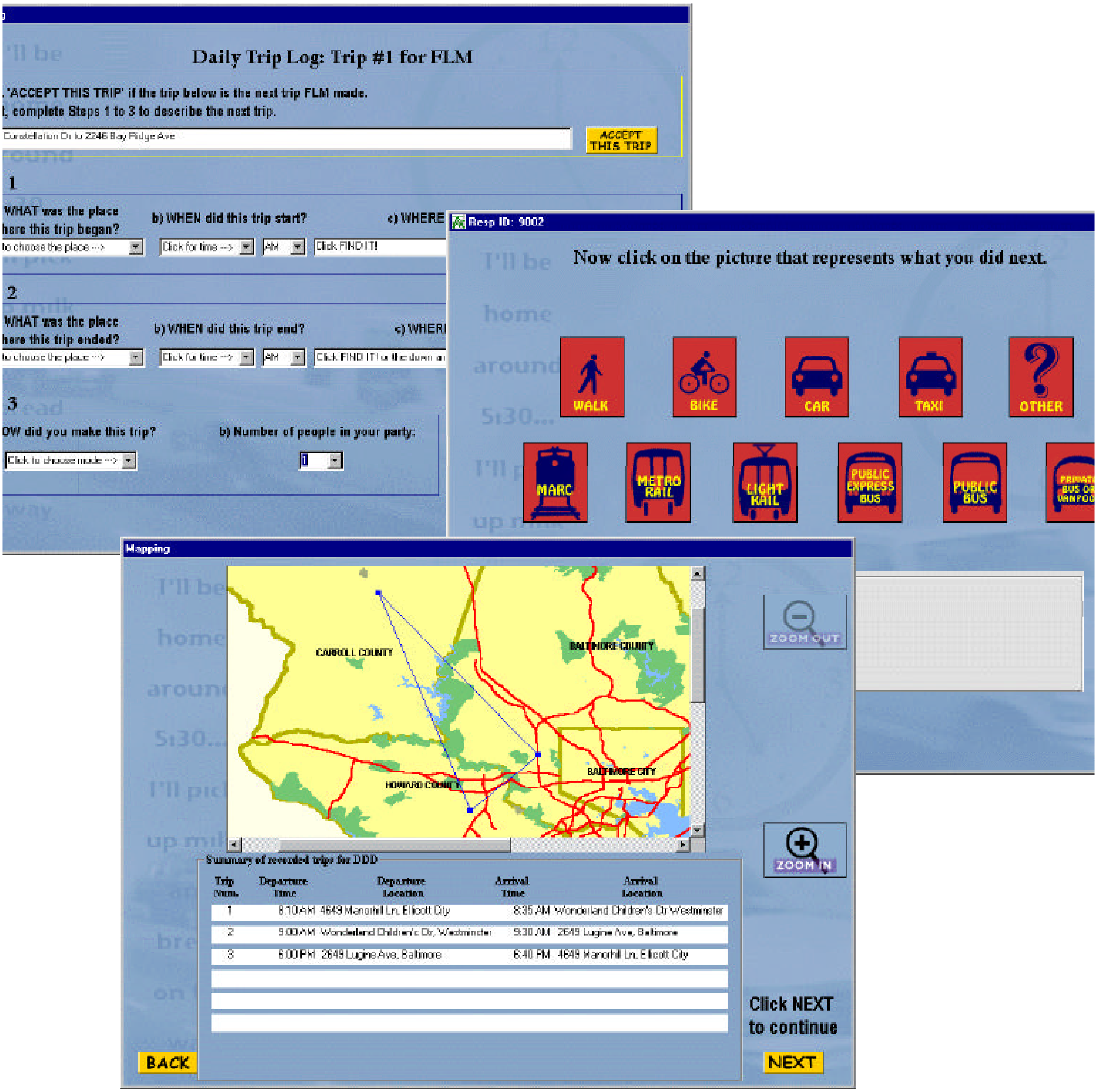
Final Project Report – SBIR Contract No. DTRS57-98-C-00068

Computer-Based Intelligent Travel Survey System: CASI/Internet Travel Diaries with Interactive Geocoding



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PREFACE

This report describes the work that was performed by Resource Systems Group, Inc. under a Phase 1 Small Business Innovation Research (SBIR) contract issued by the US DOT Research and Special Programs Administration's Volpe National Transportation Systems Center. The project's Contracting Officer's Technical Representative was Jerry Everett of the Federal Highway Administration (FHWA) and that role was accepted by Elaine Murakami, also of FHWA, when Jerry resigned to assume a staff position at the University of Tennessee. Elaine had, in any case, been involved with the project since its inception.

Thomas Adler and Leslie Rimmer of Resource Systems Group were the primary authors of this report. Leslie was also the system architect for both the travel diary and for the Baltimore geocoding field test survey. Stephen Lawe was the senior software engineer for the project and several other Resource Systems Group staff participated in various parts of the project work.

ACKNOWLEDGEMENTS

We wish to acknowledge the invaluable assistance and guidance provided by Elaine Murakami and Jerry Everett as Technical Representatives for the project. We especially appreciate Jerry and Elaine's efforts to develop funding for this area of work in the first place and for their enthusiasm in providing technical direction for the work. Several others at FHWA and the Bureau of Transportation Statistics attended project meetings and offered helpful suggestions along the way. Finally, we wish to thank the Baltimore Metropolitan Council, its modeling peer review panel and our project contractor, URS/Greiner, Woodward and Clyde for providing us the opportunity to field a survey that included respondent-interactive geocoding.

Any errors or omissions in this report are, however, the sole responsibility of the authors.

PROJECT SUMMARY

The purpose of this project was to improve travel survey instruments by including interactive geocoding and the additional “intelligence” that is provided by this geographic information, and by improving the way in which surveys are administered. Although the project has applications to all types of travel surveys, the focus of this SBIR Phase 1 study was narrowed to Internet-based Computer Assisted Self-Interview (CASI) travel surveys using respondent-interactive geocoding. This focus builds on the technologies that Resource Systems Group had previously developed and applied and complements a concurrent GeoSystems SBIR Phase 1 study whose focus was Computer Assisted Telephone Interviewing (CATI) with operator geocoding.

Software was developed for two particular travel survey applications: conventional travel/activity diaries and revealed/stated preference surveys to support mode choice model development. The former is an obvious and important travel survey application while the latter is a type of application in which the additional adaptation allowed by geographic information can very significantly enhance the survey. The travel diary software was developed to a functioning prototype level. The mode choice survey application was developed and refined to support a full field application.

The respondent-interactive geocoding module is common to both of the survey applications developed in this work. The geocoding module supports four alternative respondent input options: street address, nearest intersection, establishment (business) name and direct map point-and-click. The field application demonstrated that respondents use, and often need, each of these options to accurately identify the place that they visited. This is particularly the case for non-home, non-work destinations, for which most respondents simply do not know an actual street address.

This report also describes experience with CASI and Internet survey instruments and provides guidelines, based on this past experience, for further development of Internet-based administration options for travel surveys.

There is clearly an opportunity to use the approaches described here to both improve the quality of travel survey data and to reduce the cost of the data collection. We expect that these approaches will increasingly find their way into travel surveys. We hope that the travel data that are produced can improve the quality of travel demand models and, ultimately, of the transportation planning decisions that result from their use.

1. INTRODUCTION

Travel surveys almost universally require the collection of geographic information. In most cases, this geographic information is collected from the respondent and processed after the survey is completed. This "post-processing" inevitably results in information being lost because the respondent does not provide enough information to accurately place the geographic locations reported. Equally significant is the opportunity lost in not being able to use the geographic information to adapt the questionnaire to the respondent's conditions.

The purpose of this project was to create new travel survey instruments that include interactive geocoding and the additional "intelligence" that is provided by this geographic information. Potential applications include the full range of travel survey types for which computer-based administration is used. Although the project has applications that span this range, the focus of this SBIR Phase 1 study was narrowed to Computer Assisted Self-Interview (CASI) surveys. This focus builds on the technologies that Resource Systems Group had previously developed and applied and complements the concurrent GeoSystems SBIR Phase 1 study whose focus is Computer Assisted Telephone Interviewing (CATI).

The prototype development further focuses on two particular travel survey applications: conventional travel diaries and stated preference surveys for mode choice model development. The former is the most obvious and direct travel survey application while the latter is a type of application in which the additional adaptation allowed by geographic information can very significantly enhance the survey.

This report begins by summarizing the travel survey needs and issues that this project was designed to address. General functional specifications are outlined for travel survey applications, for geocoding software and for supporting geographic data. Two software prototypes that incorporate the interactive geocoding concepts are described: a demonstration version of a travel diary survey and a fully functional stated preference survey that was fielded for a mode choice model development project in Baltimore. The report concludes with recommendations for next steps and an implementation plan.

2. TRAVEL SURVEY NEEDS AND ISSUES

TRAVEL SURVEY APPLICATIONS

Travel surveys are used for a wide variety of purposes and are administered in a similarly wide variety of forms. A review conducted for the Travel Model Improvement Program (TMIP) tabulated the surveys that were conducted by a selected set of 65 Metropolitan Planning Organizations (MPOs) and found that each conducted, on average, between two and three surveys over about five years. These included household travel/activity diary surveys, stated preference surveys, vehicle intercepts (origin-destination), panel surveys, visitor surveys and transit on-board surveys.[1] The household surveys alone covered almost 200,000 respondents (over 500,000 contacts) and cost well over $12 million to conduct.

In addition to those surveys conducted by MPOs, the US DOT, state DOTs, transit agencies and others involved in transportation planning commission conduct many surveys directly. The US DOT's National Personal Transportation Survey (NPTS) and American Travel Survey are among the largest and most prominent travel surveys. Resource Systems Group alone has conducted more than 50 travel surveys for organizations other than MPOs since 1990. These include general travel/attitude surveys, policy-directed surveys (e.g. congestion pricing), surveys to support Major Investment Studies, corridor-oriented surveys, customer satisfaction surveys and several other types.

In general, it can be said that surveys have become an integral tool in the transportation planning process. This has been attributed in part to the more sophisticated modeling needs occasioned by the 1990 Clean Air Act Amendments (CAA) and the 1991 Interstate Transportation Efficiency Act (ISTEA).[2] ISTEA's successor, TEA-21, and the additional model enhancements coming out of US DOT and US EPA's Travel Model Improvement Program (TMIP) create additional demands on travel survey applications. However, the increased use of travel surveys could also be seen as simply mirroring the increased use of survey research in all sectors. Surveys can be (and generally are) the most direct and cost effective way to answer basic questions about consumer markets.

TRAVEL SURVEY METHODS

In part because of the wide variety of survey applications in transportation planning, there are many approaches used to administer the surveys. Residence-based phone, mail and, much less commonly, direct home interviews are used for general travel/activity diary surveys. Phone recruitment and interviewing have become very widely used in this type of survey, in some cases in a hybrid phone/mail/phone type of administration. This in large part results from the low cost of, and virtually universal access to, telephone service, combined with the increased efficiency afforded by modern Computer-Assisted Telephone Interviewing (CATI) systems.

Intercept surveys are generally used to capture information about travelers who are not easily found using residence-based random sampling. These can include travelers in a particular corridor, transit passengers, visitors or others who comprise a small portion of the resident population but who can be found at particular locations. Intercept methods have also been used to survey populations who can, in theory, be easily found at their residence but who may not be willing to take the time, while at home, to complete a detailed telephone or mail questionnaire.

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[1] Cambridge Systematics, *Scan of Recent Travel Surveys*, US DOT Report DOT-T-97-08, June 1996.
[2] See, for example, Cambridge Systematics, *Travel Survey Manual*, US DOT Publication FHWA-PL-96-029, July 1996.

Resource Systems Group has used Computer Assisted Self Interviewing (CASI) extensively in this type of application, conducting intercepts at motor vehicle registration centers, transportation terminals, shopping malls, rest areas and other locations where portions of the target population often find themselves with "time on their hands". Care must be taken to balance locations to avoid sampling biases, but the advantage is that response rates can be measurably higher than using conventional telephone or mail sampling. CASI surveys can also use graphics, icons and other visual tools to assist the respondent and hold attention.

While many travel surveys are conducted using a single type of administration, there are also many applications where multiple methods are used to collect the necessary information. The most common of these is the use of on-board transit intercept surveys to augment samples collected using residence-based surveys. With transit shares in most U. S. cities well below 10%, the data derived from a random sampling of residences does not typically provide sufficient coverage of transit riders to support mode choice model estimation. On-board sampling enriches the residence-based sample. This combined "choice-based" sample can then be used to efficiently estimate mode choice models.[3]

Multiple administration methods can also be combined with multiple instruments to more effectively sample all segments of the population. For example, phone can be used for a general residence-based sample with pencil-and-paper interviewing (PAPI) for transit on-board sampling. The alternative instruments may be used because other instruments do not provide access to the target population or because the alternatives provide some substantive or cost advantage. For example, Resource Systems Group has designed and conducted surveys with four distinct, but exactly parallel instruments to access different segments of the target population: phone (CATI), intercept CASI, toll plaza and transit on-board PAPI and Internet (CASI) with phone and toll plaza recruit.

In one survey, phone recruiting was used to capture electronic toll subscribers (whose phone numbers were provided) and a random sample of area residents; all phone recruits were given CATI or Internet completion options. The CASI intercept was used to capture a broader sample of those who are not easily captured by phone recruit. The toll plaza intercept was used to capture non-residents; all were given the option of PAPI or Internet instruments.[4] The experience with this survey was that the multiple methods can be used to derive consistent information and that providing the option of Internet completion reached segments of the population that have proved increasingly elusive to telephone interviewing: the more affluent, mobile professionals.

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[3] Ben-Akiva, M.E. and S.R. Lerman, *Discrete Choice Analysis*, MIT Press, 1996.

[4] Adler, T.J., W. Ristau and S. Falzarano, "Traveler Reactions to Congestion Pricing Concepts for New York's Tappan *Transportation Research Record*, forthcoming, 1999.

GEOGRAPHIC INFORMATION IN TRAVEL SURVEYS

As discussed above, travel surveys are conducted for a wide variety of purposes. However, there is one commonality among virtually all major travel surveys: the need to collect geographic information to describe the location of the respondent and/or the locations of trips made (or to be made) by the respondent. Transportation service has a spatial dimension that, generally, is an important context to travel surveys. Geographic location information provided by respondents can be used to determine the part of the transportation service that is available and how the respondent might use the system.

In practice, most travel surveys collect geographic data but use those data only after the survey is complete and the data have been converted into "geocodes". Performing geocoding interactively – at the time that a respondent is completing a travel survey – can provide substantial benefits to the quality and efficiency of the data collection. First, the respondent/interviewer can flexibly use any combination of business name, street address or nearest intersection to verify a match to the location of interest and can correct any error before the interview proceeds. This substantially reduces the error associated with these data. Second, post-processing and manual geocoding become unnecessary; eliminating a time-consuming, expensive and generally tedious task. Third, a higher level of geographic precision can be assured in the process, sometimes by eliciting from the respondent successive place refinements. Finally, real-time, interactive geocoding enables an "intelligent interview" that can use the trip origins and destinations to dynamically configure other elements of the travel survey.

The dramatically improved efficiencies and accuracy that can be achieved by interactive geocoding are sufficient justification for significant investment in the technologies that enable this approach. However, the ancillary benefits in enabling more intelligent adaptive travel interviews are perhaps an even more important motivation for these technologies. Knowing a respondent's trip origin and destination allows subsequent responses (such as travel mode and trip length) to be screened for consistency with known travel conditions. It allows more detailed probing of issues that apply only within certain subareas of the region. Finally, information about a traveler's origin and destination enables stated preference and other "future conditions" questions to be framed within the more realistic context of the known travel conditions for the respondent's current trips.

The importance of obtaining accurate origin and destination information, and using that information to adapt the remainder of the travel survey increases with more sophisticated travel forecasting models. For example, the data required to support the very detailed activity-based trip/travel planner component of TRANSIMS can be derived only from very detailed and sophisticated activity/travel surveys.[5]

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[5] *TRANSIMS Model Design Criteria*, Travel Model Improvement Program, US DOT/US EPA, June 1995.

A NEW APPROACH TO TRAVEL SURVEYING

Three particular travel survey approaches can be applied to augment those that have been used in past work.

1. **Computer-Assisted Self Interviewing (CASI)** –Resource Systems Group has used a set of graphically-rich CASI survey instruments (IVIS –Interactive Video Interview Station) in dozens of past travel survey applications. Experience with these instruments has indicated that the graphical user interface, photographic images, icons and other related “multimedia” elements hold respondent interest, improve accuracy and increase response rate.
2. **Internet administration** –Internet is becoming a viable option for reaching selected segments of the population and as one option within a multi-method survey. Internet is an attractive alternative to phone or other administration options for at least three reasons. First, similar graphically-rich elements can be used as in other CASI surveys. Second, the Internet option appears to be preferred by affluent, mobile professionals who have high refusal rates in phone-only surveys. And, third, Internet surveys can be highly cost-effective; the marginal costs consist only of those for whatever recruitment methods are used.
3. **Respondent interactive geocoding** –The advantages of interactive geocoding are enumerated above: improvements in the accuracy of location information, reduction in post-processing cost, increased geographic precision and the enabling of adaptive “intelligent” survey elements.

The objective of this project is to develop tools that enable these approaches to be applied to travel surveys. The following sections of this report outline the general specifications and initial trials of these approaches.

3. FUNCTIONAL SPECIFICATIONS

There are at least four “layers” of detail that are involved in creating travel survey software that accomplishes the project objectives. In this section, the basic requirements of CASI travel survey applications, of the software to enable interactive geocoding, of the data that supports the geocoding and of Internet administration are outlined.

CASI TRAVEL SURVEY APPLICATIONS

Travel surveys that are conducted as computer-assisted self-interviews (CASI) can take advantage of the internal branching and error checking that computer interviewing enable and, in addition, can use graphics to facilitate respondent tasks. The ways in which these capabilities are used in travel surveys depend in part on the specific type of survey being conducted. For the purposes of this project, travel/activity diaries have been selected as the focus. For these, as for other types of travel surveys, a key purpose of the questionnaire is to collect information about trips that were made or activities that were undertaken by the responding household. However, the questionnaire should also collect information about the household's structure and other factors that influence its travel needs.

The following are questionnaire elements that form the core of many travel surveys, including travel diaries.

- Household structure
    - Number of adults, children
    - Number of licensed drivers
    - Socio-economic status
- Trip information – for all trips made by all members of the household
    - Trip start and end times
    - Activities at trip ends (purposes)
    - Travel mode
        - For auto – occupancy, operating and parking costs
        - For transit – submode, access/egress modes, fare, breakdown of travel time (access, ride, egress), party size
    - Location of trip origin/destination

The advantage of a computer-based survey is that answers can be verified and checked for consistency with the previously entered information. In general, "error-trapping" is performed for three classes of errors:

1. Logical Errors – which are not possible or inconsistent with previously answered information.
2. Procedural Errors – which are unlikely, but possible, given the other information which is known about the household.
3. Missing Information – cases where the respondent simply neglected to answer a question.

Logical error-traps catch answers that are impossible such as a trip end time being earlier than a trip start time. Although the survey is relatively simple to complete, there are several logical error-traps that can be performed. A sample of other logical error traps include:

- A family member under 15 who claims to have a drivers' license
- A family member claiming to be over 150 years old
- An auto trip with 3 occupants shared by more than 3 members in the household.
- A trip that started and ended at the same location.

Procedural error-traps involve answers that seem unlikely but may be possible. In these instances, warnings are given to the respondent. The respondent may then elect to continue or correct the answer. Examples of procedural error-traps include:

- A family that collectively made no trips
- A person who does not return home at the end of the day
- A person who leaves home by auto but returns by transit
- A person who leaves home by transit and returns by auto

Finally, missing information is simply answers that the respondent neglects to fill out. In these instances, the user is prompted. This level of real-time help assists the respondent and assures that the survey is filled out completely and accurately.

GEOCODING SOFTWARE

The ability to display maps and geo-reference locations is an important part of the survey software. With this capability, the respondent is provided with several alternative methods for identifying locations including:

1. selecting a location on the map,
2. entering the closest intersection,
3. entering the street address, and
4. searching a list of businesses

Respondents' entries can be validated and they can be provided with a visual representation of their trip. These capabilities result in an efficient way to collect and validate geographic information. In addition to storing the street address of each location, using a geo-referenced map also allows the collection of longitude and latitude values. This information provides flexibility in using the results. For instance, instead of storing only a predefined Transportation Analysis Zone (TAZ), also storing the longitude and latitude allows the data to be useful even after changes are made to a zone structure.

SOFTWARE VENDORS

To support these capabilities, a Geographic Information System (GIS) software package called MapObjects developed by Environmental Systems Research Institute, Inc. (ESRI) is being used. MapObjects is a collection of tools that programmers can use to create GIS enabled software packages.

Prior to selecting MapObjects, the full range of available GIS options was explored. MapObjects was chosen primarily because it:

1. supports both stand-alone and internet applications,
2. supports a wide range of different data conventions,
3. is accessible from high-level development languages such as Visual Basic, C, and C^{++},
4. has an intuitive object-based environment, and
5. has a well defined upgrade path and is developed by a well-established GIS industry leader (ESRI)

While there are several GIS packages on the market today, very few of these have been “deconstructed” into a set of software tools that can be used by developers. Even fewer support Internet applications. Table 1 lists the software packages considered, the firms that offer them, and a brief overview of the software features.

Table 1: GIS Packages

PRODUCT	DEVELOPER	OVERVIEW
MapObjects 2.0	ESRI	Internet toolbox of GIS developer hooks
MapObjects 1.2	ESRI	Windows based toolbox of GIS developer hooks
MapObjects LT	ESRI	Simplified set compared to MapObjects 1.2
ArcView 3.1	ESRI	GIS application with developer hooks
AutoCad Map 3.0	AutoDesk	Links GIS to AutoCad
AutoDesk MapGuide	AutoDesk	Internet based application
AutoDesk World	AutoDesk	GIS components for developers
Maptitude	Caliper	Simplified GIS application enhanced by GISDK
Transcad	Caliper	Transportation-rich GIS application with developer hooks
GIS+ 3.0	Caliper	Simplified GIS application can be linked through OLE to other applications
GISDK	Caliper	Provides applications or webs sites with GIS Support
GeoEngine	ETAK	Fast Windows based toolbox of GIS developer hooks
QueryEngine	ETAK	Database query developer tools
PathEngine	ETAK	Calculates the best route between two locations
NavEngine	ETAK	Real-time navigation acquisition of vehicles
UfosNet	RST International Inc.	Windows-based implementation of the 4-step travel demand modeling process
Connect	MapQuest	Internet maps and driving directions in real time for other internet sites
InterConnect	MapQuest	Internet maps and driving directions in real time for other internet sites
TripConnect Plus	MapQuest	Internet maps and driving directions in real time for other internet sites
MapInfo Professional	MapInfo	Desktop and client/server mapping software
MapBasic	MapInfo	Programming language for MapInfo Professional
MapX	MapInfo	OCX to add mapping features within Windows applications
MapXtreme	MapInfo	Internet map server
MapMarker	MapInfo	Geocoding software that supports internet use
Manifold	Manifold Net Ltd.	Inexpensive GIS with built-in mathematical algorithms
GeoMedia	Intergraph Corp.	GIS software
GeoMedia Network	Intergraph Corp.	Extensions for network analysis
GeoMedia Web Map	Intergraph Corp.	Internet map server
IguanaSpace	Iguana, Inc.	Desktop manager for GIS and transportation software
IguanaWebWorks	Iguana, Inc.	Internet access to transportation models

GEOGRAPHIC DATA

DATA VENDORS

For this project six sources of data for mapping were considered. The table below lists each source and highlights the differences related to price, navigational quality and geocode rate, which are the key functional criteria for this component. For the Baltimore study, GDT's Dynamap 2000 data was chosen since it has a high reported geocode rate and Resource Systems Group was able to negotiate an affordable price as a value-added reseller.

Table 2: Geographic Data Vendors

NAME/VENDOR	ADVANTAGES	DISADVANTAGES
US Census Tiger Files	Very inexpensive, 1997/98 now available	Low geocode rates, low navigational quality
ETAK	High navigational quality	Lower geocode rates than Dynamap 2000, expensive
Navtech	High navigational quality	Lower geocode rates than Dynamap 2000, expensive
MPO	Varies: Can have high geocode rates, up-to-date	Not available in all areas, may have use restrictions
GDT's Dynamap 1000	Very inexpensive	Not up-to-date
GDT's Dynamap 2000	Affordable, high geocode rates, up-to-date	Navigational quality not as high as ETAK and Navtech

A business database for the entire six-county Baltimore region was purchased from Database America (ABI). Records were screened to include businesses of five or more employees and exclude businesses related to industry and manufacturing with fewer than ten employees. The final dataset included over 58,000 records that were "pre-geocoded" using Dynamap 2000. The Dynamap database was able to geocode almost 95% of the total ABI records.

INTERNET ADMINISTRATION

Internet surveying has grown significantly over the past several years, providing a substantial amount of experience about how to appropriately administer surveys in this medium. The following are the general guidelines that Resource Systems Group has used in its Internet survey applications and which would be applied to any travel diaries developed as part of this effort.

1. **Internet completion should be provided as an *option* as part of a multi-method, multi-instrument survey.** Although up to 50% of adults in areas of the U.S. have access to the Internet, the Internet population is not representative of the full population. Resource Systems Group's past Internet survey work has indicated that response rates among selected

segments of the population can be increased by offering Internet completion. However, those who do not have Internet access must be given equivalent opportunities to participate in the survey.

2. **For most travel survey applications, the Internet itself should not be used as the medium for recruiting participants.** The Internet population is not a random subset of the full population and the portion that can be reached by any point(s) of access is a further selective subset. For the majority of "mainstream" travel survey applications, recruiting to an Internet instrument should be done using telephone, mail, intercept or other methods equivalent to those being used for the other instruments.

3. **Access to the questionnaire should be provided only through a respondent-unique, secure point of entry.** It is critical to ensure that each recruited respondent has the opportunity to complete one and only one questionnaire, that the questionnaire can be completed over multiple sessions and that others who are not recruited do not complete the survey. This can be accomplished using either passwords or entry points that are uniquely assigned to each recruited participant.

4. **The questionnaire should use standard browser input devices or equivalent devices whose use is easily interpreted.** Internet browsers have set a de facto user interface standard. In some cases, the standard input devices are quite appropriate for questionnaire responses. However, different devices can be programmed which, in other cases, provide easier-to-use and more intuitive input options and these should be used where appropriate.

5. **The questionnaire should be programmed to allow access from the most common browsers and operating systems.** A baseline browser level that encompasses 90% or more of those in current use should be set as the programming target. For those using browsers below the baseline, a version update link should be provided. Java, JavaScript and Dynamic HTML can be used to enhance the questionnaire for those browsers that support those capabilities, but an alternative basic version must be available for those whose browsers have incompatibilities with these enhancements.

6. **The questionnaire should provide a low bandwidth alternative.** It should be expected that respondents will have connect speeds that vary by a factor of ten or more. In general, the survey should be programmed using the wide variety of bandwidth-conserving techniques that are available such that users at the low bandwidth end do not experience significant form loading or response delays. In some cases, it may be appropriate to program both high and low bandwidth versions of a questionnaire. However, there is little or no empirical experience to indicate how differences in the versions might affect response so the use of alternative versions should be taken with caution.

7. **On-line and off-line support should be available to all respondents.** Inevitably, some respondents will have technical problems or will have questions about the survey purpose or content. "Live" support should be prominently offered through both e-mail and toll-free telephone lines.

A survey that is developed with an Internet administration option that follows these guidelines should provide data that are equivalent with those data provided by other methods, assuming that other elements of the instruments are directly parallel.

4. PROTOTYPE DEVELOPMENT AND TESTING

A key part of this project was the development of a proof-of-concept software demo. Initially, it was expected that this would take the form of a partial prototype, implementing only the key features of the approach. However, development of the geocoding software module proceeded more rapidly than initially expected and this allowed more time to be spent on development of other elements of the travel diary application. It also allowed the geocoding module to be used in a mode choice survey application that had been planned for the Baltimore MPO. The following sections describe these two applications.

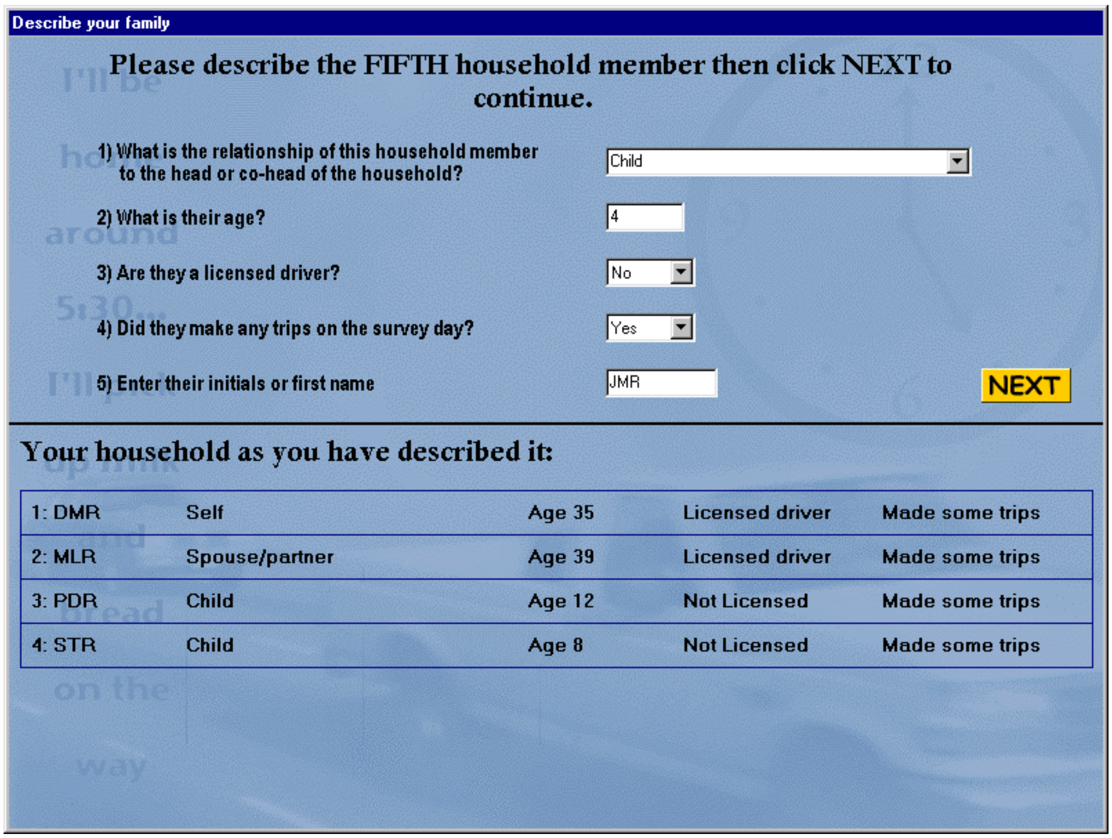
TRAVEL DIARY

The prototype software is designed to demonstrate most of the capabilities that could be programmed into an Internet-based travel diary system. Throughout the design and development phases, particular emphasis was placed on reducing the burden that is placed on respondents who are asked to complete travel diaries for their entire household. Since the software is targeted for Internet administration, it was assumed that users would have some computer skills including experience with navigating with a mouse and using common Internet controls. In the event that users would require assistance, access to on-line context-specific help and technical assistance via a toll-free phone line would be available.

In an Internet administration environment, respondents who are recruited to participate would be assigned a URL (Universal Resource Locator - web address) and password or, if they have e-mail, would be sent a unique entry address. When they are ready to complete the travel diary they would log onto the site and input their password or access via the unique entry point to gain access to the survey questionnaire. They could exit without finishing the survey, and continue where they left off at a later date by reentering their password. This allows those who have easy access to the Internet to fill out their trips at different times of the day, as convenient.

On entering the questionnaire, the respondent is given a brief introduction and instructions on how to complete the survey. The respondent is then instructed to complete a preliminary form to describe each member of the household. Following the completion of this form (Figure 1), each household member has a unique identifier and it is known whether or not each person made trips on the survey day.

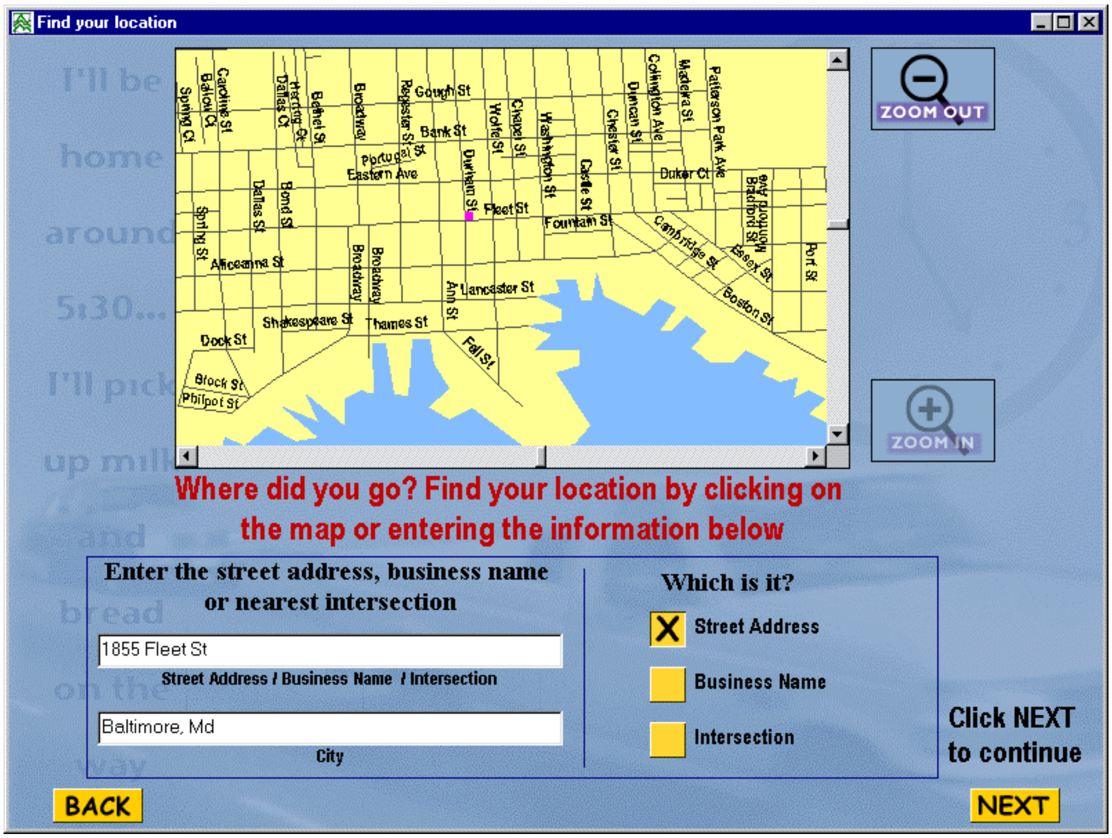
Figure 1: Describe Household Members



The next form contains the Trip Log. Household members who made trips are asked to supply information for every trip they made throughout the day including purpose, time, location, mode and party size. Locations can be geocoded using street address, business name, nearest intersection, or by clicking on a map (Figure 2).

Transit users are asked to further describe the access, egress and line haul modes they used in making their trip. For any trip with a party size of two or more, the respondent is prompted to indicate which, if any, household members made the trip with them. This information is used for subsequent household members who shared trips, eliminating the need for them to re-enter trip information that was previously supplied in an earlier entry ~~a~~ concept called “rostering” which is described in more detail later in this section.

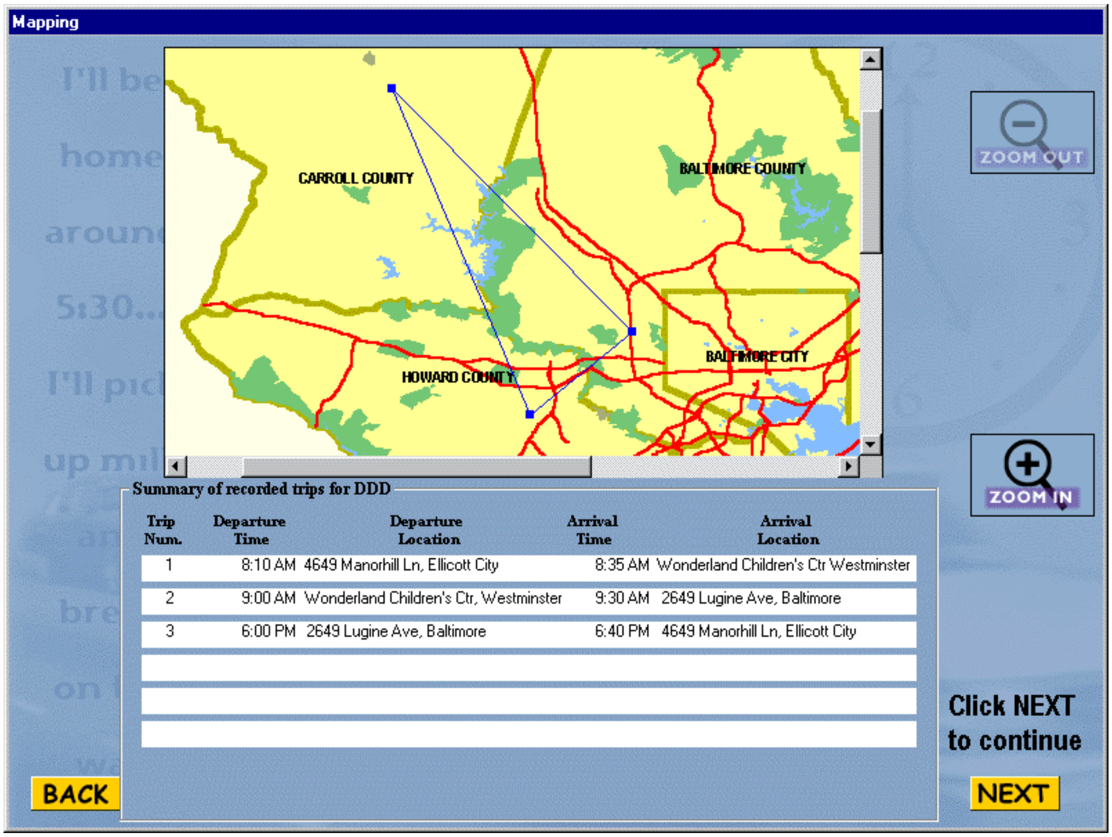
Figure 2: Type Address, Business, Intersection, or Click the Map



Once a trip has been completely described, the user records the trip by clicking a button prompting the software to perform a series of diagnostic checks to ensure that all the information is accurate. If any inconsistencies are detected, the user receives a message describing the error so they can make corrections. Once all inconsistencies are corrected, the user is presented with several options: 1) start a new trip for the current household member; 2) display the current trip log; 3) start a new trip log for the next household member; or 4) go to the final section. Appendix B contains a complete list of error messages and consistency checks contained in this initial test version of the software.

Selecting the option to start a new trip for the current household member resets the trip log form. The destination information from the previous trip is moved to the origin information of the new trip eliminating the need for the user to enter redundant information. Also, once the home location has been geocoded, all subsequent trips beginning at a location defined as home are automatically geocoded for the user. If the user wants to display the current trip log, the locations previously geocoded are shown on the map connected by lines in the order in which the trips were made. A text-based summary of the log is also displayed on the same form (Figure 3). In the Internet implementation of the travel diary, the text-based summary will be editable.

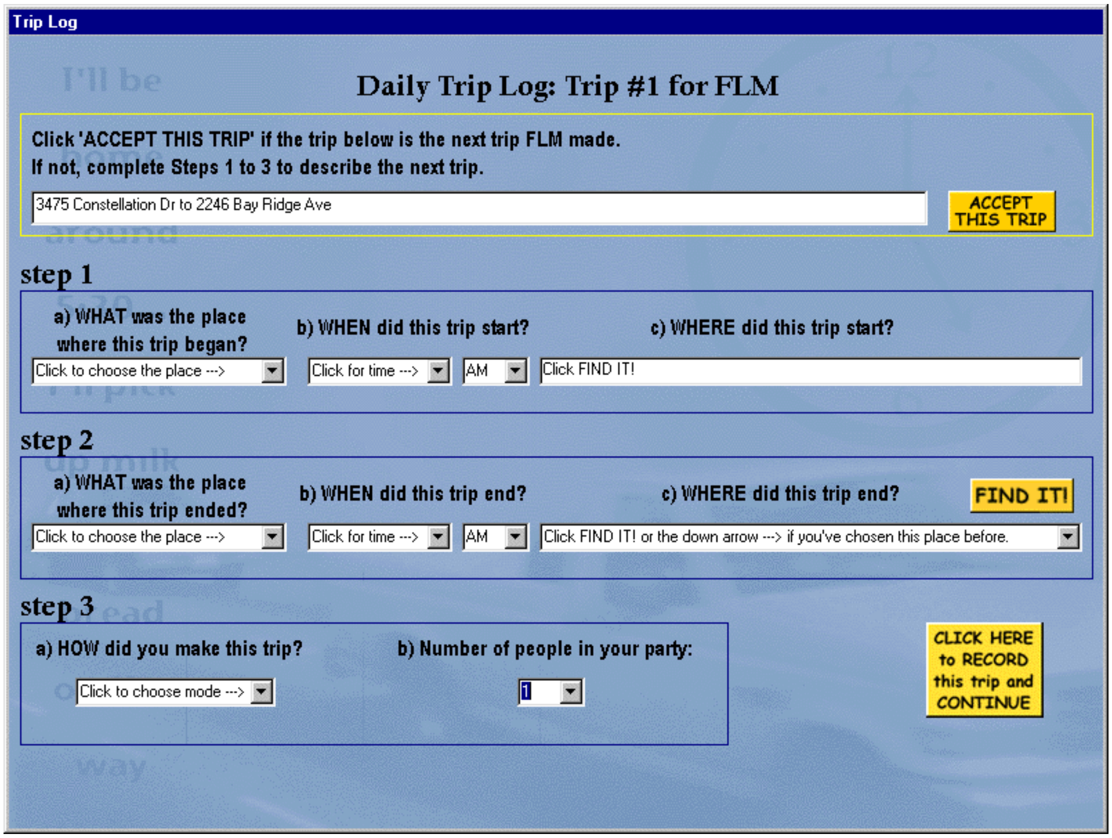
Figure 3: Display Current Trip Log



When the user is ready to start a new trip log for the next household member, the software first searches through all of the previously logged (or *rostered*) trips to see if the new household member shared a trip with a previous household member. If a match is found, the earliest shared trip that the new household member made is shown at the top of the log (Figure 4). The user has the option of accepting the rostered trip or describing a new one. Particularly for non-licensed household members (i.e., children) who made all their trips with other household members (i.e., parents) the rostering capability significantly improves the efficiency of logging trips.

Once the travel diaries are completed for every household member who made trips, the user is directed to a form containing demographic questions. These questions can be easily customized to include the information that will be used for a particular application. In the prototype software, questions regarding income, housing type, vehicles owned and free-form comments are included.

Figure 4: Rostered Trip



MODE CHOICE SURVEY

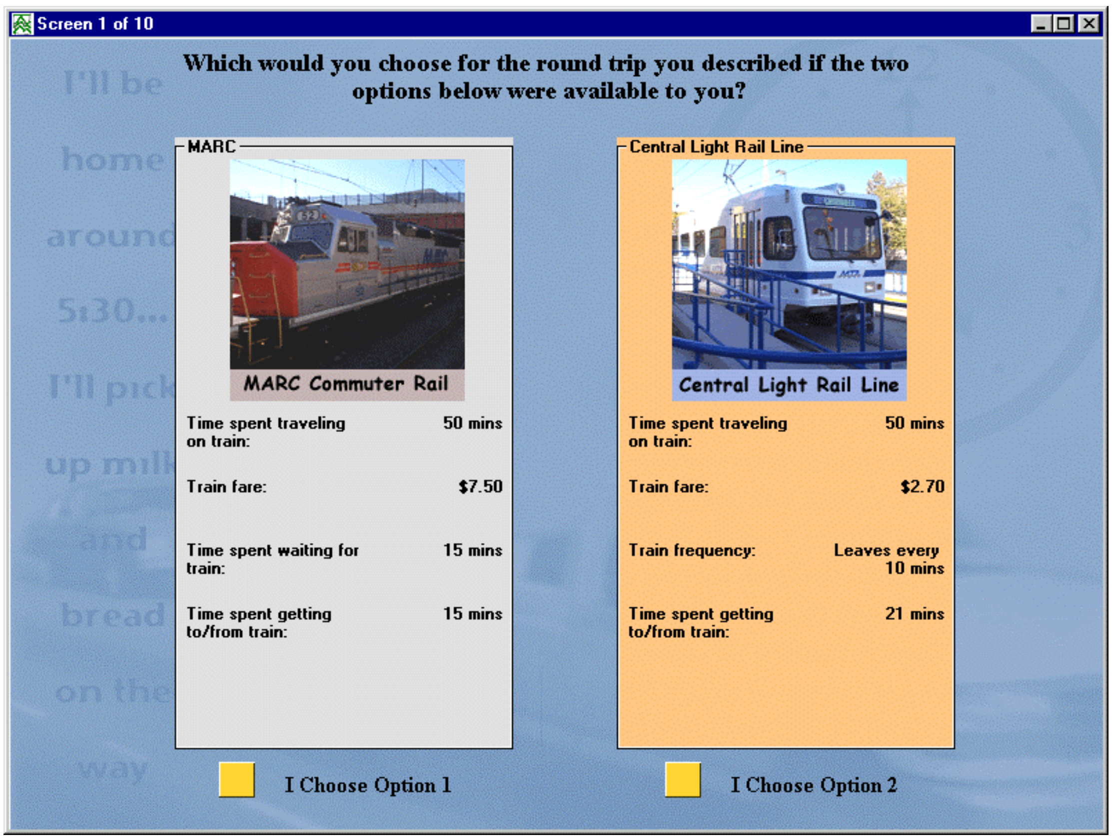
While the prototype software was being developed for this contract, the Baltimore Metropolitan Council (BMC) contracted with URS Greiner, Woodward and Clyde (URS) to update their regional travel demand model. URS subcontracted with Resource Systems Group for the development and analysis of a survey to support mode choice modeling. The timing of this BMC contract provided an opportunity to field test the respondent-interactive geocoding component of the software that was being developed for the SBIR contract. Specifically, the field test would provide information about how users would respond to the geocoding interface.

SURVEY DESIGN

The survey was designed to collect both “revealed preference” and “stated preference” mode choice information about a recent round trip the respondent made that began and ended at their home and was made by either car or public transportation. The questionnaire contained five main sections: 1) general trip questions; 2) a description of the current and potential future travel options in the region; 3) context-specific stated preference exercises; 4) household questions; and 5) questions regarding computer use and Internet access. The general trip questions focused on the details of the round trip the respondents were asked to describe including times, costs, mode and party size. Every trip was geocoded using the technology developed for the prototype software. The BMC supplied a TAZ data layer so each location was geocoded to both to latitude/longitude and TAZ. The latitude/longitude data will allow the BMC to reassign the data if the TAZ structure changes in the future.

A set of ten stated preference mode choice experiments was constructed using the information provided by the respondent. The experiments allowed the respondents to trade-off key service attributes such as travel time, cost, transit headway and the overall attractiveness of mode alternatives (Figure 5).

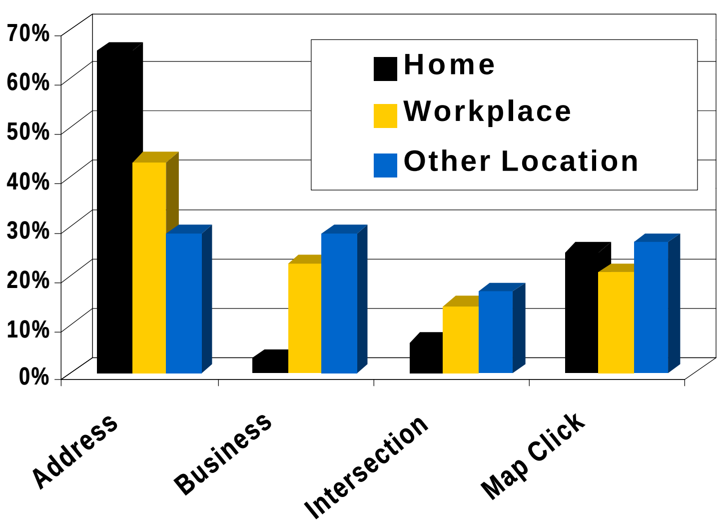
Figure 5: Example State-Preference Screen



The survey was administered to more than 600 residents of the Baltimore region over a seventeen-day period. Sites were selected in each of the six outlying counties and Baltimore City based on a previously established survey sampling plan and including shopping malls, office parks, drivers' licensing facilities and welfare centers. Four laptop computers were set up in each location. Passersby were intercepted in areas proximate to the survey site and screened for participation in the survey. No incentive was provided to respondents.

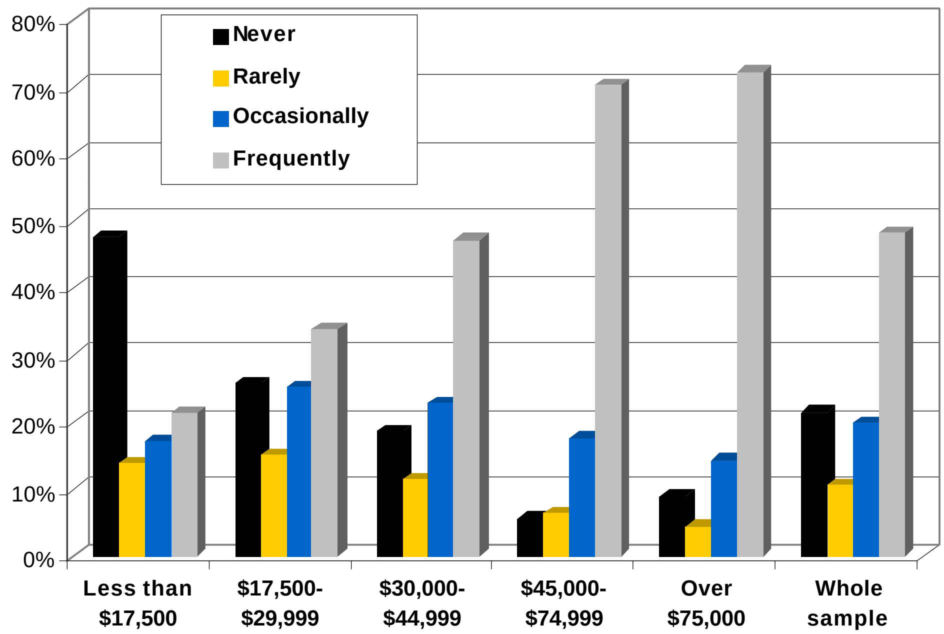
In addition to the geographic information, the survey software gathered data on the respondents' interaction with the geocoding module. These data differentiated among the four geocoding methods (street address, business name, nearest intersection, or direct click on map) that were available for the respondents to use. They show that respondents used different methods depending on the type of trip they were describing (Figure 9). The majority of home and work locations were geocoded using street address while trips made for other purposes were geocoded using all four methods. Address-based geocoding was successful as a first attempt approximately half the time. The fall-back (and fail safe) method respondents used when other methods failed was map point-and-click. On average, respondents required approximately two attempts to successfully match their location, and the data show that success rates improved within surveys, indicating a learning effect.

Figure 9: Geocoding Methods by Location Type



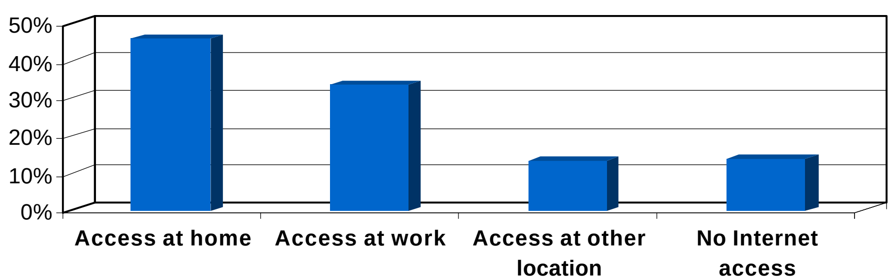
Several questions were asked regarding computer use to determine the fraction who would likely use an Internet-based survey option. Twenty-one percent of the sample indicated they never use computers, while almost 50% use computers frequently (Figure 6). Computer use is strongly related to income. Almost half of the lowest income respondents never use computers, while over 70% of the highest income respondents use computers frequently.

Figure 6: Frequency of Computer Use



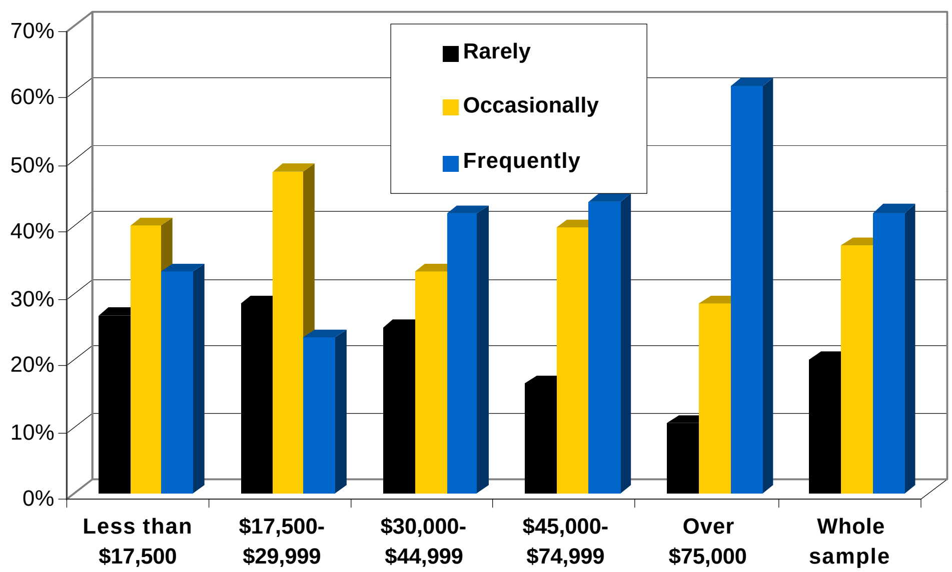
Of the respondents who use computers, 14% do not have access to the Internet (Figure 7). The figure below shows the locations where Internet users have access. It should be noted that this question was asked in a multiple select format so users who have access both at home and work would select both options.

Figure 7: Computer Users' Location of Internet Access



A final question regarding frequency of Internet use was posed to computer users who indicated they had Internet access at a minimum of one location. Over 40% indicated that they use the Internet frequently (Figure 8). While still present, the income effect was not as pronounced when compared to computer use.

Figure 8: Internet Users' Frequency of Internet Use



The Baltimore field experience indicated that respondent-interactive geocoding is a viable approach and that respondents use a variety of methods for specifying geographic locations. While addresses and nearest intersections are commonly requested in travel surveys, respondents prefer to use business names and map point-and-click options, when they are provided, for some locations. It is also clear that a sufficiently large and diverse segment of the population currently has access to the Internet so that an Internet survey option should be provided.

5. IMPLEMENTATION PLAN

The work to date demonstrates that the approach is technically feasible now and provides substantial advantages over conventional survey methods. The software is already developed to a point where Resource Systems Group will begin marketing the approach for any new travel survey projects. Independent of this project, the core software used for the interactive geocoding module will improve (e.g., the next version of MapObjects will allow more control over map appearance), the accuracy of the geographic data will improve and the population's access to computers and Internet will increase. However, there is still significant testing, refinement and enhancement that is required to develop the product so that it is positioned for full deployment across the range of applications. Six areas of further work have been identified which will ensure that the approach is adopted for appropriate applications.

1. **Conversion of the prototype travel diary to Internet field-ready.** The current travel diary prototype was programmed as a proof-of-concept and requires further development in three areas before a full field application. First, the existing application should be pre-tested with a small sample to develop refinements to the questionnaire flow and formatting. Second, the Internet conversion should be completed and tested under the baseline target browsers. And third, the questionnaire should be customized to meet the needs of the agencies with which field applications are planned.

2. **Enhancements to the interactive geocoding module.** There are several areas in which the existing geocoding module should be enhanced. First, the map appearance should be improved. A bug in the current MapObjects version prevented several map appearance enhancements that were originally planned, including a graphical display of major places and employers and use of standard road/route symbols. A bug work-around was provided by ESRI, so these and other appearance improvements are now possible. Second, the data from the Baltimore application should be reviewed and field staff de-briefed to identify areas where respondents had difficulty or where missed matches should have been found.

3. **Travel diary split sample Internet/CATI field test.** Before Internet becomes widely used, it will be important to determine how surveys using Internet completion compare to those from CATI or other self-completion methods. Of particular interest is how the Internet self-reported trip-making compares to the operator-prompted trip-making derived from CATI completions. To isolate the administration method effect, it is important to split the sample of those who have Internet access into a control group who get a CATI survey and a second group who are provided the Internet version. It would be interesting as well to compare CATI-directed geocoding with respondent-interactive geocoding and this type of comparison could be made if the GeoSystems CATI system is available in time for this field test.

4. **Refinement of the travel diary application and Internet application.** The field test will be programmed to provide additional feedback about both the travel survey application and the Internet interface. The data from this test should be used to create a refined, "marketable" version of the survey system.

5. **Exploration of links with other geocoding approaches such as GPS.** Conceptually, it should be possible to link GPS-generated data into the Internet travel diary application so that a GPS-derived trip "skeleton" is available as a starting point for some trips. The

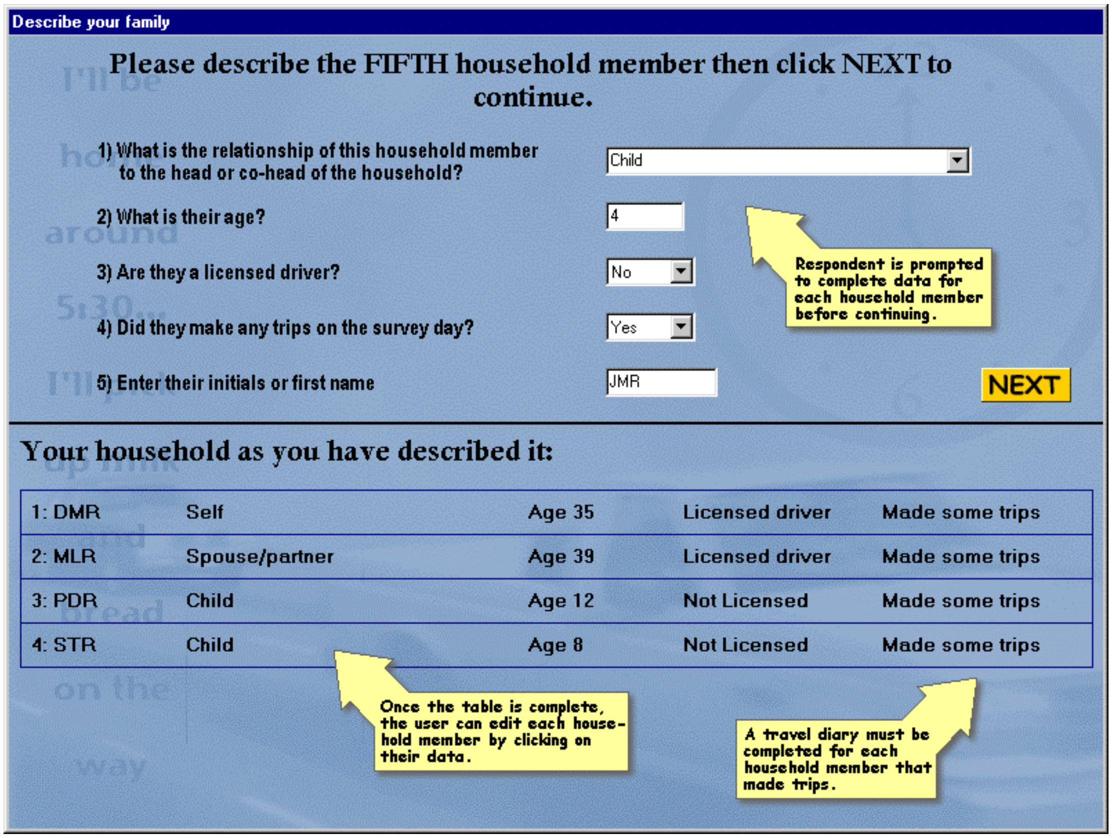
software should be designed so that, as this type of technology improves, the data can be used to further reduce respondent burden.

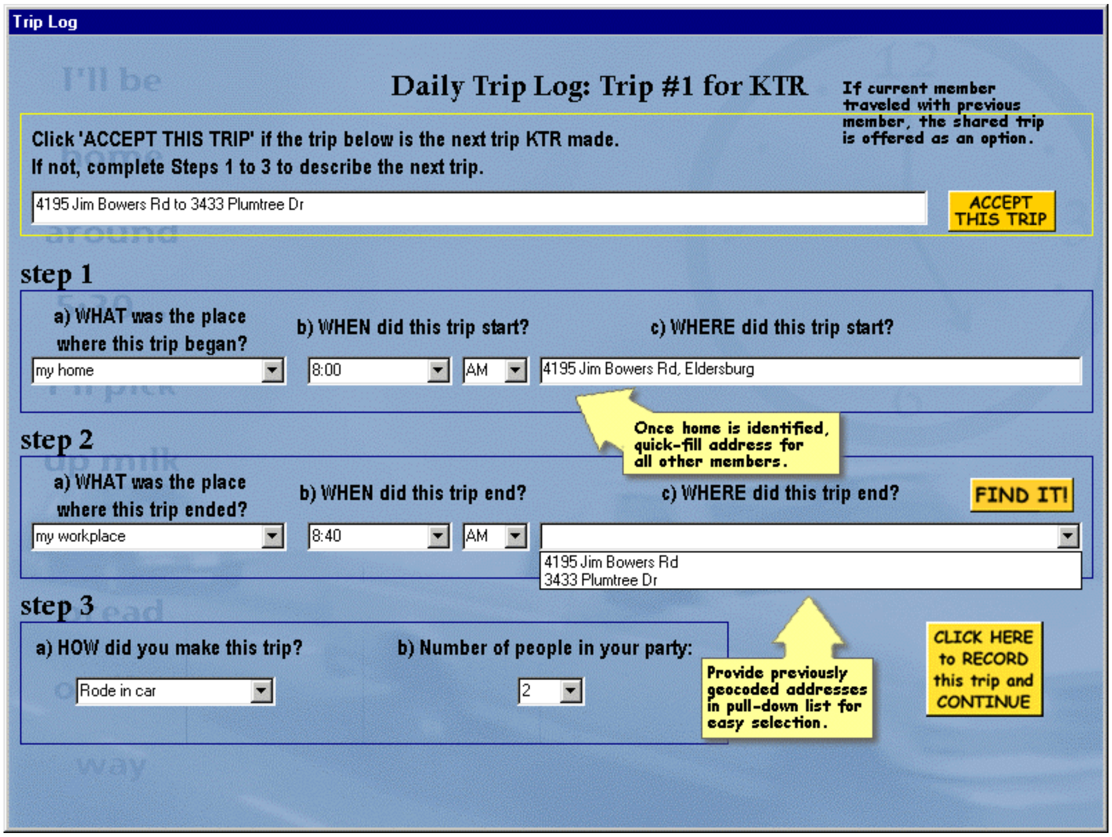
6. **Development of other travel survey applications.** The travel diary application is the core application product from this work, but it is relatively straightforward to add modules that use the geographic intelligence derived from the interactive geocoding elements. Resource Systems Group found, in one of its past travel diary surveys, that inclusion of stated preference and opinion questions in a travel diary actually increased response rates, despite the added length. The Baltimore demonstration includes a stated preference module that can be generalized for other applications. There are other geographical focus applications that, similarly, could be added relatively easily either to a base travel diary survey or as separate stand-alone survey.

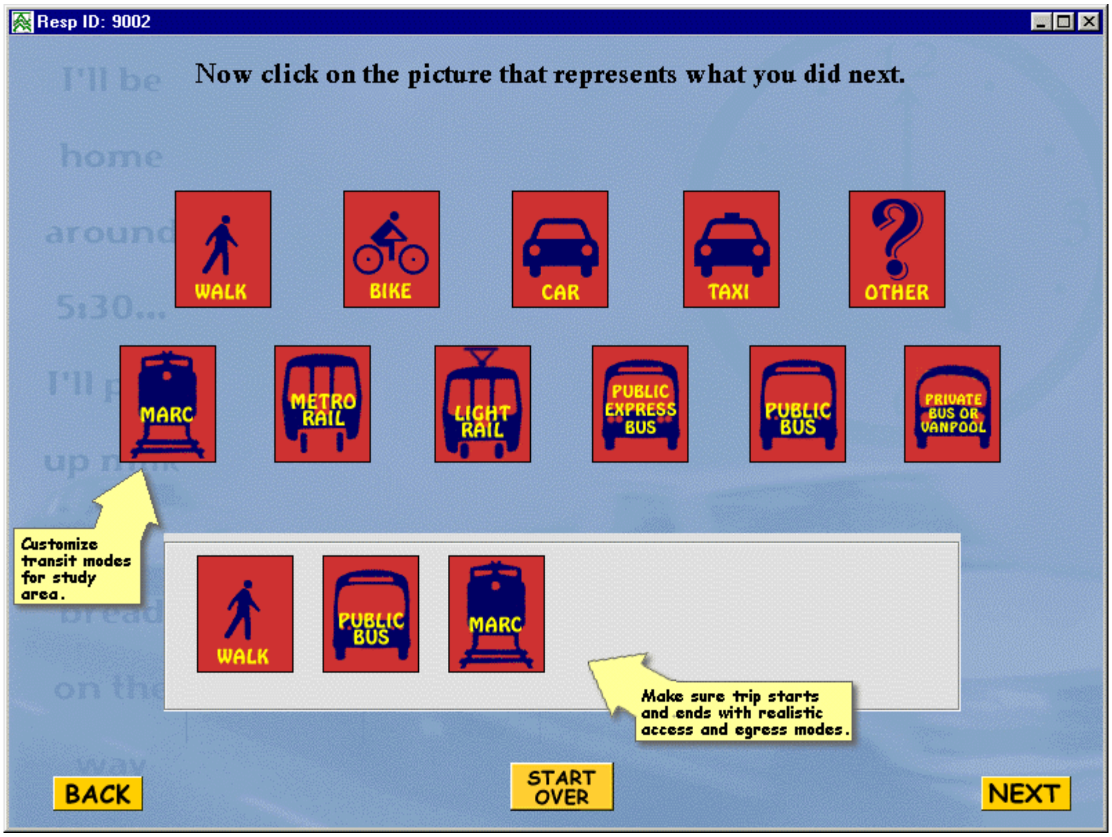
There is clearly an opportunity to use the approaches described here to both improve the quality of travel survey data and to reduce the cost of the data collection. We expect that these approaches will increasingly find their way into travel surveys. We hope that the travel data that are produced can improve the quality of travel demand models and, ultimately, of the transportation planning decisions that result from their use.

APPENDIX A

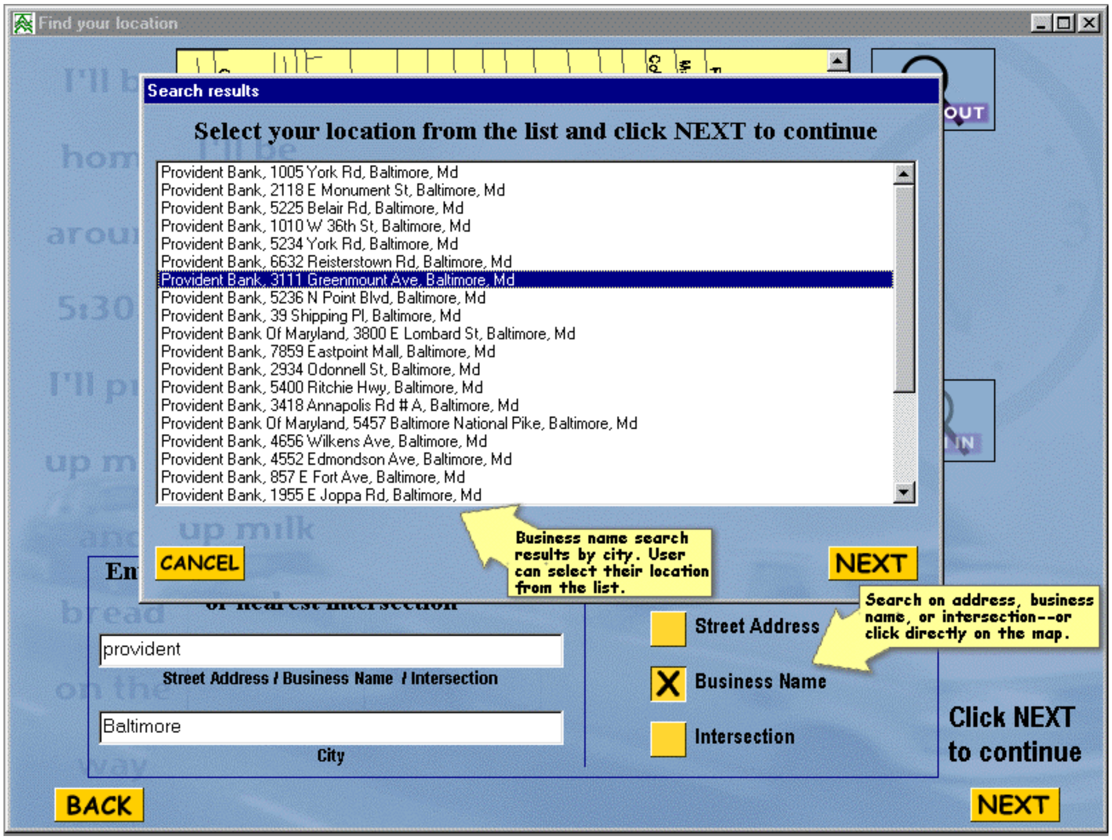
SAMPLE SCREENS FROM THE SOFTWARE DEMO AND THE BALTIMORE SURVEY

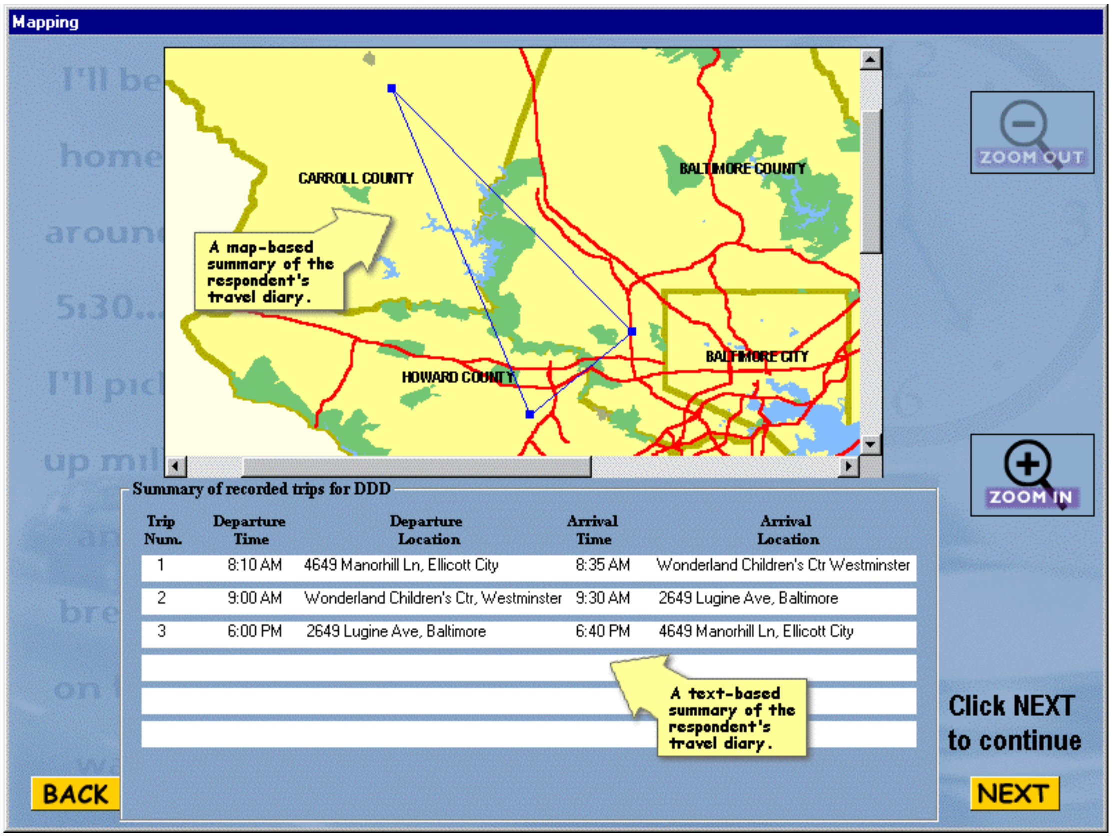



Trip Log
Daily Trip Log: Trip #1 for KTR
If current member traveled with previous member, the shared trip is offered as an option.
Click 'ACCEPT THIS TRIP' if the trip below is the next trip KTR made.
If not, complete Steps 1 to 3 to describe the next trip.
4195 Jim Bowers Rd to 3433 Plumtree Dr
ACCEPT THIS TRIP
step 1
a) WHAT was the place where this trip began?
b) WHEN did this trip start?
c) WHERE did this trip start?
my home
8:00
AM
4195 Jim Bowers Rd, Eldersburg
Once home is identified, quick-fill address for all other members.
step 2
a) WHAT was the place where this trip ended?
b) WHEN did this trip end?
c) WHERE did this trip end?
FIND IT!
my workplace
8:40
AM
4195 Jim Bowers Rd
3433 Plumtree Dr
step 3
a) HOW did you make this trip?
b) Number of people in your party:
Rode in car
2
Provide previously geocoded addresses in pull-down list for easy selection.
CLICK HERE to RECORD this trip and CONTINUE

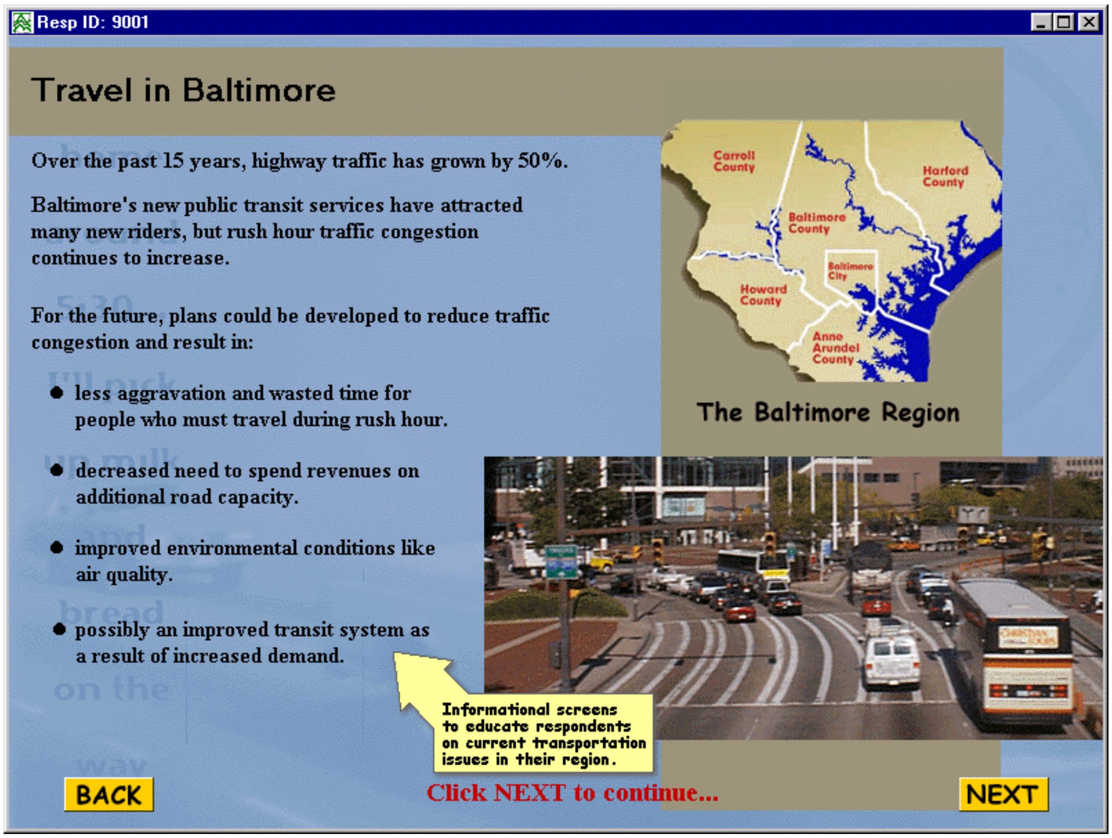

Resp ID: 9002
Now click on the picture that represents what you did next.
WALK
BIKE
CAR
TAXI
OTHER
MARC
METRO RAIL
LIGHT RAIL
PUBLIC EXPRESS BUS
PUBLIC BUS
PRIVATE BUS OR VANPOOL
Customize transit modes for study area.
WALK
PUBLIC BUS
MARC
Make sure trip starts and ends with realistic access and egress modes.
BACK
START OVER
NEXT

Geocoding

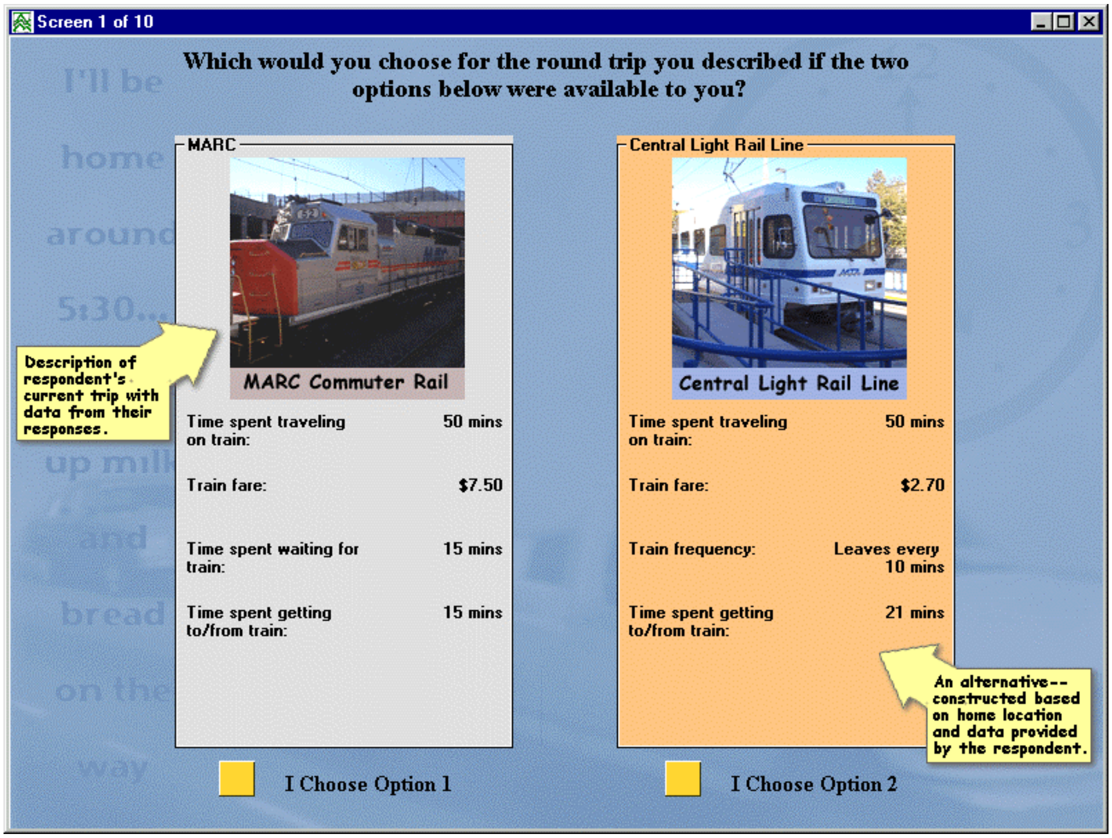

Find your location
Search results
Select your location from the list and click NEXT to continue
Provident Bank, 1005 York Rd, Baltimore, Md
Provident Bank, 2118 E Monument St, Baltimore, Md
Provident Bank, 5225 Belair Rd, Baltimore, Md
Provident Bank, 1010 W 36th St, Baltimore, Md
Provident Bank, 5234 York Rd, Baltimore, Md
Provident Bank, 6632 Reisterstown Rd, Baltimore, Md
Provident Bank, 3111 Greenmount Ave, Baltimore, Md
Provident Bank, 5236 N Point Blvd, Baltimore, Md
Provident Bank, 39 Shipping Pl, Baltimore, Md
Provident Bank Of Maryland, 3800 E Lombard St, Baltimore, Md
Provident Bank, 7859 Eastpoint Mall, Baltimore, Md
Provident Bank, 2934 Odonnell St, Baltimore, Md
Provident Bank, 5400 Ritchie Hwy, Baltimore, Md
Provident Bank, 3418 Annapolis Rd # A, Baltimore, Md
Provident Bank Of Maryland, 5457 Baltimore National Pike, Baltimore, Md
Provident Bank, 4656 Wilkens Ave, Baltimore, Md
Provident Bank, 4552 Edmondson Ave, Baltimore, Md
Provident Bank, 857 E Fort Ave, Baltimore, Md
Provident Bank, 1955 E Joppa Rd, Baltimore, Md
CANCEL
Business name search results by city. User can select their location from the list.
NEXT
Search on address, business name, or intersection--or click directly on the map.
provident
Street Address / Business Name / Intersection
Baltimore
City
Street Address
X Business Name
Intersection
Click NEXT to continue
OUT
IN
BACK
NEXT

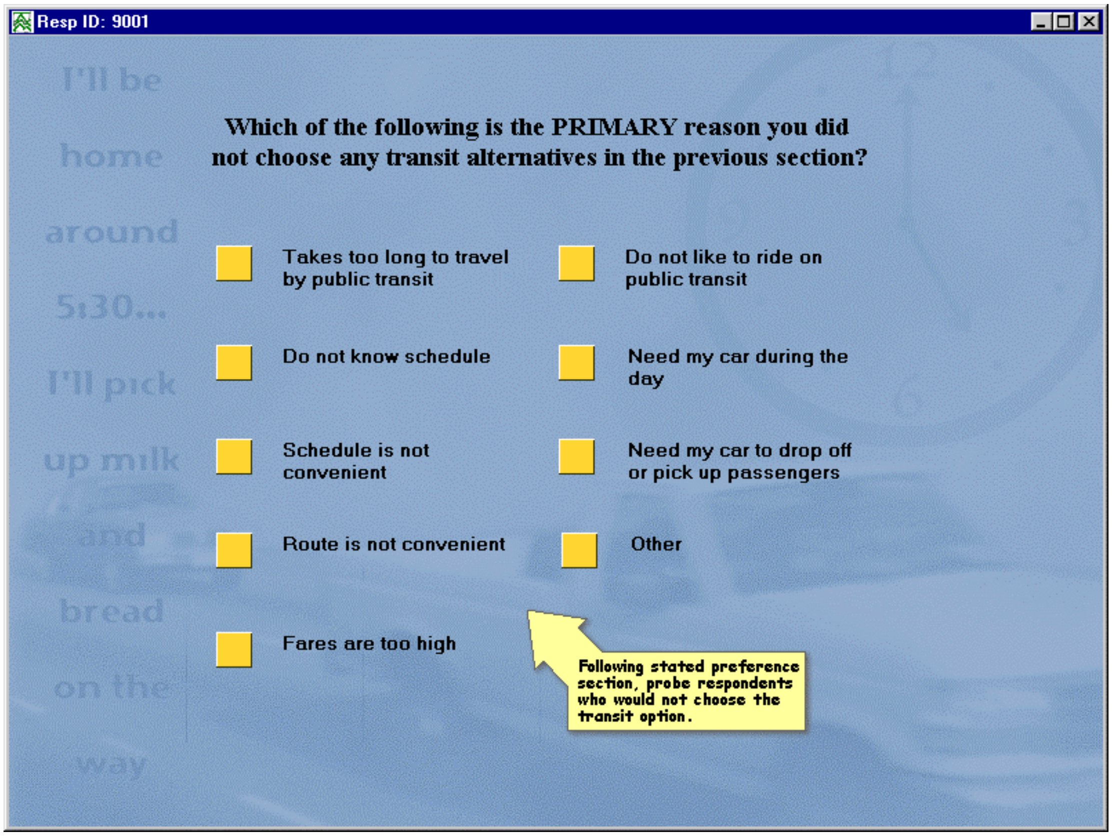


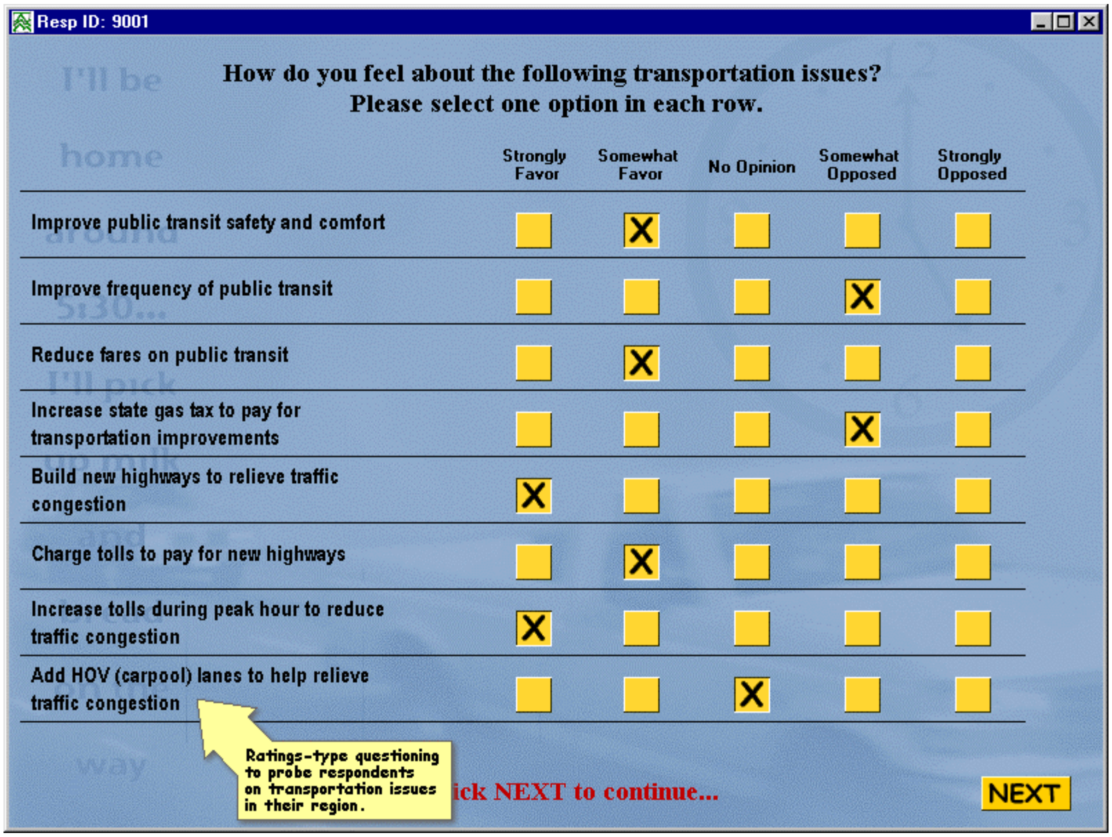
Trip Num.	Departure Time	Departure Location	Arrival Time	Arrival Location
1	8:10 AM	4649 Manorhill Ln, Ellicott City	8:35 AM	Wonderland Children's Ctr Westminster
2	9:00 AM	Wonderland Children's Ctr, Westminster	9:30 AM	2649 Lugine Ave, Baltimore
3	6:00 PM	2649 Lugine Ave, Baltimore	6:40 PM	4649 Manorhill Ln, Ellicott City


Resp ID: 9001
Travel in Baltimore
Over the past 15 years, highway traffic has grown by 50%.
Baltimore's new public transit services have attracted many new riders, but rush hour traffic congestion continues to increase.
For the future, plans could be developed to reduce traffic congestion and result in:
less aggravation and wasted time for people who must travel during rush hour.
decreased need to spend revenues on additional road capacity.
improved environmental conditions like air quality.
possibly an improved transit system as a result of increased demand.
Carroll County
Harford County
Baltimore County
Baltimore City
Howard County
Anne Arundel County
The Baltimore Region
Informational screens to educate respondents on current transportation issues in their region.
BACK
Click NEXT to continue...
NEXT


Resp ID: 9001
Baltimore's Transportation Options
A brief presentation of the current transit modes available in the study area.
Bus
MARC Commuter Rail
Central Light Rail Line
Baltimore Metro
In addition to highways, Baltimore has:
Buses of three types:
Local buses that serve most of the region
Express buses that serve longer trips
Express premium buses that have more comfortable seating for long trips
The Baltimore Metro serving the central area
The Central Light Rail Line
MARC Commuter Rail serving the Baltimore suburbs
BACK
Click NEXT to continue...
NEXT


Screen 1 of 10
Which would you choose for the round trip you described if the two options below were available to you?
I'll be home around 5:30... up milk and bread on the way
MARC
MARC Commuter Rail
Time spent traveling on train: 50 mins
Train fare: $7.50
Time spent waiting for train: 15 mins
Time spent getting to/from train: 15 mins
Central Light Rail Line
Central Light Rail Line
Time spent traveling on train: 50 mins
Train fare: $2.70
Train frequency: Leaves every 10 mins
Time spent getting to/from train: 21 mins
Description of respondent's current trip with data from their responses.
An alternative--constructed based on home location and data provided by the respondent.
I Choose Option 1
I Choose Option 2


Resp ID: 9001
Which of the following is the PRIMARY reason you did not choose any transit alternatives in the previous section?
Takes too long to travel by public transit
Do not like to ride on public transit
Do not know schedule
Need my car during the day
Schedule is not convenient
Need my car to drop off or pick up passengers
Route is not convenient
Other
Fares are too high
Following stated preference section, probe respondents who would not choose the transit option.
I'll be home around 5:30... I'll pick up milk and bread on the way



Resp ID: 9001

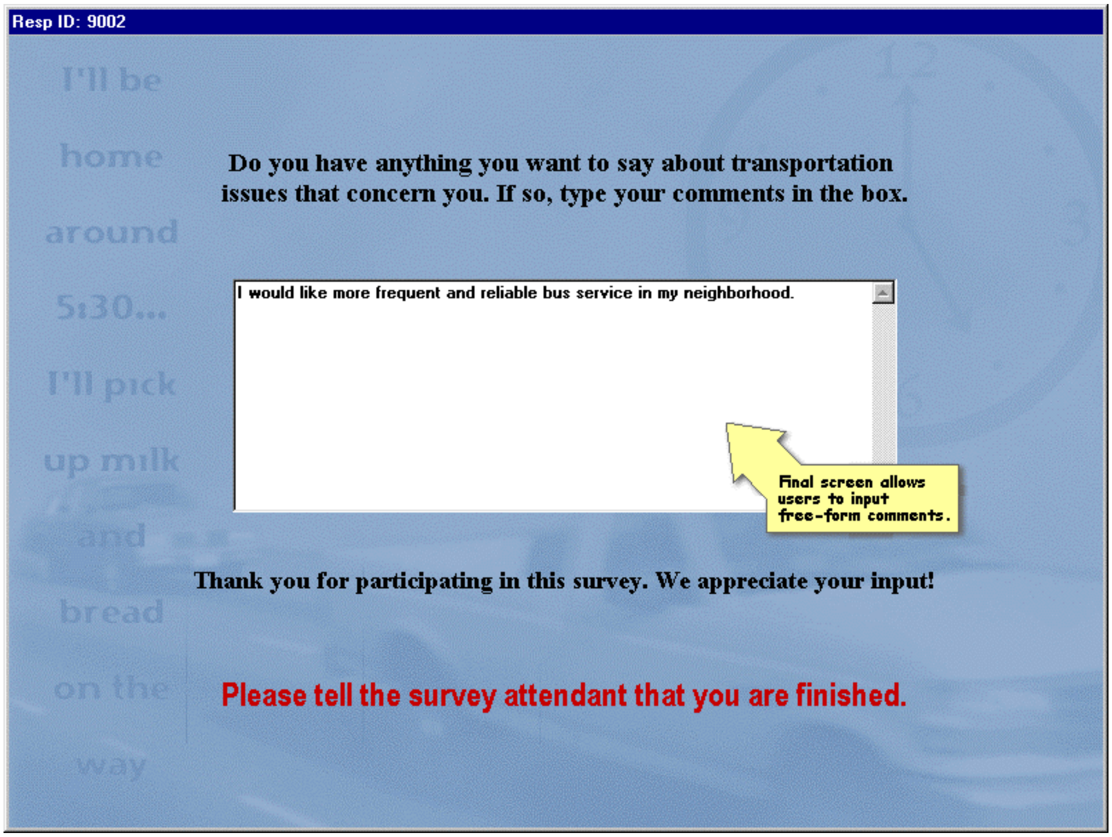
How do you feel about the following transportation issues?
Please select one option in each row.

	Strongly Favor	Somewhat Favor	No Opinion	Somewhat Opposed	Strongly Opposed
Improve public transit safety and comfort		X			
Improve frequency of public transit				X	
Reduce fares on public transit		X			
Increase state gas tax to pay for transportation improvements				X	
Build new highways to relieve traffic congestion	X				
Charge tolls to pay for new highways		X			
Increase tolls during peak hour to reduce traffic congestion	X				
Add HOV (carpool) lanes to help relieve traffic congestion			X		

Ratings-type questioning to probe respondents on transportation issues in their region.

ick NEXT to continue...

NEXT


Resp ID: 9002
I'll be home around 5:30... I'll pick up milk and bread on the way
Do you have anything you want to say about transportation issues that concern you. If so, type your comments in the box.
I would like more frequent and reliable bus service in my neighborhood.
Final screen allows users to input free-form comments.
Thank you for participating in this survey. We appreciate your input!
Please tell the survey attendant that you are finished.

APPENDIX B

DEMO SOFTWARE ERROR MESSAGES AND CONSISTENCY CHECKS

HOUSEHOLD INFORMATION

You must select from the list of family relation options before proceeding (Step 1).

You must enter an age between 1 and 120 before continuing (Step 2).

You must enter the initials or first name of this family member before continuing (Step 5).

The family member can not be a licensed driver if their age is below 15.

There is already a person in the house called (*insert name*). Each family member must have a unique name.

There can only be one person in the household who is designated as 'Self'.

There can only be two members designated as spouse / parent in the household.

You can not edit the household members until you have entered all (*insert family size*) members.

You must select from the list of family relation options before proceeding (Step 1).

You must have at least 1 member in your household.

You can not enter more than (*insert number of household members*) in your household.

TRAVEL DIARY

This trip must start at a later time than the previous trip ended.

This trip must end at a later time than the previous trip ended.

The time you ended your trip is not later than when you started it.

This trip ends after the roster trip. Are you sure you want to log this trip?

You must first select a start time before continuing.

You must first select a end time before continuing.

You must first select what place this trip started before continuing.

You must first select what place this trip ended before continuing.

You must first select a mode before continuing.

We can not find a person in the household who made any trips.

You must enter an access mode, a transit mode, and an egress mode before continuing.

Please click on the picture that represents how you got from the transit station or stop to your destination.

We will only need the first 6 modes in your trip. Click the NEXT button to continue.

Excluding yourself, you said there were (*insert number of occupants –1*) people in your party. You have just selected (*insert number selected*) household member(s). Please check your answers or click CANCEL to go back and change the number on the previous screen.

Are you sure you want to move to the next person?

GEOCODING

You can not continue without entering street address, business name, or intersection.

Please enter a city name before we search the address.

This is not a valid intersection name.

You must select either the street address, business name, or intersection button.

No records were found that meet your search criterion.

There were (*insert number of records*) records that met your search criterion. Please try again with more information.

Could not search for this name.

We could not find the city you entered. Please try again or get the attendant for help.

(*Insert address*) not found.

Intersection of (*insert intersection #1*) and (*insert intersection #2*) not found.

Please select one of the locations before leaving.