which a person got lost as a function of the study variables is shown in Table 7. A four-way ANOVA showed that there were no significant differences for any of the study variables on the frequency of getting lost except for the type of navigation assistance ($F_{1,657}$=4.54; p<.02). Drivers using the Ali-Scout system became lost more frequently (6.96 percent of trips) than those using either TetraStar (2.26 percent) or Written Instructions (1.74 percent). Because of this significant difference between navigation systems and the fact that getting lost affects the number of turns, number of wrong turns, time spent at zero velocity, trip length, and duration, the remaining GPS-based results will be presented without trips in which the driver got included in the statistical calculations.

Table 7: Percentage of Trips in Which a Driver Got Lost as a Function of Driver Familiarity, Traffic Conditions, Trip Number, and Navigation System

	Unfamiliar				Familiar			
	Nonpeak		Peak		Nonpeak		Peak	
	Trip 1	Trip 2	Trip 1	Trip 2	Trip 1	Trip 2	Trip 1	Trip 2
Ali-Scout	3.4	6.9	6.9	3.4	14.3	10.7	3.4	6.9
TetraStar	7.1	0.0	3.8	0.0	3.3	0.0	3.7	0.0
Written Instructions	0.0	3.6	0.0	0.0	3.3	3.3	3.6	0.0

Number of Turns: Figure 5 shows the average number of turns per trip as a function of INAS, driver familiarity, traffic conditions, and trip number. Trips in which the driver got lost are not included. A four-way ANOVA showed that there was a significant main effect of trip ($F_{1,633}$=31.85; p<.0001) and a significant interaction between navigation system and trip ($F_{2,633}$=28.76; p<.0001). As shown in Figure 4, it can be seen that these significant effects were due to the decrease in the number of turns per trip for Ali-Scout and TetraStar in trip two coupled with an increase in turns per trip for Written Instructions. The decrease in turns per trip for the electronic INAS was probably due to increased familiarity with the devices and area. Such an explanation does not account for the increase in turns per trip for Written Instructions. An examination of the routes taken by users of Written Instructions showed that over 90 percent followed the exact route they were given. It turned out that these randomly selected routes differed in the number of required turns depending upon the direction in which the route was driven, with second trips having one more turn than first trips. This extra turn resulted from the fact that in the study area many intersections require the driver intending to make a left turn to first go through the intersection, make a U-turn, and then turn right onto the street they intended to be on. These so-called "Michigan-Turns" change a single left turn into two turns.

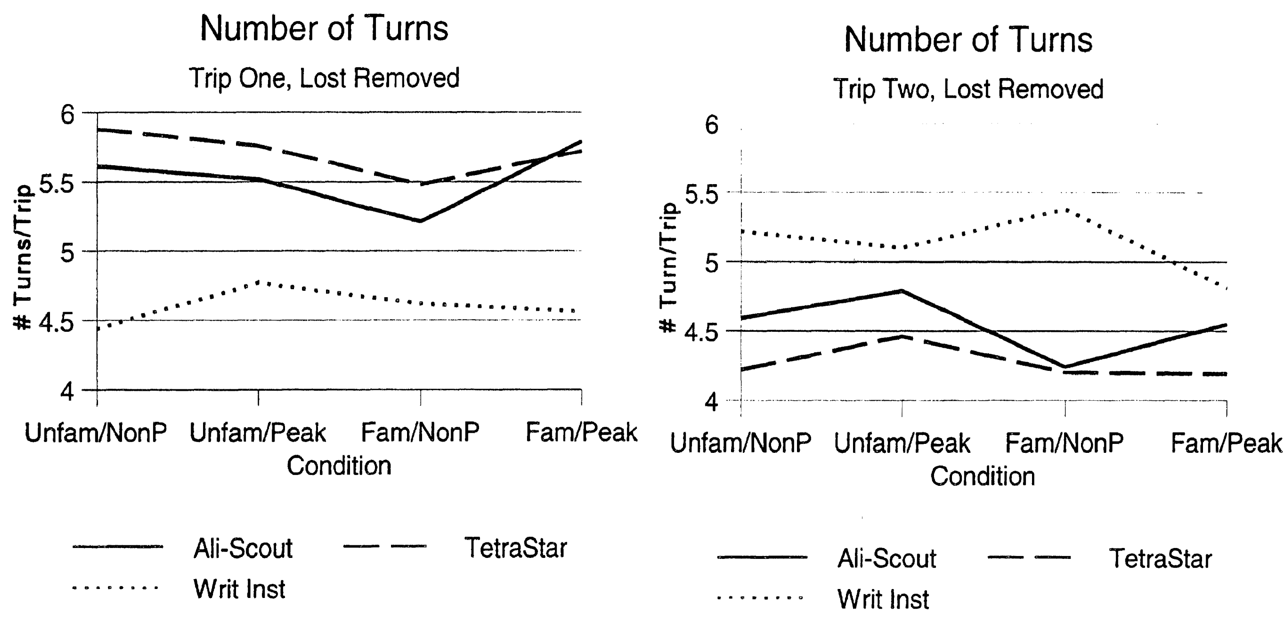


Figure 5: Average number of turns per trip as a function of INAS, driver familiarity, and traffic conditions. Averages for the first trip are shown in the left half of the figure and averages for the second are shown in the right half. Trips in which the driver got lost are not included.

Number of Wrong Turns: Figure 6 shows the average number of wrong turns per trip as a function of INAS, driver familiarity, traffic conditions, and trip number. Trips in which the driver got lost are not included. A four-way ANOVA revealed several significant effects. First, there was a significant main effect navigation system ($F_{2, 633}$=8.04; p<.0005) with drivers tending to make more wrong turns with Ali-Scout and TetraStar than with Written Instructions. Second, there was a significant main effect of driver familiarity with test area ($F_{1, 633}$=7.21; p<.01). Drivers who were familiar with the area tended to make fewer wrong turns per trip than those who were unfamiliar. Third, there was a significant main effect of trip number ($F_{1, 633}$=30.99; p<.0001). Far fewer wrong turns were made during the second trip in all conditions of the study. Finally, there was a significant interaction between INAS and traffic conditions ($F_{2, 633}$=3.38; p<.05). This interaction shows that the tendency for making wrong turns was generally greater during peak traffic conditions for Ali-Scout and TetraStar, whereas traffic conditions had no effect of wrong turn making for Written Instructions.

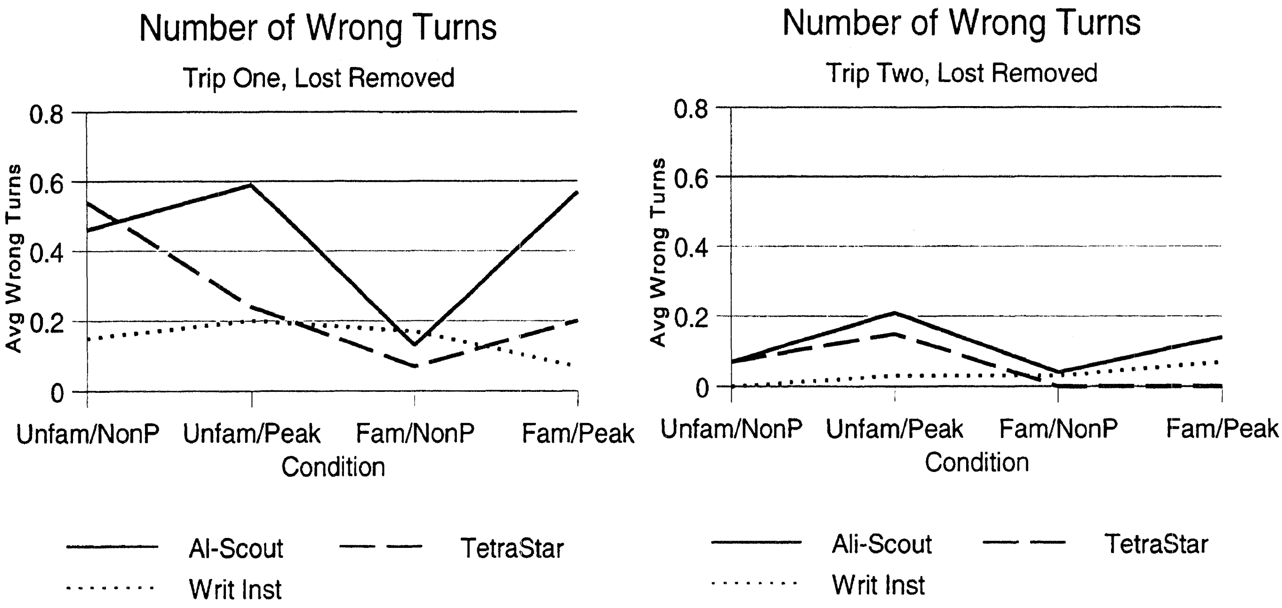


Figure 6: Average number of wrong turns per trip as a function of INAS, driver familiarity, and traffic conditions. Averages for the first trip are shown in the left half of the figure and averages for the second are shown in the right half. Trips in which the driver got lost are not included.

A three-way (INAS x familiarity x traffic condition) ANOVA calculated on trip one only showed that in the first trip the number of wrong turns per trip differed significantly between navigation systems ($F_{2, 313}$=5.87; p<.005) and that drivers who were familiar made fewer wrong turns than unfamiliar drivers ($F_{1, 313}$=5.35; p<.05). A three-way ANOVA for trip two revealed no significant differences between INAS and showed that drivers during peak traffic conditions made more wrong turns than drivers in nonpeak times ($F_{1, 320}$=4.01; p<.05).

Time Spent at Zero Velocity: The average number of seconds during a trip in which drivers were not moving as a function of the study variables is shown in Figure 7. A four-way ANOVA showed only a significant main effect of traffic conditions ($F_{1, 650}$=46.81; *p*<.0001), with greater time spent at zero velocity during peak traffic conditions than nonpeak times. A three-way ANOVA on trip one only, revealed a significant main effect for INAS, with times spent at zero velocity longest for Ali-Scout and shortest for TetraStar ($F_{2, 327}$=4.66; *p*<.05). Again, there was a significant effect of traffic conditions ($F_{1, 327}$=31.08; *p*<.0001). A three-way ANOVA calculated on trip two data only showed the same significant effect of traffic conditions found in trip one ($F_{1, 323}$=15.98; *p*<.0005). In addition, there was a significant interaction between traffic conditions and driver familiarity ($F_{1, 323}$=4.99; *p*<.05) and a significant interaction between all variables ($F_{2, 323}$ =3.42; *p*<.05). These interactions show that there was little difference on time spent at zero velocity for familiar drivers by device or traffic conditions.

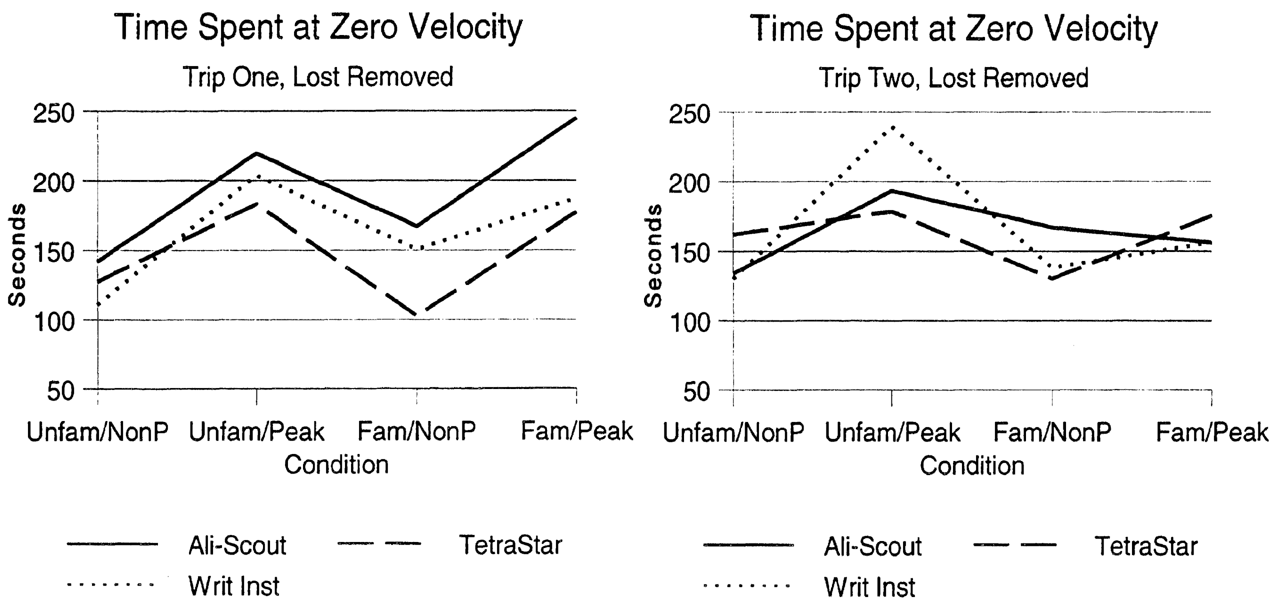


Figure 7: Average number of seconds spent at zero velocity (wait time) as a function of INAS, driver familiarity, and traffic conditions. Averages for the first trip are shown in the left half of the figure and averages for the second are shown in the right half. Trips in which the driver got lost are not included.

Trip Length: The average trip length as a function of the study variables is shown in Figure 8. A four-way ANOVA revealed that there was a significant effect of trip number on the length of a trip, with the second trip significantly shorter than the first ($F_{1, 670}$=5.15; *p*<.05). There was also a significant effect of driver familiarity with familiar drivers taking shorter trips than unfamiliar drivers ($F_{1, 670}$=12.44; *p*<.0005). Also discovered was a significant main effect of INAS ($F_{2, 670}$=3.30; *p*<.05) with Ali-Scout trips significantly longer (7.5 miles) than trips driven with either TetraStar (7.3 miles) or Written Instructions (7.3 miles). There were also significant interactions between trip and navigation system ($F_{2, 670}$=6.29; *p*<.005) and navigation system and traffic conditions ($F_{2, 670}$=4.94; *p*<.01). These interactions show that trip lengths were shorter for both Ali-Scout and TetraStar drivers in the second trip, while Written Instruction trip lengths remained fairly constant for both trips, and that for both trips, Ali-Scout users tended to take longer length trips during peak traffic conditions.

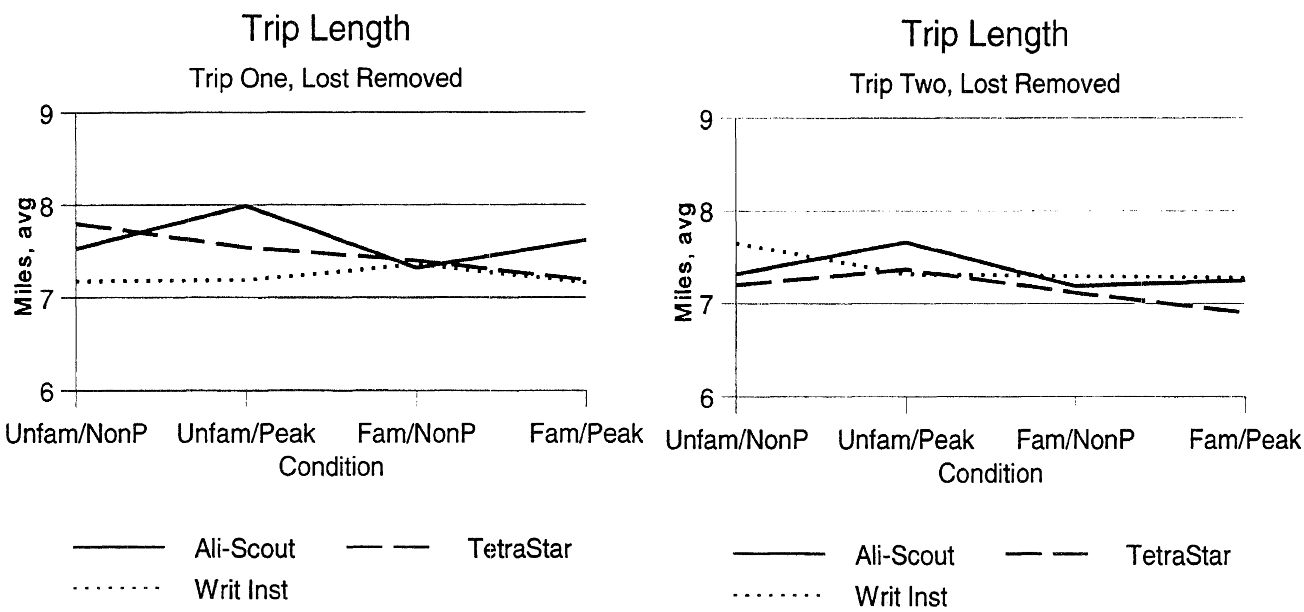


Figure 8: Average trip length in miles as a function of INAS, driver familiarity, and traffic conditions. Averages for the first trip are shown in the left half of the figure and averages for the second are shown in the right half. Trips in which the driver got lost are not included.

A three-way ANOVA calculated using trip one data only showed significant differences between navigation systems ($F_{2,330}$=6.11; p<.005), driver familiarity ($F_{1,330}$=4.46; p<.05), and an interaction between INAS and traffic conditions. These results show that in the first trip, trip length was shortest for Written Instructions, familiar drivers tended to take shorter routes than unfamiliar drivers, and that Ali-Scout trips lengths were affected by traffic conditions (peak trips lengths were longer) whereas trip lengths for the other two INAS were not. A three-way ANOVA calculated on trip two data only showed significant main effects of navigation system ($F_{2,670}$=4.94; p<.01) and familiarity ($F_{2,670}$=4.94; p<.01) and no significant interactions. These results again show that familiar drivers take slightly shorter routes than unfamiliar drivers and that users of TetraStar drove shorter length routes than drivers of the other two INAS.

Trip Duration: Averaging over all trips and with trips in which the driver got lost removed from the analysis, the average trip duration was 1,018 sec (about 17 minutes). Average trip durations for the study variables, with trips in which the driver got lost removed, are shown in Figure 9. A four-way ANOVA showed that there were significant main effects of traffic conditions ($F_{1,671}$=44.48; p<.0001) and driver familiarity ($F_{1,671}$=4.06; p<.05). As expected, trip duration was longer during peak traffic conditions than during nonpeak times and familiar drivers tended to have shorter duration trips than unfamiliar drivers. There was also a significant interaction between navigation system and trip ($F_{2,671}$=7.64; p<.001) showing that trip duration was decreased for both the electronic INASs (Ali-Scout and TetraStar) in trip two, whereas trip duration remain fairly constant between trips for Written Instructions. Even though subjects received classroom training on the electronic INAS, these results show the necessity for some on-the-road experience with the navigation systems. This learning effect suggests that the most impartial comparison between systems would be comparisons between systems used in trip two, after drivers using unfamiliar technology have had a chance to gain some experience.

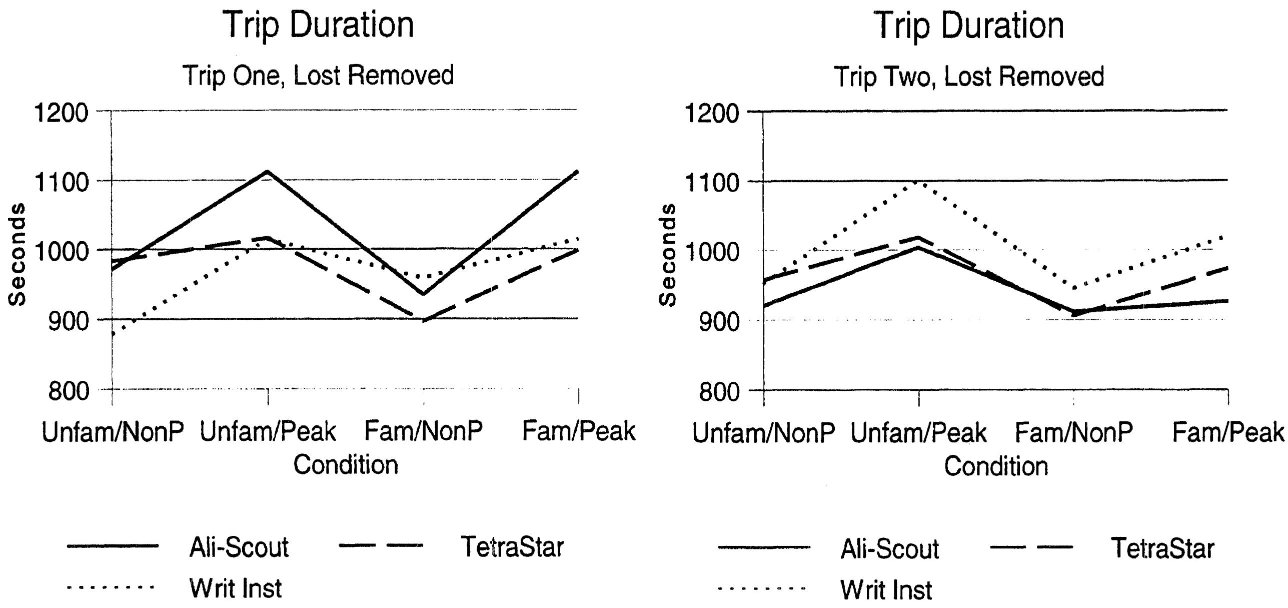


Figure 9: Average trip duration in seconds as a function of INAS, driver familiarity, and traffic conditions. Averages for the first trip are shown in the left half of the figure and averages for the second are shown in the right half. Trips in which the driver got lost are not included.

A three-way ANOVA calculated on the trip one data only showed significant main effects of both INAS ($F_{2,331}$=3.37; p<.05) and traffic conditions ($F_{1,331}$=22.47; p<.0001). The INAS effect was due to the fact that Ali-Scout trips tended to be of longer duration than trips taken with TetraStar or Written Instructions. A three-way ANOVA on trip two data only showed significant effects of INAS ($F_{2,340}$=5.77; p<.005), traffic conditions ($F_{1,340}$=23.34; p<.0001), and driver familiarity ($F_{1,340}$=8.36; p<.005). In trip two, with trips in which driver got lost not considered in the analysis, trips were of longer duration with unfamiliar drivers and for trips taken during peak traffic conditions.

The effect of INAS for second trips showed that both Ali-Scout and TetraStar users had shorter duration trips than users of Written Instructions. *Post hoc* comparisons between navigation systems in trip two showed that these differences were statistically significant ($F_{1,224}$=12.07; p<.001 for Ali-Scout vs Written instructions; $F_{1,230}$=5.24; p<.05 for TetraStar vs. Written Instructions). On average, with lost trips removed, second trips taken with Ali-Scout and TetraStar were about 50 seconds, or 5 percent, faster than trips taken with Written Instructions. Table 8 shows trip time savings in trip two for users of the electronic INAS (Ali-Scout and TetraStar) over Written Instructions for all study variables. As can be seen in this table, the greatest trip time saving over Written Instructions occurred during the peak traffic conditions.

Table 8: Trip Time Savings (Percentage and Seconds) for Ali-Scout and TetraStar Over Written Instructions as a Function of Driver Familiarity and Traffic Conditions.

		Familiarity	
		Unfamiliar	**Familiar**
Traffic Conditions	**Nonpeak**	1.4%; 13.5 sec	3.9%; 36.5 sec
	Peak	8.1%; 89.2 sec	6.9%; 70.2 sec

Questionnaire Data

All subjects were asked to complete a questionnaire (Appendix F) and no subjects declined. However, some subjects declined to answer certain questions or gave invalid answers. All valid answers are included in the questionnaire analyses.

Subjects were asked: *Considering both trips that you drove in this study, how often did you follow the recommendations to turn?* Subjects responded using a seven-point scale anchored with the labels "never" for one and "always" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 9. As can be seen in this table, respondents reported that they nearly always followed the navigation recommendations they received during the study. Across all conditions in the study, 84.6 percent of respondents reported either a "six" or "seven" to this question. A three-way ANOVA (In-vehicle navigation assistance system, driver familiarity, and traffic conditions) revealed that there were no significant differences between respondents on any of the study variables.

Table 9: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Considering both trips that you drove in this study, how often did you follow the recommendations to turn? (1=Never; 7=Always)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	3.4 (1)	0.0 (0)	3.4 (1)	0.0 (0)	3.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	3.4 (1)	3.4 (1)	0.0 (0)	3.4 (1)
2	3.4 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	10.7 (3)	0.0 (0)	0.0 (0)	10.3 (3)	3.4 (1)	0.0 (0)	10.3 (3)
3	3.4 (1)	0.0 (0)	0.0 (0)	6.9 (2)	7.1 (2)	0.0 (0)	13.3 (4)	0.0 (0)	6.9 (2)	0.0 (0)	3.4 (1)	3.4 (1)
4	0.0 (0)	3.4 (1)	3.4 (1)	0.0 (0)	0.0 (0)	3.6 (1)	3.3 (1)	0.0 (0)	0.0 (0)	6.9 (2)	10.3 (3)	6.9 (2)
5	6.9 (2)	3.4 (1)	0.0 (0)	3.4 (1)	3.6 (1)	0.0 (0)	6.7 (2)	6.9 (2)	0.0 (0)	17.2 (5)	0.0 (0)	0.0 (0)
6	6.9 (2)	10.3 (3)	6.9 (2)	10.3 (3)	10.7 (3)	0.0 (0)	13.3 (4)	6.9 (2)	10.3 (3)	13.8 (4)	10.3 (3)	6.9 (2)
7	75.9 (22)	82.8 (24)	86.2 (25)	79.3 (23)	75.0 (21)	85.7 (24)	63.3 (19)	86.2 (25)	69.0 (20)	55.2 (16)	75.9 (22)	69.0 (20)

Those who did not always follow the recommended turns were asked to indicate the reasons why they choose to not follow the recommendation. Since the reasons may have varied on different turns, subjects could indicate more than reason for not following the recommendations. The most commonly reported reasons were:

- Knew of a faster route (27.1 percent; n=26)
- Believed that the turn would take them into traffic congestion (20.8 percent; n=20)
- The recommended turn was not clear (17.7 percent; n=17)
- Believed that the turn would take them away from destination (7.3 percent; n=7)
- The turn was suggested too late (6.3 percent; n=6)
- Miscellaneous other reasons (20.8 percent; n=20)

Subjects were instructed: *Please indicate your level of satisfaction with the navigation assistance available to you while driving in the study.* Subjects indicated level of satisfaction on a seven-point scale anchored with the labels "very satisfied" for one and "not at all satisfied" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 10. An examination of this table reveals that drivers were generally very satisfied with the INAS they used in the study. A three-way ANOVA showed that there were no significant differences in level of satisfaction except for a main effect of INAS ($F_{2,333}$=11.40; p<.0001). This difference results from the fact that Ali-Scout users were less satisfied overall than users of the other two systems. Averaging across the driver familiarity and traffic condition variables we find that 63.8 percent of Ali-Scout users responded with either a one or two, whereas 82.9 percent of TetraStar users and 87.5 percent of Written Instruction users reported either one or two.

Table 10: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Please indicate your level of satisfaction with the navigation assistance available to you while driving in the study (1=Very Satisfied; 7=Not at all Satisfied)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	55.2 (16)	70.4 (19)	86.2 (25)	39.3 (11)	76.7 (23)	71.4 (20)	55.2 (16)	66.7 (20)	85.2 (23)	26.7 (8)	53.3 (16)	75.0 (21)
2	17.2 (5)	11.1 (3)	3.4 (1)	25.0 (7)	6.7 (2)	14.3 (4)	13.8 (4)	20.0 (6)	0.0 (0)	23.3 (7)	26.7 (8)	14.3 (4)
3	6.9 (2)	11.1 (3)	6.9 (2)	25.0 (7)	10.0 (3)	0.0 (0)	17.2 (5)	6.7 (2)	0.0 (0)	20.0 (6)	10.0 (3)	7.1 (2)
4	6.9 (2)	3.7 (1)	3.4 (1)	7.1 (2)	0.0 (0)	10.7 (3)	6.9 (2)	0.0 (0)	3.7 (1)	3.3 (1)	6.7 (2)	0.0 (0)
5	6.9 (2)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	3.4 (1)	3.3 (1)	3.7 (1)	16.7 (5)	0.0 (0)	3.6 (1)
6	6.9 (2)	3.7 (1)	0.0 (0)	3.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	7.4 (2)	6.7 (2)	3.3 (1)	0.0 (0)
7	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	3.6 (1)	3.4 (1)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)

Subjects were Instructed: *Please indicate your level of distraction while using the navigation assistance available to you while driving in the study.* They indicated level of distraction on a seven-point scale anchored with the labels "very distracting" for one and "not at all distracting" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 11. As shown in this table, the level of distraction while driving was generally low. A three-way ANOVA showed that there were no significant differences in level of distraction except for a main effect of INAS ($F_{2, 339}$=7.27; p<.001). This difference results from the fact that users generally found the Ali-Scout system more distracting than either TetraStar or Written Instructions. Averaging across driver familiarity and traffic conditions, 62.7 percent of Ali-Scout users reported at least some level of distraction using the system (i.e., a response of less than seven), whereas 48.7 percent of TetraStar users and 41.2 percent of Written Instruction users reported some level of distraction using the INAS during the study.

Table 11: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Please indicate your level of distraction while using the navigation assistance available to you while driving in the study (1=Very Distracting; 7=Not at all Distracting)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.4 (1)
2	6.7 (2)	0.0 (0)	0.0 (0)	3.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	7.4 (2)	3.3 (1)	0.0 (0)	0.0 (0)
3	3.3 (1)	3.4 (1)	3.6 (1)	3.6 (1)	0.0 (0)	10.0 (3)	10.0 (3)	3.3 (1)	3.7 (1)	6.7 (2)	6.7 (2)	10.3 (3)
4	0.0 (0)	3.4 (1)	3.6 (1)	14.3 (4)	3.3 (1)	3.3 (1)	16.7 (5)	0.0 (0)	3.7 (1)	13.3 (4)	0.0 (0)	0.0 (0)
5	16.7 (5)	10.3 (3)	10.7 (3)	14.3 (4)	10.0 (3)	16.7 (5)	6.7 (2)	13.3 (4)	0.0 (0)	23.3 (7)	0.0 (0)	6.9 (2)
6	26.7 (8)	27.6 (8)	25.0 (7)	32.1 (9)	36.7 (11)	26.7 (8)	30.0 (9)	20.0 (6)	14.8 (4)	20.0 (6)	56.7 (17)	13.8 (4)
7	46.7 (14)	55.2 (16)	57.1 (16)	32.1 (9)	50.0 (15)	43.3 (13)	36.7 (11)	63.3 (19)	70.4 (19)	33.3 (10)	36.7 (11)	65.5 (19)

Subjects were instructed: *Please indicate your level of confidence in the accuracy of the navigation assistance available to you while driving in the study.* Participants indicated level of confidence on a seven-point scale anchored with the labels "very confident" for one and "not at all confident" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 12. The table shows that a large majority of the study participants had a high degree of confidence in the accuracy of the navigation assistance they received in the study. A three-way ANOVA showed that there were no significant differences in level of confidence in the navigation accuracy except for a main effect of INAS ($F_{2,\ 343}$=9.45; p<.0005). This difference resulted from the fact that users reported less confidence in the accuracy of Ali-Scout navigation assistance than the assistance received with either TetraStar or Written Instructions. Averaging across driver familiarity and traffic conditions, we find that a high level of confidence (i.e., a response of either one or two) is reported by 66.4 percent of Ali-Scout users, while 86.7 percent of TetraStar and 91.4 percent of Written Instruction users reported high levels of confidence in the navigation accuracy of the INAS.

Table 12: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Please indicate your level of confidence in the accuracy of the navigation assistance available to you while driving in the study (1=Very Confident; 7=Not at all Confident)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	60.0 (18)	70.0 (21)	79.3 (23)	41.4 (12)	63.3 (19)	70.0 (21)	43.3 (13)	73.3 (22)	81.5 (22)	36.7 (11)	43.3 (13)	86.7 (26)
2	23.3 (7)	16.7 (5)	10.3 (3)	27.6 (8)	20.0 (6)	20.0 (6)	26.7 (8)	16.7 (5)	3.7 (1)	40.0 (12)	43.3 (13)	13.3 (4)
3	10.0 (3)	6.7 (2)	3.4 (1)	17.2 (5)	10.0 (3)	3.3 (1)	13.3 (4)	6.7 (2)	0.0 (0)	6.7 (2)	6.7 (2)	0.0 (0)
4	0.0 (0)	3.3 (1)	6.9 (2)	6.9 (2)	3.3 (1)	6.7 (2)	10.0 (3)	0.0 (0)	3.7 (1)	6.7 (2)	3.3 (1)	0.0 (0)
5	0.0 (0)	3.3 (1)	0.0 (0)	3.4 (1)	0.0 (0)	0.0 (0)	3.3 (1)	3.3 (1)	3.7 (1)	3.3 (1)	3.3 (1)	0.0 (0)
6	6.7 (2)	0.0 (0)	0.0 (0)	3.4 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.7 (1)	6.7 (2)	0.0 (0)	0.0 (0)
7	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	3.3 (1)	0.0 (0)	3.7 (1)	0.0 (0)	0.0 (0)	0.0 (0)

Subjects were instructed: *Please indicate how helpful the navigation assistance you received during the study was for you in finding the study destinations.* Subjects indicated level of helpfulness on a seven-point scale anchored with the labels "very helpful" for one and "not at all helpful" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 13. As shown in this table, the reported level of helpfulness while driving was generally high. A three-way

ANOVA showed that there were significant differences in level of helpfulness by INAS ($F_{2, 343}=5.34$; $p<.01$) and driver familiarity ($F_{1, 343}=9.51$; $p<.005$). The main effect of INAS resulted from the fact that users found the Ali-Scout and TetraStar systems to be less helpful in finding study destinations than the Written Instructions. Further, users found TetraStar to be more helpful than Ali-Scout. Averaging across familiarity and traffic conditions, users reported high levels of helpfulness (i.e., a response of either one or two) 73.1 percent of the time for Ali-Scout, 81.5 percent of the time for TetraStar, and 86.3 percent of the time for Written Instructions. As expected, the effect of driver familiarity on reported helpfulness resulted from the fact that familiar drivers found the systems to be less helpful in finding destinations than unfamiliar drivers. Averaging across INAS and traffic conditions, we find that 86.5 percent of unfamiliar users reported high levels of helpfulness compared with only 74.0 percent of familiar drivers.

Table 13: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Please indicate how helpful the navigation assistance you received during the study was for you in finding the study destinations (1=Very Helpful; 7=Not at all Helpful)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	66.7 (20)	86.7 (26)	86.2 (25)	51.7 (15)	66.7 (20)	73.3 (22)	50.0 (15)	44.8 (13)	85.7 (24)	40.0 (12)	36.7 (11)	70.0 (21)
2	20.0 (6)	10.0 (3)	3.4 (1)	24.1 (7)	20.0 (6)	10.0 (3)	16.7 (5)	27.6 (8)	0.0 (0)	23.3 (7)	33.3 (10)	16.7 (5)
3	6.7 (2)	0.0 (0)	3.4 (1)	6.9 (2)	6.7 (2)	3.3 (1)	13.3 (4)	3.4 (1)	3.6 (1)	13.3 (4)	16.7 (5)	6.7 (2)
4	3.3 (1)	0.0 (0)	6.9 (2)	6.9 (2)	0.0 (0)	13.3 (4)	20.0 (6)	13.8 (4)	3.6 (1)	10.0 (3)	10.0 (3)	3.3 (1)
5	0.0 (0)	3.3 (1)	0.0 (0)	3.4 (1)	3.3 (1)	0.0 (0)	0.0 (0)	6.9 (2)	3.6 (1)	3.3 (1)	3.3 (1)	0.0 (0)
6	3.3 (1)	0.0 (0)	0.0 (0)	6.9 (2)	0.0 (0)	0.0 (0)	0.0 (0)	3.4 (1)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)
7	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)	0.0 (0)	3.6 (1)	6.7 (2)	0.0 (0)	3.3 (1)

Subjects were instructed: *Please indicate your impression of the overall appearance of the navigation assistance device or written instructions you received during the study.* Subjects indicated their impression of the INAS appearance on a seven-point scale anchored with the labels "very pleasing" for one and "not at all pleasing" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 14. As shown in this table, impressions of the INAS appearances were generally high. A three-way ANOVA revealed a significant difference in impressions by INAS ($F_{2,344}$=7.53; p<.001). All other effects were nonsignificant. The main effect of INAS resulted from the fact that users were less impressed with Ali-Scout's appearance than users of the other two systems. Again, averaging across driver familiarity and traffic conditions we find highly positive impressions (i.e., a response of either one or two) in 63.9 percent of Ali-Scout users, 83.3 percent of TetraStar users, and 83.8 percent of Written Instruction users.

Table 14: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Please indicate your impression of the overall appearance of the navigation assistant device or written instructions you received during the study (1=Very Pleasing; 7=Not at all Pleasing)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	36.7 (11)	60.0 (18)	69.0 (20)	48.3 (14)	60.0 (18)	36.7 (11)	26.7 (8)	70.0 (21)	75.0 (21)	36.7 (11)	36.7 (11)	66.7 (20)
2	30.0 (9)	33.3 (10)	20.7 (6)	24.1 (7)	13.3 (4)	36.7 (11)	26.7 (8)	20.0 (6)	21.4 (6)	26.7 (8)	40.0 (12)	10.0 (3)
3	20.0 (6)	3.3 (1)	3.4 (1)	13.8 (4)	13.3 (4)	3.3 (1)	30.0 (9)	6.7 (2)	0.0 (0)	16.7 (5)	16.7 (5)	13.3 (4)
4	6.7 (2)	0.0 (0)	3.4 (1)	13.8 (4)	10.0 (3)	16.7 (5)	10.0 (3)	0.0 (0)	0.0 (0)	6.7 (2)	3.3 (1)	6.7 (2)
5	3.3 (1)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	3.3 (1)	3.3 (1)	3.3 (1)
6	3.3 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	6.7 (2)	3.3 (1)	0.0 (0)	0.0 (0)	10.0 (3)	0.0 (0)	0.0 (0)
7	0.0 (0)	3.3 (1)	3.4 (1)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	3.6 (1)	0.0 (0)	0.0 (0)	0.0 (0)

Subjects were instructed: *Please indicate how safe you felt driving while using the navigation assistance available to you in the study as compared to your everyday driving.* Subjects indicated their level of perceived safety on a seven-point scale anchored with the labels "much more safe" for one and "much less safe" for seven. Subject responses to this question (percentages and number of respondents) as a function of driver familiarity, traffic conditions in which they drove, and in-vehicle navigation assistance they used are shown in Table 15. As shown in this table, the majority of study participants reported at least some increase in feelings of safety (i.e., a response of less than four) using the INASs. A three-way ANOVA revealed that there were no significant main effects; however, there was a significant interaction between INAS and driver familiarity ($F_{2, 343}$=3.49; p<.05). In general, familiar drivers using the electronic INAS reported lower feelings of safety than unfamiliar drivers, whereas there was no familiarity difference for users of Written Instructions.

Table 15: Percentages and Number of Respondents (N) as a Function of Driver Familiarity, Traffic Conditions, and INAS (Ali-Scout=AS; TetraStar=TS; Written Instructions=WI)

Please indicate how safe you felt driving while using the navigation assistance available to you in the study as compared to your everyday driving(1=Much More Safe; 7=Much Less Safe)

	Unfamiliar						Familiar					
	Nonpeak			Peak			Nonpeak			Peak		
	AS	TS	WI	AS	TS	WI	AS	TS	WI	AS	TS	WI
1	30.0 (9)	50.0 (15)	17.9 (5)	27.6 (8)	23.3 (7)	20.0 (6)	16.7 (5)	23.3 (7)	25.0 (7)	10.0 (3)	26.7 (8)	36.7 (11)
2	16.7 (5)	20.0 (6)	28.6 (8)	24.1 (7)	30.0 (9)	13.3 (4)	30.0 (9)	23.3 (7)	32.1 (9)	10.0 (3)	23.3 (7)	20.0 (6)
3	10.0 (3)	16.7 (5)	7.1 (2)	27.6 (8)	16.7 (5)	23.3 (7)	23.3 (7)	30.0 (9)	0.0 (0)	30.0 (9)	16.7 (5)	0.0 (0)
4	43.3 (13)	13.3 (4)	46.4 (13)	20.7 (6)	26.7 (8)	43.3 (13)	30.0 (9)	20.0 (6)	42.9 (12)	40.0 (12)	30.0 (9)	43.3 (13)
5	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)
6	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	0.0 (0)	0.0 (0)
7	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	3.3 (1)	3.3 (1)	0.0 (0)

Subjects were asked: *Did you get lost at any time during your driving in the study?* They responded by indicating either yes or no. About 11 percent (n=39) of subjects who responded to this question reported that they felt lost at least some time during either of their trips. This percentage is greater than the percentage of drivers who were classified as getting lost based upon GPS data. This difference is not surprising, however, because a person who feels lost may still be driving on the correct route. Also, those who had difficulty finding the initial route or destination but drove a direct route between the origin and destination were not marked as lost, but drivers may have felt lost. Averaging across driver familiarity and traffic conditions, we find that the percentage of drivers who felt lost was 14.4 percent for Ali-Scout users, 12.6 percent for TetraStar users, and 5.8 percent for Written Instruction users. A three-way ANOVA showed that these percentages were not significantly different, nor were any other main effects or interactions.

Those subjects indicating that they got lost were asked to indicate how they think they got lost. A summary of their responses can be found in Table 16 as a function of the navigation system they were using. As expected, this table shows that many drivers who had difficulty finding the initial route or the destination considered themselves to be lost. It also shows that many drivers believed they got lost because they could not understand the navigation information available.

Table 16: Reasons Why Drivers Thought they Got Lost as a Function of Navigation Assistance System (Values are Percentage of Lost Drivers Using INAS who Gave that Reason)

Reasons Why Drivers Thought they Got Lost	Ali-Scout (n=17)	TetraStar (n=15)	Written Instructions (n=7)
Difficulty Locating Destination	23.5	40.0	14.3
Difficulty Understanding Instructions/Display	29.4	20.0	14.3
Difficulty Locating Initial Route	17.6	20.0	14.3
Followed Own Route	23.5	6.7	14.3
Could Not Make Recommended Turn	11.8	6.7	28.6
System Failed	5.9	0.0	0.0
Other	5.9	6.7	14.3

Subjects were asked: *For assistance in reaching your destinations, how do you rate the following sources of route-guidance information?* Subjects rated each of five sources of route-guidance information using a seven-point scale anchored by the labels "poor" for one and "excellent" for seven. The five sources were a standard road map, verbal directions from a passenger, verbal directions from other people, written directions, and electronic in-vehicle route-guidance. Table 17 shows that average response for each source of information as a function of the navigation assistance system used by the respondent. As shown in this table, navigation assistance utilizing verbal directions was rated least favorable, whereas electronic in-vehicle route guidance was rated the most favorable. Three-way ANOVAs calculated separately for each source of information showed that there were no significant differences between users of the three INAS except for responses to electronic in-vehicle route-guidance ($F_{2, 296}$=16.59; p<.0001). For this source of information, those who had experience with electronic in-vehicle navigation assistance rated it more favorably than those who had Written Instructions.

Table 17: Average Rating for Various Sources of Route-Guidance as a Function of INAS Respondent used in the Study (1=Poor; 7=Excellent).

Source of Route-Guidance Information	Ali-Scout	TetraStar	Written Instructions
Standard Road Map	5.44	5.39	5.27
Verbal Directions from Passenger	4.52	4.42	4.47
Verbal Directions from Other People	4.07	3.76	3.81
Written Directions	5.50	5.23	5.53
Electronic In-Vehicle Route-Guidance	6.06	6.52	5.56

Subjects were asked: *If you were about to drive in an unfamiliar area, which of the following sources of route-guidance information would you like to use?* Subjects indicated likelihood of use for each of five types of route-guidance information using a seven-point scale anchored by the labels "definitely would not like" for one and "definitely would like" for seven. The five types of route-guidance information were a standard road map, verbal directions from a passenger, verbal directions from other people, written directions, and electronic in-vehicle route-guidance. Table 18 shows the average response for each type of information as a function of the INAS used by the subject in the study. Again we find that the verbal directions were these least likely sources of route-guidance information that drivers would use and electronic in-vehicle route-guidance information was the most likely. Three-way ANOVAs calculated separately for each type of information showed that there were significant differences between users of the three INAS in their responses to verbal directions from a passenger ($F_{2, 310}$=3.23; p<.05) and electronic in-vehicle route-guidance ($F_{2, 310}$=17.06; p<.0001). In the case of verbal directions from a passenger, the significant difference results from the fact that those using Written Instructions during the study rated this type of information higher than those using the electronic INAS. The latter main effect was due to the fact that those who had experience with electronic in-vehicle navigation assistance rated it higher than those who had had Written Instructions.

Table 18: Average Likelihood of Using for Various Types of Route-Guidance Information in an Unfamiliar Area as a Function of INAS used in the Study (1=Definitely would not like; 7=Definitely would like).

Source of Route-Guidance Information	Ali-Scout	TetraStar	Written Instructions
Standard Road Map	5.71	5.58	5.90
Verbal Directions from Passenger	4.47	4.44	4.99
Verbal Directions from Other People	4.03	3.65	4.24
Written Directions	5.59	5.60	5.84
Electronic In-Vehicle Route-Guidance	6.40	6.80	5.99

The next four questions were asked of only those who used the electronic in-vehicle navigation assistance systems (Ali-Scout and TetraStar). Subjects were asked: *For the following items, assume that the navigation system you used in the study was available nationwide. Given this scenario, how useful do you think the system would be for....* Listed were four types of trips: commuting trips, out-of-town vacation trips, out-of-town business trips, and local nonwork driving. Subjects rated the usefulness of the system they used in the study for each type of trip using a seven-point scale anchored by the labels "not at all useful" for one and "extremely useful" for seven. The average responses for each type of trip by INAS are shown in Table 19. Overall, respondents tended to think that both Ali-Scout and TetraStar would be useful for all four types of trips and most useful for out-of-town trips. Three-way ANOVAs calculated separately for each type of trip showed that there were significant differences between users of Ali-Scout and TetraStar in their ratings of system usefulness for out-of-town vacation trips ($F_{1, 206}$=12.63; p<.001) and out-of-town business trips ($F_{1, 203}$=17.86; p<.0001). In both cases the significant difference results from TetraStar users giving higher ratings than users of Ali-Scout.

Table 19: Average Likelihood of Using Various Types of Route-Guidance Information in an Unfamiliar Area as a Function of INAS used in the Study (1=Not at all useful; 7=Extremely useful).

Type of Trip	Ali-Scout User	TetraStar User
Commuting Trip	5.03	4.92
Out-of-Town Vacation Trip	6.19	6.69
Out-of-Town Business Trip	6.28	6.83
Local Non-Work Driving	4.32	4.44

Subjects were asked: *How much would you be willing to pay for the system as an option on a new car?* Again only Ali-Scout and TetraStar users were asked to respond by writing down a dollar amount. The mean amount of money Ali-Scout users were willing to pay for the system as an option on a new car was $342 (*sd*=$326) while TetraStar users were willing to pay an average of $526 (*sd*=$409). Table 20 shows the dollar amount distribution as a function of system used.

Table 20: Summary of How Much Drivers are Willing to Pay for Ali-Scout and TetraStar as an Option on a New Car. Values are the Percent and Number (n) of Drivers Who Indicated Amounts In the Dollar Ranges.

Dollar Amount Range	Ali-Scout User (n=102)	TetraStar User (n=106)
$0	5.9 (6)	0.9 (1)
$1 - $200	43.1 (44)	20.8 (22)
$201 - $400	21.6 (22)	22.6 (24)
$401 - $600	15.7 (16)	31.1 (33)
$601 - $800	6.9 (7)	8.5 (9)
$801 - $1,000	4.9 (5)	9.4 (10)
$1,001 - $1,500	1.0 (1)	3.8 (4)
$1,501 or more	1.0 (1)	2.8 (3)

Subjects were asked: *How much would you be willing to pay for the system to add to your present car?* Only Ali-Scout and TetraStar users were asked to respond by writing down a dollar amount. The mean amount of money users were willing to pay for the system to add it to their present car was $261 (*sd*=$311) for Ali-Scout and $401 (*sd*=$407) for TetraStar. Table 21 shows the dollar amount distribution as a function of system used.

Table 21: Summary of How Much Drivers are Willing to Pay for Ali-Scout and TetraStar to Add to their Present Car. Values are the Percent and Number (n) of Drivers Who Indicated Amounts In the Dollar Ranges.

Dollar Amount Range	Ali-Scout User (n=99)	TetraStar User (n=102)
$0	17.2 (17)	9.8 (10)
$1 - $200	41.4 (41)	26.5 (27)
$201 - $400	19.2 (19)	28.4 (29)
$401 - $600	15.2 (15)	17.6 (18)
$601 - $800	3.0 (3)	5.9 (6)
$801 - $1,000	2.0 (2)	6.9 (7)
$1,001 - $1,500	1.0 (1)	2.0 (2)
$1,501 or more	1.0 (1)	2.9 (3)

Subjects were asked: *How much extra per day would you be willing to pay for the system as an option on a rental car?* Only Ali-Scout and TetraStar users were asked to respond by writing down a dollar amount. The mean amount of extra money per day users were willing to pay for the system as an option on a rental car was about $12 (*sd*=$24) for Ali-Scout and about $10 (*sd*=$13) for TetraStar. Table 22 shows the dollar amount distribution as a function of system used.

Table 22: Summary of How Much Extra Per Day Drivers are Willing to Pay for Ali-Scout and TetraStar as an Option on a Rental Car. Values are the Percent and Number (n) of Drivers Who Indicated Amounts In the Dollar Ranges.

Dollar Amount Range	Ali-Scout User (n=97)	TetraStar User (n=106)
$0	6.2 (6)	3.8 (4)
$1 - $10	77.4 (75)	78.3 (83)
$11 - $20	4.1 (4)	10.4 (11)
$21 - $30	7.2 (7)	3.8 (4)
$31 - $60	1.0 (1)	1.9 (2)
$61 - $100	2.1 (2)	1.9 (2)
$101 or more	1.0 (1)	0.0 (0)

Finally, all subjects, including those using Written Instructions, were Instructed: *Please indicate any comments that were not addressed in the survey you may have about the experiment or the navigation assistance you received.* One hundred forty-two subjects (39.4 percent) gave us additional comments. These comments, listed verbatim, as a function of INAS used, driver familiarity, and traffic conditions can be found in Appendix G. Identifying words and comments have been edited out.

DISCUSSION AND CONCLUSIONS

The purpose of the study was to compare how drivers used and what they thought about three specific in-vehicle navigation assistance systems (INAS); Ali-Scout, TetraStar, and Written Instructions. Because these systems provided navigation assistance in distinctly different ways and are representative of different classes of INAS, this study was also a comparison of different types of navigation assistance. Drivers who were both familiar and unfamiliar with the road network in the study area participated, and the study was conducted both during peak and nonpeak traffic times. The three systems were compared through observation of driving behaviors (as determined by a GPS tracking system) and through self-reported use and opinions.

We found that users of both Ali-Scout and TetraStar had more difficulty in getting to the initial route and finding the destination once they were near it than did those with Written Instructions, with Ali-Scout users having the most difficulty. Thus, the INAS with the as-you-drive presentation of guidance information performed less well than the INASs with all-in-advance information on these measures. At least two explanations can account for this result. First, it may be that users of INASs need turn-by-turn guidance that starts from when they begin driving and continues until they pull into their destination. This type of guidance was provided only by Written Instructions in the present study. A second explanation is that the autonomous mode information (Ali-Scout) and the map information (TetraStar) required too much processing at a single glance for drivers to be able to easily use the information while driving. The fact that drivers of Ali-Scout and TetraStar had less difficulty on the second trip suggests that the latter explanation is more likely and that on-the-road experience with the electronic INAS, which few drivers had tried before, is beneficial. On the other hand, drivers of all INAS had much less difficulty with route start and end points in the second trip. Since in the second trip the origin and destinations were switched, driver familarity with the locations undoubtedly helped them locate the route and find the destination.

We also found that very few drivers got lost using any of the INAS, including drivers who were unfamiliar with the area, suggesting that all three systems are quite good at providing navigation assistance. When the systems were compared on this variable, however, we found that the majority of lost drivers were using Ali-Scout. Given that users of Ali-Scout tended to get lost about as frequently in trip one as in trip two, the frequency of getting lost cannot be attributed to a lack of experience with the system. Based upon the questionnaire responses, it is more likely that one or more of the following occurred: 1) the icons or voice messages used to convey navigation information were difficult to understand; 2) communication between vehicle and roadside beacons was disrupted part of the time leaving drivers in autonomous mode; or 3) turn recommendations were provided too late for the driver to execute them, because errors that built up in the dead-reckoning calculation used by Ali-Scout to locate the vehicle. An examination of Ali-Scout user responses to the question about reasons for getting lost, support each of these contentions.

The study also showed that the average number of turns per trip varied significantly by trip number, with number of turns for both Ali-Scout and TetraStar decreasing in the second trip. Again, these results show the need for on-the-road practice with the electronic INAS before efficient use is observed. The analysis of the number of wrong turns showed the same learning effect. In the first trip, users of the electronic INASs made more wrong turns per trip overall, than did users of Written Instructions. This difference disappeared in the second trip, where, on average, only about one wrong turn was executed in every ten trips made. As expected, for both trips, familiar drivers made fewer wrong turns than did unfamiliar drivers.

A potential benefit of dynamic-guidance systems over static-guidance ones, is that they could help the driver avoid traffic congestion. One measure of the amount of traffic congestion encountered during a trip is length of time spent at zero velocity (wait time). Overall, we found no difference for this variable between navigation systems. Thus, it appears that the dynamic information used by Ali-Scout either was not accurate or there simply were no alternate routes with less congestion.

The analysis of trip length showed that, overall, trips driven with Ali-Scout tended to be longer than trips taken by users of TetraStar or Written Instructions. While significant, the average difference was less than 3 percent (.2 miles) of the total trip distance. Considering only trips in which drivers had some experience with the INASs (i.e., trip two), we found that TetraStar users had the shortest length trips, while Ali-Scout and Written Instruction users had trip lengths that were about the same.

Perhaps the most important comparison of the INASs in this study was the analysis of trip duration. As expected, we found that drivers who were familiar with the road network in the study area drove shorter duration trips than drivers who were unfamiliar, for each INAS studied. Also as expected, trip durations were longer during peak traffic times. The traffic condition variable is of particular interest because the dynamic, as-you-drive system we tested, Ali-Scout, is designed to provide routing that avoids high traffic areas. The potential benefit of this feature should be greatest during peak traffic conditions. If Ali-Scout were to provide additional trip-time savings over static systems during peak traffic times, we would expect to find a significant interaction between navigation system and traffic conditions. We did not find this interaction in any of the statistical comparisons that we made.

Also of interest was the comparison of INAS on trip duration by trip number. For the first trip, we found that users of Ali-Scout tended to drive longer duration routes than drivers of the other two systems. However, once the drivers had gained experience with the system, we found that in the second trip users of both electronic INAS showed nearly identical trip durations and were significantly faster than trips taken by users of Written Instructions. Thus, when lost drivers are not considered and users have experience with the system, it appears that as-you-drive guidance instructions lead to routes that are faster than INASs that utilize instructions given all-in-advance.

The self-reported opinions of the various INASs showed consistent results. A large percentage of study participants were very satisfied with the system they used, reported at least some level of distraction while driving, had very high levels of confidence in the accuracy of the system, thought the system was useful, and had highly positive impressions of the systems. We also found that the majority of users of all three systems felt an increased level of safety relative to driving without the system. There was no statistical difference between INASs on this measure. Further, there were no crashes or reports of near-crashes for any participant in the study.

Comparisons between INAS on the other opinion variables were also consistent. Ali-Scout users reported less satisfaction, higher levels of distraction while driving, less confidence in accuracy, lower levels of helpfulness in finding destinations, and lower impressions of the overall appearance of the system than did users of either TetraStar or Written Instructions. TetraStar and Written Instruction users did not differ greatly on any of these same variables. As such, the two static route guidance systems we tested in the study were more highly valued than was the dynamic route guidance system we tested. This is, perhaps, not surprising since we also found that the dynamic feature of Ali-Scout did not seem to provide faster routes or ones that were less congested than those provided by TetraStar.

Very few drivers reported feeling lost during the study, regardless of the INAS they were using. This finding agrees with the automated GPS tracking data. Comparing across the INAS, however, we found that users of the as-you-drive INAS (Ali-Scout and TetraStar), felt lost more frequently than users of the all-in-advance system (Written Instructions). This result suggests that the requirement of keeping track of new information as it arrives during a trip may disrupt the cognitive mapping of certain drivers, leading to feelings of not knowing where they are located.

When asked to rate the quality and likelihood of using various types of route guidance information, all users, regardless of INAS used, rated electronic in-vehicle route-guidance more favorably and more likely to be used in an unfamiliar area if it were available than any other type of route guidance information. Thus, there is general public support of these electronic INAS, and those who had experience with electronic route-guidance, rated it higher than who had not used it. Interestingly, the majority of users rated verbal directions from either a passenger or an other person as neither a poor nor excellent source of information, and as one they neither liked nor disliked.

When asked about the likelihood of using the specific system they tested in the study while driving in an unfamiliar area, users of both Ali-Scout and TetraStar thought they would be highly useful on out-of-town trips (Written Instructions users were not asked this question) and useful, but to a lesser degree, in commuting and local driving. These results point out the fact that a majority of drivers do not find great benefit in route guidance in familiar, everyday trips. Rather, they want guidance in areas that are visited less often or are completely unfamiliar.

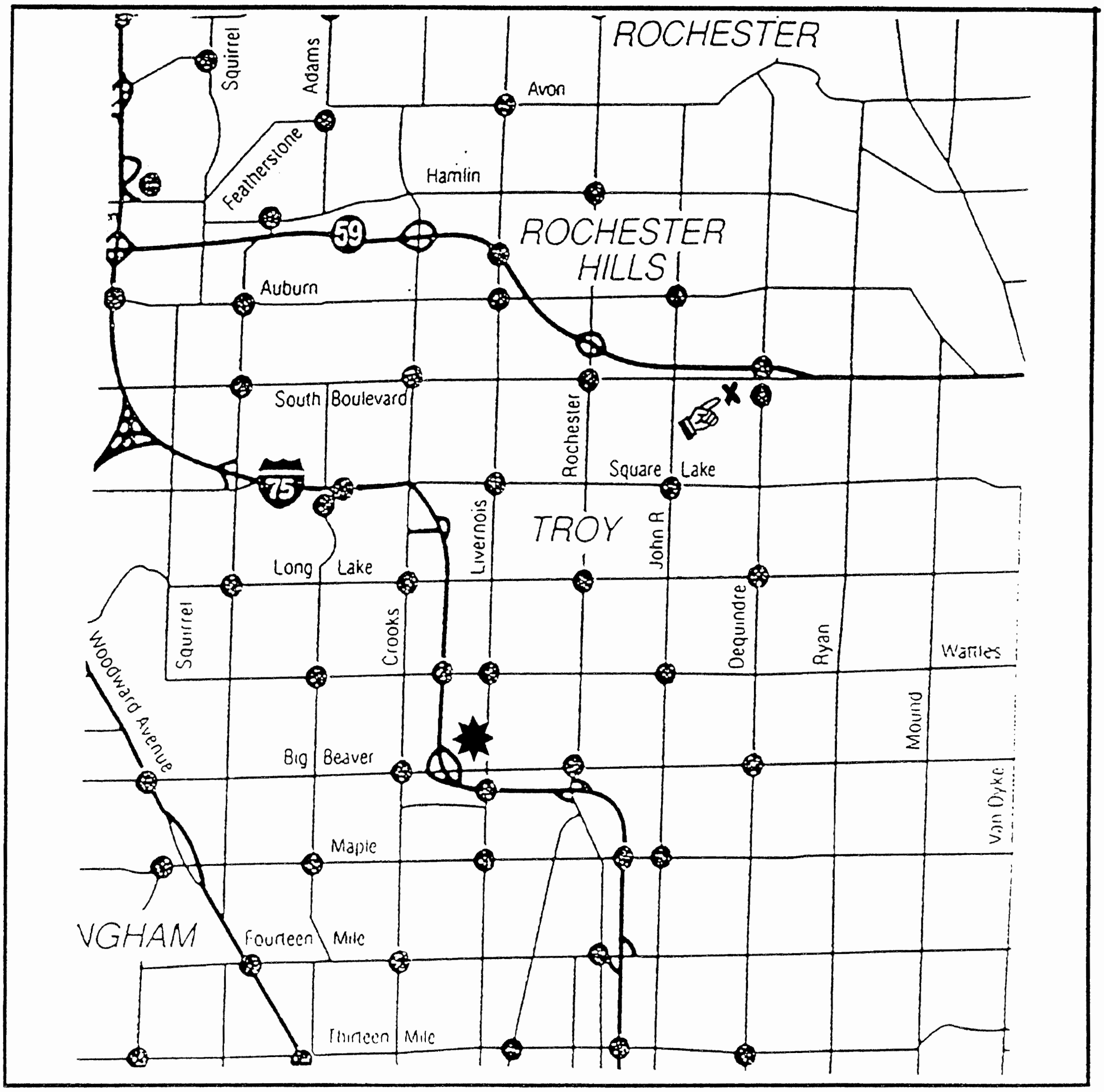
We found that users of TetraStar were willing to pay more to have the system installed in a new car or in their present car than were Ali-Scout users. On average, TetraStar users were willing to pay $526 for the system on a new car and $401 to add to their present car, whereas Ali-Scout users were only willing to pay $342 and $261 for the Ali-Scout. One feature of infrastructure-intensive systems like Ali-Scout (i. e., the roadside beacons and traffic operations center computer) is that once the infrastructure has been installed and paid for by a community or some other organization, the cost for individuals to have a unit installed in their vehicles would be relatively small. On the other had, systems like TetraStar, where the map data base, route calculation, tracking system, and information display unit are self-contained, would be relatively expensive because all components would have to be purchased by the individual user. Therefore, it is likely that a system like Ali-Scout would cost less than a system like TetraStar.

In conclusion, we ask the question: How did the systems compare? We found that the systems that presented guidance information as-you-drive required the driver to have on-the-road experience before they performed as well as or better than the all-in-advance system. In many cases, a single trip was all the experience that was needed. With this experience, the as-you-drive systems led to consistently shorter duration trips. We also found that the static systems were generally better liked than the dynamic system. This finding probably results from two factors. First, even though we consider Ali-Scout to be a system that is representative of dynamic, as-you-drive INAS, drivers had some difficulty with the Ali-Scout autonomous mode guidance ("as the crow flies") utilized by Ali-Scout during trip start and end points. This feature is not specific to dynamic, as-you-drive INAS, but rather to Ali-Scout, and may have led to a less favorable evaluation of this type of INAS. A second factor that may be related to the less positive findings for dynamic, as-you-drive INAS is the fact that the dynamic system tested did not seem to lead to trips that were faster or less congested. As mentioned earlier, this lack of a dynamic route guidance benefit may have been due to a lack of less-congested routes or it may have resulted from an inability of the Ali-Scout system to adequately predict traffic congestion. The Ali-Scout system is designed to predict only recurrent traffic congestion. Recall that the dynamic information used by Ali-Scout is probe-vehicle link times averaged with link times derived from road classification and speed limits on a day-of-the-week, time-of-day basis. As such, the dynamic information for calculating a route is based partially upon probe-vehicle link data from that same time of day *one week earlier.* In this sense, there is no "real-time" traffic information and nonrecurrent congestion cannot be identified. It may be that nonrecurrent congestion information is the type of traffic information that is most important in dynamic as-you-drive INAS. Systems that can consistently provide this level of in-vehicle dynamic route guidance still have many developmental hurdles to overcome such as accurate incident detection and confirmation, calculation of the incident's effect on the traffic in the network, and getting this information to the vehicle in a manner that is timely enough to be useful. Thus, based upon the results of the present work, we conclude that a static INAS with as-you-drive information presentation, such as TetraStar, performs better than the other types of INAS tested and is more favorably perceived by drivers.

APPENDIX A:

Maps Showing the Origin-Destination Pairs and the Printed Instructions Used in the Written Instructions Condition.

O-D Pair: Liberty Center and Flynn Park



Legend: ✷ Liberty Center
☞ Flynn Park

Directions: Liberty Center Parking Lot to Flynn Park

1700 block of South Boulevard near Dequindre

1) Exit parking area to Livernois Rd.

2) Turn Left onto Livernois Rd.

3) Follow Livernois Rd. to Long Lake Rd.

4) Turn Right onto Long Lake Rd.

5) Follow Long Lake Rd. to John R Rd.

6) Turn Left onto John R Rd.

7) Follow John R Rd. to South Boulevard

8) Turn Right onto South Boulevard

9) Flynn Park is on the Right

10) Park in the parking lot nearest to South Boulevard.

Directions: Flynn Park to Liberty Center Parking Lot

3100 block of Livernois Rd.

1) Turn Left onto South Boulevard.

2) Follow South Boulevard to John R Rd.

3) Turn Left onto John R Rd.

4) Follow John R Rd to Long Lake Rd.

5) Turn Right onto Long Lake Rd.

6) Follow Long Lake Rd. to Livernois Rd.

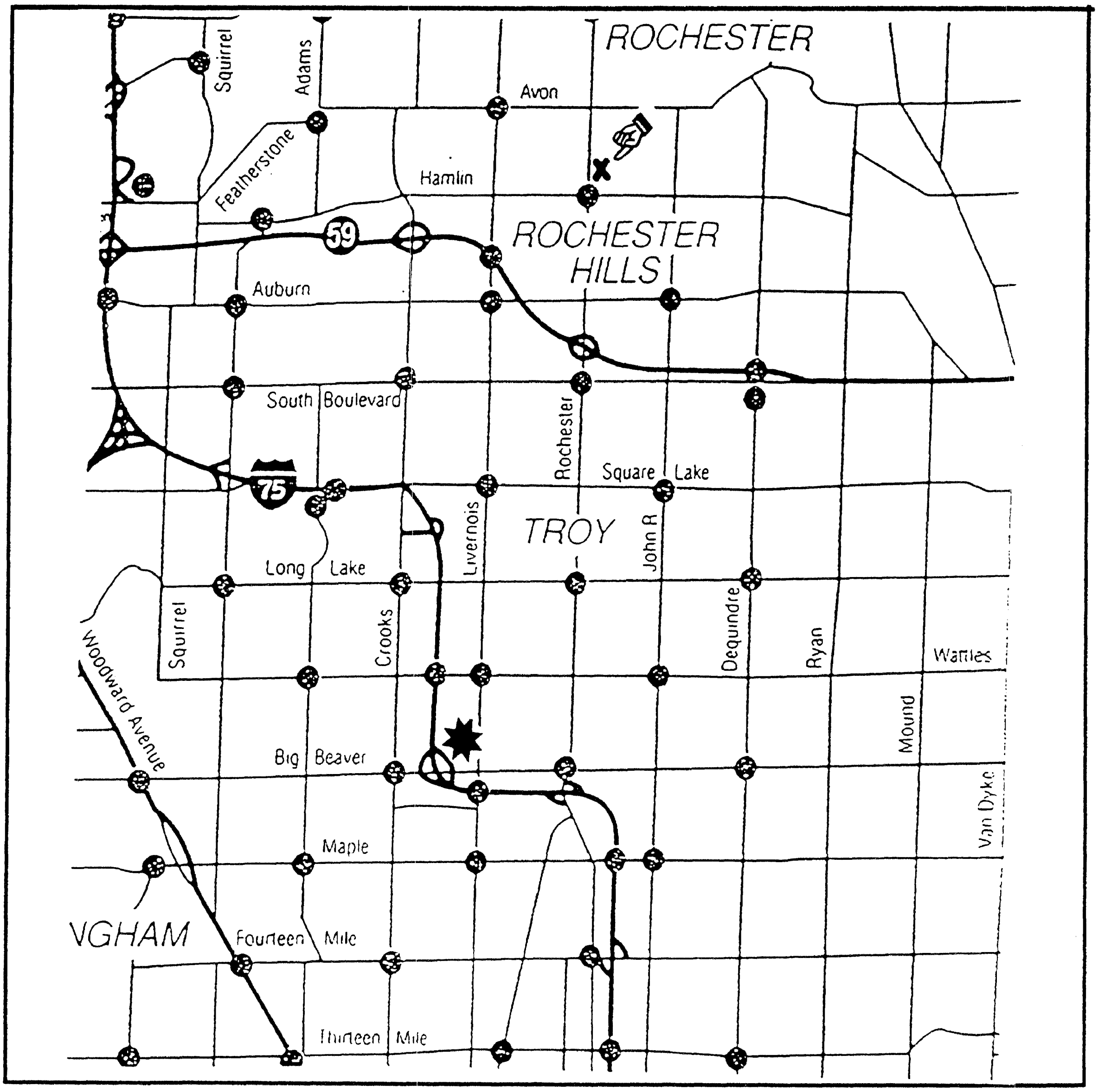
7) Turn Left onto Livernois Rd.

8) Follow Livernois Rd. To Liberty Center parking lot.

9) Liberty Center Parking Lot is on the right side of the road.

10) Park in the same place that you started.

O-D Pair: Liberty Center and Bordine's Nursery



Legend: ✷ Liberty Center
☞ Bordine's Nursery

Directions: Liberty Center Parking Lot to Bordine's Nursery

1835 South Rochester Rd.

1) Exit parking area to Livernois Rd.

2) Turn Left onto Livernois Rd.

3) Follow Livernois Rd. to Long Lake Rd.

4) Turn Right onto Long Lake Rd.

5) Follow Long Lake Rd. to Rochester Rd.

6) Turn Left onto Rochester Rd.

7) Follow Rochester Rd. to Bordine's Nursery.

8) Bordine's Nursery is on the northeast corner of the intersection of Rochester and Hamlin roads.

9) Park by the large flag pole in the parking lot.

Directions: Bordine's Nursery to Liberty Center Parking Lot

3100 block of Livernois Rd.

1) Exit Bordine's Nursery at Rochester Rd.

2) Turn Left onto Rochester Rd.

3) Follow Rochester Rd. to Long Lake Rd.

4) Turn Right onto Long Lake Rd.

5) Follow Long Lake Rd. to Livernois Rd.

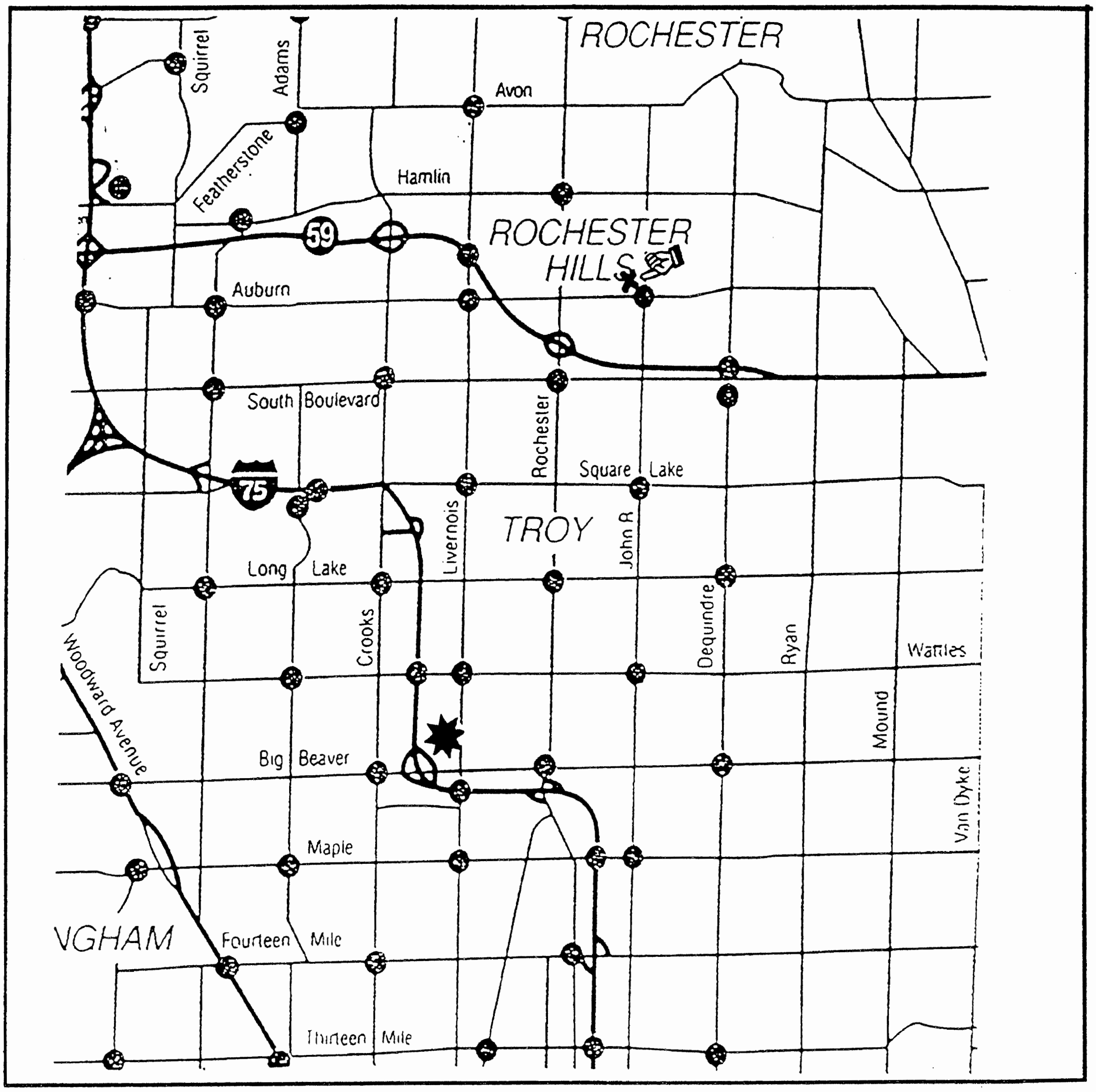
6) Turn Left onto Livernois Rd.

7) Follow Livernois Rd. to the Liberty Center Parking Lot.

8) The Liberty Center Parking lot is on the Right side of Livernois Rd.

9) Park in the same place that you started.

O-D Pair: Liberty Center and Arbor Drugs



Legend: ✷ Liberty Center
☞ Arbor Drugs

Directions: Liberty Center Parking Lot to Arbor Drugs

965 East Auburn Rd.

1) Exit parking area to Livernois Rd.

2) Turn Left onto Livernois Rd.

3) Follow Livernois Rd to Long Lake Rd.

4) Turn Right onto Long Lake Rd.

5) Follow Long Lake Rd. to John R Rd.

6) Turn Left onto John R Rd.

7) Follow John R Rd. to Arbor Drugs.

8) Arbor Drugs is located on the northwest corner of John R. and Auburn roads.

9) Park in the lot closest to the intersection.

Directions: Arbor Drugs to Liberty Center Parking Lot

3100 block of Livernois Rd.

1) Exit Arbor Drugs parking area to John R Rd.

2) Turn Right onto John R Rd.

3) Follow John R Rd. to Long Lake Rd.

4) Turn Right onto Long Lake Rd.

5) Follow Long Lake Rd. to Livernois Rd.

6) Turn Left onto Livernois Rd.

7) Follow Livernois Rd. to Liberty Center parking lot.

8) Liberty Center parking lot is on the right side of the road.

9) Park in the same place that you started.

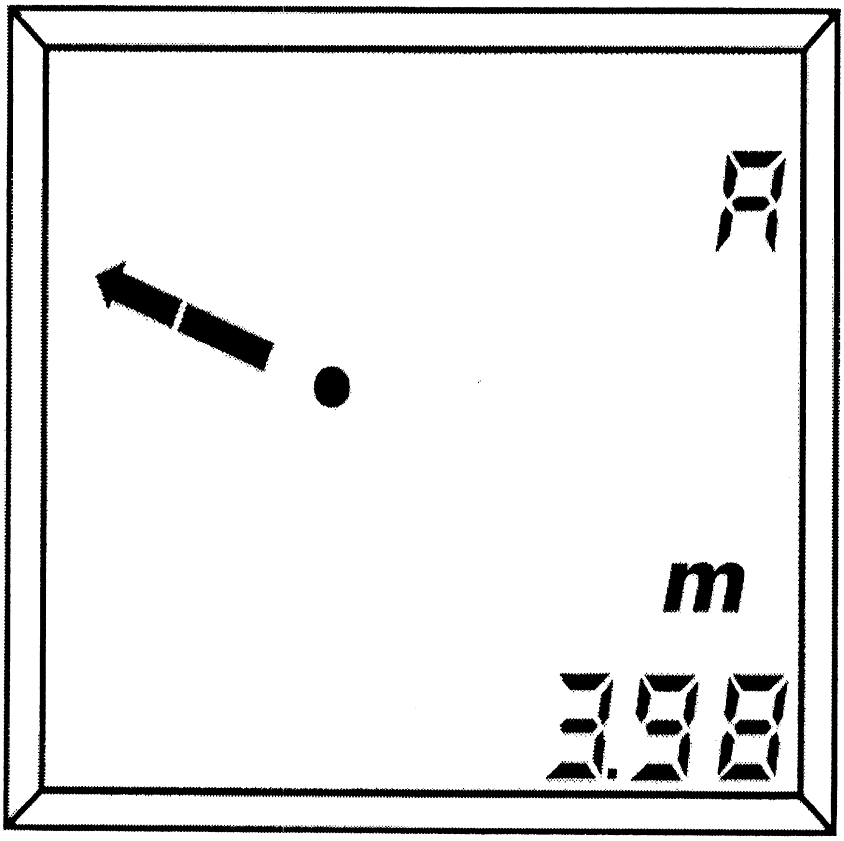
APPENDIX B:

Printed Training Materials for Ali-Scout and TetraStar

ALI-SCOUT NAVIGATION UNIT

FAST-TRAC PROJECT
OAKLAND COUNTY, MICHIGAN
SUMMER, 1996

AUTONOMOUS MODE



✿ Destination is 3.98 miles in the direction of the arrow "as the crow flies."

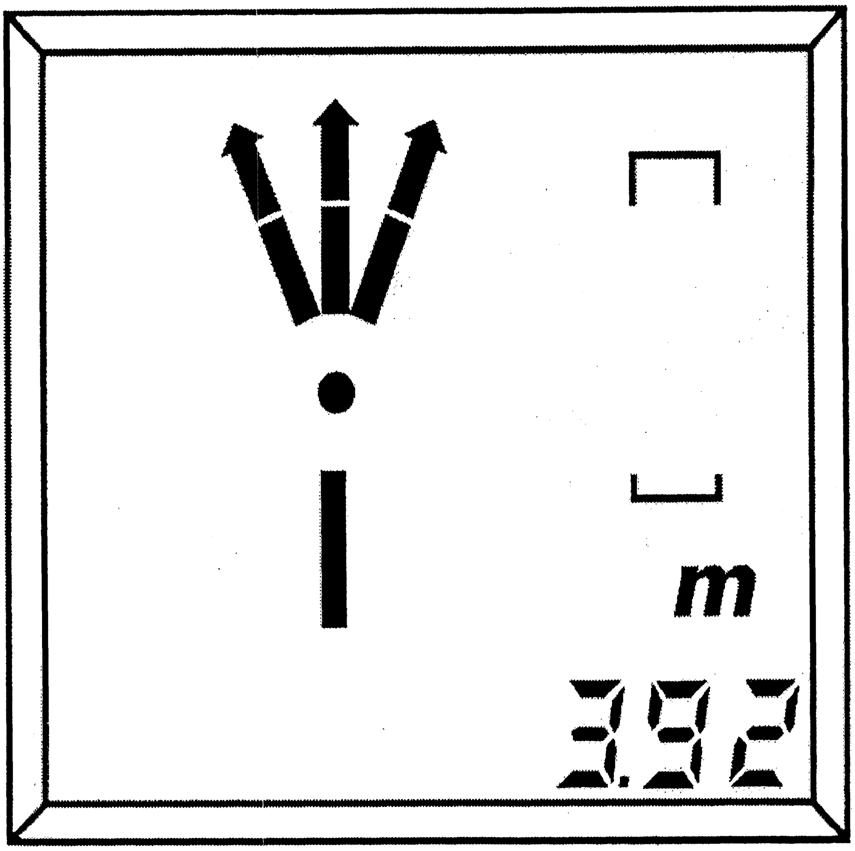
✿ This is a typical start-up display.

✿ When you pass a beacon, you will leave autonomous mode and go into guided mode.

ALI-SCOUT

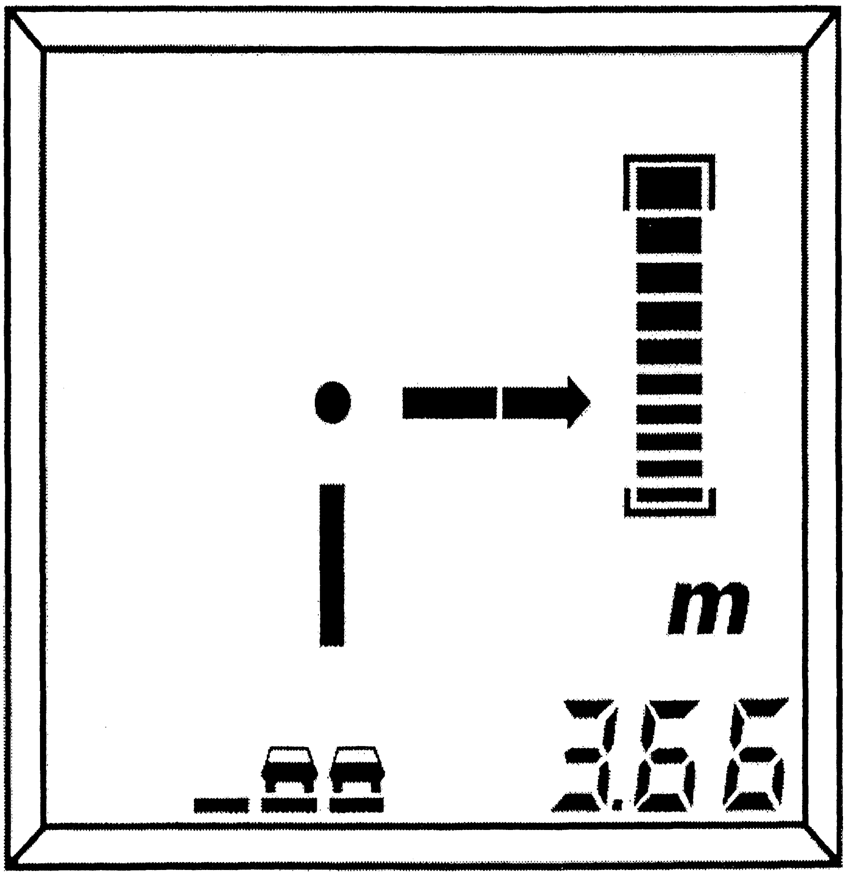
- In-vehicle navigation system.
- Calculates "fastest" route.
- Takes into account road closures, major traffic problems, and daily traffic patterns.

FOLLOW MAIN ROAD



✿ Continue on the road that you are on.

PREPARE FOR MANEUVER

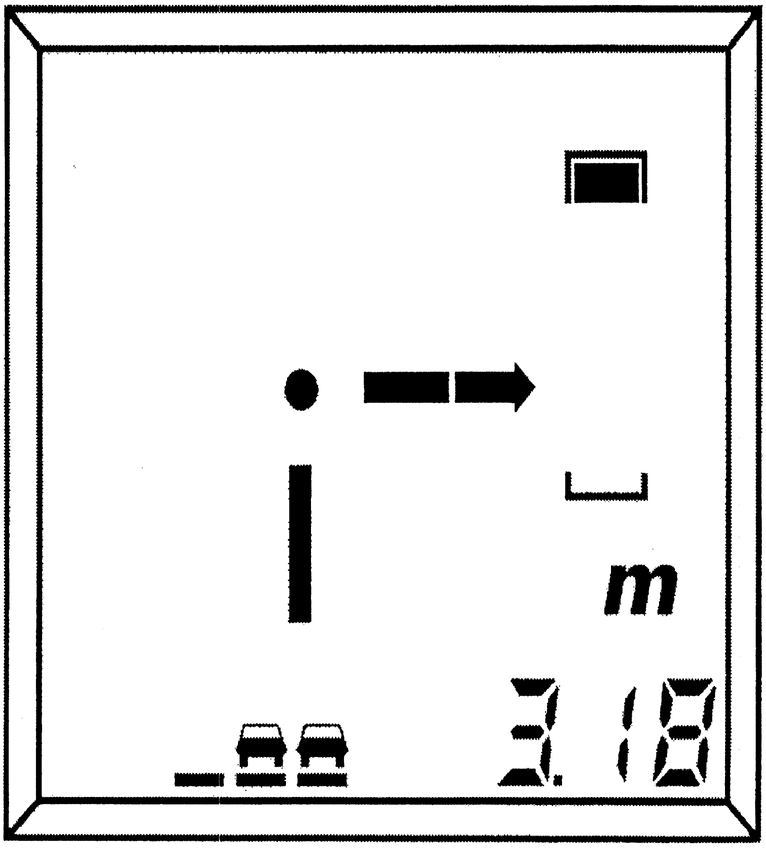


✿ Move into one of the two right lanes, you will be turning right soon.

✿ Be sure to check for traffic before moving over.

✿ Vertical bar shows the relative distance to the right turn.

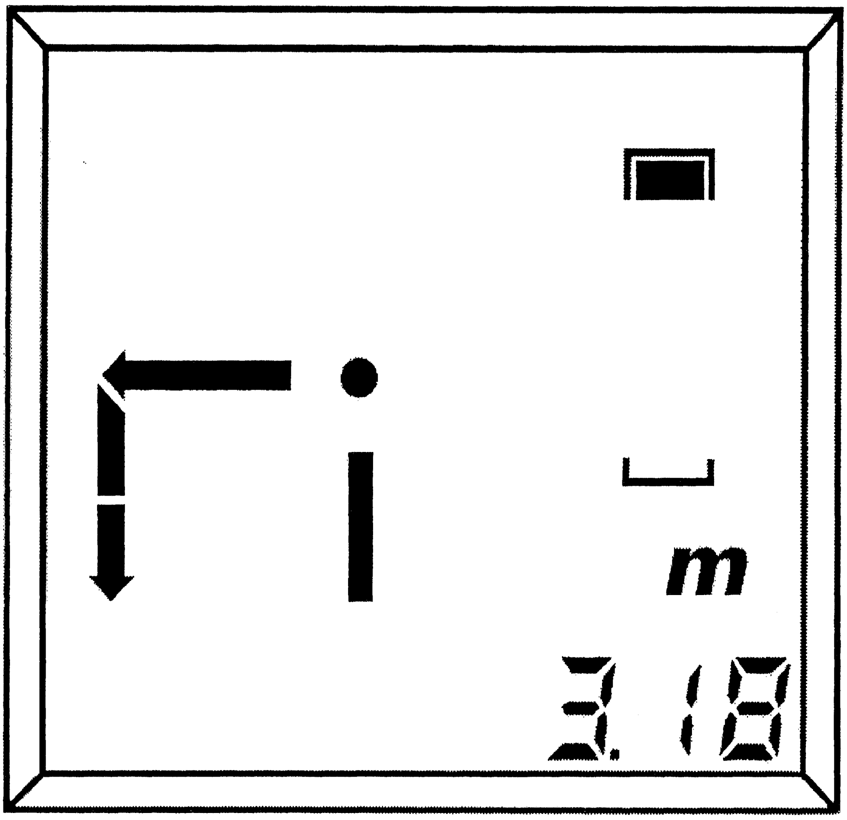
EXECUTE MANEUVER



✿ Turn right.

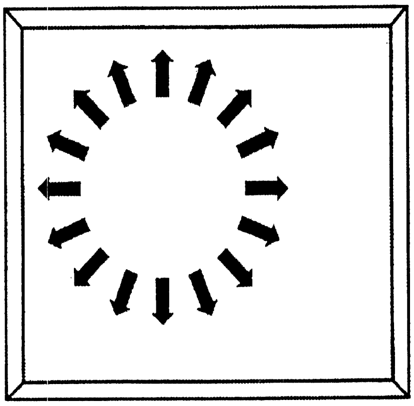
✿ Always check if it is safe to turn before proceeding.

MICHIGAN BOULEVARD
LEFT TURN



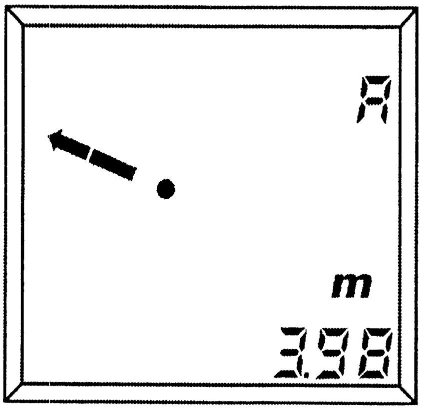
✿ **Turn left by making a right turn then left across the median and then left again.**

LEFT RECOMMENDED ROUTE



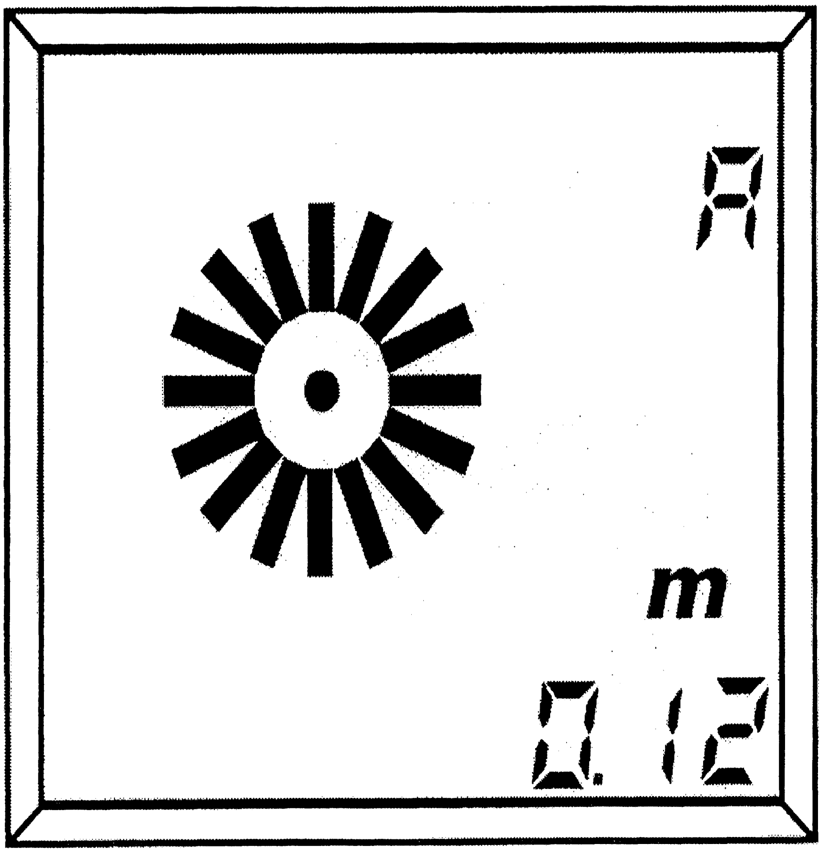
☹ You have left the route recommended by ALI-SCOUT and are no longer in Guided Mode.

☹ The next display you will see will be the Autonomous Mode display, which shows the distance and direction to the destination.



☺ When you pass another beacon, you will go into Guided Mode.

DESTINATION AREA



- ✿ You are within .12 miles of your destination.
- ✿ You are now in Autonomous Mode.

TETRASTAR NAVIGATION UNIT

TROIKA STUDY
FAST-TRAC PROJECT
OAKLAND COUNTY, MICHIGAN
SUMMER, 1996

TETRASTAR

- Satellite based Global Positioning (GPS) navigation system.

- Uses a map and information data base of the region.

- Calculates "fastest" route.

- Does not take into account traffic problems.

TETRASTAR

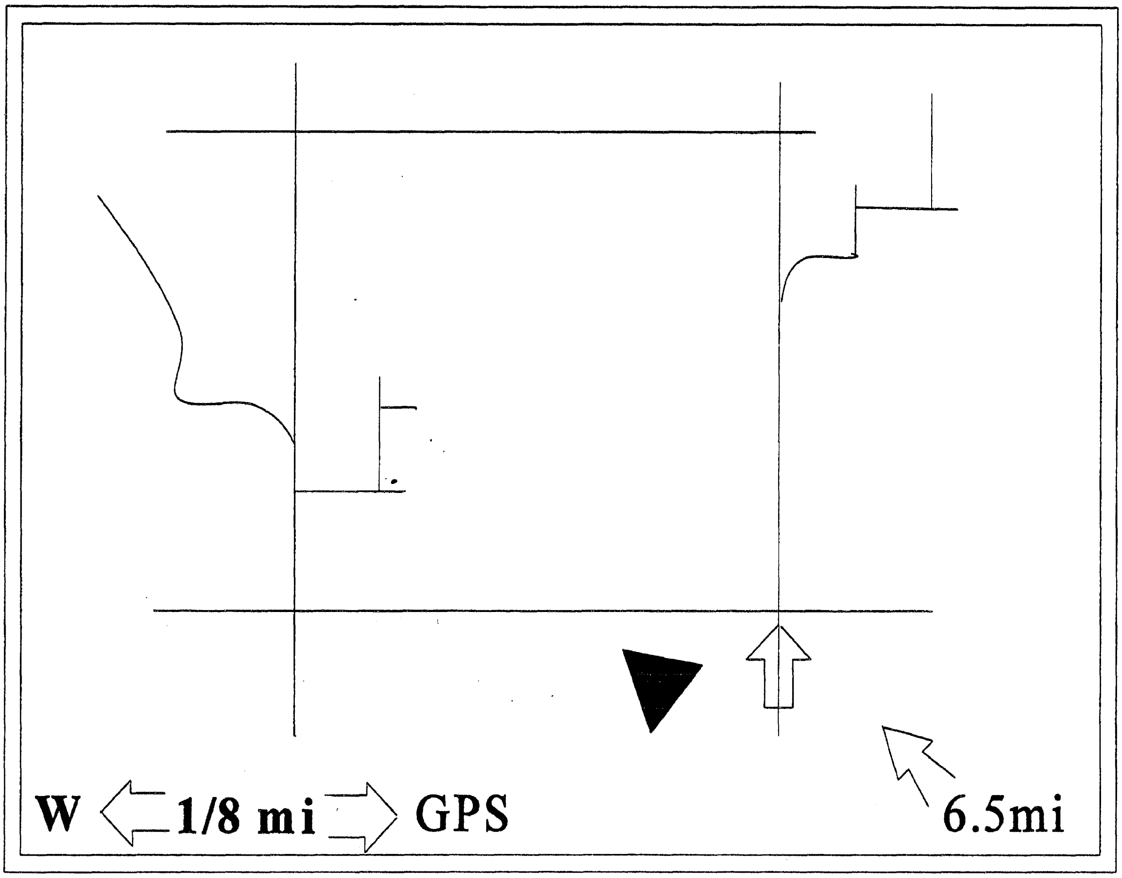
✿ Information given:

- ✲ Visually, by display unit
- ✲ Audibly, by voice instruction

✿ Two types of guidance:

- ✲ Map, route display
- ✲ Manuever instruction

ROUTE GUIDANCE INITIAL SCREEN

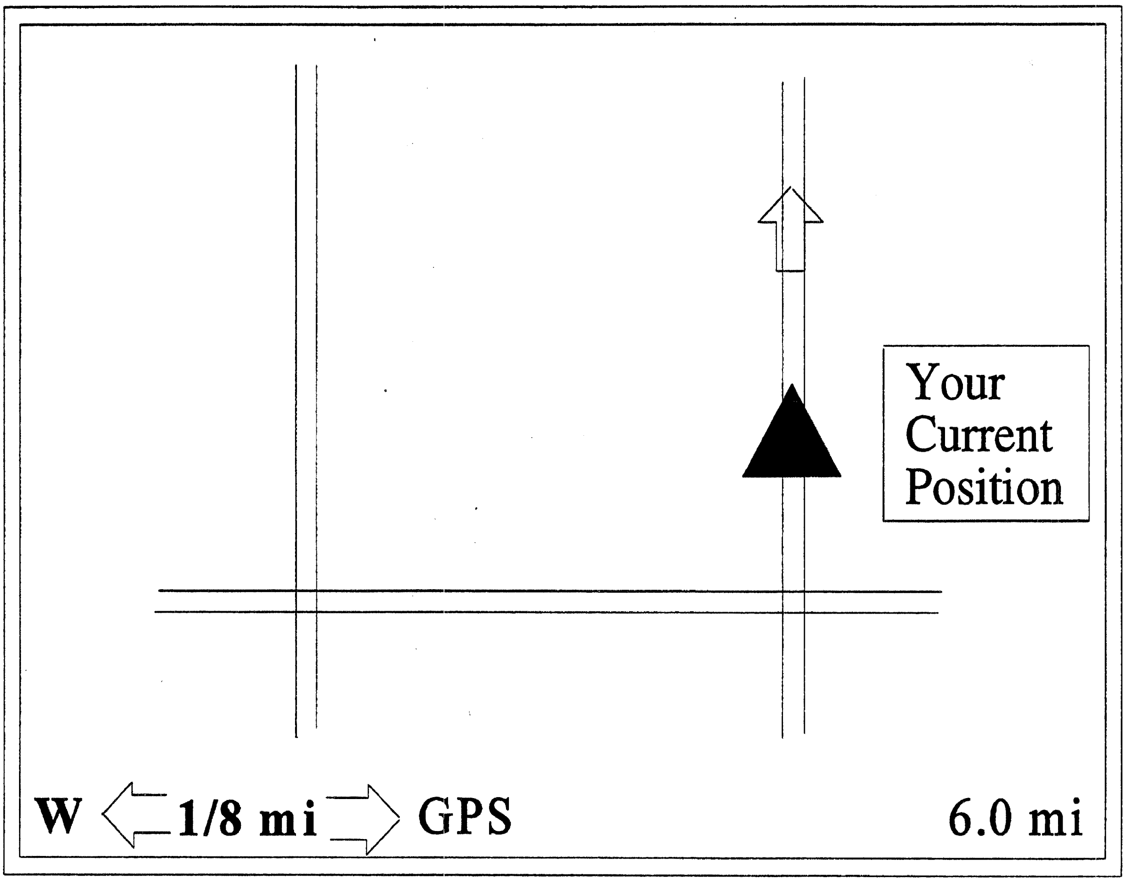


✿ Route guidance initial screen (while the vehicle is off a named road or speed is less than 5 mph).

✿ A yellow arrow indicates the direction to take to begin the planned route.

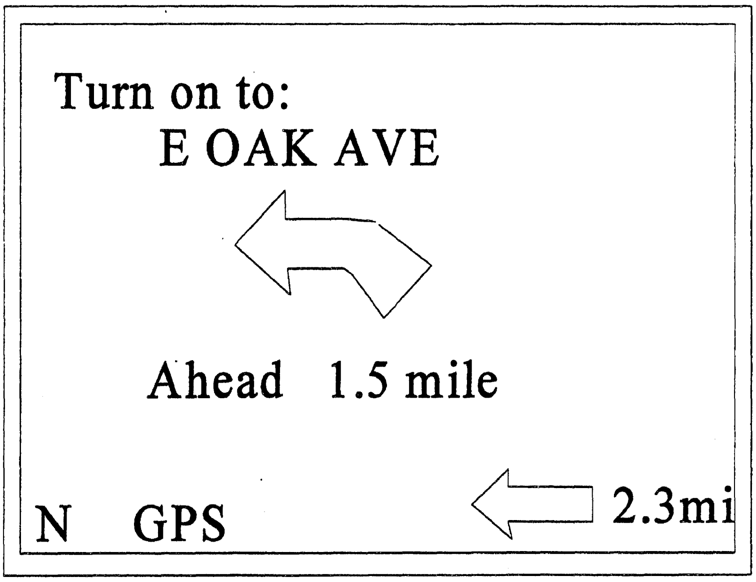
✿ The highlighted lines show the path of the planned route.

ROUTE MAP

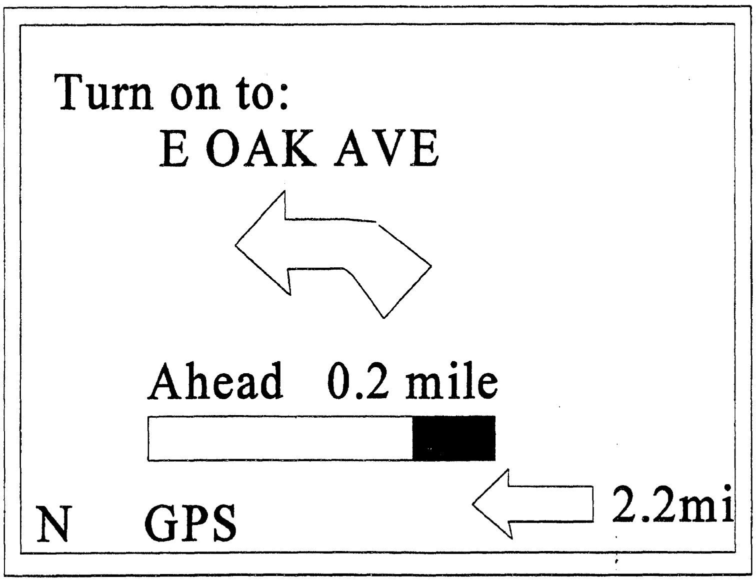


- GPS Symbol, compass heading
- Direction and distance to the destination.
- Map scale bar
- Route direction arrow

MANEUVER SCREEN

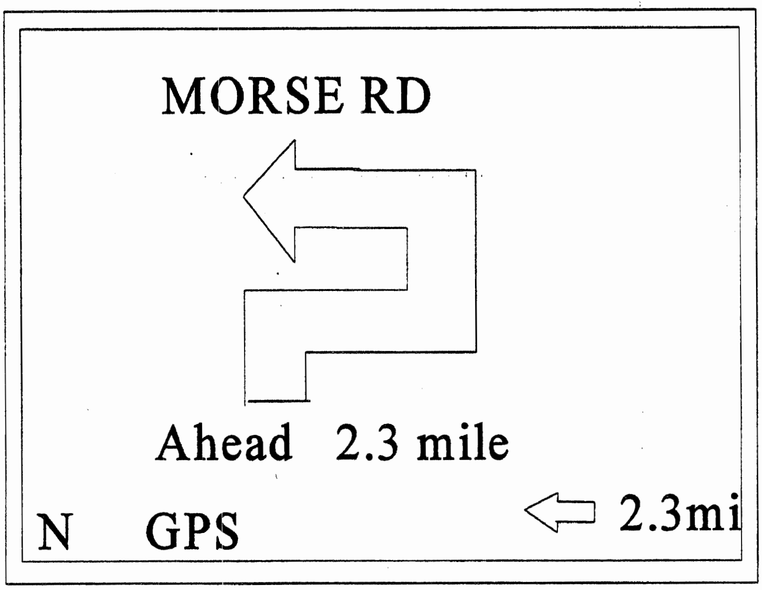


✿ **A voice announcement will say "Left Turn Ahead."**



✿ **Distance bar shrinks as the vehicle approaches the turn. The unit beeps right before the turn.**

DOUBLE MANUEVER SCREEN

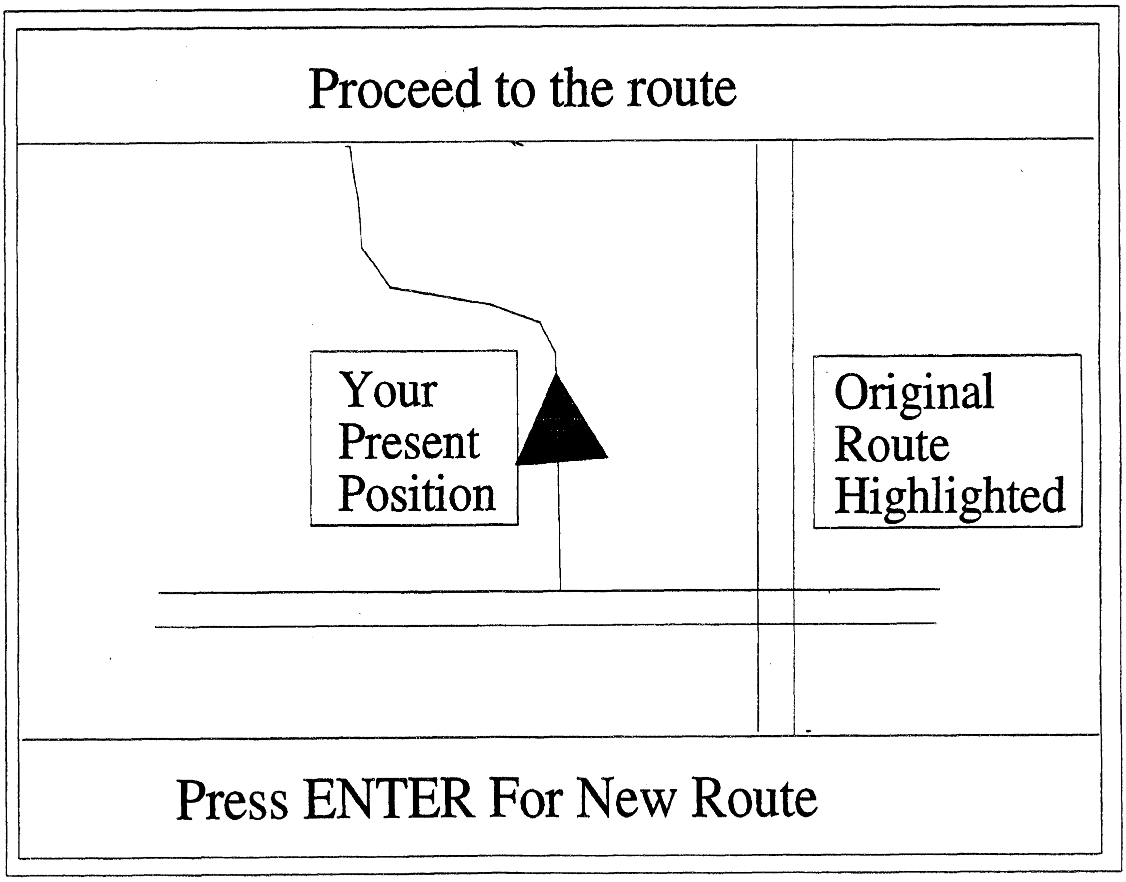


✿ **If two manuevers are very close together, TetraStar will display a Double Manuever symbol so that the driver will not miss the second turn. Once the first manuever is completed only the second turn will be shown.**

LEFT RECOMMENDED ROUTE

☹ **Ocassionly, you may miss a turn or not wish to follow the route plan.**

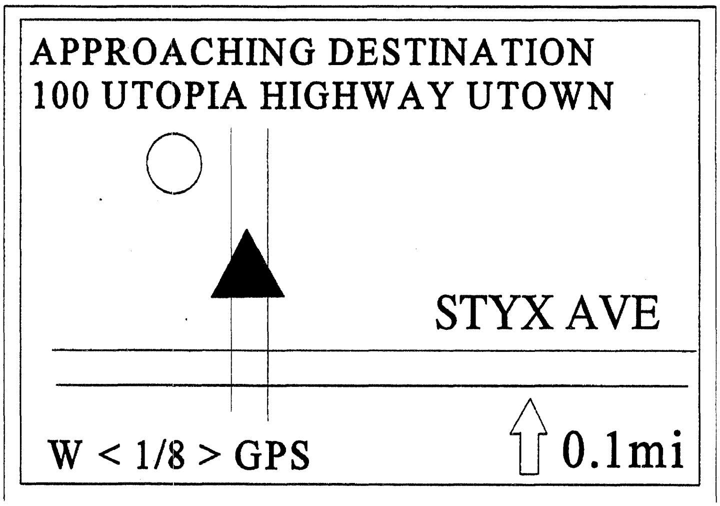
☹ **If the vehicle has left the planned route, the Off-Route Map Screen comes up accompanied by three short beeps.**



☺ **Press ENTER for new route to the Destination.**

ARRIVAL

- **Arrival display map. Voice announcement wil say "Destination Ahead."**



- **Arrival Message**

You have arrived at

100 UTOPIA HIGHWAY
UTOWN

This screen stays on for 6 seconds

APPENDIX C:

Procedures Used for Selecting and Matching O-D Pairs

In order to conduct the Troika Study, it was necessary to select several Origin-Destination (O-D) pairs that were as similar as possible for use in the study. The following describes the procedures used for the selection and matching of these pairs.

Criteria

In order to select O-D pairs, several criteria needed to be satisified. The following criteria were used in the selection of the O-D pairs:

1. Beaconed Area

All origins and destinations and the most direct paths between them had to be in the beaconed area.

2. Proximity to Beacon

Each origin and destination had to be close to a beacon.

3. Minimize Transporting of Subjects

The origins and destinations had to be chosen in a way that minimized the need to transport subjects from the FAST-TRAC Field Office at the Liberty Center to the starting locations and then back to the Liberty Center.

4. Availability of alternate routes

There had to be several routes between the O-D pair that could be selected by the navigation systems. There could be no "dominant" route (i.e., a route that is clearly shorter than all the rest or, for some other reason, always selected).

5. Similarity of route sets

The set of direct routes between each O-D pair had to be similar across the O-D pairs with respect to attributes such as road type, traffic controls, land use, and traffic. This means that if there was a path between one O-D pair that was primarily on multilane roadways with heavy traffic, there needed to be a corresponding path in the set of routes between the O-Ds of the other pairs also. While it was desirable that the number of direct routes between each O-D pair was the same, we recognized that this was not possible. Accordingly, there had to be multiple direct paths between each O-D pair and that the numbers of these paths within each set had to be similar.

6. Availability of staging area

Each origin and destination had to have an adequately-sized and safe staging area for conduct of the study; that is, a place for the experimenter to wait for subjects and a place for subject vehicles to park while drivers were receiving instructions. The staging area had to be a large paved area off of the road, such as a parking lot that is not very busy.

Selection Process

The first condition limited the location of all origins and destinations to the FAST-TRAC beaconed area, shown in Figure 10. The need to minimize the transportation of subjects to and from the Liberty Center at the beginning and end of their trips dictated the decision to have the subjects make two trips. A subject started at the Liberty Center and drove to a specified study site destination where he or she was met by a researcher. The subject then drove from the study site back to the Liberty Center. In this way, the Liberty Center was the origin for a subject's first trip and the destination for the second trip. The Liberty Center was located near a beacon and the large, safe parking area and thus satisified the condition for a staging area.

With the Liberty Center specified as a beginning and end point of each O-D pair, it was then necessary to identify a set of destination sites that satisfied the alternate route availability and similar route set criteria, that were located close to a beacon, and that met the staging area requirements.

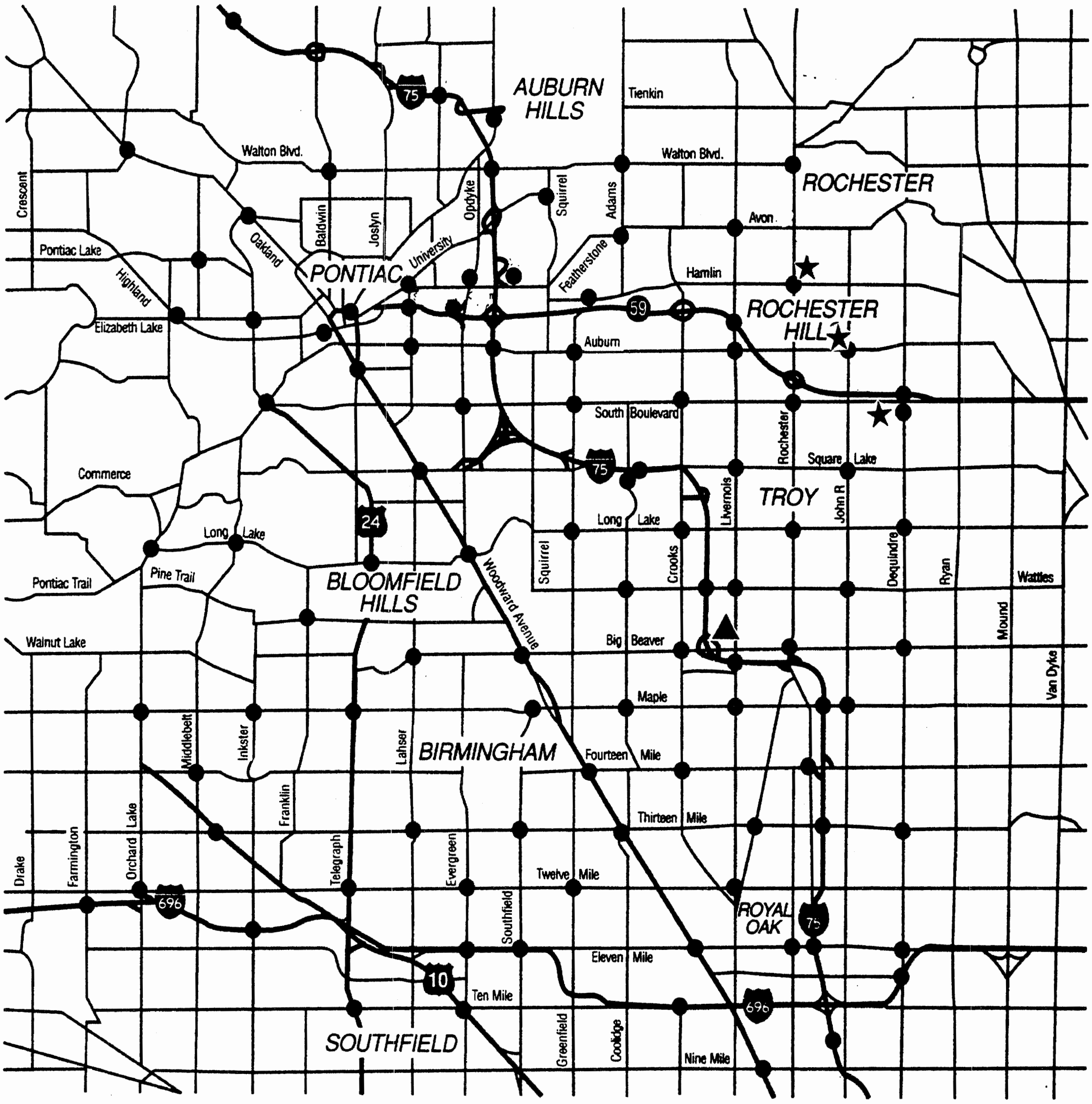


Figure 10: FAST-TRAC project area map located in Oakland County, Southeast Michigan showing Ali-Scout beacon sites (●), Troika Study sites (★), and the Liberty Center (▲).

It can be seen in Figure 10 that the Liberty Center is located near Interstate 75 (I-75), in the area where I-75 makes a jog from the north-south direction to an east-west direction, and then back again to the north-south. Further north, the direction of I-75 changes again to an east-west direction. Because of this jog, the most obvious and shortest routes to sites southeast or northwest of the Liberty Center are on I-75. This makes I-75 a dominant route to possible study sites to the southeast or northwest of the Liberty Center. Since dominant routes are unacceptable to the study, the search for study sites was limited to areas southwest and northeast of the Liberty Center.

Field investigations by the researchers found that the roads, densities of development, traffic volumes, and traffic control in the area southwest of the Liberty Center were different from those northeast of the Liberty Center. Trips of the same distance and on similar roads took much longer in the southwest area than in the northeast area. This meant that it would be difficult to get similar sets of routes between the Liberty Center and a site in the southwest area and the Liberty Center and a site in the northeast area. This dictated that study sites should be selected from only one of these two areas.

Continued field investigation found the area northeast of the Liberty Center was relatively homogenous with respect to roads, density of development, traffic volumes, and traffic controls, whereas there was much more variability in these factors for the area southwest of the Liberty Center. Since it would be easier to identify study sites with similar sets of routes to the Liberty Center in a homogenous road and traffic area, the southwest area was dropped from consideration, limiting the search for sites to the beaconed area northeast of the Liberty Center.

Approximately 12 candidate sites about seven miles from the Liberty Center were considered as possible destination sites. A distance of seven miles was selected because this was the longest distance possible that kept destinations within the beaconed area. Sites that met the conditions for beacon proximity and staging area requirements were further screened for matching distances and travel times. Since there were many routes possible for each O-D pair, the time and distance measures were matched on routes recommended by the static Ali-Scout system. This was done to eliminate any researcher bias in the route choice. At the time of O-D pair selection Ali-Scout in static mode guidance was the only INAS available to the researchers. Next, the availability of alternate routes and the similarity of the route sets were examined for the potential destination sites that matched on the time and distance of the static Ali-Scout routes.

The Study Sites

Three locations satisfied all criteria for destination sites. These sites were located at Flynn Park, on the south side of South Boulevard west of Dequindre; the parking lot for Arbor Drugs at the northwest corner of Rochester Road and John R; and the parking lot of Bordine's Nursery on the northeast corner of Hamlin and Rochester Roads. Since these sites would serve as the destination of a subject's first trip and the origin of the subject's second trip, there would be *six* O-D pairs in the Troika study. The sites are indicated on Figure 10. Table 23 shows the characteristics of the initial route as recommended by the static Ali-Scout system for all six O-D pairs.

As discussed previously, the roads, land use, and types of traffic in the beaconed area to the northeast of the Liberty Center were relatively homogenous. The road network in this area is characterized by a mile grid road pattern. All the intersections in the mile square grid are signalized. The roadside environment is suburban and there is commercial development on the corners of most of these intersections. All the roadways are two-way. Rochester Road carries higher volumes of traffic than the other north-south roads and also has more roadside development than the other north-south roads in the area of concern. There is a mix of two-lane and multilane roadways in the network. The roads closer to the Liberty Center in the southwest part of this area tend to have curb and gutters, while more of the roads to the northeast have gravel shoulders.

Table 23: Comparison of the Six O-D Pairs on Routes Driven Using Ali-Scout Static Guidance.

Origin	Destination	Distance (miles)	Travel Time (min)	Roads	Traffic Control	Land Use	Type of Traffic
Liberty Center	Flynn Park	7.4	14.9	mile roads	Signals at mile road intersections	Suburban, commercial at mile road intersections	~ 2% truck & bus, LOS B/C*, offpeak
Flynn Park	Liberty Center	7.5	14.2	mile roads	Signals at mile road intersections	Suburban, commercial at mile road intersections	~ 2% truck & bus, LOS B/C*, offpeak
Liberty Center	Arbor Drugs	7.1	14.6	mile roads	Signals at mile road intersections	Suburban, commercial at mile road intersections	~ 2% truck & bus, LOS B/C*, offpeak
Arbor Drugs	Liberty Center	7.1	14.9	mile roads	Signals at mile road intersections	Suburban, commercial at mile road intersections	~ 2% truck & bus, LOS B/C*, offpeak
Liberty Center	Bordine's Nursery	7.5	14.7	mile roads	Signals at mile road intersections	Suburban, commercial at mile road intersections	~ 2% truck & bus, LOS B/C*, offpeak
Bordine's Nursery	Liberty Center	7.3	14.6	mile roads	Signals at mile road intersections	Suburban, commercial at mile road intersections	~ 2% truck & bus, LOS B/C*, offpeak

* LOS - Level of Service. LOS B indicates relatively light traffic volumes with a vehicle's ability to maneuver somewhat affected by other traffic. Traffic volumes in LOS C are higher than in LOS B and a vehicle's ability to maneuver is definitely affected by other traffic.

The paths from the Liberty Center to the three study sites follow the grid pattern and inevitably share many of the same segments. The similarity of the sets of routes between each O-D pair was examined and found to be adequate for the purposes of the Troika study. Table 24 shows the number of direct paths and their directions between the Liberty Center and the study sites and shows path types common to all three path sets.

Table 24: Features of the Route Sets Between Each O-D pair							
O-D Pair	**Number of Direct Routes**	**Existence of Route on Multilane Road with Heavy Traffic**	**Existence of Route on Two-lane Road with Light Traffic**	**Existence of Route with Only Three Turns**	**Existence of a Freeway Only Route**	**Existence of Route ½ on Mullti-Lane, Heavy Volume, ½ on Two-Lane Lower Volume**	**Directions of All Paths in Route Set**
Liberty Center - Flynn Park	7	yes	yes	yes	yes	yes	North and East
Liberty Center-Arbor Drugs	10	yes	yes	yes	yes	yes	North and East
Liberty Center-Bordine's Nursery	6	yes	yes	yes	yes	yes	North and East
Flynn Park - Liberty Center	7	yes	yes	yes	yes	yes	South and West
Arbor Drugs - Liberty Center	10	yes	yes	yes	yes	yes	South and West
Bordine's Nursery - Liberty Center	6	yes	yes	yes	yes	yes	South and West

APPENDIX D:

In-Vehicle Data Sheet

VEHICLE DATA COLLECTION SHEET

RUN # _______ DESTINATION Bordine's Flynn Park Arbor Drugs

Familiar / Unfamiliar Peak / Nonpeak Mostly sunny / Mostly cloudy / Rain

FILE NAME _______.LOG DATE ___/___/ 96 VEHICLE _____

SUBJECT NAME ______________________________ **T A M**

HOME ASSISTANT

1. Set trip odometer to zero.
2. Set navigation system (if being used) to destination.
3. Set clock to zero.
4. Time subject leaves. ______:______
5. Start clock, start data collection, and send subject on their way.

FIELD ASSISTANT

1. Stop clock. Record elapsed time. ______MIN ______SEC
2. Set clock to zero.
3. Record trip odometer reading ______.______mi
4. Set trip odometer to zero.
5. Set navigation system (if being used) to destination.
6. Star clock and send subject on their way.

HOME ASSISTANT

1. Stop clock and data collection. Record elapsed time. ______MIN ______SEC
2. Set clock to zero.
3. Record trip odometer reading ______.______mi
4. Set trip odometer to zero.
5. Subject completes survey.
6. Subject fills out and signs receipt. Pay subject.
7. Give debriefing form to subject.
8. On the first day of each week that we run subjects, record total car miles. ______________

APPENDIX E:

Text of Debriefing Sheet

Navigation Experiment

Summer, 1996

Thank you for participating in our navigation experiment. Your participation will allow us to better understand how people find their way through an environment when different types of navigation information is available. You participated in one of the three conditions in the experiment. In one condition, the person had only a map and written instructions to find their way to the destinations. In another condition, the person had an in-vehicle navigation system called *TetraStar*, that provided turn-by-turn instructions to the destinations. In the final condition, the person had an in-vehicle navigation system called *Ali-Scout*, that provided both compass and turn-by-turn instructions to the destinations as the person drove, taking into account local traffic conditions. All three conditions were run at the same time using the same destinations so that the weather and current traffic patterns would be the same for all three people. By keeping track of how people drive in these different navigation assistance conditions, we hope to improve the types of navigation assistance that are available to drivers. If you have further questions or comments please contact Dr. David Eby or Dr. Lidia Kostyniuk at 810-971-9174.

David W. Eby, Ph.D.
Lidia P. Kostyniuk, Ph.D.

APPENDIX F:

Troika Study Questionnaire

TROIKA SURVEY

Ali-Scout / TetraStar / Written Directions

UMTRI

Social and Behavioral Analysis Division

FAST-TRAC PROJECT
OAKLAND COUNTY, MICHIGAN

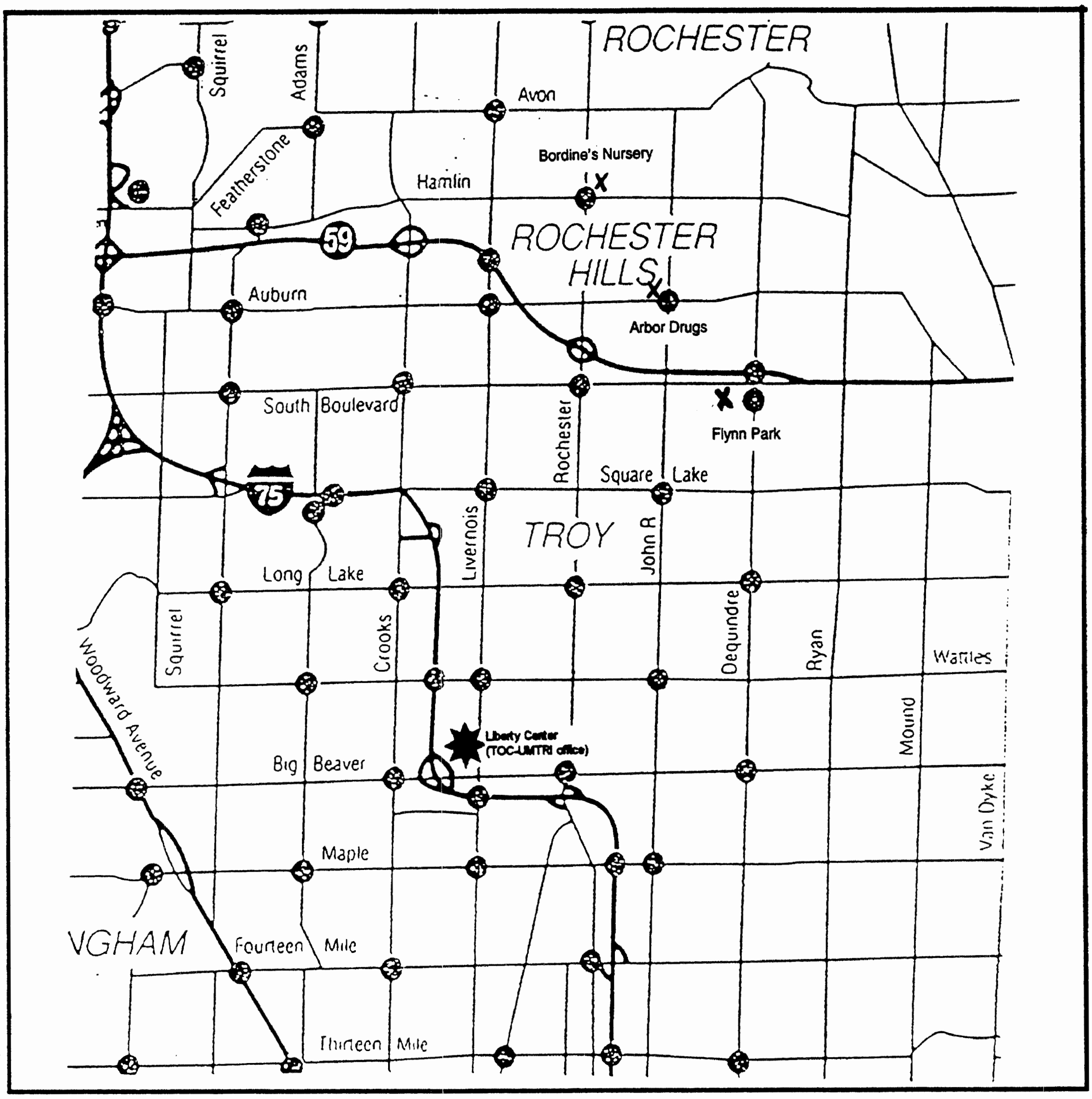
NAME:____

DATE: __________________________________

Instructions

Please complete this questionnaire and return to the researcher. All answers should be marked directly on this survey. When the survey refers to the "navigation assistance available," we mean either the Ali-Scout device, the TetraStar device, or the written instructions that were in the vehicle during your trips in the study. Please answer as completely as possible. As discussed at the beginning of the experiment, all of your answers will be kept strictly confidential. If you have any questions, please ask the researcher. Thank you for participating in our study.

1. On the map provided, please draw the routes you drove to the first and second destinations. Mark the routes with arrows to indicate which direction you traveled. If the same route was used for both trips then draw a single route only.



2. Considering both trips you drove in this study how often did you follow the recommendations to turn?

Never						Always
1	2	3	4	5	6	7

(If always, skip to question 4)

3. Considering the times that you did not take the recommended turn, please indicate the reason(s) you did not follow the recommendation. Please check all that apply.

- ☐ Knew of a faster route
- ☐ Believed that the turn would take me away from the destination
- ☐ Believed that the turn would lead me into traffic congestion
- ☐ The turn was suggested too late
- ☐ The recommended turn was not clear to me
- ☐ Not enough room to merge
- ☐ Other (please indicate): ______________________________

4. Please indicate your level of satisifaction with the navigation assistance available to you while driving in the study.

Very satisfied						Not at all satisfied
1	2	3	4	5	6	7

5. Please indicate your level of distraction while using the navigation assistance available to you while driving in the study.

Very distracting						Not at all distracting
1	2	3	4	5	6	7

6. Please indicate your level of confidence in the accuracy of the navigation assistance available to you while driving in the study.

Very confident						Not at all confident
1	2	3	4	5	6	7

7. Please indicate how helpful the navigation assistance you received during the study was for you in finding the study destinations.

Very helpful						Not at all helpful
1	2	3	4	5	6	7

8. Please indicate your impression of the overall appearance of the navigation assistance device or written instructions you received during the study.

Very pleasing						Not at all pleasing
1	2	3	4	5	6	7

9. Please how safe you felt driving while using the navigation assistance available to you in the study as compared to your everyday driving.

Much more safe						Much less safe
1	2	3	4	5	6	7

10. Did you get lost at any time during your driving in the study?

☐ Yes ☐ No

If yes, please indicate how you think you got lost.

____

____

____

11. When you drive in urban areas, do you generally listen to traffic reports?

☐ Yes ☐ No

12. Are you willing to divert from a driving route that you normally use to avoid congestion or a traffic incident?

☐ Yes ☐ No

13. How many out-of-town vacation trips did you make in the last 12 months?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 or more

(If zero, skip to question 15)

14. When driving between two locations on vacation, what type of route do you generally prefer? Check all that apply.

☐ One that is the fastest between the two locations

☐ One that is the shortest distance between the two locations

☐ One that avoids using freeways

☐ One that is most scenic

☐ One that avoids or utilizes certain parts of town

☐ One that is the safest

☐ Other (please indicate): ______________________________

15. How many out-of-town business trips did you make in the last 12 months?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 or more

(If zero skip to question 17)

16. When driving between two locations on business, what type of route do you generally prefer? Check all that apply.

- ☐ One that is the fastest between the two locations
- ☐ One that is the shortest distance between the two locations
- ☐ One that avoids using freeways
- ☐ One that is most scenic
- ☐ One that avoids or utilizes certain parts of town
- ☐ One that is the safest
- ☐ Other (please indicate): ______________________________

17. When driving in unfamiliar areas, are you generally confident or unconfident in finding your way around?

Very unconfident						Very confident
1	2	3	4	5	6	7

18. How frequently do you use road maps?

- ☐ At least once a week
- ☐ 1-3 times per month
- ☐ Once every 2-6 months
- ☐ Once a year
- ☐ Less than once a year

19. For assistance in reaching your destinations, how do you rate the following sources of route-guidance information?

	Poor						Excellent
a. Standard road map	1	2	3	4	5	6	7
b. Verbal directions from passenger	1	2	3	4	5	6	7
c. Verbal directions from other people	1	2	3	4	5	6	7
d. Written directions	1	2	3	4	5	6	7
e. In-vehicle route-guidance	1	2	3	4	5	6	7

20. If you were about to drive to an unfamiliar area, which of the following sources of route-guidance information would you like to use?

	Definitely would not like					Definitely would like	
a. Standard road map	1	2	3	4	5	6	7
b. Verbal directions from passenger	1	2	3	4	5	6	7
c. Verbal directions from other people	1	2	3	4	5	6	7
d. Written directions	1	2	3	4	5	6	7
e. In-vehicle guidance instructions	1	2	3	4	5	6	7

If you received only written instructions and a map during the study, please skip to question 25.

21. For the following items, assume that the navigation system you used in the study was available nationwide. Given this scenario, how useful do you think the system would be for:

	Not at all useful						Extremely useful
a. The commuting trip?	1	2	3	4	5	6	7
b. Out-of-town vacation trips?	1	2	3	4	5	6	7
c. Out-of-town business trips?	1	2	3	4	5	6	7
d. Local driving (non-work, e.g., for shopping)?	1	2	3	4	5	6	7

22. How much would you be willing to pay for the system as an option on a new car?

$____________

23. How much would you be willing to pay to add the system to your present car?

$____________

24. How much extra per day would you be willing to pay for the system as an option on a rental car?

$____________

25. Please write your date of birth in the space provided.

Month ______ Day ______ Year ______

26. Please indicate your gender by placing an *X* in the appropriate box.

☐ Male ☐ Female

27. What is the highest level of education that you have completed? (Place an *X* in the most appropriate box.)

☐ Less Than High School Diploma (or equivalent)

☐ High School Diploma (or equivalent)

☐ Some College

☐ Bachelor's Degree

☐ Some Graduate School

☐ Graduate Degree

28. What was your household's income last year (before taxes)? (Place an *X* in the most appropriate box.)

- ☐ Less than $15,000
- ☐ $15,000 to $24,999
- ☐ $25,000 to $34,999
- ☐ $35,000 to $44,999
- ☐ $45,000 to $54,999
- ☐ $55,000 to $64,999
- ☐ $65,000 to $79,999
- ☐ $80,000 to $99,999
- ☐ $100,000 or more

29. Please indicate below any comments that were not addressed in the survey you may have about the experiment or the navigation assistance you received.

APPENDIX G:

Troika Questionnaire Comments

ALI-SCOUT

Unfamiliar/Nonpeak

- I think the voice computer should be a women voice, it seems it would be more enjoyable to listen to!

- Program should avoid left turns. Routing should not be thru residential areas. System slow with turn indicators close to turns.

- I feel that the device would be very well like & used by those who are unfamiliar with traveling in distant areas. And would be a very marketable device for consumers who do a wide variety of traveling.

- Very well coordinated, friendly, courteous persons handling survey.

- It would have been nice if it had indicate the presence of the ambulance coming up behind me to better prepare me to make way for. Also if it could show the recommended posted speed on the given street/road upon which you are driving. Alerting the driver to emergency vehicles would be nice.

- The electronic navigation system did not instruct several times, including the initial turns out of the start & destination areas. I relied on the maps as much or more than the electronic device. I feel the electronic equipment could still be quite useful, particularly with regard to problematic delays, road conditions and in very unfamiliar areas.

- On first trip, system did not tell me to turn left, as I had expected it to. Auditory cues/directions were very helpful.

- Somehow on the last turn I took, (from Dequindre to S. Blvd.), the device didn't direct me to do so. I assume thats because I was close to the destination. But I feel that sometimes even though you may be close to the destination, it should inform me of a turn between 2 main roads. If without a road map and I turned right instead of left, or even went straight, I would then realize only by later realizing the direction of the arrow on the device. I guess the device is very effective, but the device misses what it should announce sometimes.

- I would like the system, and I would like to have one myself.

- I think the system works great. I would certainly purchase the system for my car.

- Very Helpful!

- If all cars are equipped a lot of kids will have an excuse in school why they shouldn't have to learn how to read a map.

- The navigation screen should include more graphics when your destinations reached.

- Not at all cost effective when compared with the cost of a simple road map, also distracting and annoying.

- The Ali-Scout system should give more advanced warning for turns.

Unfamiliar/Peak

- I think that the testers organized and explained things well. I would have made test about 50% longer, but that's because I enjoyed it so much. There was one conflict: as I was W'bound on South blvd, I received notice of left turn near Livernois. There's a road just E of Livernois and I wasn't sure just where to execute it. Lost track of countdown because I couldn't watch it and cars ahead.

- Concern if equipment in back seat & floor is held down to keep from being a projectile in an accident. Also, if the equipment can be placed in truck if available for my personal car, rather than back seat & back floor. Also, how is it applied in a van?

- Well, b/e I was not fidgeting w/the radio I payed more attention to the navigation system. It really does not do much for me. If I was lost, or in unfamiliar territory, things might have been different. Voice commands are annoying.

- Didn't locate signal ie [diagram] soon enough. The down time in this short trip was 30-40% of the time. Didn't feel like it was quick enough to begin directing me. The first decision on how to get started is mine. Thats the decision it should make.

- A little confusing

- You need to understand road maps in order to pass a beacon and begin the system. Until the system works COMPLETELY from point A to point B - I wouldn't be interested. It's only useful during the middle of a road trip - basically best for LONG TRIPS.

- I was greatly impress w/this system & would consider ordering it as an option if it were available on a new car. All personnel involved in study were very professional!

- I found the device interesting to be in the car. While it was perhaps helpful in reiterating the next step/turn I already knew I used to take, I did not find it an absolutely necessary device. I'm a map-reader (by nature) and had therefore previously analyzed the map in the car before heading out on the road. I knew exactly where to go so the device wasn't imperative in my guidance. This is not a device I would be inclined to capitalize on in the future, I would honestly say.

- The system worked fine except at one point it suggested I go right but when I did it said I had left the recommended route. This made me feel less secure with it.

- As far as appearance of the device, and as to the question of being an option on a new car, Being integrated into the dash board or console would go a long way towards being better aesthetically; similar as to how Acura's new tracking system is in their new sedans. As far as navigation goes, it is an extremely helpful device. However, a couple of features which would be nice would perhaps be: 1) in addition to the total trip distance, perhaps a distance to the next beacon at which you would change direction; 2) Give a little bit more time for directional change suggestions (turn left, turn right, etc.) With heavy traffic, I don't feel as if enough time is given to prepare for lane change. 3) It would also be helpful if the device displayed street names (ie current, next,). Even though I have never used a navigation system that displays a map of the area, I think it would be just a little more helpful (perhaps used in tandem with this device), especially if someone were to get lost or diverted from their regular route. I would also like to add my thanks for letting me participate in this study: it was an excellent experience.

- I think the device works well in conjunction with a road map but wouldn't want it exclusively. I think that you need some idea as to where you are going and the probable route you will take.

- I didn't feel that the device was accurate enough in its directions. I was unclear about the route I was supposed to take on my return

- The voice activated Directions are a little to loud and is jarring to the ear!

- I thought it was a least well organized & operated.

- Within the city, in heavy traffic, instruction (verbal) should be more proactive, instructing the driver in ample time prior to turn what lane to be in. The latter makes for more safer driving.

- The position of the system should be at eye level.

- Voice sound adjustable.

- I wouldn't use it w/o a "heads up" display. Unless it took daily traffic reports into acccount I wouldn't use it for daily commute

Familiar/Nonpeak

- I think more beacons are needed and more advance notice of turns
- I didn't not receive directions to turn on Rochester Rd. I proceed to Main St because the left turn lane was very backed up. The ringing when you approach the beacon was distracting (too loud, too many rings)
- The system WAS FINE - The length and complexity was less than expected.
- It is a good study! One problem I had found: when I am making a turn, the guiding sound comes out a little late. Sometimes I don't have enough time to change the lane when traffic is heavy.
- At first the bell sound was confusing but I soon understood what it meant. The voice giving instructions instilled confidence. I was unfamiliar with the area and would probably have gotten lost, even with the map, especially when the traffic was
- The experiment was very rewarding
- It would be a great asset to any car.
- What determines that the route we took was fastest?
- Very good directions for turns and route
- See greater application of system for regional, out state & out of state trips. Especially, if device held data about highway construction problems that you could avoid.
- The 3 beeps at signals were sometimes distracting, sometimes it would startle me if I wasn't expecting it. Also, when the destination is reached there maybe should be clearer directions (ie right side, left side, aprox how many yards, etc.).
- Beeping somewhat annoying - if I had not been familiar w/the area I'm sure I would find such a device more useful.
- My main reason for using a system as this would be to avoid traffic congestion.
- So this something that will be available in the near future? Will the driver be able to program destinations?
- The monitor must be higher for me with Biofocals

Familiar/Peak

- I really liked the navigation system used. Maybe elements of entertainment (ie video games or CD quality music could be used to be incorporated into the navigation experience. Maybe a women's voice could be used as well.

- I found the beeping after passing a beacon to be very annoying. Volume should definitely be able to be controlled on the device. Not being able to listen to the radio was disappointing, a radio relaxing me while driving.

- Seems to beep for no apparent reason when passing beacons.

- I thought the navigation system was cool! I wish I had a longer distance to drive, so I could get to utilize the system more.

- I did not find the navigation device at all helpful. I went to the nursery which you take Big Beaver E to Rochester N to get to. On the way there, it didn't turn on (off A mode) until I was practically on Rochester already which is basically useless info. or at least not very helpful info. because after that, all you need to do is stay on Rochester and simply turn into Bordine's parking lot. Then on the way back, the device didn't get off the A mode until I was on Big Beaver (practically at the test site). I didn't find the device helpful. Maybe if I was less familiar with the area... who knows. I think that for a better test of this device a more " complicated " route may be necessary. I don't mean incredibly hard either, but you do not really need navigation assistance to go from Big Beaver to Rochester.

- Felt the system should have had the flexibility to re-route once off-course. Would like a mini-map to be accessible on system at start of destination. System needs better visual placement than that used in test.

- How about a female voice on the box?! It told me to turn left when the L turn lane was already full...I had to wait to get into the turn lane.

- At the beginning when saw the miles from my destination site crossroads.

- Navigation system not very accurate Good for novice or for people unfamiliar with area but for people familiar & having a good sense of direction sometimes irritating (monotonous voice) & feel better routes available should take traffic volume into consideration & have alternatives available A graphic screen with map would be wonderful.

- The system should be placed higher for taller people - or next to the speedometer

- The only concern I would have is that if the radio was on the navigation device probably wouldn't be heard. It seem as if you need to have the radio off for full attention.

- I did this to experience what I had read about years ago as a FUTURE standard auto feature. The cash was not the motivator, but nice! Great!!

TETRASTAR

Unfamiliar/Nonpeak

- At first the street name was not the same as the one on the system. Also once I put in for new route then it displayed "For New Route Please Enter" So, even though I was on the new route - I thought it didn't take & pressed it again & again. This would work better if the person using it could try a test simulator without the car first. If the computer would not have malfunctioned I would have done perfectly.

- Your staff was extremely polite and a pleasure meeting. I really enjoyed this I wish it was a bit longer. A very interesting gadget. Wish I could take it home with me!

- On starting out on the destination the system used should alert the driver immediately if s/he starts out by going in the wrong direction instead of waiting to recalculate a better route because that will save a lot of time in the long run also will make a better trusted system

- System could tell if destination was on right or left . I think it would better placed on dash. So you don't have to look down.

- I wanted to review what I just did - Ex: like push a button to see what street I just crossed - (kind of like caller ID)

- I thought the accuracy of the locating device was pretty impressive. I was glad to have a chance to check it out. The only thing I would recommend is to have it as an HUD (Heads Up Display) on the dash. My father's car has it for the speedometer and it's awesome!

- When arriving at your destination a message from the simulated voice mechanism announcing that "you should begin to look for your landmark" with enough time given to search without anticipation of driving by your desired destination...perhaps a countdown based on the area (zone) once you've entered it and the speed at which your case is moving.

- Enjoyed the experiment - Good System

- The map shown on the screen may be a little too small for some people to see well. I liked the large arrows that showed the direction you were to turn at each turn. I found the voice and other sounds to be very helpful. It wouldn't be as effective without it.

- Very good personal and very well trained Keep up the good work!

- Again, my first conception was the device was like a game keeping the triangle on the route. When I found this did not work the directions were clear.

- On the way back the system did not work- that is it only gave me the Livernois address. No turn were given. When I got to the Liberty Center it said turn here. Did not tell me to make turns at Rochester Sq. Lake or Livernois.

- I think it's a terrific device

- I thought the maps on the display were hard to read because the printing was too small. The turning directions were printed in large enough letters

Unfamiliar/Peak

- When location is listed as a street address (with number) a visual scan of numbers is necessary to determine which side of the street is the ultimate destination. This is important on busy thoroughfares and/or 4 lane highways.

- I enjoyed this very much

- If the navigation assistance is to be used it would be useful (somehow) if it told you if there was an accident on I-75 or whatever as they come about on the radio. It shows you a larger map of where you are going once in awhile (ex on long trips) definitely should be up by the dashboard.

- The whole time I was on the road, the navigation system indicated I was somewhere else. Even after I pressed enter for new route, it did not correct. At the first destination, I turned off the car & restarted and it still was incorrect. The researcher was baffled, as was I.

- I should have asked if I should have chosen what I thought would be a more direct route over the navigation system, I liked the fact that the system counted down the footage to the turns.

- I very much liked the verbal cues to turn and enter/exit expressway.

- Box needs to be placed at eye level. Accidents (rear - enders) usually occur when people take their eyes off the road (ie use installed cell phone to dial, play w/ radio buttons pick up baby's pacifier)

- This system is very good, but it would be better if it would show or say an exact destination ex. On the right hand side etc. It is extremely good for trips, and when you drive in unfamiliar area. Thank you.

- The time stated for the survey is inaccurate. The study lasted 1 ½ hours but was predicted to last 2 ½.

- I think its nice knowing where I'm going especially when I am unfamiliar with certain areas.

- Do not catch exactly where the other person wait at the destination

- I feel it is a good system that would assist people a lot when driving in unfamiliar areas. Probably would releave a lot of stress.

- Destinations have to be made clearer. Questions of WEST Auburn vs. Auburn Rd. actually it's east Auburn. Navigation assistance should say destination is on the left side or east side not made for people who are near sighted

- Unit would be nice if higher up H.U.D. unit would even be better if in upper left or under mirror.

Familiar/Nonpeak

- I think it would be informative information to have the equipment register the direction you are going (ie: north, south, east, west)

- Assistance was very good.

- It is a good equipment if traveling in an unknown area.

- Beginning and ending instructions could be more specific.

- I really enjoyed the trip and would love to have one of my own very soon!!

- The destination was too easy, you only had to make a couple turns & it is also a very familiar place we had to go. I already knew how to get there.

- I'm glad I knew the general area to where I was going. I got a little confused towards the end, turning on to South Blvd. the system told me to go a different route then I ended up taking.

- Navigation system should also state the road you're on as well as for directions ahead. Destination directions should also include R or L ahead.

- Although I'm quite familiar with the Tri-county road system, I thought the navigation system could be quite useful to someone less familiar city. I did, however, find the verbal instructions to be somewhat distracting.

- 1. Should have option for audio Male or Female voice to give verbal instructions. 2. Audio instructions should interupt the audio of your radio. 3. Location should be in I.P. on a locking adjustable ball mount. 4. For multilane roads at about 0.5 miles before turn, audio warning to "stay Left" of stay right.

- How soon might this become a standard item in autos, buses? This may be very useful for buses going on scenic touring trips: Seniors over 62 years of age would use this system for a variety of reasons.

Familiar/Peak

- Unit Graphics could be a little better/sharper although they are adequate.

- Every one was more help then expected very helpful.

- On the return trip the computer screen went blank and I returned without the aid of the computer.

- I could not decide whether to use the system or not because I could not see the entire route is had planned for me. I also could not see the map display which would have told me if there was an alternate route nearby if there was a traffic problem. The directions screen (when to turn) was very useful, but not entirely accurate. It was most inaccurate by expressways.

- I enjoyed the System. I felt it added drive confidence - further safety-preparation - & lack of distraction of feeling lost - or uncertain where to turn.

- It would be nice to see the map displayed more instead of the next turn information. This would show you how you are progressing in addition to the mileage information. Maybe the turning instructions could appear a mile before turning. Also, the voice was helpful but could have been louder. P.S. I would be glad to participate in any further studies. This was very interesting.

- When the voice came on it didn't indicate how far in advance, a turn was or maybe that is not a concern. I did not use the map so I'm not sure if the voice & map were in coordination with one another. Map could be higher up to look at.

- Computerized vocal quality was poor.

- My destination did not address which side of the street it was on & that is useful on a Roads like Rochester.

- Would have liked screen to be tied into windshield for heads up display so didn't have to take eyes off road or have screen in dash.

- I learn visually not auditorally. I may have misinterpreted [experimenter's] directions out of the pkg lot, or I wasn't reading device properly. Also, @ destination sign showed me route/map button which gave me also more info. So on return trip I understood process much more. I still felt discombobulated coming back into pkg lot. Somewhat dyslexic.

- The navigational system should be up beside dash board instead of down. It would be easier to use.

- I think the tetra star is impressive, but is best when used in addition to standard road map.

- Hopefully you will be able to make this system interactive with: 1. construction project schedules & 2. volume data for peak/off-peak periods.

- The monitor should be in a higher place so you don't have to keep looking down. Volume on audio should be louder.

- Street print designations hard to read for people like myself who use reading glasses.

- Sometimes the audio was not as audible in indicating turning direction.

WRITTEN INSTRUCTIONS

Unfamiliar/Nonpeak

- The written instructions were most helpful. The map was used only to assure that I was on correct course (as passed cross-streets).

- Would have liked to try out the navigational device.- Good written directions.

- I would participate in other such test if ask.

- Assistants were very helpful. Could have arranged a cup of tea/coffee for volunteers.

- Could not rate 19e since I've never used one. "Out of town" in questions 13 & 15 should maybe be defined as local - other suburbs nearly or for instance another state or further away (like overnight). I assumed the later. Maybe it could be defined in time or miles from home.

- I really enjoyed myself. Thank you & good luck.☺

Unfamiliar/Peak

- The directions were very clear. I have not driven on those streets before.

- Will a copy of your final conclusions be available?

- The only thing bad about maps is that they are a bother to look at while driving! Other than that, they're Great.

- The directions were fairly simple to follow.

- It was a good experiment and good luck with the navigation system.

- Very well organized it seems. I'll send some friends who want to be subjects your way.

- The only thing I didn't like about my directions was the Bordines was described as being on the "NE Corner". I can never remember what direction I'm going. I like left and right better.

- I enjoyed this very much and am very interested in the new guidance systems. Please keep me in mind for any other opportunities to learn.

Familiar/Nonpeak

- The planned route was not that challenging to follow.

- Have no idea as to WHY!!

- I would've liked to have seen and use the on board navigation instead of a map just to see what it is all about.

- Everyone was very helpful!

- If I had to pay extra for an electronic navigation system, I would not do so. I am relatively proficient at using maps and written instructions and rather like the feeling of self-reliance I receive from doing so.

- I would have preferred to have tested the electronic navigation equipment.
- Though it would be expensive, perhaps, this type of activity should be standard requirement for driver's ed.

Familiar/Peak

- Written directions were on the money. Short and quick to the point, for going from point A to B. And B to A.
- I was glad to be a part of your study. Thanks.
- I was unable to rate "electronic in-vehicle route guidance" because I have never used it or known anyone who used it. I am very familiar with the route I drove, because I live on it and frequently drive these areas.
- The written directions were perfect for me!! Very confident of arriving at my destinations.
- I am a person who has always been most comfortable learning from or following WRITTEN directions (books, instructions, etc.). I did not use the map which was given to me at all. So, although it was by chance that I was not able to use one of the other navigation systems, it did turn out that I used the method which best suited my personality and caused me to have a low-level of anxiety. I do get very anxious when I'm not sure where I'm going.
- I probably would have taken an alternate route on my own that has less turns, but I followed the directions.
- Not clear that we could take alternative route if we wanted... asked again at Arbor Drugs stop, and when told it was ok, took what I thought a better route back.