TRAVTEK EVALUATION PLAN - FINAL
EP008

prepared for:
Federal Highway Administration
under contract DTFH61 -90-C-00063
4th April 1991

prepared by:
Farradyne Systems, Inc
and
The Center for Applied Research

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TRAVTEK EVALUATION PLAN

INTRODUCTION

This plan is a description of the proposed methods for evaluating the entire TravTek system. The plan incorporates input from all of the TravTek partners:

- General Motors (GM)
- Federal Highway Administration (FHWA)
- American Automobile Association (AAA)
- Florida Department of Transportation (FDOT)
- The City of Orlando

The plan encompasses a diverse range of concerns including:

- Human factors
- Marketing issues
- System concerns
- Global IVHS interests
- Safety issues
- Economic questions

This plan provides an outline of the studies and preliminary cost estimates associated with each part. This plan is designed to pull together the objectives of all the TravTek partners and meet each of their needs. This plan also provides a document that defines the data needs of the TravTek system to ensure that the correct data is collected and stored.

The plan revolves around ten basic evaluation approaches. Each approach includes a wide range of functions such as a highly controlled experiment, a series of questionnaires and/or group discussions. The various approaches are basically flexible methods that can be used to collect and analyze data.

The Approaches

The ten evaluation approaches are:

- Approach 1. Field study with rental car users Leisure and business travelers will be divided into three groups:
  - TravTek, users with access to all service and navigation functions
  - Navigators, users with access to autonomous navigation and service functions, but no real-time data
  - Service, users with access only to service functions. This is the control group against which the others are compared. This will allow the evaluation of driver behavior and the benefits of autonomous navigation and real-time data.
- Approach 2. Field study with local users - Local users are those local drivers with route familiarity that use vehicles for a longer period of time.

They will be divided into two groups, TravTek and Navigators. This will serve as a comparison to the users in the rental study. Also a subgroup of these drivers can serve in a camera car study of novice vs. expert users.

- Approach 3. Yoked driving study This study is a separate study with participants paid to drive simultaneously between specified origins and destinations. With drivers divided into the three grows, as above, this is specifically designed to evaluate trip time savings and congestion avoidance.

- Approach 4. Orlando test network study - This study includes paid participants who will drive a predefined route network within the TravTek area to evaluate the performance and preferences of drivers using the various navigational options located in the vehicle.

- Approach 5. Camera car study - This study will use a vehicle equipped with several cameras focused on the driver and the driving scene, audio recording, etc. and will serve as a research facility. Paid participants will drive this vehicle over the above test network. Data will be collected to evaluate how drivers interact with the system (human factors) and how it affects the driving task (safety).

- Approach 6. Debriefing and interviews - This study involves the collection of preference perception, and marketing data by interviewers. This includes debriefing of paid participants in the above studies as well as one-on-one market research interviews.

- Approach 7. Questionnaire study - This study involves the collection of preference perception, and marketing data by questionnaires. Drivers not debriefed or interviewed, will be given a questionnaire. No driver will be given more than one questionnaire type. Questionnaires will be used to collect some data proprietary to GM and AAA in addition to data of general interest.

- Approach 8. Modeling and analysis studies - This study will assist

in analyzing the results of TravTek and projecting the findings to a mature system. It will assist in predicting its consequences on traffic network performance, environmental, economic and other community benefits and driver benefits. It will also assist in modeling the effects of different levels of market penetration.

- Approach 9. TMC and traffic probe study - These studies will include an analysis of the operational aspects of the TMC and the utility of using probe vehicles including operational costs.

- Approach 10. Global evaluation - This study provides an overall evaluation of TravTek as a project including an overall interpretation of the results of all individual studies. It will also include what we learned from embarking on a cooperative project of this type with public and private sector partners. This study will concentrate on what worked and what did not, and why.

This taxonomy provides a frameworkthatwill contain all aspects of the evaluation.

The next ten sections of this report describe these approaches in more detail. The objectives of this TravTek evaluation plan have been developed with extensive input from each of the TravTek partners. The multiple approaches and their relationship with the TravTek objectives are shown in Table 1. The protocols associated with each approach provide as much information as can be currently developed.

APPROACH 1. FIELD STUDY WITH RENTAL CAR USERS

The Field Study With Rental Car Users will determine driver response to TravTek and assess the usage/impact of the TravTek system. It will determine the reduction in navigational waste by lost and confused drivers as compared to those not using TravTek. Data will be gathered to determine how drivers use the system and the features most often used. In conjunction with interviews or questionnaires, driver's acceptance and perception of the system will be accessible. This study will also determine how easy TravTek is to learn and what features give drivers the most problem and how much drivers are willing to pay for such devices. A description of the anticipated study component needed to achieve these goals is included in Appendix G.

A sample from the user population of leisure and business travelers as agreed upon by TravTek Partners enabled these users to be divided into three groups.

a. TravTek, users with access to all service and navigation functions

b. Navisators, users with access to autonomous navigation and service functions, but no real-time data

c. Service, users with access to service functions only and is the control group against which the others are compared

The division into the three groups provides a control group (Service) against which both the TravTek group and the Navigators group can be compared. Both the TravTek group and the navigator's group are needed because it is considered an important objective to evaluate the incremental benefit associated with the supply of real-time traffic data. From a marketing perspective, it is likely that the large scale implementation of these devices would be easier if the system did not depend on the institutional support of city and state infrastructure. Thus, it is important to quantify any benefits associated with the real-time data component of the system; i.e., the value added.

The major emphasis of this task will be on the sorting and analyses of the logged data to yield comparisons of trip times and system usage under various traffic conditions. In-vehicle logged data will include vehicle speed, number of stops, time at zero speed and a record of driver interactions with the system. The TMC log will keep records of all incidents and traffic conditions. The vehicle log will enable the path of each vehicle to be tracked.

By evaluating similar origin and destination pairs, a record of the journey times for multiple common routes can be developed. These routes need not be complete trips but

merely sections of routes that are commonly occurring. For example, all southbound vehicles that cross a given point on I-4 in the downtown area and end up at Walt Disney World could form one set of data. These data would then be divided into categories according to the prevailing traffic conditions. Analysis could then be performed across the three groups to determine any statistically significant difference between the two service types and the control group.

In addition, as part of Approach 6 activities, a questionnaire is to be designed and administered to all rental car drivers who are not part of the GM market research sample of 1550 rental car drivers. This questionnaire data and the in-vehicle data is to be analyzed and compared/correlated with data from other sources; i.e., TMC log, TISC log, Avis log, Oldsmobile maintenance log, police/traffic department log, and driver profiles. Analyses should address all relevant TravTek objectives.

APPROACH 2. FIELD STUDY WITH LOCAL USERS

The Field Study With Local Users will determine the acceptability of the system and its component to the local users. It will determine the reduction in navigational waste by lost and confused drivers as compared to those not using TravTek. Data will be gathered to determine how easy it is to learn TravTek and what design and operation features give drivers the most problems.

This study will also be used to determine how much drivers are willing to pay for such devices, the learning effects associated with the long term usage and to study driver behavior and the usage/impact of the TravTek system on a population that is geographically familiar with the Orlando area.

In conjunction with interviews or questionnaires, this study will be used to evaluate possible benefits to high mileage drivers who are geographically expert. This study will also enable the determination of the novice/expert shift in conjunction with the Camera Car study.

Users who live and work in different areas of greater Orlando will be identified as high mileage drivers as agreed upon by TravTek Partners. These drivers will vary in age, sex, and education. They will use TravTek vehicles for a period of several months.

These users will be divided into two groups.

a. TravTek, users with access to all service and navigation functions
b. Navigators, users with access to autonomous navigation and service functions, but no real-time data

These two groups will allow an examination of the effects of the in-vehicle system and the value added by the TMC/TISC infrastructure, They will serve as their own control group to compare how they currently navigate through traffic.

Sorting and analyses of the logged data will yield comparisons of trip times and system usage under various traffic conditions.

A subset of these drivers will also serve as paid participants in the Camera Car Study (Approach 5) of driving behavior and driver/system interaction. The objective is to learn whether there is a shift in system use, glance times, etc. when the novelty of the system has worn off.

The number of participants can be determined by gathering at least10 vehicles available for one year (that is at least 120 vehicle months) and subtracting the yoked driving study (Approach 3) requirements of 20 vehicle months. This leaves at least 100 vehicle months of usage available for the local users. If it is assumed that users will not have any additional learning associated with periods greater than two months. This will provide a sample size of at least 50 local users each for a two month period.

These users' vision and hearing will be checked. A subset of local user drivers who vary in age, sex, and educational level will participate in the camera car task at two points in time at the beginning and at the end of their TravTek vehicle use period. Measures taken at these two points will be compared for main and interaction effects.

Questionnaires similar to those given to the rental car users will be administered to the local users. The questionnaire data and the in-vehicle data is to be analyzed and compared/correlated with data from other sources; i.e., TMC log, TISC log, Avis log, Oldsmobile maintenance log, police/traffic department log, and driver profiles. Analyses should address all relevant TravTek objectives (Appendix B) l However, the major emphasis of the analysis will address issues related to learning effects and the effect of experience with the system on system usage and effectiveness.

APPROACH 3. YOKED DRIVING STUDY

The Yoked Driving Study will provide a practical way to realistically determine the real-world time savings and congestion avoidance capability that can be directly attributable to the TravTek system.

These studies will be designed so that, at a minimum, the effects of the following factors on TravTek system effectiveness can be determined:

a. Traffic Factors - peak versusoff-peakconditions, trip length, congestion levels, incident occurrence, etcetera

b. Demographic effects

c. Driver TravTek Experience - effect of increased exposure/use of the TravTek system on the effectiveness of the system

d. Driver Area Familiarity - effect of the drivers' familiarity with the geographical area on the effectiveness of the system

e. Light Conditions - effect of daylight versus nighttime conditions on the effectiveness of the system

In addition the yoked driving study can be used to determine if TravTek users drive faster than non-users, suggesting increased risk taking.

The basic research procedure should involve having paid subject drivers traverse a series of routes (origin-destination pairs). The subjects will be divided into three separate experimental conditions as used in Approaches 1 and 2.

The subjects will be instructed to complete a series of specific routes. Appendix E., Yoked Driver Study Potential O/D Pairs, illustrates a series of preliminary routes that could be used for the yoked study. To facilitate data analysis, a subset of these routes will be selected from the most frequently occurring routes found in Approaches 1 and 2. Other routes will be selected to maximize the probability of the driver experiencing delays due to congestion/heavy traffic. This will allow the potential value of real-time traffic congestion information to be evaluated. Additional routes will be selected involving difficult-to-locate destinations to allow the potential value of the Navigator functions to be identified.

To test traffic and weather conditions, drivers in each experimental group will drive the specified routes at the same time; i.e., depart from the same origin for the same destination at l- or 2-minute intervals.

Appendix E shows four potential perimeter Origin/Departure (O/D) locations and one O/D in the downtown area. It is

anticipated that trips between the perimeter sites and the downtown site will take approximately 20 minutes. Locations such as the Airport and the TMC are selected as the O/D locations because they incorporate parking and some administrative support. For example, the TMC location could be desirable because there are facilities for vehicle storage and users can access telephone and the TMC data.

The telephone in the vehicle could be used by the subjects to inform the experimenter when the vehicle is at an O/D site. Button presses on the car phone could be logged on a microcomputer. This log can then be compared with the TMC data describing the vehicle's path. Pilot testing may demonstrate that such an approach may avoid having to provide survey staff at the O/D sites.

The basic measures of effectiveness (MOEs) will, at a minimum, include the following:

a. Mean origin-destination travel time
b. Mean speed
c. Number of stops
d. Time at zero speed
e. Speed variance
f. Trip distance

Following each series of runs, the vehicle log can be downloaded for analysis.

Sample Size Considerations

Appendix F, Yoked Driving Study Sample Size Considerations, indicates some suggested numbers andvariables that can be used for estimation purposes.

APPROACH 4. ORLANDO TEST NETWORK STUDY

The Orlando Test Network Study (OTNS) will be developed, performed and analyzed to study navigation performance, preference and perception as a function of information display types-moving map displays, guidance screens, voice guidance. Also included, must be an investigation of possible interactions between display type and driver age, and night and daylight driving. The major emphasis of the OTNS is to evaluate the effectiveness of the operational aspects of the various TravTek in-vehicle features. It is anticipated that one element of this approach will include tests of the different screen types developed by GM.

Specified O/D pairs within the TravTek area designated as the Test Network and will be defined. Such a test route will pass through as many system sensors as is possible. The route will encompass a variety of highway types and conditions. It would be logical to begin the route at the TMC because it can provide vehicle tracking, database information, and parking. In addition, to avoid wasted driving time, the test network should be a loop that ends at the TMC. Part of this test network will be used by the Camera Car study.

An additional route selection requirement is the specification of O/D pairs connected by routes rated for equal difficulty and equal distance. The criteria for equal difficulty may be defined as number of left and right turns, changes in speed limit, complex intersections, freeway entrance/exits, and many others.

Hired drivers will be used to travel the test route. A TravTek vehicle configured to provide different messages and screens will be provided. The driver's response to these different displays will be noted. An in-vehicle observer can be used to obtain some of the information needed. Briefing and debriefing interviews (Approach 6) can also be used to assist in evaluating the displays.

APPROACH 5. CAMERA CAR STUDY

A Camera Car Study will be developed, performed, and analyzed to provide detailed evaluations of driver/system interactions (human factors) and the effect of the system on the driving task. Data will be gathered to evaluate how easy the predrive and drive functions are to learn and use. This study will also assist in investigating the possible safety benefits and hazards of using the in-vehicle system.

There has been much speculation on the potential effects of an in-vehicle display on driver performance. At one end of the spectrum some may contend that the equipment might serve as a major distraction and its use will result in a degradation in driver performance and safety. Others suggest that providing certain information to the driver will reduce the time needed to scan the roadway environment for directional information and thus result in a more efficient, safer driver. Also, it would be expected that there may be changes in the driver/system interactions as drivers become familiar with the system and its operation. These basic considerations must be addressed.

There are three modes of operation associated with the TravTek interface and the drivers. These are: route map display, symbolic guidance display, and supplementary voice. These three modes should be evaluated in order to compare whether one is safer than another.

Uses of the camera car will include:

a. Calibration of the OTNS. This will be accomplished by performing a subset of the OTNS with the camera car and comparing the subjective ratings by the driver and the observer with the results from the in-vehicle instrumentation.

b. Collection of independent data on relative use by drivers of highway signs, with and without the TravTek system, by using the instrumented car to measure glance times away from the roadway. This comparison will include the time taken to glance at a TravTek direction sign versus the time to glance and comprehend external direction signs with similar information content.

c. Assessment of the difficulty of the various critical events (freeway exit and entrance, street change, etc.)

d. Distraction by the TravTek display including detailed evaluations of vehicle driver interactions such as eye movements and button presses,

e. Distraction by the display when used for non-navigational purposes, such as radio and climate control.

f. Determine what types of information (screens) can be safely provided to the driver when the car is moving. What type of information,wordmessages, symbols, voice or various combinations, is most effective?

g. Determine the effects of experience as drivers become more familiar with the TravTek system. The Camera Car studies provide an excellent opportunity to evaluate the novice/expert shift associated with drivers learning how the system operates. This informationwillbe used in developing training materials/procedures.

The camera car is an instrumented vehicle with video cameras focused at the driver, the driving scene and the outside lane line. Instrumentation will also record vehicle speed, brake applications, steering wheel reversals, andverbal responses by the driver.

This instrumentation will permit the following measures of effectiveness (MOEs) to be quantified:

a. Driver Attention Factors
- number of glances
- glance duration
- glance timing (relative to critical events)

b. Vehicle Control Factors
- vehicle speed and speed variance
- brake applications
- steering reversals
- tracking behavior (lane excursions)

c. Subjective Information
- message usefulness, timeliness
- ease/difficulty of navigation task
- subject debriefing

d. TravTek System Functions
- use of HELP key, PAGE BACK key, etc.
- errors in performing task sequences
- response time in performing task sequences
- frequency of feature selection from menu

It is anticipated that the camera car will consist of a basic TravTek vehicle to which has been added a series of cameras and recorders that will provide a video image of the road to measure lane position and a camera to be focused on the eyes of the driver to estimate glance direction and duration.

A camera also focused on the drivers body and limb motions will log all interactions with the vehicle components. These video outputs could be multiplexed onto one video image or simultaneously recorded onto a multitrack tape to ensure synchronization of the signal during analysis.

In addition, the system should time stamp the video using time from the vehicle or the TMC to providesynchronizationbetween the camera outputs and the TMC

and vehicle log. An audio channel will be used to record driver and observer comments.

Paid participants will be recruited to serve as subjects. The subjects will include different ages, genders, and educational levels and will be screened for both visual, auditory capability, and color perception. A subset of the drivers will be selected from the Field Study with Local Users - Approaches 1 and 2. This subset will be tested prior to and after their long-term use of the TravTek system to access the effect of increased familiarity with the system.

The subjects will perform a series of predrive and drive tasks, including navigation of the Orlando Test Network. These tasks will include data entry, making and receiving phone calls, adjusting the climate control, selecting radio stations, use of the service directory, trip planning, route following, and many other considerations.

The MOEs will be recorded for each driver as he/she negotiates a specific set of routes. The experimental condition will be changed, while controlling for order of presentation effects, from route-to-route.

The analysis could use a within subjects design analysis of variance techniques to examine the effects of the three experimental conditions on the various MOEs. For example, this could determine if drivers accessing one type of display have an increase in glance frequency, glance duration centerline violations as compared to their performance with another mode.

Although the major thrust of the analysis will be on comparisons between the three display modes, some additional comparisons can be made between some of the experimental results and existing human factors literature. Driver visual search behavior has been researched well over many years.

Comparisons with existing driver glance duration parameters and control condition behaviors (such as climate control/radio adjustments) can be used to estimate the potential safety impacts of TravTek. It is important, however, to realize that direct comparisons with data collected in driving simulators and data collected using eye-marker cameras must be very carefully made.

Data to be gathered and made subject to these analyses will include:

a. Information on frequency of utilization of various control buttons to measure learning and propensity to make errors, etc.

b. Compare "route map" versus "Guidance map". Compare which ones drivers use and under what conditions. Critical situations, such

as when there is a mid-route correction, may provide an opportunity for this type of comparative evaluation. Is the level of safety reduced relative to routine driving in these critical situations? How can this be measured?

c. Collect distributions of glance durations while the driver is reading and/or operating or receiving instructions from TravTek. Compare with baseline glance durations for use of mirrors, speedometer, radio, and other instruments and reading road signs. Collect above data for light, medium, and heavy traffic conditions to form the basis for a model of how drivers allocate their spare capacity in the driving task. Do the drivers like the location of the display? Is the display accessible?

d. Evaluate the effectiveness of visual/audible display of messages. Is the level of visibility of the display adequate? Is the audible level of advice adequate?

e. To what extent does TravTek reduce the time the driver takes to read road signs. This will be measured using an instrumented vehicle to compare glance times to road signs both with and without TravTek.

f. Does the driver using TravTek have a perception of being able to focus on traffic rather than signs, etc. for navigation? This question should be addressed by display mode, i.e., map, guidance, visual-only display,visual plus audible display.

APPROACH 6. DEBRIEFING AND INTERVIEW STUDY

Approaches 6 and 7 involve the development and administration of a series of debriefings, interviews, and written questionnaires. The purpose of this task is to collect subjective and attitudinal data from the TravTek participants. This information will be used in the various task activities to address many TravTek objectives and evaluation goals (Appendix B). Participants will include drivers from the field study with rental users (Approach 1), the field study with local users (Approach 2), the Orlando test network study (Approach 4), and the Camera car study (Approach 5).

1. A Debriefing And Interview Study will be planned, performed and analyzed. The objective of this subtask is to collect and analyze comparable subjective data from drivers who participate in each of the various TravTek field studies. This data will include information on driver preferences, perception of IVHS benefits, ratings of system usability and learning, and marketing issues. Both interviews (a structured set of questions) and debriefings (a less structured request for comments) will be used.

Paid participants in Approach 4 will be debriefed or extensively questioned by the experimenter in those studies. Questions which are relevant to each study will be developed by the investigators. In addition, a core of questions will be held constant in all interviews. Participants in the field study with local users, the Orlando Test Network study and the Camera Car study will be included.

A subset of Field Study Rental users will be interviewed/debriefed as part of the market research effort. A subset of (n=50) Field Study drivers will be paid for their time participating in one-on-one in-car market research interviews to be conducted independently by GM.

The data will be analyzed by subject/market segment variables, including correlation with performance measures gathered from the studies in which the drivers participated.

APPROACH 7. QUESTIONNAIRE STUDY

A Questionnaire Study will be planned, performed and analyzed on preferences, perception, marketing and other subjective/attitudinal information from drivers who participate in TravTek studies. This will provide subjective data that will address many TravTek objectives and evaluation goals (see Appendix B) l This questionnaire will address issues not specifically addressed in the questionnaire used in the Approach 3 Field Studies.

The Questionnaire study will evaluate driver satisfaction with the TravTek in-vehicle system.

Market research questionnaires will be given to all TravTek field study rental users. A selected subset of 1550 of the rental car users will be mailed a questionnaire to be developed, distributed and analyzed by GM Research. All of the remaining rental car users will be given the market research questionnaire to be developed under this task. Some rental users will be debriefed and/or interviewed. There will be a core of questions held constant across questionnaires. This information will be shared.

In addition to marketing questions, there will be questions about human factors, perception of IVHS benefits, etc. A detailed description of the various study components is contained in Appendix H - Study Components For The Questionnaire Study. It may be necessary to provide an initiative to encourage rental user response to the questionnaire. .

Sample Plan - The Study Groups

The participants will be assigned to one of the following three groups, or car configurations:

a. TravTek - All participants will have access to all service and navigation functions, i.e., AAA Tour Book, local activities and yellow pages, and the database with appropriate sub-systems.

b. Navigators - participants with access to autonomous navigation and service functions, but with no real-time data from the TMC.

c. Service - participants with access only to service functions. This is the control group against which the others are compared.

Dividing the sample into these three groups will allow the benefits of the Navigation functions and the advantages of real-time congestion data to be measured. The overall sample will be derived from participants using the rental cars. The sample will be derived from participants using the rental cars.

The principle study factors include:

a. Age
b. Household income
c. Employment status
d. Years of AAA membership
e. Type of car ownership

Study cells include specific factor levels such as the age group 25 to 35 years or owners of Domestic Luxury automobiles. In all cases, there will be an attempt to balance the sex of the principal driver/car owner and purchase behavior. Secondarily, family type is also important. Even though, this characteristic may not drive user reaction or car sales, having a variety of family compositions is considered desirable, not a necessity.

The intent is to cell balance and obtain enough usable responses to allow for factor segmentation and cross-analysis. The objective is to get a minimum study cell size of 300 observations and at least 100 observations per sub-cell, e.g., Use primary personal car for business reasons within study cell Leisure and vacation traveler.

The field test sample will be drawn from AAA members planning a trip to Orlando, Florida during the demonstration period through AAA clubs that agree to recruit for the study. Selection of clubs will be based on geographic location and club size and balanced by census division.

For recruitment purposes specific AAA travel centers will be assigned to recruit for particular participants by sample group. Each center will only receive recruitment and project materials for the group it is recruiting. Thus, three travel counselor training manuals, three sets of recruitment materials, and three different Project Packets will have to be developed and distributed.

Further, materials and procedures related to the airport briefing, in-service evaluation, airportdebriefing, and the mail survey will be developed based on the participant's awareness of the car's capabilities. Each stage of the process will have three unique, though not mutually exclusive, procedures.

The demographics of the projected subject population are described in Appendix I - Subject Demographics.

The data analysis will address the previously listed market research objectives. In addition, additional data from the in-vehicle log and the TMC will be obtained to correlate with the participants subjective response. This information will include: miles traveled; functions used; sub-functions (features used); frequency of functions used; errors made, e.g., wrong function keys used; time on the road: times "zoomed"; routes displayed (micro versus macro); average length of routes used; average time on routes used;

average speed: time at zero speed; and other considerations.

APPROACH 8. MODELING AND ANALYSIS STUDY

Develop analysis procedures that utilize the results of TravTek studies and to project these findings to a mature system. This analysis should utilize the modeling work developed for the TravTek system by Queens College.

These studies will include, but will not be limited to:

a. A prediction of the consequences of the TravTek system and subsystems on traffic network performance.

b. The environmental, economic, and other community and individual driver benefits.

c. The effects of different levels of market penetration of these devices into the driving population, includingtheir impact on points a and b.

The simulation models should be used to analyze the TravTek network and determine the effects of the network on TravTek-equipped drivers diverting around blockages.

Determine the consequences, if any, of oscillations due to diversions, i.e., the consequences of TravTek-equipped vehicles moving to uncongested routes, causing these to be congested and then switching back to the other routes.

A Safety Evaluation will be developed and performed to gather data on details of incidents that cause congestion on the entire TravTek network. An evaluation should be performed to answer such questions as:

a. Does TravTek provide advance warnings that enable drivers to avoid and anticipate traffic and weather related incidents?

b. Can drivers recognize hazards at points in time that better enable the drivers to react safely?

Collect data on the accident history of the 100 TravTek vehicles relative to typical Avis accident history. Investigate what types of accidents are prevented or caused by the TravTek unit?

APPROACH 9. TMC AND TRAFFIC PROBE STUDY

Questionnaires should be developed and administered and the responses should be used to check for validity of data. System operator logs can be used to determine up-time of Travtek central computers. The TMC log can be used to determine up-time of connected components (communication system, etcetera). TMC log analysis can determine how often probe vehicle was the chosen data source for dynamic link times. Interviews with TIN users should be used to determine if the TMC has been providing credible data. Appendix J - Travtek Data Sources lists the currently planned data sources.

As a minimum the following issues should be addressed:

a. Does TravTek provide credible, real-timetraffic information and link times via data transmissions to test vehicles, the Traffic Information Network (TIN) and possibly others? Test the communications system between the TMC and the vehicles.

   This task should include verifying the content and timeliness of link travel time and incident information as compared with known conditions. Test the communications system between the TMC and the TIN network. This should include testing dial-up as well as leased

line connections. Tests could include the transmission accuracy (bit error rate) of a line and the response time for various operations.

Travel time and incident reports could be compared to known conditions. Testing of the quality of link travel time and incident information sent to the vehicles/TIN is also important. These tests should include a comparison of the incidents entered with those transmitted. In addition, the link travel times transmitted should be compared with calculated and estimated times based on the data available to the system. Testing the accuracy of data transmitted to the TIN users will be performed by comparing the information received to that available at the TMC.

The ease of use of the TIN interface should be evaluated and the reliability of connections underunusualcircumstances should also be tested (abrupt hang-ups, never hanging up, etc.).

b. Does it provide the information about the entire TravTek traffic network of freeways, toll roads and arterial streets? The map and database available at the TMC will be checked. They should contain active links for the entire traffic network. The effectiveness of coverage by looking at which links are covered by the various data sources (i.e. Vehicles cover it all, Freeway Management Center (FMC) covers which freeways, models cover which areas, etc.) will also be determined.

The frequency of providing information for each link will be determined from historical data.

c. Determine the degree of automation that has been achieved. Evaluate the process of obtaining and providing information and attempts to minimize the level of effort of the people involved in providing, fusing, and distributing the information. Generate statistics on the following items to determine the level of effort required by the operator: number of dynamic link travel times that were generated by the system for each automated source; number of dynamic link travel times that were generated by the system for each manual source: number of times the operator was forced to override dynamic link time generate: in the system; number of incidents registered with the system, what the sources were, and how many were confirmed.

d. Determine the level of

processing at TIN sources or the Traffic Management Center (TMC) as opposed to accomplishment of the processing in the in-vehicle subsystems. This task could involve evaluating the data provided to the vehicle, what the vehicle did with it, and then determining if those tasks could be accomplished at the TMC. Generate feedback from the TIN users by performing surveys. These surveys could cover levels of user satisfaction with each feature, system accuracy, and ease of use for the system. These could be supplemented by statistics on the number of calls/requests made for information by TIN users.

e. Evaluate the risk and cost of development, implementation and operation of the TIN and TMC. The minimizing of risks associated with the development of new control systems can be best achieved by adopting a formal approach to the development cycle. FIPS PUB 38 defines the software life cycle as:

Definition stage - where the functional requirements documentation and the data requirements documentation is produced and agreed upon.
Design stage - where the system and subsystem specifications are developed and the program anddatabasespecifications are defined.
Programming stage - during which the coding is performed and the manuals are prepared and the test plan is developed.
Test stage - where all system tests are performed.

The above stages should be used to evaluate the development of the TravTek system and develop recommendations and guidelines for future system development.

f. Evaluate system reliability. Evaluate the amount of operational up-time for each hardware and software component of the TMC. This information could be obtained from system logs and operator reports. Gather information from the system operators on areas where improvements could be made or problems exist.

g. Evaluate the operational effectiveness and benefits associated with 24 hour operation of the TMC. Determine the continuing availability of the various data sources, their cost, and their utility. Evaluate the ongoing costs for hardware and software maintenance. Evaluate the cost versus benefits of the system operator. Determine the utility of continuing TravTek operation following the completion of the currently scheduled project.

h. Determine the ability of the system to adapt to different sources of data, and what level of effort is required to do so. Determine the ease with which the TravTek system can be replicated by others.

APPROACH 10. GLOBAL EVALUATION

Perform a Global Evaluation which will coalesce the results of all studies in the TravTek Evaluation Plan and provide overall interpretations of the data from these individual sources. To evaluate what has been learned from TravTek as a cooperative project between public sector partners. Such an evaluation shall as a minimum include:

a. An analysis of all the converging and diverging evidence that TravTek objectives were or were not met. Amacroevaluation and interpretation of results in the context of TravTek claims and constraints.

b. An evaluation of TravTek as a project and process may require that the TravTek Partners, collaborators, workers, etc. be interviewed and/or asked to complete questionnaires.

c. Comparison with other systems around world. Collect data in TravTek that is similar to the evaluation data that has been collected in evaluation of similar systems around the world. For example, some evaluation data is available for the German Ali-Scout system. In addition, during this evaluation, the evaluation of the Pathfinder project is due to be completed,

Economic models will be used to

determine the effects of such IVHS type projects on the local economy. Such benefits could include:

a. Increase in local business to support TravTek hardware and systems

b. Increase in commerce due to congestion reduction

c. Shift/increase in those business that are included in the service features of TravTek

The information from all the other approaches will be used to determine the degree of excess travel that would be saved by using TravTek type devices. Determine the saving associated with recoverable navigational waste that can be attributed to the route optimization process. Compare this with other studies for validation. Use these data to estimate the potential savings associated with IVHS systems on the US oil consumption.

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APPENDIX A - DATA STORAGE AND LIBRARIAN

INTRODUCTION

The TravTek project is complex and will generate large amounts of data. These data need to be made available to all the partners. In addition, the various contractors selected to perform the evaluations defined in the ten approaches will require access to these data.

These data will provide a valuable resource that should not be lost. Nor should this data be dispersed to multiple locations where each organization may keep tabs only on the data relating to their specific interest.

This section proposes a data storage process and a TravTek librarian whose basic responsibility will be to ensure the collection, safe storage, and appropriate dissemination of the TravTek data. The librarian is not intended to form an active part of the TravTek system, but act as more of a depository with archival functions.

DATA TYPES

There are multiple types of data that are required to be kept by the librarian. Although these are predominantly data files that are generated by the system and its experimenters, each partner may wish to use the librarian as a mechanism to provide a storage facility for its own files. For example, historical copies of the map base or the in-vehicle services files.

The data files will be generated from four principal origins:

- The log files from the TMC. These include records of all data received and transmitted in addition to historical profiles of the traffic conditions, incidents, TIN user reports, etcetera
- The vehicle logs that are generated within the vehicle that keep a record of the data on the vehicle processes; the drivers' actions: and questionnaire data
- The TISC logs that will record event data, phone interactions; other vehicle records and questionnaire data
- The experimental data records frommultiple contractors who will be performing the experiments associated with the ten approaches.

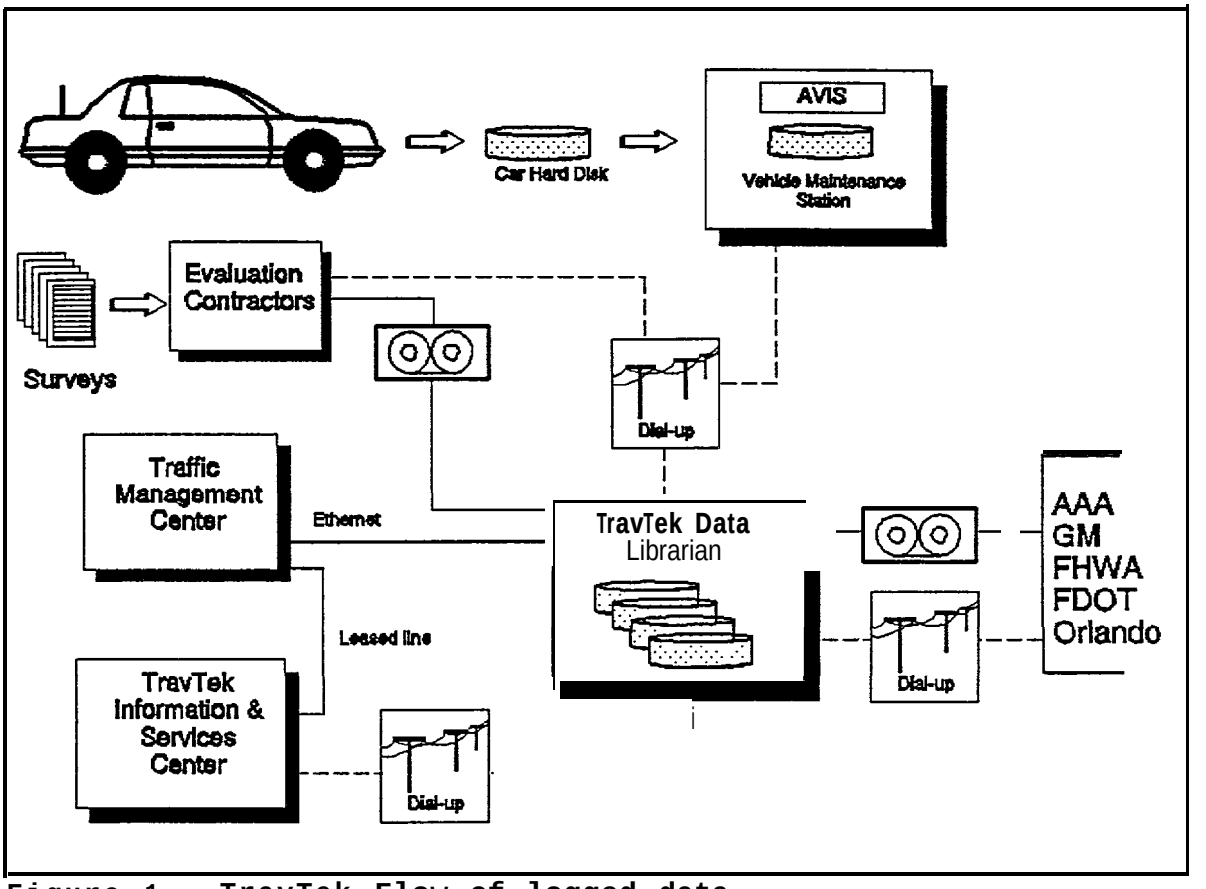

Figure 1. TravTek Flow of logged data.

Figure 1 shows a data flow diagram of the TravTek system.

It is assumed that each of the partners will keep proprietary data to themselves. In addition, only the TravTek partners and explicitly authorized contractors will be allowed access to the data held by the librarian. To avoid the potential disaster associated with fire that might cause all data to be lost; off-site storage is required.

LOCATION AND HARDWARE

The TMC or the TISC both provide potential locations for the librarian. However, the TMC will be provided with multiple phone lines which is likely to very advantageous for file transfers. In addition the State/City have available funds to pay for the librarian and there is available space in the TMC. An additional reason for selecting the TMC is that there will be operational reasons for the evaluation contractor to work at, or nearby, the TMC to make use of the data provided by the TravTek operators' workstation. This physical proximity allows access to both real-time and historical data and could be advantageous. It is

recommended that the librarian reside at the TMC.

Data Storage Capacity

Table 1 indicates the estimates of the data rates from the various origins.

DATA ORIGIN	MBytes/week
TMC Logs	15
Vehicle Logs	25
TISC	2
Evaluation contractors	1
TOTAL =	43

Table 1. Weekly data storage requirements

The following assumptions have been made:

- The evaluation contractors numbers will be the worst case that will occur during the yoked driving study.
- 100 percent utilization of the system

As the table indicates at least 43 MBytes of data per week should be planned when sizing the storage requirements.

Hardware

The TravTek hardware, at the TMC, consists of a network of three microcomputers that are configured in a client/server relationship. Although it is not necessary to add the library computer to this network, doing so will enable the TMC to transfer files directly. This will reduce the load on the modems. Figure 2 shows a potential configuration of the TravTek and library computers. The library computer has its own dedicated modem. This will be connected to a dial up line that will be used for file transfers. Users, such as evaluation contractors will be able to upload files to the librarian at their leisure. The library will run a bulletin board to allow file transfers 24 hours per day. The TISC, which is a particular case will upload their data files in the same manner

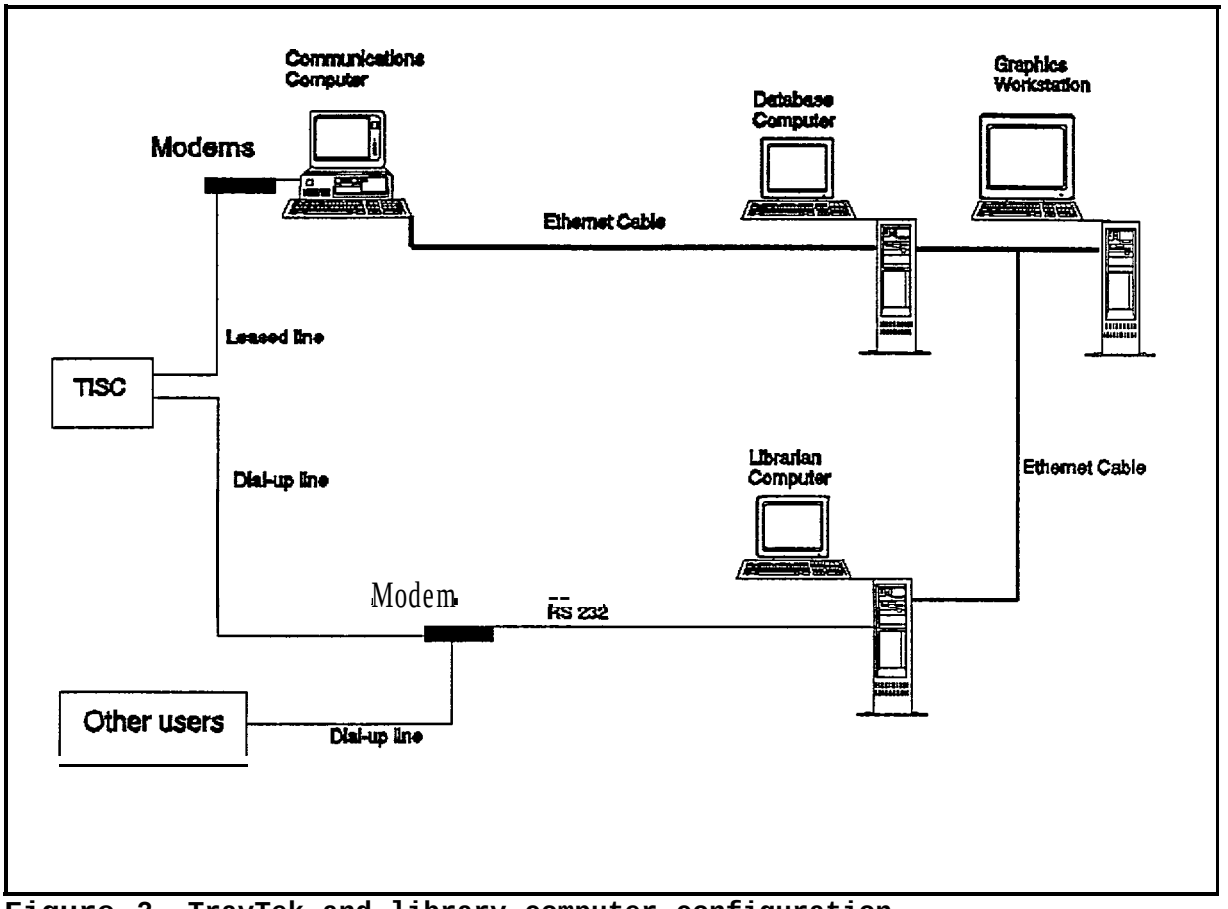

Figure 2. TravTek and library computer configuration.

as other users. The use of the TISC's dedicated line for file transfer is not appropriate. These library files are of a lower priority than other data in a real-time system. This line should be dedicated to transferring event data files to the database computer and for the TMC to transmit vehicle alert codes to the TISC.

It is recommended that the hardware and tape backup system for the library should be the same as the database computer. Such an approach makes use of familiarity with the system and only one type of tape is required. It will be necessary that the library computer have much greater disk storage. This should be in the order of 1 gigabytes which will allow on-line storage of three months worth of data. Twice the tape capacity should be kept free to facilitate tape copying. The tape format is fairly common. Large organizations might already have one and others can purchase units that will read 250 Mbyte tapes for approximately $2,000. The tape system uses a QIC-2 interface and DC 600 series tapes. The tapes are readable under DOS, OS/2, and Macintosh computers. A DC6250 tape will store 250 MBytes of data and currently costs

approximately $30. A Tecmar QT 150 tape using Sytos Plus software is suggested. A printer will also be included in the system.

The library computer will be operating under OS/2. A multitasking system is required in order that the bulletin board system (BBS) for uploading data can run continuously while the librarian is performing other functions. Magnum, a BBS package operates under OS/2 and is suggested. Using a bulletin board rather than a communication program allows all origins to upload data using their own communication program.

File Formats

The TISC will use a UNIX operating system, the TMC will use OS/2 the vehicle will have a third operating system. There are no common file naming conventions between these systems. Additionally the evaluation contractors could use DOS, Apple, or other systems although IBM clones are most likely.

It is proposed that no database program be used by the librarian. All files should be flat ASCII format with fixed column widths. This format can be read by all known database programs and virtually any other software application that is capable of importing a file. Neither spaces nor commas are suitable as delimiters as much of the data will consist of text.

This format is not efficient from the point of view of the software developer. It is likely that each data origin will be producing files in a manner that is best for their software processes. It is the intention that this format applies only as the data is delivered to the librarian. For example, the vehicle log data could be put in this format after downloading from the vehicle to the VMS. The VMS could perform the formatting and compression prior to delivery to the librarian.

Some of the data files will be the actual questionnaires. Some of the questionnaire responses will be in the nature of long comments. This means that wide columns will need to be specified, however, these can be read by most database programs without difficulty. The negative impact of wide columns on file sizes will be ameliorated by the compression process described below.

Data File Naming Convention

It is proposed to base the TravTek file naming convention on DOS file formats. This is the lowest common denominator and can be read by all operating systems. This convention only applies to data files. It is anticipated that each partner will have a main directory in which they will be able to store any software required without naming restrictions. The purpose of this is for the

librarian to provide off-site storage for the other TravTek subsystems, if required.

One directory and its subdirectories will contain data. The proposed TravTek data file naming convention is defined below.

All filenames must consist of eight characters with three characters in the extension. When no information or data exists for a specific position then an X must be used. Specifying an obligatory file name length and specified default character removes

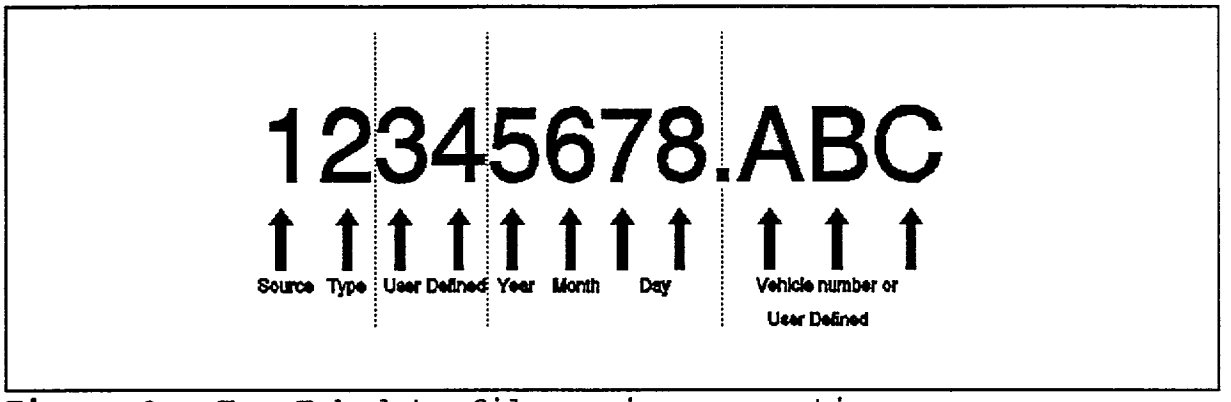

Figure 3. TravTek data file naming convention.

ambiguities when wildcards are used. The data file name is illustrated in Figure 3. Each character can be either any of 25 letter (not X) or 10 numerals, zero to nine for a total of 35 combinations.

The first character is the origin designator. This is used to define the part of TravTek that provides the data. Only the librarian will be able to define new origins. The following origins are defined here:

ORIGIN	LETTER
AAA/TISC	A
GM/vehicle	G
TMC	T

All files generated by GM that are to be stored in the data directory will start with G. Each origin must use only their letter. As more origins are required letters will be allocated by the librarian. It is anticipated that each new evaluation contractor will be allocated an origin designator.

The second character is the type of file. These designators should be defined by the origin in such a manner that they form a sub category that follows some conventions. For example, all TMC log

files for broadcast data will use the label type B. Thus all TMC broadcast files will have TB as the first two characters. Incoming TMC data will be labelled I. Type designators should be logged with the librarian and included in the read me files for users to view.

Characters three and four can be defined by the origin. If they are not defined, XX should be used.

The next four characters designate the date the file was opened. Character five is the last digit of the year. Character six is the month with November as A and December as B. Characters seven and eight are the day, leading zeros must be used.

The three extension characters are user-defined with the exception of the numbers 001 to 256 that are reserved for vehicle numbers. Again, leading zeros must be used.

This numbering scheme will allow all users to be able to access their individual data requirements with relative ease. Using DOS nomenclature the following series of commands provide some idea of how this convention can be used.

Examples

A*.* will find all files from the AAA/TISC.

*.063 will find all files from vehicle number 63, including questionnaire data relating to that vehicle's driver.

G???2207.045 will find all GM/vehicle files for vehicle 45 on the 7th of February 1992.

If AAA were to designate the type Q to their questionnaire files then AQ*.008 will find all AAA questionnaire data relating to vehicle number eight.

Compression Format

All files kept by the librarian should be delivered in compressed format, stored in compressed format, and transmitted in compressed format. The most widely used compression algorithm is ZIP from PKWARE. This is a shareware ($25) program and can be legally copied to all users of the TravTek data.

This compression utility, using a common format across various operating systems, is available for use in these environments:

+ DOS
+ UNIX (1stQ 1991)
+ Mac (extract only)
+ VMS
- Amiga, and others

```
PKZIP (R)  FAST!  Create/Update Utility  Version 1.1  03-15-90 Copr. 1989-1990 PKUARE Inc. All
Rights Reserved.  PKZIP/h for help PKZIP Reg. U.S. Pat. and Tm. Off.

Usage: PKZIP [-b[path]] [options] zipfile [@list] [files...]
Options summary - consult the PKUARE documentation for additional information
  -x<filespec|@list> = exclude filespec(s)          -z = add zipfile comment
  -d = delete files          -f = freshen files     -i = add changed files
  -1 = display license info  -u = update files      -m[u,f] = move files
  -a = add files             -b = create temp zipfile on alternate drive
  -c = add/edit file comnents -C = add comnents to new files only
  -k = keep same ZIP date    -0 = set ZIP date to latest file
  -q = enable ANSI comments  -s<pwd> = Scramble files with password
  -r = recurse subdirs       -$[drive] = save volume label
  -t[mmddyy] = Compress files on or after specified date (default=today)
  -e[x,i,s] = use maXimal compression/Implode only/Shrink only
  -<p|P> = store pathnames ¦ p=recursed into ¦ P=specified & recursed into
  -<w|W><H,S> = ¦ w=include ¦ W=don't include ¦ Hidden/System files
  -<j|J><H,S,R> = ¦ j=mask ¦ J=don't mask ¦ Hidden/System/Readonly attributes
  -v[b,c,d,e,n,p,s,r,t]        view  ZIP  [Brief  listing/show  Comnents/sort  by  -
Date/Ext/Name/Percentage/Size/sort Reverse/Technical (long) listing]
zipfile = ZIP file name.  Default extension is .ZIP
file    = Names of files to compress. Wildcards *,? ok. Default is ALL files.
@list   = listfile containing names of files to add or view etc.
If you find PKZIP fast, easy, and convenient to use, a registration of $25 would be appreciated.  If
you send $47 or more you wi 11 receive, when available, the next version of the PKZIP, PKUNZIP, and
PKSFX programs. Please state the version of the software that you currently have. Send check or money
order to:
PKWARE, Inc.
7545 N. Port Washington Rd.
Glendale, WI 53217
```

Table 2. PKWARE screen.

Table 2 indicates the basic features and extensions available. The DOS version, together with a 68 page documentation file (in electronic format) has been distributed to all TravTek partners. The latest version, together with its documentation, will be available from the librarian.

Read Me Files

The data files will be stored in a fixed column width format. The user of the data will need to know which data is in which columns.

A system of read me files will be produced and maintained by the librarian.

A basic read me file that defines the file origins and types should be constantly maintained. This will enable users, other than the originator of the data, to understand the basic formats.

Other read me files that provide additional information on specific data should be added on an as needed basis.

LIBRARIAN JOB DESCRIPTION

Functions

The librarian's function is to acquire, maintain, and disseminate all the TravTek commonly held data. The librarian's qualifications should include the following:

- A familiarity with computers and file storage.
- A background that includes some experience with use of communication programs.
- An ability to be logical and organized in terms of developing and maintaining the data library.
- The personal qualities necessary to track down missing data sources and ensure their delivery.

The librarian should be employed at least three months prior to full TravTek operation. During this period, the librarian should start becoming familiar with TravTek and the librarian functions. Schedules should be developed for which types of data and its delivery times. Labelling procedures should be formulated.

The librarian should produce a brief monthly report to the TravTek partners indicating currently available data and any configuration changes during the previous month. In addition, this report should define any missing data.

Operating Hours

It is not anticipated that the librarian will be available outside the office hours of other City staff. Authorized users of the data will have the ability to upload data to the librarian 24 hours per day. Downloading data (from the librarian) will only be allowed with the active cooperation of the librarian during office hours. Allowing all users access to the main files through the BBS could compromise the security of the data and could make tracking data requests difficult.

Backup procedures

As files are received at the librarian's machine they should be logged and placed in a temporary directory. Following inspection for the correct format, the files will then be placed in the correct directory location.

Each day, these files should be automatically backed up onto a tape. This tape is for disaster recovery only.

Once per month, two copies of the previous months files should be made. The first of these should be kept by the librarian. The second of these should then be mailed to the TravTek evaluation oversight contractor who will provide off-site storage. This contractor will have no responsibility for data dissemination. There are no hardware requirements at this off-site location. The tapes merely need to be stored.

When requests for data are made to the librarian, their responsibility will be to find these files and supply them to the requestor. These data might be on several tapes, on the disk or in both locations. The librarian will copy these files to a holding directory on the disk. The delivery could be via the BBS and floppy disk or tape depending on the file sizes and urgency.

All file transactions should be logged. The log should include a list of the files, where they came from, to whom they were sent and the transfer date. This logging procedure should include requests for data from TravTek partners.

APPENDIX B - TRAVTEK OBJECTIVES AND EVALUATION GOALS

These objectives and evaluation goals are derived from the surveys of the TravTek partners.

A. Trip/Network Efficiency
 1. Congestion Avoidance
 2. Time Savings
 3. Pollution Reduction
 4. Fuel Savings
 5. Reduced Vehicle Operating Cost
B. Benefits to Non-TravTek Users
C. Driver Performance/Behavior/Satisfaction
 1. Driving/Navigation behavior
 2. Perception of Congestion, Time, Safety
 3. Usability/Learning
 4. Feature Use
 (Route guidance, voice guidance, phone, local info. etc.)
 5. User Friendliness/Driver Satisfaction
D. Safety
E. System and Subsystem Performance
 1. Hardware
  a. Reliability
  b. Compatibility
 2. Software
  a. Reliability
  b. Compatibility
 3. Data
  a. Accuracy (map, local information, etc. databases)
  b. Timeliness
 4. Operations/Procedures
  a. Data collection (map, traffic, events, local information)
  b. Data input-TMC, TISC
  c. Driver recruitment, training, debriefing
  d. Helpline management
  e. Vehicle management
  f. Vehicle maintenance
F. Image
G. Impact Future Transportation/Travel standards
 1. Generalizable/Transportable
 2. Technology Transfer
H. Feature Preferences
I. Price/Cost
 1. Willingness, personal vehicle
 2. Willingness, rental vehicle
 3. Infrastructure (TMC, TISC)
J. Local Area Impact

1. Improvements Beyond travTek Operating Period
2. Routing Through Sensitive Areas (neighborhoods, hospitals, etc.)
3. Local Driver Usage
4. Local Jurisdiction, Policy Issues
5. Macroeconomic Benefits

APPENDIX C - TRAVTEK OBJECTIVES, GOALS, SOURCES AND APPROACHES

TRAVTEK OBJECTIVE/EVALUATION GOAL: A. TRIP/NETWORK EFFICIENCY

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
A.1 CONGESTION AVOIDANCE		
Speed variance (ride quality) deviations of one-minute speeds/trip)	In-vehicle log	1,2,3,4,5
Number of stops or instances of D-speed/trip	In-vehicle log	1,2,3,4,5
Speed (averaged over trip)	In-vehicle log TMC tog (probe reports)	1,2,3,4,5,9
Number of miles/trip	In-vehicle log TMC log (?)	1,2,3,4,5,9
Number of new routes offered to drivers because of congestion/traffic incident information	In-vehicle log	1,2,3,4,5
Number of new routes accepted	same	same
Frequency of broadcast/reception of Dynamic Link limes	In-vehicle log TMC *log*	1,2,3,4,5,9
Incident types, start and end times, locations tsee PERCEPTION OF TIME C.2]	TMC	9
A.2 TIME SAVINGS		
Trip Time (Origin/Destin.)	In-vehicle log TMC log	1,2.3,4,5,9
Total Travel Time [within a given time period)	In-vehicle Log	1,2
Total Time at O-speed [see PERCEPTION OF TIME C.21	In-vehicle log	1,2
A.3 POLLUTION REDUCTION		
Noxious Emissions		
Derived from measures of amount of fuel consumed, miles · traveled, number and time of O-speed, etc.	Avis Log (odometer, fueling) Driver Fueling Logs In-vehicle log TMC Log	1,2,8 9,8
A.4 REDUCED VEHICLE OPERATING COST		
Cost of Vehicle Maintenance (amount of parts and Labor used)	Avis log Oldsmobile records	1, 2, 8
Cost of Fuel (amount of oil and gasoline used)	Avis Log Driver Fueling log (?)	1, 2, 8

** Note the approach numbers correlate with the numbered bullets in the scope of work.

TRAVTEK OBJECTIVE/EVALUATION GOAL: B. BENEFITS TO NON-TRAVTEK USERS

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Decreased Network Congestion (traffic measures, collisions)	Traffic/police reports Control group-in-vehicle logs	8, 9 1,2,3,8,9
Decreased Network Travel Time	Baseline trip time data Control group in-vehicle logs	8,9 1,2,3,4,8,9
Resulting Reductions in -Pollution -Fuel -Vehicle Operating Cost		8
[Macroeconomic benefits, see LOCAL AREA IMPACT, J.5] Csee SAFETY. D]		8,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: C. DRIVER PERFORMANCE/BEHAVIOR/SATISFACTION

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
C.1 DRIVING/NAVIGATION BEHAVIOR		
Effect on driving task performance [cross reference: SAFETY (D)]		
-Eyes on road vs eyes off road:	Camera data	5
-number of glances		
-amount of time/glance		
-timing of glances		
-speed of vehicle	In-vehicle log	5
-Number and type of vehicle lose of control maneuvers	In-vehicle log	5
-steering reversals	Experimenter reports	
-brake applications, etc.	tans tracker data	
-Lane excursions, etc.	Other camera data	
	Special instrumentation	
-Driver reactions to displayed messages (new route, etc.)	same	
-Stops to use O-speed and park allowable functions	In-vehicte log Camera data Experimenter reports	1,2,4,5
Novice/Expert Shift	Same as above	2, 5
-Improvement in performance over time (measures taken at different points in time, same driver with local use of vehicle between) [see LEARNABILITY (c.3)]	(driving task performance)	
Improvement in navigation [cross reference: SAFETY (D)]	In-vehicle log	1,2,3,4,5
-See TRIP EFFICIENCY (A.l,A.2)		
-See USABILITY/LEARNABILITY (C.2)		
-Amount of time driver spends lost		
-derived from driven route data	In-vehicle log	2,3,4,5,8
-Amount of time driver spends looking for signs, distracted	Camera data	
-Subjective measure of navigation ease/difficulty	Experimenter reports	
	Debriefing/Questionnaire	1,2,3,4,5,6,7
Driver Compliance		
-Percentage of TravTek routes accepted/driven	In-vehicle log	1,2
	Debrief/Questionnaire	6,7
C.2 PERCEPTION OF CONGESTION, TIME, SAFETY		
Driver Perception of Time/Congestion	Experimental tog	3,4,5
	Experimenter reports	
	Debriefing/Questionnaire	1,2,3,4,5
Driver Perception of Safety	Experimenter reports	3,4,51,2,3,4,5
	Debriefing/Questionnaires	

C.3 USABILITY/LEARNABILITY		
The following are measures of Usability for Park and D-speed functions (data entry, trip planning, initiating communications, reposition functions):		
Number and type of button presses -frequency in use of HELP key, GOBACK key, etc. -errors in performing task sequences -response time in performing task sequence	In-vehicle Log Camera data Experimenter reports	1,2,3,4,5,8 5 5
In addition, the following are measures of Usability for Drive functions (navigating, receiving communications): -Also see DRIVING/NAVIGATION BEHAVIOR (C.1):		
Performance on specific route following, way finding, etc. tasks -number of errors -time to complete tasks	In-vehicle Log Camera data Experimenter reports	1,2,3 3.4.5 3,4,5
The following are measures of Usabitity for predrive and drive functions:		
Use of TravTek Helpline	In-vehicle tog TISC log	1,2,3,4
Subjective driver measures of Usability	Questionnaire Debriefing	1,2,3,4,5 3,4,5
The following are measures of Learnability:		
Improvement in usability measures over time (Learning curve) -Reduction in errors and time performing task sequences -Reduction in use of Help key, GDBACK -Reduction in use of TravTek Helpline	In-vehicle tog Camera data Experimenter reports In-vehicle Log TISC log	1,2,3,4,5,8 5 5 1,2,3,4
Subjective measure of Learnability Ease of Learning	Questionnaire Debriefing	1,2,3,4,5 3,4,5
Novice/Expert Shift in Driving/Navigation Behavior [See DRIVING/NAVIGATION BEHAVIOR (C.1)]		
C.4 FEATURE USE		
Nunber of times a feature of interest is picked from menu	In-vehicle log Experimenter reports Camera data	1,2,3,4,5 5 5
C.5 USER FRIENDLINESS/DRIVER SATISFACTION		
Subjective measures of user friendliness/satisfaction General impressions of -Usefulness of information -Format of info. presentation -Timeliness info. presentation - Criticisms (e.g. confusing/intimidating)	Questionnaires Interviews/Debriefing	1,2,3,4,5,7- 1,2,3,4,5
Subjective measures of user friendliness/satisfaction Specific impressions of -Features	Questionnaires Interviews/Debriefing	1,2,3,4,5,7. 1,2,3,4,5
Subjective measures of user friendliness/satisfaction - Training & Orientation	Questionnaires Interviews/Debriefing	1,2,3,4,5,7 1,2,3,4,5
Subjective measures of IVHS concepts -[See Perception of Congestion, Time, Safety (C.2)] -Sense of travel security	Sam as above In-vehicle Log	1,2

TRAVTEK OBJECTIVE/EVALUATION GOAL: D. SAFETY

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCE5 OF DATA	APPROACHES
Effect on Driving Task Performance [cross reference: Driving/Navigation Behavior (C.1)] Improvement in Navigation Behavior [cross reference: Driving/Navigation Behavior CC.111 Congestion Avoidance [cross reference: Trip/Network Efficiency (A.1)]		
Collision Avoidance -Number and type of accidents: -reported to police, etc. -reported to, discovered by Avis	Police, etc logs Avis log	1,2,1a
-Number and type of near misses	Experimenter reports Questionnaires Debriefing, Intervieus Experimental logs	3.4.5 1,1a,2,3,4,5, 1,1a,2,3,4,5 3,4,1a

TRAVTEK OBJECTIVE/EVALUATION GOAL: E. SYSTEM AND SUBSYSTEM OBJECTIVE/EVALUATION

E.1 HARDUARE E.2 SOFTWARE E.3 DATA		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
E.1 Hardware Reliability (test and evaluation phases) -Types and frequencies of component failure -Diagnosed cause of failures Compatibility (test phase)	Vehicle maintenance log	1,2
E.2 Software Reliability (test phase) Compatibility (test phase)		
E.3 Data Accuracy (test and evaluation phases -Map, local information databases -Real time traffic data	TISC log TMC log Police/traffic reports	1,2
Timeliness (test and evaluation phases>	In-vehicle log TMC log Questionnaires, Interview/Debriefs	1,2,4,6,7
E. 4 OPERATIONS/PROCEDURES		
a. Data collection <map, events, local information, traffic) b. Data input - TMC, TISC c. Driver recruitment, training, debriefing d. Helpline management e. Vehicle management f. Vehicle maintenance	TMC log Operator Logs Operator reports Vehicle logs Interviews with operators and City staff	I9

TRAVTEK OBJECTIVE/EVALUATION GOAL: F. IMAGE

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
Changes in public perception of TravTek Partners, IVHS over time	Phone Interviews	6,7,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: G. IMPACT FUTURE TRANSPORTATION/TRAVEL

G.1 GENERALIZABLE/TRANSPORTABLE 6.2 TECHNOLOGY TRANSFER		
HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
G.l Generalizable Map and Local Information Databases in formats which can be used in other locations - geographically -physically	DOD, SAE, etc.	8,10
Transportable (portable product potential) [see Market Research Plan]	Puestionnaire Interviews/Debriefs	1,2 1,2,4
6.2 Effective transfer of technology and knowledge -research reports -conference presentation -other presentations - TravTek experts work on future projects	DOT, SAE Standards Citations	10
Model Traffic Management Center	Questionnaire (traffic planners)	7,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: H. FEATURE PREFERENCES

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
[cross reference: DRIVER PERFORMANCE, FEATURE USE (C.4)] Frequency of use of each function and feature	In-vehicle log Camera data	1,2,5 5
Preference ratings	Questionnaires Interviews/Debrief	7, above 6, above

TRAVTEK OBJECTIVE/EVALUATION GOAL: I. PRICE/COST

HYPOTHESES AND MEASURES OF EFFECTIVENESS	SOURCES OF DATA	APPROACHES
1. Willingness to buy in personal vehicle	Questionnaire Interview/Debrief	1,2,4,6,7
2. Willingness to buy in rental vehicle	same	same
3. Infrastructure (TMC, TISC)	Records of exnenditures	8,10

TRAVTEK OBJECTIVE/EVALUATION GOAL: J. LOCAL AREA IMPACT

J.1 IMPROVEMENTS BEYOND TRAVTEK OPERATING PERIOD J.2 ROUTING-THROUGH SENSITIVE AREAS J.3 LOCAL DRIVER USAGE J.4 LOCAL JURISDICTION, POLICY ISSUES J.5 MACROECDNOMIC BENEFITS-		
HYPOTHESES AND MEASURES OF EFFECTIVENESS:	SOURCES OF DATA	APPROACHES
J.1 Improvements Beyond TravTek Operating Period		
J.2 Routing Through Sensitive Areas Frequency and circumstances of occurrences	TMC log Police Log (complaints)?	8.10
3.3 Local Driver Usage Same as tourist usage, but with Local high frequency cat- use population, over longer period of use		‘1,2,3,9
[see Novice/expert shift, Driving/Navigation Behavior (C.2)]		2
3.4 Local Jurisdiction, Policy Issues		10
5.5 Macroeconomic Benefits		8,10

APPENDIX D. MARKET RESEARCH PLAN

Mail Survey/Questionnaire - The principle form of attitudinal data collection will be a mail survey. There will be some overlap between the mail survey and the debriefing questions. The objective is to have responses from a nationally balanced sample (weighting by geographic census division, if possible) and also one that is socio/demographically balanced. In some cases, balance on "type of car generally drive" is important. (Type will be at the make/series level, classified by vehicle segment, e.g., "Entry-Near luxury" car that includes the Lexus, Infinity, Volvo, Saab, and Peugeot as defined in General Motors' Market Research Proposal dated 2/14/90.)

Questionnaire Content

Many of the research objectives will be analyzed through the follow-up questionnaire. Below is an outline of suggested subjects that are to be covered in the questionnaire:

1. System & sub-system Performance
   Physical attributes -
   Location, orientation and size of the monitor
   Display readability in all driving conditions (day, rain, heavy traffic, etc.)
   Location, size, ease of use of the control buttons
   General aesthetics of the unit
   Service problems with the system, sub-system, car
   Software attributes -
   Graphics on screen
   Voice qualities
   Color enhancements
   Date attributes -
   Transaction time
   Readability, quality of the route maps
   Various map scales
   Orientation of display maps to actual road
   Accuracy and timeliness of information (i.e. traffic reports)
   Erroneous information (illegal turns, not leading to destination, not reporting congestion, etc.)
   Operations/Procedures -
   Overall ease of use
   Data entry complexity
   Paging to reach desired information

2. Driver Performance/Satisfaction
   Overall impression of the TravTek system
   Training and orientation
   Useability, friendliness and learning functions (i.e. system features)

Willingness to let the system navigate (follow route, accept redirections)
Comparisons of system to conventional navigation aids (maps, Triptiks, another person, etc.)
Ease of finding destinations, trip planning
Any changes in customary driving habits (attention to driving, reading of road signs, taking more or fewer trips)
Subjective responses (anxiety, confidence, confusion, clarity, intimidation, security, etc.)

3. Safety (Collision Avoidance)
Perceived value in both normal and adverse driving conditions
Helpfulness in summoning assistance when needed
Timeliness and usefulness in alerting driver to upcoming conditions (i.e. congestion or incidents) and redirecting
Avoidance of collisions, incidents and congestion
Driving distractions or hazardous situations created by operating the system, particular features, time needed to take eyes off the road
Accessibility of the system (audible and visual) to the driver without creating a hazardous situation

4. Trip/Network Efficiency
Usefulness as a navigation aid, route guidance
Transaction time
Perceived time and fuel savings
Value of local information
Quantity, quality and promptness of information
Promptness of TISC assistance

5. Local Area Impact

6. Feature Preferences
Preference or dislike for certain system or vehicle functions
Frequency of use for various system or vehicle functions

7. Impact Standards (Industry/Related Industry)

8. Benefits to Non-TravTek Users

9. Image Perception
Pre-and post-impressions of each of the partners, the TravTek system and in-vehicle navigation systems in general

10. Price/Cost
Necessity of the TravTek system to travel
Willingness to pay for all or part of the system at what price
Viability of equipment being factory-installed or optional
As optional equipment, preference for purveyor
Preference for type of hardware used to update system

Expected cost for upgrades

A follow-up telephone call or postcard will be used to enhance response.

Routine response tabs will be available to keep Partners updated.

Other research might be employed such as:

Telephone Interview - Used to get specific Partner information. This can also increase response if the participant was not a part of the debriefing sample.

Focus Groups - Depending on participant clustering, focus groups are a viable research tool and can be used for selective Partner research. Focus groups will not include Florida residents or "snow-birds."

APPENDIX E - YOKED DRIVER STUDY POTENTIAL O/D PAIRS

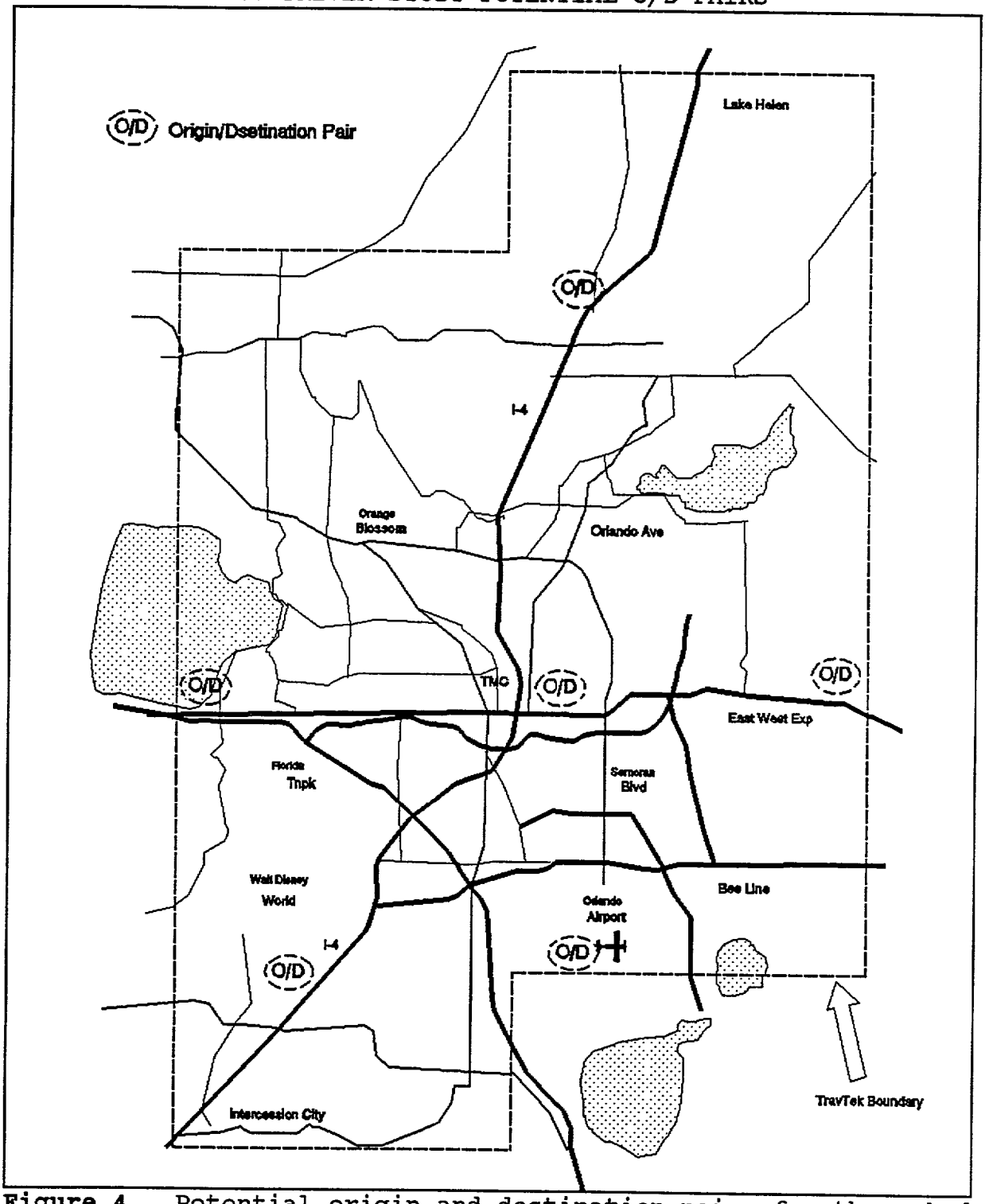

Figure 4. Potential origin and destination pairs for the yoked driving study.

APPENDIX F - YOKED DRIVING STUDY SAMPLE SIZE CONSIDERATIONS.

The required sample size is dependent on the variability found in the dependent measures (MOEs) and the size of the difference which we wish to detect. The table illustrates the sample size requirements for standard deviations of 2.5 and 5.0 minutes and a detectable difference of 1.0, 2.5 and 5.0 minutes. These assume a base case of the 20 minute journey described above.

REQUIRED SAMPLE SIZE Based on Cohen: Power Analysis (Power + 0.8, Alpha = 0.05)			
	Minutes	Standard Deviation	
3X2X2 Design		2.5	5.0
Detectable Difference	1.0	444	972
	2.5	72	240
	5.0	36	72
3X2X2X2 Desisn			
Detectable Difference	1	456	984
	2.5	96	264
	5.0	48	96

Table 13. Yoked driving study sample size.

The top half of table shows the sample required by a 3x2x2 design. Such a design might look at experimental conditions (N=3) and two other 2-factor variables, i.e., Traffic factors (peak and off-peak) and Driver Age (old versus not old). The bottom half of the exhibit shows how the sample size must be increased if an additional a-factor variable (i.e., Driver Sex or Light Condition) is considered.

Drivers will be briefed and instructed to drive between the above origins and destinations. A driver from each group will be sent out at one minute intervals from the same origin to the same destination and experience the same traffic and weather conditions. This study should be run both at peak and off peak hours. The drivers will be debriefed in Approach 6.

The analysis will examine differences between the experimental conditions (TravTek, Navigator, Service) and, using Analysis of Variance and Analysis of Covariance techniques. It will also determine the interaction between such factors as driver gender, driver age, trip length, and other considerations

Analyses will compare differences between groups and interactions with trip length, peak/off peak, and driver age.

APPENDIX G - ORLANDO TEST NETWORK STUDY DESIGN CONSIDERATIONS

Experiments could be run as a between subject design or as a within subject design. A within subject design has the advantages of reducing error due to individual differences in driving style and allowing preference data to be obtained. However, once the driver has navigated from origin to destination, he or she know the route. This is the reason for establishing O/D pairs connected by routes rated for equal difficulty. Each driver can navigate with every information display condition driving a different O/D pair of the test network. The design will be counterbalanced. Debriefing/questionnaires will yield data on preferences and perception of time savings, safety, etc.

Analyses can compare logged data for each experimental condition to evaluate main effects as well as interactions between display type, age, and day/night considerations. Comparisons should be made on preference and perception data for each condition and with logged performance data. Experimental conditions may include:

a. Control condition with paper maps only
b. Route map display only (moving, heading up map with route overlay)
c. Guidance map only (static maneuver by maneuver display)
d. Voice guidance, voice navigation only and/or in addition to guidance map.

Independent variables may include; age groups, education level, traffic density.

Various vehicle display configurations may include:

a. Guidance display with audio,
b. Guidance map without audio,
c. Route map with audio,
d. Route map without audio,
e. No guidance or navigation help.

Other experimental considerations may include:

a. Increase driver workload--3 groups: need to change route, need to change radio or A/C, noise or other non-manual distraction (i.e. conversation with passenger).

b. Impose additional secondary tasks, such as, emphasis on completing trip in a minimum time.

c. Measures of performance: two types of data could be collected, contemporaneous data on specific critical events and summary data collected at the end of a trip. The critical events will

include activities such as exit to and entrance from freeways, change of street, change of route.

Learning

An understanding of the rate at which drivers learn to use the system is needed for two aspects of the safety evaluation with the local users. One aspect is the time that is necessary before a driver makes the complete transition from a naive driver to a driver who is completely familiar with the system. This time could be as short as one trip and as long as a hundred or more trips. The value of this length of time will determine the scheduling of drivers in the Test Network.

The second consideration of the rate of learning is more directly related to the safety of the system. If a driver performs poorly and is uncomfortable with the system it may be necessary to provide more extended training for drivers. If drivers generally perform well from the beginning, it would help to confirm the hypothesis that this system does not degrade safety. For these reasons, the studies of rate of learning should be done at the earliest possible time. One possible approach to the study of learning rate would be to use a subset of conditions from the OTNS. Using the OTNS can supplement the learning information found in Approaches 1 and 2.

APPENDIX H - STUDY COMPONENTS FOR THE QUESTIONNAIRE STUDY

The following study components need to be developed.

Recruitment - participants will include the group of AAA members and, if necessary, non-members who agree to take part in the TravTek market research. They will be selected based on quota needs. Also, based upon quota, participants will be selected for debriefing. Upon acceptance of project involvement, participants will be shown a video, or other form of visual display, of the project's overview, car and system involved, and any other information to help them determine participation. Before their scheduled departure from home (or possibly at time of recruitment), participants will receive a Project Package reinforcing their participation in the project as well as some other informative materials. Full-time Florida residents and winter residents will not be included in the sample. The sample will involve only active automobile drivers.

Recruitment will begin in late 3rd or early 4th quarter 1991. Early in 2nd quarter 1991, notices of the project and a call for involvement will be developed and inserted in club publications to help attract members, especially those who might not normally use AAA Travel Agencies. Included will be a Send in/Call notice for further information. It is expected that a minimum trip duration of at least 4 but no more than 6 days will be included in the recruitment guidelines.

All necessary legal disclaimers should be reviewed before being signed upon participant's arrival in Orlando. The travel counselor will inform participant that a follow-up call might occur and that they might be asked to participate in a focus group with other volunteers. Finally, participants for GM's 50 one-on-one in-car interviews to be done on the Orlando Test Network will be recruited and designated at this time.

AAA Research will monitor the recruitment quotas and provide periodic reports of progress.

Airport Briefing - Upon arrival in Orlando, participants will be re-introduced to the car and the TravTek system. This briefing needs to be informative and encouraging. At this point, some simple system entry (e.g., participant name and hotel destination) should be conducted to relieve any anxiety that exists.

The Project Packet will be reviewed and all forms, e.g., disclaimers, will be signed, if not already done so. Participants will also schedule an in-service evaluation time, i.e., a short telephone interview, conducted at scheduled times of their stay. If applicable, a debriefing time will be scheduled. Nevertheless,

they will be reminded to return to the airport at the end of their vacation from 1 to 2 hours before plane departure.

In-service Evaluation - TravTek staff will follow-up on the scheduled telephone interviews with participants to discuss progress. This will be outside the functions of trip and system emergencies handled by the TravTek Information Service Center (TISC). However, in-service Evaluation will most likely be handled by TISC.

This phase will help determine the system learning curve and answer routine questions such as problems with the system, misconceptions of the project and/or TravTek system and possible schedule changes, and many more.

Further, participants (business and leisure/vacation) scheduled for the 50 one-on-one personal interviews will be confirmed or solicited, if necessary.

Debriefing - The recruitment monitor will contact participants scheduled for debriefing (selected based on quota at time of briefing and a part of the participant's Project Package). Each debriefing will last less than 20 minutes and will involve at least 50% of the participants. The response group will be balanced demographically and by car ownership.

All participants will be given, or mailed, a detailed survey questionnaire, with postage-paid return envelope, and asked to complete as soon as possible (reinforcement of the possible incentive for questionnaire delivery).

AAA Research staff will monitor the debriefing process. Routine response tabs and verbatims will be available. The appropriate Partner will be notified of any response that might have an immediate impact on the project. Video taping is being considered.

Mail Survey - The principal form of attitudinal data collection will be a mail survey. There will be some overlap between the mail survey and the debriefing questions. The objective is to have responses from a nationally balanced sample with weighing by geographic census division, if possible and also one that is socio/demographically balanced. In some cases, balance on the type of car generally driven is important. Type will be at the make/series level, classified by vehicle segment, e.g., Entry-Near luxury car that includes the Lexus, Infinity, Volvo, Saab, and Peugeot as defined in General Motors' Market Research Proposal dated 2/14/90.

A follow-up telephone call or postcard will be used to enhance response. Routine response tabs will be available to keep Partners

updated.

Other research might be employed such as:

- Telephone Interview - Used to get specific Partner information. This can also increase response if the participant was not a part of the Debriefing sample.
- Focus Groups - depending on participant clustering, focus groups are a viable research tool and can be used for selective Partner research. Focus groups will not include Florida residents or "snow-birds."

APPENDIX I - SUBJECT DEMOGRAPHICS

Probable study factors will be based upon participant demographics, family type, type of traveller, car purchase behavior and ownership. The following tables describe each:

FAMILY TYPE	%
Married Couple HHs	
w/children < 18	31%
w/o " <18*	30
Single Parents Family	
w/children < 18	8
w/o " <18	5
Living Alone	12
Male	
Female	

Table 14. Family type grouping.

CAR OWNERSHIP'	#
Domestic Luxury	3 0 0
Import Luxury	275
Domestic Compact/ Midsize/Large	250
Import Compact/ Midsize	200
Sports Car	2 0 0
Midsize Type "A" Van	175
Sport Utility	150
GH Subsample =	1,550

Table 15. Car ownership grouping.

AAA TENURE	%
<2years	5%
2<5	25
5<10	26
10+	44

Table 16. Tenured grouping.

TYPE OF TRAVELER	%
Leisure/Vacation	85%
Business-Use	15%

Table 17. Business and vacation grouping.

AGE GROUP	U.S.	AAA	GM.
25<35	18%	15%	30%
36<45	15	17	
46<55	10	14	33
56<65	9	19	
66+	13	31	37

Table 18. Age grouping.

PURCHASE BEHAVIOR	%
New Car Buyer*	75%
Used Car Buyer	25%

*Purchase new car at least every 3-4 years.

Table 19. Purchase behavior grouping.

INCOME(k$s)	U.S.	AAA	GM.
<20	37%	19%	30%
20<40	32	34	
40<59	15	24	35
60<74	9	9	
75<99	4	8	
100+	3	6	35

Table 20. Income.

EMPLOYMENT STATUS	%
Employed full time	65
Retired	28
Other	7

Table 21. Employment.

It should be noted that cell quotas will not, in all cases, sum to 100 percent because not all groups within a particular study factor will be sampled.

APPENDIX J - TRAVTEK DATA SOURCES

1. In-vehicle log
   a. Vehicle location, navigation status
   b. Communications to and from TMC, TISC, etc.
   c. Driver interactions with system
2. TMC log
   a. probe reports
   b. incident reports (times, types and sources)
   c. results of dynamic link time calculations
   d. congestion messages, etc. to vehicles
3. TISC log
   a. requests for road service (time, types, vehicle id, outcome, etc.)
   b. HELPLINE requests (driver name, type of request, time, outcome)
4. Avis log
   a. vehicle id, driver info., odometer readings in and out
   b. fueling records
5. Driver fueling log
6. Oldsmobile maintenance log
   a. complaint, diagnosis
   b. part replacement
   c. labor cost
   d. vehicle or component downtime
7. Police/traffic department log
   a. incident reports, etc.
   b. road closings, construction, etc.
   c. citizen complaints
8. Experimental logs
9. Driver Profiles
10 Questionnaire and Interview Data