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A Report from the University of Vermont Transportation Research Center

Designing the All-in-One Vermont Transportation Survey

Final Report

TRC Report 17-004
September, 2017

Lisa Aultman-Hall & Jonathan Dowds

Designing the All-in-One Vermont Transportation Survey

September, 2017

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Disclaimer

The information contained in this report was compiled for the use of the Vermont Agency of Transportation and the Chittenden County Regional Planning Commission. Conclusions and recommendations contained herein are based upon the research data obtained and the observations of the researchers, and are not necessarily to be construed as Agency or Commission policy. This report does not constitute a standard, specification, or regulation. Neither VTrans nor CCRPC assumes liability for its contents or the use thereof.

Executive Summary

“All-in-One” Program Recommendations

Recommended Schedule and Content:

- Five year data collection cycle. 1/5 of the total sample surveyed annually between 9/15 and 10/15
- All Question Bank modules (Transportation Planning and Travel Diary components)

Key Considerations:

- Minimizes the total cost to collect Transportation Planning and Travel Diary survey components
- Ensures statewide customer satisfaction and attitudinal data on an annual basis
- Ensures statewide/Chittenden County specific travel data on a 5-year cycle to support travel models
- Likely to capture many part-year residents
- Smooths out single-year travel anomalies in travel behavior data
- Equal annual costs

Recommended Recruitment Strategy:

- Random, address-based recruitment using two postcard solicitations and a random prize drawing participation incentive.

Key Considerations:

- Consistent with current best practice
- Facilitates statewide data collection while ensuring an adequate sample for CCRPC travel modeling
- Outperformed convenience samples capturing low-income/older Vermonters in recent VT surveys
- Supports a statistically rigorous weighting process since respondent selection probability is known

Recommended Retrieval Method:

- Web-based survey tool

Key Considerations:

- Automatic geocoding improves spatial data accuracy
- Currently accessible to a wider set of Vermonters than smartphone-based survey Apps
- Lower cost per completed household for travel diary collection than telephone or paper retrieval
- Greater predictability in data processing costs than phone and paper surveys

Recommended Sampling Unit:

- Household
- Retain data from partially completed households as part of a supplemental person-based dataset

Key Considerations:

- Supports travel modeling by VTrans and CCRPC
- Increases the sample size for analysis of the customer satisfaction and attitudinal variables

Recommended Sample Size:

- 2,500 total households statewide over a 5-year survey cycle including:
- 1,200 in Chittenden County and 1,300 in the rest of Vermont

Key Considerations – Sample size is sufficient to:

- Conduct statewide analysis of trends related to customer satisfaction and attitudes annually
- Conduct regional analysis of trends related to customer satisfaction and attitudes every 5 years
- Support VTrans and CCRPC model updates every 5 years with similar accuracy to the NHTS
- Enable weighting based on key demographic variables such as age and income

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1 Introduction and Objectives

Data collection on transportation services, travel demand, customer satisfaction, and future system needs is critical for the planning and operation of the overall transportation system. Although traffic counts, travel speeds and other system measures can often be collected automatically, public opinion and travel demand patterns are much more complicated and costly to collect and are usually measured with survey instruments.

Traditionally, interviews, paper mail-back and telephone surveys have been the primary survey data retrieval methods used by transportation agencies in the United States. Given current limitations of these data retrieval methods related to response rates, sample representativeness, and the decreasing prevalence of landline telephones, data collection methods have been evolving. Increased access to broadband Internet, data-enabled mobile devices (e.g. smartphones and tablets), and other GPS-enabled technology has created new opportunities for improving the quantity, accuracy and completeness of travel data collection. Numerous agencies are implementing or evaluating web-based or mobile device-based data collection. Many newer data retrieval methods have the ability to directly collect geo-coded routes as well as trip origin and destination data but limitations of these newer retrieval methods are still being investigated. Some agencies are also exploring opportunities to use third party data sources such as aggregate data derived from cell phone towers or credit card transactions to replace traditional travel demand surveys. These methods are still not completely validated and, in general, are best suited for larger metropolitan areas where Census tracts and traffic analysis zones are small and travel volumes large.

Within this landscape, data collection costs and capabilities, and consequently the state of practice for administering transportation surveys, are changing rapidly. This project examined recent survey data from Vermont and travel survey approaches from non-Vermont agencies to develop a set of recommendations for an on-going, coordinated approach to transportation data collection for transportation and planning agencies including the Vermont Agency of Transportation (VTTrans) and the Chittenden County Regional Planning Commission (CCRPC), each of which maintain a travel demand forecasting model.

A wide range of recent Vermont survey data were analyzed for this project and additional data were collected specifically for the project to answer questions related to the development of a Vermont-focused survey program. The VTTrans Long Range Transportation Planning Survey (LRTPS 2016) and the CCRPC rMoves Travel Survey (CCRPC 2016) utilized different survey recruitment strategies and three different data retrieval methods. Analysis of these data, together with US Census data from the American Community Survey (ACS), generated insights for several methodological issues. In addition, the project team paid for the inclusion of a question in the annual Vermonter Poll (2017) conducted by the Center for Rural Studies at the University of Vermont (UVM) on smartphone ownership to further consider the viability of mobile device-based data collection in the Vermont context. Original on-road in-vehicle GPS and cell strength data collection was undertaken by the research team in the fall of 2016 to better understand coverage in Vermont's rural areas. A literature review of issues relating to household versus person-based data was conducted. Finally discussions with consultants and transportation planning professionals outside of Vermont were held regarding their recent travel and transportation survey experiences.

1.1. Project Objectives

The objective for the All-in-One Vermont Transportation Survey Project was to design a transportation survey program to efficiently meet the on-going transportation and travel data needs of Vermont transportation and planning agencies by providing:

1. a concise and consistent set of transportation survey question modules (the “Question Bank”) appropriate for survey data collection and repeated use in Vermont, and
2. an implementation strategy for an on-going statewide survey program.

This survey system is intended to provide an efficient and reliable method to collect the data captured by prior agency-based surveys as well as to fill travel demand model calibration needs that have previously been met by the Federal Highway Administration’s (FHWA) National Household Travel Survey (NHTS) add-on data.

All project work involved active input from the technical advisory committee (TAC) consisting of representatives from the Vermont Agency of Transportation (VTrans), Chittenden County Regional Planning Commission (CCRPC) and Lamoille County Planning Commission (LCPC). Questions in the Question Bank are intended to meet the needs identified by stakeholders at state and regional agencies as documented in an earlier project by Aultman-Hall and McRae (2014) and through continuing conversations with this TAC. These needs are:

1. Assessing system performance (including for special population groups) & customer satisfaction
2. Updating the VTrans Statewide Travel Model and the CCRPC Travel Demand Model (forecasting)
3. Quantifying travel behavior of Vermonters
4. Quantifying transportation energy use and associated emissions
5. Supporting research on accessibility, public transit, ride sharing, electric vehicles, non-motorized transportation, adaptation planning/ resiliency and long distance travel (including tourism)
6. Assessing the relationship between travel and alternative land use plans

1.2. Report Organization

Chapter 2 of this report provides background information regarding recent transportation survey programs, both inside and outside of Vermont, and an overview of the benefits and drawbacks of different survey data retrieval methods. Chapter 3 describes the structure and development the Question Bank. Appendix A contains the full Question Bank while Appendix B describes the information sources reviewed to select these questions. Chapter 4 describes the 5-year survey program that is recommended based on the research undertaken in this project. Chapter 4 includes eight subsections: 4.1) survey schedule and content; 4.2) recruitment strategy; 4.3) data retrieval method; 4.4) sampling unit; 4.5) sample size; 4.6) estimated survey costs 4.7) other survey program design factors and 4.8) technical advantages and limitation of direct or secondary mobile-device data collection.

Chapter 5 summarizes possible next steps in advancing implementation of an All-in-One survey program as well as research that would better prepare Vermont for use of new emerging technology-based data collection to fill data needs for modeling travel in Vermont. Technical appendices (Appendix C through F) of the report provide additional documentation of the technical analysis that led to the recommendations in Chapter 4.

2. Background

The first section of this Chapter, 2.1, summarizes recent transportation surveys in Vermont and other jurisdictions that were deemed particularly useful to inform the All-in-One approach. The second section 2.2, provides important context regarding different data retrieval methods. It highlights recent surveys that have used each of the retrieval methods as well as important criteria for evaluating these methods in terms of cost and data quality. This allows us to identify the subset of feasible options for different components of the All-in-One survey program.

2.1. Transportation Surveys and Survey Programs

Travel behavior data, often collected through a travel diary or log, are the most complicated transportation survey data to obtain. In 2009, VTrans, CCRPC, and the UVM Transportation Research Center (TRC) jointly purchased an “add-on” sample of the National Household Travel Survey (NHTS) that surveyed the one-day travel choices of members of over 1650 Vermont households. Most of the 2009 NHTS “add-on” agencies were states and larger metropolitan planning organizations (MPOs) and the Vermont statewide sample was recognized as a distinct sample of rural residents in the larger national sample. Numerous other transportation surveys are undertaken in Vermont including policy opinion surveys conducted by VTrans (2000, 2006 and 2016) and CCRPC (2000, 2006, 2012) and research surveys on rural accessibility and long-distance travel conducted by UVM TRC since 2006. While each of these Vermont transportation surveys served an important goal, there is the potential to coordinate survey efforts to maximize efficiency and improve the ability to integrate data from multiple surveys.

Other agencies are implementing changes in their programs as well. Many recent travel surveys have been conducted using web-based and/or mobile device-based data collection components. The 2016-2017 National Household Travel Survey (NHTS) is using a web-based format for the first time (TRB 2016). The NHTS is arguably one of the most comprehensive one-day household travel surveys conducted in the United States. The 2016 dataset will include travel data from approximately 129,000 households for all persons at least 5 years of age. A minimum of 250 households in Vermont will be included. These data will be available to Vermont users but thus far there are no plans to release detailed geocodes to agencies that did not purchase an add-on sample. At a January 2017 meeting of the TRB NHTS Task Force, the consultant conducting the NHTS survey indicated a large number of participants were electing to complete by telephone or were seeking assistance by telephone. The NHTS utilized address-based recruitment including two letters with survey materials, cash incentives and two reminder postcards.

In 2014, Vermont elected not to participate in the 2016 NHTS add-on program (Aultman-Hall and McRae 2014) in large part due to relatively high cost per completed household. This and the need to determine a replacement for the NHTS data (especially the travel data used for travel demand model updates) motivated the initiation of this research project. Many agencies conduct their own travel surveys distinct from the NHTS. Most tend to be larger metropolitan areas or state DOTs. For example, the New York Metropolitan Transportation Council (NYMTC) conducted their regional household travel survey in 2010-2011. Data were collected from 19,000 households in 29 counties in 3 states using multiple data retrieval methods: phone, mail, web surveys, and wearable GPS receivers. The Greater Toronto Area has conducted a travel survey every 5-years since 1986 using their partner, the University of Toronto, for data management and warehousing services. In 2011, they collected data from 159,000 households using phone surveys. The Connecticut DOT recently partnered with the University of Connecticut to

conduct a shorter web-based travel survey in 2016 (7,500 households) and was considered during this project a more appropriate model for Vermont due to its limited survey length. Ohio DOT (ODOT) is using mobile device-based data collection for both long distance and local travel data collection. The Puget Sound Regional Council (PSRC) elected in 2017 to use smartphone data collection for 20% of its data collection from 3,100 households. Both ODOT and the PRSC are using a rolling data collection strategy with ODOT rotating through each of its ten highway districts over a 10-year period and PRSC collecting their data in three waves over six years. Cost containment efforts are also common. PRSC is re-using their 2014-2015 survey questions to save design costs and the four largest MPOs in California opted this year to perform their next travel diary survey in common for their agencies (the size and cost of the surveys is yet to be determined).

These and other recent survey efforts are useful for informing transportation data collection efforts in Vermont. While many of these cases were not scaled appropriately for replication in Vermont (e.g. several surveys include a very large number of households), they served as additional inputs into program development process. The 2009 NHTS included 150,000 households nation-wide. California's 2013 survey was the largest outside of an NHTS, including approximately 44,000 households. The Atlanta Regional Commission (ARC) surveyed 10,000 households in 2011 and included 10% GPS. The Montreal Transportation Survey was last conducted in 2013 with 79,000 households and interestingly, like Toronto, is still conducted by telephone. Plans for the 2018 Montreal survey are still for use of telephone data retrieval. Such large sample sizes, while cost-prohibitive for Vermont, often ensures adequate coverage of all modes. Like our Canadian neighbors, phone surveys such as the UVM Vermonter Poll are still viable in Vermont. This method was considered but ultimately not recommended for the All-in-One program. In Europe, New Zealand and Australia, many survey programs still use in-home interviews successfully.

Ensuring that all individuals over a certain age in each household complete the survey (and thus that the household can be considered "complete") is often a large component of survey cost. Some survey programs allow for proxy reporting by other members of the household but others do not. In many programs including the 2009 NHTS, data for incomplete households is discarded. Concern for this practice in terms of cost efficiency motivated the investigation of household versus individual sampling unit for Vermont (Section 4.4).

Some of the most recent, and most expensive, travel surveys were those with in-vehicle or on-person GPS components for a subset of respondents (California 2012, New York 2011 and Atlanta 2011). Expensive and labor-intensive GPS surveys have fallen out of favor quickly for the more straightforward mobile-device based survey pointing to the possibility of exciting changes on the horizon but also the need to carefully consider retrieval methods, especially those which may exclude parts of the population due to access to technology. Retrieval method also impacts the type and quality of data that can be collected.

2.2. Survey Retrieval Methods

Every survey data retrieval method has specific advantages and disadvantages. Three established and two emerging methods for collecting travel data are defined below. Each data retrieval method's performance on five key evaluation criteria are highlighted in Table 1 for the established methods and in

Table 2 for the emerging methods. Note that survey recruitment, in which individuals or households are invited to participate in the survey, is distinct from data retrieval when the data are collected.

Methods for collecting travel data:

1. **Paper Survey:** Respondents fill-out and mail-back a hard copy paper survey. This was one of two retrieval methods used for the 2016 VTrans LRTPS.
2. **Telephone Survey:** Respondents are contacted by phone (landline and cell phones are now both used) and an interviewer records respondent's answers and may prompt for additional details. The UVM 2017 Annual Vermonter Poll was collected by telephone.
3. **Online Survey:** Respondents fill out a web-based, electronic survey on a computer, tablet or smartphone. This was one of the two retrieval methods used for the 2016 VTrans LRTPS.
4. **Mobile Device App:** Respondents use a smartphone App designed specifically for transportation data collection. Most Apps collect some data automatically and prompt the respondent to enter other data after a trip or day has been completed. The CCRPC 2016 travel survey used this method with the App rMoves. Some other passive Apps do not require user input at all, and thus reduce the burden to participants. Most infer data based on tracking location. These Apps cannot provide information about trip purpose, attitudes, complete demographics or travel party composition. Unless specifically noted, references to mobile device data collection in this report refer to Apps that include both passive data collection and active survey data collection.
5. **Secondary Data Sources:** Travel behavior data can be purchased from some "big data" sources including blue-tooth readers, cell towers, or credit card transactions. For example, companies such as AirSage or StreetLight sell aggregated transportation data, especially Origin-Destination (OD) tables by zone. Agencies usually provide their traffic analysis zone (TAZ) spatial boundary data and the private company typically returns an OD matrix that may be disaggregated by time of day or trip purpose. Home and work locations are often inferred but sociodemographic data for individuals is not known. Data may be weighted to some extent based on Census information.

Note here that there is a difference between using data-enabled mobile devices (smartphones) to complete a web-based survey versus true mobile device-based data collection that uses the location services of the device to track travel and automatically generate some of the trip data. In the first case, the user will have to interactively enter all location data as though they were using a web browser on a computer or laptop, potentially using maps, and in the second case the device collects location data that the user may add to or correct.

The Vermont transportation planning survey components (modules 1-4 of the Question Bank in Appendix A), which involves multiple choice, Likert scales and limited open-ended questions, could reasonably be conducted using any of three data retrieval methods:

- a) a paper survey
- b) a telephone survey or
- c) an online survey

Table 1. Characteristics of Established Travel Survey Retrieval Methods

Retrieval Method	Paper Survey	Telephone Survey	Online Survey
Demographic Representation	No inherent limitations on demographic representation. Older participants and women have higher response rates in general.	Typically limited to households with land lines, often excludes cell-phone only households. Likely to over represent older Vermonters.	Limited to respondents with Internet access. May under represent older and/or low income. Possible geographic variability given slower Internet in rural areas.
Completeness of Data	Methods that rely on respondent recall exclusively may not be as accurate as those that provide prompts based on automatically recorded location (see Table 2). Shorter trips, some legs of tours and non-motorized travel are most often missed. These methods more easily facilitate collect of data for every person (including children) in household either directly or by proxy reporting thus creating complete household-based data.		
Spatial Accuracy of Location Data	Location data is limited to a street address or street intersection. Requires significant post-processing and generally has only moderate spatial accuracy.		Locations can be selected/confirmed on an interactive map, reducing the need for post-processing and increasing accuracy.
Participant Burden	Increasing question number and complexity create significant burden.	Increasing question number and complexity increase burden. Respondent can find it helpful to have interviewer assistance.	Survey burden may be lower as questions can be tailored to the specific respondent (e.g. skipping questions). Surveys may be stopped and continued later. Data may be auto-populated for repeat trips.
Cost	Mail and printing costs can be significant and are proportional to sample size.	Costs are proportional to sample size.	Low marginal costs for increasing sample size. Telephone support can be costly.

Table 2. Characteristics of Emerging Travel Survey Retrieval Methods

Retrieval Method	Mobile Device Survey App	Secondary Data Sources
Demographic Representation	Limited to respondents with smartphones although some agencies have tried loaner programs. Likely to underrepresent older and/or low income Vermonters to a greater degree than online surveys. Possible geographic variability due to variable cellular service.	Representativeness varies by source. Individual demographic data not included. Data are usually provided on an aggregate basis to protect confidentiality which is more challenging in rural zones.
Completeness of Data	Can improve trip recall, especially of shorter and discretionary trips including active travel, by location prompts for probable trips. Data may be missed when phone is off or has poor cell/GPS signal strength.	Unknown.
Spatial Accuracy of Location Data	Locations are best auto-populated from phone GPS and can be confirmed on an interactive map, reducing the need for post-processing and increasing accuracy. Cell tower-based locations are less accurate.	Depends on data source and aggregation procedures.
Participant Burden	Survey burden may be especially low since questions can be tailored to the specific respondent and some data can be auto-populated, including for repeat trips. Participants may incur data costs, device battery drain and have privacy concerns.	None.
Cost	Creation of a custom App (rather than use of an existing App) may be costly and result in on-going upgrade costs. Low marginal costs for increasing sample size. Telephone support can be costly.	Purchase prices tend to be substantial.

All three of these retrieval methods have been used successfully in Vermont in recent years. The 2017 annual UVM Vermonter Poll conducted by landline and cell phone by the UVM Center for Rural Studies had a 20.1% response rate. The VTrans LRTPS 2016 used a mixed web and paper retrieval method and had an 18.4% response rate (41.9% of respondents utilized the web-based survey and 58.1% completed the paper survey). Web-based retrieval has been used successfully for several northern New England based surveys conducted by UVM TRC in the last 5 years. Cost and expected demographic coverage are the most relevant criteria for selecting among these options.

The travel diary component of the Vermont survey program (module 5 of the Question Bank in Appendix A) could reasonably be conducted by one of two data retrieval methods:

- a) web-based survey or
- b) a mobile device based survey.

We assess that it is not practical to collect accurate location data by paper or phone and that the length of a telephone survey that includes a travel diary (as much as 2-hours per person) is an unreasonable respondent burden. Data accuracy as well as cost and demographic coverage are considerations in selecting between these two options for the travel diary.

The choice of survey retrieval method will impact *how* survey questions are implemented but they should not impact what data are collected and thus which questions are included. Questions for inclusion should be based on the agency data needs (Chapter 1) and the retrieval method (Chapter 4) must ultimately be able to handle all questions needed.

3. Development of the Survey Question Bank

The complete set of recommended questions for each of five modules is provided in Appendix A. The large majority of these questions have been used in previous surveys. This should reduce the funding required for survey design in the future All-in-One program. To develop the Question Bank and ensure it adhered to current best practices in transportation survey design, the research team reviewed detailed questions within a survey guidance document produced by the National Cooperative Highway Research Program and five recent travel surveys:

- a) NCHRP Report 571: Standardized Procedures for Personal Travel Surveys (Stopher et al. 2008),
- b) VTrans Long Range Transportation Plan Public Opinion Survey (LRTPS 2016),
- c) National Household Travel Surveys (NHTS) 2009,
- d) National Household Travel Surveys (NHTS) 2016,
- e) Connecticut Department of Transportation Statewide Transportation Survey for 2016, and
- f) Chittenden County 2016 Regional Transportation Survey (CCRPC 2016).

From these sources, the research team designed a set of questions to meet the data needs of the Vermont's transportation agencies, reflecting the specific travel behavior, land-use, and development patterns of the state. This research leveraged and expanded on current and prior work by members of UVM TRC research team who assisted the consultant in the development of the VTrans Long Range Transportation Plan Public Opinion Survey. The 2012 CCRPC customer satisfaction planning survey was reviewed for the LRTPS design. The two NHTS surveys were of interest because of their comprehensive

nature. The CTDOT 2016 survey was conducted by ConnDOT in conjunction with the University of Connecticut. This survey had a number of features – especially the emphasis on a streamlined questionnaire and DOT-university partnership – that are similar to the All-in-One Program. The CCRPC 2016 survey was similarly streamlined using a standard travel survey design by one of the limited number of consultants, RSG Inc., that conduct this type of work in the US.

The Question Bank design was also informed by the work of Transportation Research Board’s *Task Force on Understanding New Directions for the National Household Travel Survey*. The work of the Task Force, which included project PI Dr. Lisa Aultman-Hall, was to consider potential modifications to the NHTS to ensure that the survey satisfied the data needs of the transportation community (Saphores et al. 2013).

Appendix B documents the process used to select survey questions for the All-in-One modular Question Bank. It tabulates the questions that were assessed from each of the six distinct survey sources reviewed as well as notes about how/why questions were or were not incorporated into the Question Bank. To facilitate comparisons across these resources, questions with similar content were combined into single entries within these tables. For example, the 2009 NHTS asked respondents about the number of phone lines in their households while the 2016 NHTS asks respondents whether or not their household has a landline telephone. In Table B1 in Appendix B these questions are combined into a single “Number/type of household telephones” entry.

In order to maximize consistency with the 2016 VTrans LRTPS, in cases where question wording varied across the reviewed sources, LRTPS question wording was maintained in the absence of a compelling research rationale to make a wording change. In some cases, question wording or answer options were altered based on recent UVM TRC experience analyzing the LRTPS data and developing new surveys related to long distance travel and social relationships. A small number of questions were omitted from or add to those included in the LRTPS but the overall question selection for the Question Bank is largely consistent with the LRTPS. Since the LRTPS did not include a travel diary, the suggested diary questions here are derived from the NHTS, Connecticut DOT, and the CCRPC 2016 survey.

Ultimately, the exact final version or wording of numerous questions in the Question Bank will vary in a limited way based on the data retrieval method. The selection of survey retrieval method will for the most part not alter the content of the question however. The use of a smartphone App for survey data, for example, could eliminate the need for respondents to enter the time, start and end locations of most trips since Apps can frequently capture this information passively. Similarly, depending on whether the survey uses the individual or the household as the survey unit (Section 4.4), some questions may need to be repeated so that data are collected for all members of the household. A brief overview of the purpose and uses of each of the five survey modules is provided in the following five sections.

3.1. Socio-Demographic and Travel Module

The **socio-demographic and travel context** module questions collect information about the respondent and the respondent’s household. These questions cover attributes including ages, education levels, and employment status of household members, as well as household size, household income, neighborhood type, and information about the household’s vehicle fleet.

It is very important to note that socio-demographic variables will allow survey samples to be weighted to reflect the composition of the Vermont or Chittenden County¹ population as a whole, enabling estimates of statewide or countywide travel behavior. In addition these variables facilitate tracking changes in travel behavior among subsets of the Vermont population (e.g. travel behavior of school children or elderly residents) that may have important implications for policy. Demographic variables are also required as predictor variables in travel models in order to forecast travel into the future. These variables are also used in a variety of transportation research applications.

The questions in this module are recommended for inclusion in all Vermont transportation surveys in this form to ensure consistency moving forward. Vehicle questions may be omitted from attitudinal or customer satisfaction surveys but should be included with all travel surveys that include a travel diary. Data in this and all other sections should be collected in as disaggregate a measure as is practical. Data aggregation after the survey is completed is straightforward, but data disaggregation is often not possible and when attempted can add error to the analysis being performed.

3.2. General Travel Behavior Module

The **general travel behavior questions** gather information about the regular or typical travel behavior of survey respondents. Since these questions cover broader themes and longer timeframes than the travel diary questions, they are likely to capture less common behaviors, such as bicycling or transit use, that may not be used by a large percentage of the sample and may not take place on the specific travel day or days covered by the travel diary.

The general travel behavior questions also cover unmet travel demand, an area that is often poorly understood but is important to Vermont for several reasons. Unmet or unrealized travel demand is the set of trips that Vermonters would like to make given a different transportation context but that are not made currently. These potential trips may be unrealized for a variety of reasons including barriers related to infrastructure availability, time budgets, physical capability, and economic means. Vermonters with limited disposable income may be unable to visit out-of-town family. Vermonters in an area with limited sidewalks might want to take more walking trips, for example, but refrain from doing so because of safety concerns. Unrealized trips are not captured by traffic counts and many other data collection methods that only record travel that actually occurs. Recent UVM research has demonstrated that understanding unrealized demand is important for measuring quality of life and accessibility particularly for children, older citizens and remotely located residents.

Long distance travel is also included in this module. No single definition of long distance travel is widely accepted but it has been defined as trips over a certain distance (50, 100, 500 miles etc.), trips that include an overnight stay or trips that include a particular mode such as air travel. Depending on the definition used, long distance travel may account for 30-40% of the passenger miles traveled. Tourist travel, a key driver of the Vermont economy, and travel to metropolitan areas for access to personal services such as medical care, especially important for rural Vermont residents, often involve long distance travel. Long distance travel is also important to accurately include external traffic in the statewide or CCRPC model. As evident at the September 2017 International Conference on Travel Survey Methods in Montreal QC, most jurisdictions are still struggling with how to effectively include long-

¹ Chittenden County is highlighted here because it is the only sub-state region in Vermont to have its own travel demand forecasting model.

distance travel in their household travel surveys. A limited number of states collected long-distance trips in their 2016 NHTS add-on questions but the last national US survey of long-distance travel was 1995. UVM has conducted 3 unique surveys on long distance travel since 2012 and written a paper using the long-distance data in the LTRPS. The Question Bank includes a new set of long-distance travel questions in the based on this research. We propose that the cost of including these additional questions is very limited and worthwhile to continue the State of Vermont's national leadership in this research area.

3.3. Attitudes about Transportation Issues Module

The **attitudes about transportation issues** questions collect information about Vermonter's attitudes toward transportation priorities and are useful for ensuring that Vermont's transportation agencies are being responsive to the needs of the population. Although the importance of these questions is being increasingly recognized by planners and modelers, these types of questions can become too numerous in many surveys. Consistent with the All-in-One goals, the number of questions in this module was minimized in order to keep the survey streamlined, to reduce the survey burden placed on potential respondents and to minimize cost for the agencies conducting the survey.

Since these questions evaluate important contemporary issues, the attitudes questions are more likely to need to be updated over time to reflect changing policy priorities and concerns. In order to reflect the current agency priorities and leverage the work done in the development of the LTRPS by agency staff and members of this team, the majority of the current travel attitudes questions are from the LTRPS. (The survey design for LTRPS was included review and inclusion questions from the most recent CCRPC attitude survey). A small number of additional questions deemed of high-value were identified in the 2016 NHTS and added to this section. We recommend re-consideration of the question content at the end of the 5-year survey program recommended in Chapter 4.

3.4. Customer Satisfaction Module

The **customer satisfaction questions** provide Vermont's transportation agencies with the data needed to assess public perceptions of agency services. Customer satisfaction questions help agencies meet the performance measurement requirements introduced in MAP-21 (FHWA 2013) and enhanced in the FAST Act (FHWA 2017) since measurement includes qualitative evidence such as customer satisfaction and perceptions (FHWA 2016). Customer satisfaction surveys are an explicit tool in the state's Transportation Asset Management Implementation Plan (VTrans 2014) and support VTrans' stated goal to continually pursue innovation, excellence and quality customer service (VTrans 2016). The customer service questions included in the Question Bank are derived from the LTRPS and may also change over time as described in section 3.3.

3.5. Travel Diary Module

The **travel diary module** supports travel modeling, performance measurement, and research in Vermont. This section tracks all travel activities undertaken by a specific person/household for a given study period, typically one day. The data collected include the origin, destination, mode(s), travel party, length and purpose of every trip taken on that day. From these data, origin and destination information can be updated in travel models and the agency can track important travel trends (e.g. mode share) of interest to policy makers. The travel data are often tabulated into linked trip legs or chains and coded as

trip tours. The research value of travel log data is greatly enhanced when approximate geocodes for home and destination locations are included in the dataset. The need for geocoded data has been extensively discussed by the TRB NHTS taskforce but no plans for the NHTS 2016 geo-code data have been formulated. For many years, more extensive survey efforts have focused on full activity recording recognizing that travel is most often a derived demand rooted in the need or desire to participate in activities that are spread across space. We are not recommending a more intensive activity-based survey that includes non-travel activities be undertaken at this time in Vermont. If future travel model updates include the development of activity-based simulation models then this survey approach could be re-considered.

3.6. Question Bank Summary

Standardized questions will allow data from different survey implementations to be combined, allow trends to be tracked over time and minimize the cost of repetitive survey design. Modules from the Question Bank (Appendix A) can be extracted and combined to create shorter surveys that meet particular needs related to transportation planning, travel demand modeling, and assessing customer satisfaction. As discussed in Chapter 4, however, in many cases greater cost efficiency can be achieved by administering a smaller number of comprehensive surveys that include the full Question Bank content.

The standardized Question Bank provides Vermont transportation agencies with three primary benefits:

1. The **cost** and effort of creating future surveys is reduced since the time required to design and pre-test questions is minimized.
2. The **quality** of future survey results is maximized by ensuring that the appropriate questions are included in the survey. The survey bank question selection process balanced the need to include essential questions with the need to limit the total number of questions in a given survey to limit the burden on survey respondents.
3. By establishing standardize wording and response options, the survey bank ensures that survey results can be **compared over time**. Even relatively small changes in survey wording can elicit different answers from survey respondents, making comparisons across surveys unreliable. Standardizing survey wording avoids this risk. In addition to facilitating cross survey comparisons, consistent question wording enables data from multiple surveys conducted in a similar timeframe (e.g. separate VTrans and CCRPC surveys) to be combined to increase sample, potentially supporting additional analysis of otherwise difficult to capture segments of the population (e.g. minorities groups and active transportation users).

4. Vermont All-in-One Survey Program Recommendations

The analysis conducted for this project and documented in this Chapter, as well as Appendix C to F, supports the following program recommendation:

- Survey Schedule and Content - a yearly survey schedule with full Question Bank content conducted in September to October for both weekdays and weekends (section 4.1)
- Recruitment Strategy - Address-based, random recruitment with 2-contact postcards and random prize drawing incentives (Section 4.2)
- Data Retrieval Method - web-based (Section 4.3)
- Sample Unit – households (but retain incomplete households for a separate person-based database) (section 4.4)
- Sample Size - A five-year, total sample size of 2,500 households – 500 per year with 240 per year in Chittenden County to ensure valid data for CCRPC model (Section 4.5)
- Cost Estimate - annual cost of \$69,000 excluding incentives and analysis (section 4.6)
- Options and other factors (section 4.7)
 - 2-day travel diary duration
 - travel by external visitors to Vermont

4.1. Survey Schedule and Content

Decisions regarding how and when to administer a survey impact many facets of the survey program including what data are collected, total survey costs, and participant burden. Continuous surveys, for example, allow comparisons between seasons but increase survey costs by requiring on-going technical support. Conducting multiple, smaller surveys can reduce participant burden but require larger total sample size and, therefore, also increase cost.

In order to minimize total cost associated with final design and programming and to achieve the goal of collecting statewide customer satisfaction and attitudinal data on an annual basis, we recommend administering a single survey instrument, consisting of all five Question Bank modules, on a 5-year cycle with 1/5 of the total sample collected each year. Given that part-year residents are important in Vermont we recommend a Sept. 15th – Oct. 15th survey window to include many part-year residents. Data should be collected for both weekday and weekend days by assigning some participants a weekday travel day and others a weekend travel day.

Continuous surveys have the advantages of capturing seasonal variation and more seasonal residents. Given our

SCHEDULE & CONTENT

Recommended Schedule: Five year data collection cycle with 1/5 of the total sample surveyed annually between Sept. 15 and Oct. 15

Recommended Content: All Question Bank modules (Transportation Planning and Travel Diary components)

Key Considerations:

- Minimizes the *total cost* to collect Transportation Planning *and* Travel Diary survey components
- Ensures statewide customer satisfaction and attitudinal data on an annual basis
- Ensures statewide and Chittenden County specific travel behavior data on a 5-year cycle to support travel model updates
- Likely to capture many part-year residents
- Smooths out single-year travel anomalies in travel behavior data
- Equal annual costs

relatively small sample size compared to samples in large metropolitan areas or larger states (which can exceed 40,000 households), running the survey all year instead of once per year would increase survey costs unnecessarily. As described in Section 4.6, the costs for technical support are proportional to the time duration of the survey effort not necessarily the number of households in the survey. Therefore, a continuous survey schedule is not recommended for the All-in-One program.

The team also estimated the survey costs for an alternative schedule where the transportation planning modules (modules 1-4) is conducted annually and travel diary module (module 5) is only administered once every five years. This alternative schedule requires a large sample in one year in order to achieve the desired level of accuracy for the travel diary data. While it would meet the Agency goal of having customer satisfaction data every year it requires a larger overall sample size over time and, as discussed in Section 4.6, is expected to be more costly overall than the recommended schedule. Moreover, any anomalies such as weather, the economy or special events that might impact a single survey period (such as the flooding of the Mississippi River in 2001 which affected travel patterns in the NHTS) would be mediated with the recommended approach as data are collected in every year.

With regards to survey content, high survey burden can result in low survey completion rates. Surveys that include a travel diary (module 5) are known to be particularly burdensome since the diary often requires entering data on multiple trips per day. Burden can be reduced by eliminating questions altogether or by asking individual respondents a randomized subset of the complete survey. Since the Question Bank development process aimed to eliminate questions that are not of high value to Vermont transportation agencies, dropping additional questions is not feasible. Using a randomized subset of the full Question Bank would require an increase in sample size to achieve the same target accuracy, likely increasing the overall cost of the survey program. Consequently, we do not recommend this approach for the All-in-One program.

4.2. Recruitment Strategy

Determining the appropriate recruitment method was a vital step in the development of the proposed All-in-One survey implementation plan for Vermont. The recruitment strategies used for LRTPS 2016, random address-based recruitment, and CCPRC, convenience sampling, as well as the purchase of a paid sample representative of the Vermont population, all offer different advantages and drawbacks.

Random address recruitment, used for the 2016 LRTPS and the 2016 NHTS, ensures that all households have an equal opportunity to participate in transportation surveys and provides the potential that recruited households or individuals are demographically representative

RECRUITMENT STRATEGY

Recommended Recruitment Strategy: Random, address-based recruitment using two postcard solicitations and a random prize drawing participation incentive

Key Considerations:

- Consistent with current *best practice*
- Facilitates statewide data collection while ensuring an adequate sample for travel modeling by CCRPC
- Outperformed convenience sampling capturing low-income and older Vermonters in recent Vermont surveys
- Supports a statistically rigorous weighting process since the selection probability is known for each respondent

of the state as a whole. Differences in response rates among different regions and/or demographic groups, however, are likely to produce a set of respondents that is less representative than the recruits. Additionally, mailing cost for random address-based recruitment are a significant contributor to overall survey cost. Low response rates require that the number of households invited to participate in the survey significantly exceed the target sample size and many invitees who eventually participate require more than one invitation before they respond. The 2016 LRTPS achieved an 18.4% response rate but only 7.8% of invitees responded after the first mailing.

Non-mail approaches such as email and advertisement are less expensive per unit. These recruitment strategies produce convenience samples that are likely to deviate substantially from statewide demographics and it is impossible to calculate respondents' probability of selection (which is used in the most statistically rigorous weighting processes). Deviations between the distribution of sample and population demographics can be addressed to a certain extent by weighting responses to match Census demographics as long as an adequate number of respondents in each subset of the population has been collected. While the application of weighting factors is very common with surveyed data, there is a risk that the weighting process may omit factors that influence travel behavior, resulting in a weighted sample that is also biased. This risk is increased with a convenience sampling approach.

Many professionals interviewed during the project highly recommend the use of survey incentives to improve recruitment success rates, especially where participation is expected to be low. These same professionals also noted the relative lack of research on best practice in this area, however. Trussell and Lavrakas (2004) demonstrated that cash incentives are effective but could not measure an optimal incentive level with certainty. Survey incentives, often sent with the survey recruitment letter, can also be a major component of cost. Because incentives are often provided in a mail-back recruit letter, the shift towards web-based surveys has corresponded to an increase in lottery or draw-based prizes for incentives. For example, the 2013 UVM Longitudinal Survey of Overnight Travel was web-based and achieved over 50% retention throughout a year of monthly surveys by using either an iPod and iPad drawing each month (Aultman-Hall et al. 2015).

Address-based random mail-out solicitations are the current best practice for survey recruitment and is the recommended strategy for the All-in-One program using two mailing contacts. To minimize the cost of this recruitment effort, we recommend using postcard mailings and incentives based on a random prize drawing. Though this recruitment method is more costly than convenience sampling, it is consistent with the best statistical practices and, when comparing the LRTPS 2016 and CCRPC 2016 sample (see 4.2.1 and 4.2.2), it performed better than convenience sampling in capturing low income and older Vermonters. With sufficient sample size, weighting can be used to correct for biases in sample demographics. A thorough review of weighting methods and variables are required even with address-based random sampling.

A panel survey approach was considered in which each person or household is surveyed repeatedly, often once per year, to measure intrapersonal variability, lifecycle variation and other changes over time. This method has fallen out of favor due to high attrition rates as participants move out of the study region or discontinue their participation for other reasons. Because discontinued respondents need to be replaced in order to maintain an adequate sample size, recruiting costs are not eliminated. The technical demands of weighting the panel of respondents to get a representative sample are also

significant. The purchase of a paid sample representative of the Vermont population was considered cost prohibitive and is not recommended.

This remainder of this section compares the LRTPS address-based sample (Section 4.2.1) and CCRPC convenience sample (section 4.2.2) to U.S. Census data. Both recruitment efforts produced samples that required weighting in order to better represent the population of Vermont. Bias in the CCRPC 2016 response suggests a need to very carefully design recruiting if these methods are chosen. The CCRPC 2016 survey included numerous cyclists and walkers that were not necessarily distinguishable by the variables typically used for weighting. CCRPC participants came from three e-newsletters: the MPO, neighborhood newsletter and a bicycle pedestrian advocacy group. These three groups were different in terms of sociodemographics and also travel behavior (see Appendix D).

4.2.1. Comparison of the LRTPS Samples to Census Data

The LRTPS 2016 used random address-based recruitment targeting five study regions shown in Figure 1.

An initial postcard invited participants to complete a web-based survey. The second mailing included the website but also a paper version of the survey. This was easily done because the LRTPS did not include a travel diary.

Since the LRTPS utilized random address recruitment, spatial analysis of patterns in response/non-response among household recruited to participate in the LRTPS as well as demographic comparisons between respondents and U.S. Census data can be used to evaluate the effectiveness of random address based recruitment for generating demographically representative samples. The addresses of invitees who did not reply either by web or paper were also provided by RSG Inc. This allowed the unique opportunity to consider the attributes of those who replied and those who did not.

The urban and rural areas of Vermont vary from each other. The differential distribution of origins and destinations and availability of transit services at a minimum is expected to relate to different opinions and travel behaviors across the state. For these reasons, ensuring adequate response rate and



Figure 1. LRTPS study regions (LRTPS 2016)

spatial coverage is very important in design of a survey program. The LRTPS offered an ideal way to consider spatial patterns in response rates for a postcard-based recruit for both a web-based and a paper survey.

In total 12,000 households were recruited to participate in the LRTPS and the address information for 10,208 of these households (including 1,876 out of 2,232 responding households) was sufficient for geolocation. Response rates are tabulated by LRTPS study region and county in Table 3. Geo-located households as well as their response/non-response status are show in Figure 2. Response rates show no statistically significant difference at either the regional or county level. These results indicate that a random address-based recruit is a solid way to ensure geographic coverage in a transportation survey in Vermont.

Table 3. LRTPS Response rate by county and region

Region & County		Recruits	Response Rate
Central	Lamoille	264	22.0%
	Orange	285	18.9%
	Washington	689	20.2%
	Regional Total	1,238	20.3%
Champlain Valley	Addison	494	19.8%
	Chittenden	2,456	19.2%
	Franklin	690	16.7%
	Grand Isle	114	18.4%
	Regional Total	3,754	18.8%
Northeast	Caledonia	836	20.0%
	Essex	125	14.4%
	Orleans	775	16.6%
	Regional Total	1,736	18.1%
Southeast	Windham	744	17.9%
	Windsor	940	17.2%
	Regional Total	1,684	17.5%
Southwest	Bennington	633	16.4%
	Rutland	1,163	17.8%
	Regional Total	1,796	17.3%
Statewide Total		10,208	18.4%

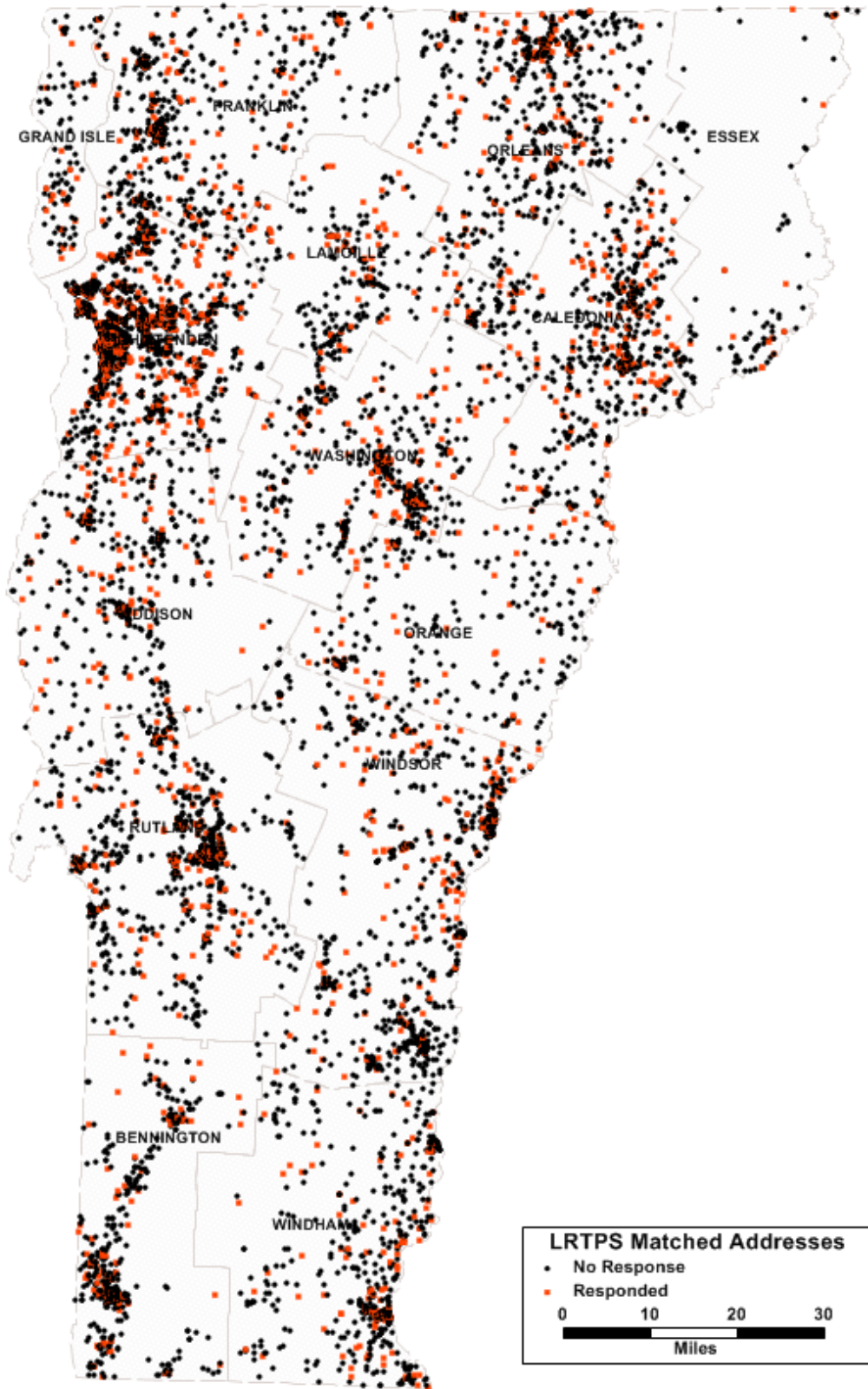


Figure 2. Response status for 10,208 geo-coded households recruited to participate in the 2016 LRTPS

The random address recruitment strategy is intended to produce a representative sample of respondents. To test the effectiveness of this recruitment strategy, we compared respondent demographics to demographic data provided by the U.S. Census Bureau's American Community Survey (ACS). These analyses were conducted using the raw, unweighted LRTPS responses and then repeated using the weights created for the LRTPS study based on respondents' gender, age, income and home region. The results are summarized in Table 4. Additional detail on each of these comparisons is provided in Appendix C.

Table 4. Overview of demographics differences between the LRTSP and ACS

Variable	Distribution of Unweighted Responses Matches ACS	Distribution of Weighted Responses Matches ACS
Gender	*	--
Age	**	**
Income	**	--
Household Size	**	*
Education (respondents 25+)	**	**
Employed (respondents 25+)	**	*
Commute Mode (respondents 25+)	**	**

-- Differences not statistically significant, * Significant at P = .1, ** Significant at P = .05

Overall, as compared the ACS data, the LRTPS sample is older, higher income, and better educated than the state population at large. The LRTPS oversamples females, two-person households, single occupancy vehicle commuters and non-workers. Note, that while the weighting used for the analysis of the LRTPS eliminates that statistically significant difference in the distributions of gender, income and employment, the distribution of the weighted respondents still differ from the population for the remaining variables. Weighting using sociodemographic variables improves a database but does not make it perfectly accurate.

4.2.2. Assessing Convenience Sampling with the CCRPC2016

Numerous methods of convenience sampling have increased in usage especially as response rates for telephone and mail-back surveys have decreased over the last two decades and the use of on-line surveys has increased. Convenience sampling consists of inviting individuals who can be easily contacted to participate in the survey. These individuals may be recruited by email, social media, employer list serves or advertisement. The groups or lists used for recruitment may have a particular interest in the survey subject matter. This method of sampling provides no expectation that the sample will be representative. The advantage of a convenience sample is it may be possible to generate a large sample with significantly lower recruitment costs. Weighting the sample to represent the population may be possible if adequate numbers of respondents within each subset of the population are recruited.

The CCRPC 2016 relied on convenience sampling during a much shorter time period than usual. The CCRPC rMoves study recruited participants using an open-link recruitment survey distributed through the CCRPC newsletter, Local Motion list serve and the community e-newsletter Front Porch Forum. In

total, 604 of the 847 individuals who completed the recruitment survey were eligible to participate and 247 (40%) of those individuals activated the rMoves App. The final dataset included 163 individuals who completed at least one full day of the survey and 64 individuals with partial data collection.

The demographics of the participants in the CCRPC rMoves study exaggerate some of the same biases seen in travel surveys in general including the LRTPS sample. In order to consider these patterns, the distribution of individuals by household income, age, household size, number of vehicles and gender are tabulated against the U.S. Census data from the ACS 2015 5-year estimates for Chittenden County (see Table 5 through Table 9). The breakdown of the Chittenden County LRTPS respondents is also provided for reference. The CCRPC sample is not statistically significantly different from the ACS in terms of either gender or number of household vehicles but did differ significantly for the other demographic variables. Notably, lower income and older respondents are more underrepresented in the CCRPC convenience sample compared to the LRTPS address-based sample (see Table 5 and Table 6). Individuals in single person households are similarly underrepresented (Table 7). In general, the convenience sample collected for CCRPC 2016 performed well in terms of gender representativeness and attracting younger respondents that are underrepresented in many other surveying efforts. But the method did less well capturing lower income respondents. As shown in Figure 3, the sample was well distributed spatially especially given the small sample size.

Table 5. Distribution of household income in CCRPC 2016

Household Income	ACS**	CCRPC¹	LRTPS²
Less than \$25,000	17.8%	2.4%	11.1%
\$25,000 to \$34,999	8.1%	2.9%	6.7%
\$35,000 to \$49,999	12.6%	6.7%	12.4%
\$50,000 to \$74,999	18.1%	17.3%	20.5%
\$75,000 to \$99,999	14.5%	21.2%	18.3%
\$100,000 to \$149,999	17.2%	30.3%	18.1%
\$150,000 to \$199,999	6.0%	11.1%	8.1%
\$200,000 or more	5.7%	8.2%	4.9%
Total	100%	100%	100%

ACS/CCRPC significantly different at $p = .01$; ¹n = 208, ²n = 371

Table 6. Age Distribution in CCRPC 2016

Age	ACS**	CCRPC ¹	LRTPS ²
25-34 years	20.6%	23.6%	15.4%
35-44 years	18.2%	28.2%	11.5%
45-54 years	21.8%	21.8%	18.7%
55-64 years	19.7%	18.2%	24.2%
65-74 years	11.1%	7.3%	19.4%
75 years or older	8.6%	0.9%	10.8%
Total	100.0%	100.0%	100.0%

**ACS/CCRPC significantly different at $p = .01$; ¹ n = 220, ² n = 434

Table 7. Distribution of Household Sizes in CCRPC 2016

Household Size	ACS**	CCRPC ¹	LRTPS ²
1 person	27.6%	11.5%	23.6%
2 people	38.2%	42.3%	45.0%
3 people	15.3%	22.5%	15.9%
4+ people	18.9%	23.8%	15.6%
Total	100.0%	100.0%	100.0%

**ACS/CCRPC significantly different at $p = .01$; ¹ n = 227, ² n = 449

Table 8. Gender Breakdown in CCRPC 2016

Gender	ACS	CCRPC ¹	LRTPS ²
Male	48.8%	47.6%	48.7%
Female	51.2%	52.4%	50.7%
Other	N/A	0.0%	0.7%
Total	100.0%	100.0%	100.0%

ACS/CCRPC samples not significant different; ¹ n = 227, ² n = 448

Table 9. Breakdown of Household Vehicle Availability in CCRPC 2016

Vehicles	ACS	CCRPC ¹	LRTPS ²
No vehicle available	7.4%	4.0%	4.9%
1 vehicle available	33.5%	29.1%	26.5%
2 vehicles available	41.5%	47.1%	45.2%
3 vehicles available	12.9%	15.0%	15.8%
4 or more vehicles available	4.7%	4.9%	7.6%
Total	100.0%	100.0%	100.0%

ACS/CCRPC not significantly different; ¹n = 227, ²n = 449

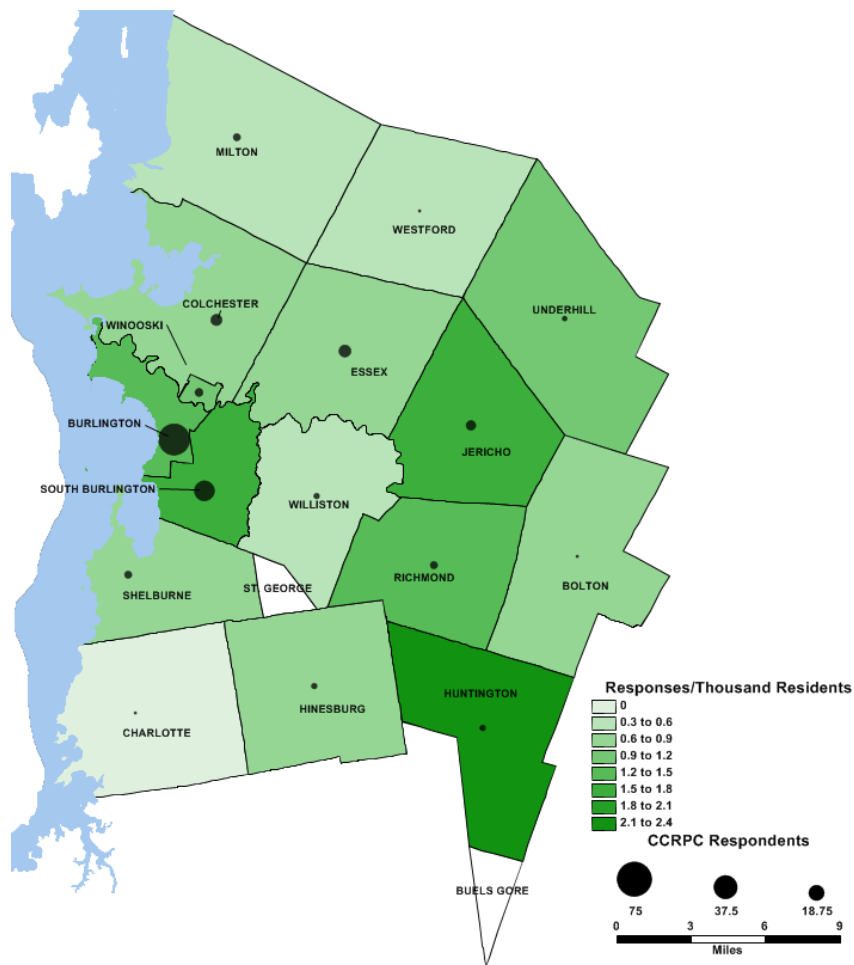


Figure 3. Spatial distribution of CCRPC 2016 respondents

4.3. Data Retrieval Method

Every survey data retrieval method has advantages and disadvantages. Phone surveys had a significant advantage in that the process could include screening questions and thus a stratified random sampling to ensure adequate numbers of cyclists or transit riders. Declining rates of landline ownership and phone survey participation have made phone retrieval less viable. Paper surveys can be completed by almost anyone and therefore have a very low risk of coverage error but this retrieval method is expensive due to printing, mailing and data coding costs. Moreover, the cost is unpredictable because it depends on response rate. It is also difficult to collect geocoded data using paper surveys (or phones) and as a result the data have lower spatial accuracy than the various digital data retrieval methods coming into common use in the transportation field. Paper surveys are also known to result in missed trips, especially shorter trips. Phone surveys allow for human interviewers to prompt for different details or trips and to clarify definitions that can improve data quality relative to paper surveys.

Phone surveys are costly to conduct, however. Web and mobile-device based surveys have fixed up-front costs for programming and very low marginal costs for each additional survey completed. These surveys allow for automatic location geocoding. Mobile-device based surveys also show particular promise in capturing short trips that are missed in other surveys.

In recent years, an increasing number of agencies have utilized web and mobile-device based survey retrieval methods. Concerns remain, however, that these methods may exclude vulnerable populations that have limited or no access to these technologies. Given the limited population and transportation survey budgets in Vermont we recommend allowing larger agencies and regions in other states to continue to pursue this important travel data collection innovation before adopting this technology and reconsidering App-based surveys after the first 5-year cycle.

Analysis of data from the LRTPS and the Vermonter Poll indicates that Internet access is substantially higher than smartphone access in the state of Vermont. Only 5.7% of LRTPS respondents reported that they did not have any means to access the Internet (see Section 4.3.2) whereas 21.4% of Vermonter Poll respondents reported no access to a smartphone (Section 4.3.3). Currently, mobile device-based data collection may be insufficient to provide a representative sample in Vermont. Consequently, a web-based data retrieval method is recommended for the All-in-One survey program. A web-based survey is effective for collection of both the transportation planning and travel diary components. Online surveys provide automatic geocoding, improving data completeness and quality relative to paper and phone-based surveys while also offering cost savings. Online surveys are cost competitive with mobile Apps and, as described in this section, are accessible to a wider group of Vermonters at this time. Online surveys are also more supportive of household-based data collection (recommended in Section 4.4) than

RETRIEVAL METHOD

Recommended Retrieval Method:
Web-based survey tool

Key Considerations:

- Automatic geocoding improves spatial data accuracy
- Currently accessible to a wider set of Vermonters than smartphone-based survey Apps
- Lower cost per completed household for travel diary collection than telephone or paper data collection
- Greater predictability in data processing costs than phone and paper surveys

mobile-device based surveys since they do not require a separate device for each member of the household.

In the event that the Vermont transportation agencies opted to pursue a survey without the travel diary module of the Question Bank, phone and mail-back survey options might be viable retrieval methods. In this case, cost per respondent would be a reasonable method for selecting between these options.

This remainder of this section describes the difference between paper and online respondents to the LRTPS (Section 4.3.1) as well as demographic differences in access to the Internet (Section 4.3.2) and smartphones (Section 4.3.3) found in the LRTPS and the Vermonter Poll respectively. Appendix C contains the additional detailed tabulations of demographic variables, customer satisfaction, issue importance and travel behavior by LRTPS retrieval method. It is important to note that we do not know which of these retrieval methods resulted in a more representative sample in terms of issue importance or travel behavior since the true, population level measures are not known for these variables. The only population level standards available are those collected by the U.S. Census.

4.3.1. Demographic Comparison of Paper and Online LRTPS Respondents

While potentially more accurate and less burdensome than traditional retrieval methods, online surveys do risk excluding Vermonters without access to the Internet. Moreover, empirical evidence suggests that data collection may be influenced by retrieval methods. To assess the possible differences between paper (57.5%) and online (42.5%) respondents, the project team considered the reported travel behavior, levels of customer satisfaction and transportation issues prioritization after weighting / controlling for gender, age, income and region in the LRTPS. The online sample was weighted to match paper sample in terms of gender, age, income and region. Table 10 through Table 12 show the distribution of responses for the paper and weighted online samples for variables with statistically significant differences: household size, level of education and self-described neighborhood type. Paper surveys were more likely to be completed by smaller households, less educated individuals and individuals living in small villages or towns.

Table 10. Weighted LRTPS Household Size by Retrieval Method

Household Size	Online survey	Paper survey
1 person	27.8%	34.3%
2 people	48.7%	42.2%
3 people	12.2%	12.6%
4 people	7.5%	7.6%
5 people	2.8%	2.1%
6 people	0.8%	0.8%
7 people	0.3%	0.5%

Table 11. Weighted LRTPS Education Level by Retrieval Method

Highest level of education	Online survey	Paper survey
0-11 years, no diploma	2.2%	3.9%
High school graduate or GED	13.6%	25.1%
Some college, no degree	17.9%	17.6%
Associate's degree	9.8%	10.1%
Bachelor's degree	29.0%	23.1%
Graduate degree or higher	27.6%	20.3%

Table 12. Self-described Neighborhood Type Retrieval Method

Neighborhood Type	Online survey	Paper survey
Urban/Suburban	34.9%	36.5%
Small village/town	26.7%	33.5%
Rural	38.4%	30.0%

The proportion of respondents using online and paper surveys for each LRTPS region and each county are shown in Table 13. The difference in the proportion of online respondents is statistically significant at both the regional and county levels. Appendix C contains the tabulation of the weighted data comparing other demographic variables, customer satisfaction, issue importance and travel behavior. While the paper and web respondents were not different based on every measure, they were different based on many measures. It is important to note that we do not know which of these retrieval methods resulted in a more representative sample in terms of issue or travel behavior.

Table 13. LRTPS Retrieval Method by County

Region & County		Online survey	Paper survey
Central	Lamoille	37.9%	62.1%
	Orange	37.0%	63.0%
	Washington	49.6%	50.4%
	Regional Total	44.2%	55.8%
Champlain	Addison	43.9%	56.1%
	Chittenden	51.0%	49.0%
	Franklin	40.0%	60.0%
	Grand Isle	38.1%	61.9%
	Regional Total	47.8%	52.2%
Northeast	Caledonia	35.3%	64.7%
	Essex	33.3%	66.7%
	Orleans	38.0%	62.0%
	Regional Total	36.3%	63.7%
Southeast	Windham	38.4%	61.7%
	Windsor	41.4%	58.6%
	Regional Total	40.0%	60.0%
Southwest	Bennington	30.8%	69.2%
	Rutland	41.6%	58.5%
	Regional Total	37.9%	62.1%
Statewide Total		42.5%	57.5%

4.3.2. Access to the Internet

Widespread access to the Internet and/or smartphones in the Vermont population is necessary for web-based or mobile-device based retrieval methods to be successful. The LRTPS collected information about Vermonters' Internet access. Tables 14 - 19 summarize the levels of Internet access available to different populations within in Vermont as measured by the weighted LRTPS sample. Respondents were characterized as having limited access if they reported that they did not have access to the Internet at home or on a mobile device but could access the Internet in other ways (e.g. at work, school, or via public wifi hotspots). Statewide, 84.9% of respondents in the weighted LRTPS sample had home-based Internet access and 94.3% of respondents reported at least some form of Internet access (Table 14). This compares to 79.1% of households in the 2015 ACS. Approximately 52% of respondent had used a mobile device for Internet access and 5% used a mobile device primarily (i.e. did not have home access as well). Nationally, the Pew Foundation found that 64% of American adults owned a smartphone and 7% rely on these devices as their primary mode of Internet access (Smith and Page 2015). Methods for accessing

the Internet are broken out by region and self-defined neighborhood type in Table 14 and Table 15 respectively. Table 16 breaks out Internet access among online and paper survey respondents. There are meaningful differences that should be kept in mind as the survey program is implemented and data are analyzed.

Table 14. Internet Access by Region (LRTPS)

Region	None	Limited	Home No Mobile	Home and Mobile	Mobile No Home
Central	7.7%	3.3%	37.0%	47.9%	4.1%
Champlain Valley	3.5%	3.9%	34.6%	54.3%	3.7%
Northeast	10.9%	6.6%	39.6%	32.3%	10.7%
Southeast	4.9%	2.4%	47.0%	40.6%	5.1%
Southwest	6.4%	6.7%	35.2%	45.2%	6.6%
Statewide	5.7%	4.2%	37.6%	47.3%	5.1%

Table 15. Internet Access by Neighborhood Type (LRTPS)

Neighborhood Type	None	Limited	Home No Mobile	Home and Mobile	Mobile No Home
Urban/Suburban	5.7%	4.5%	32.8%	53.1%	4.0%
Small Town/Village	5.8%	4.5%	41.2%	41.8%	6.7%
Rural	4.8%	3.5%	41.1%	45.9%	4.8%

Table 16. LRTPS Means of Accessing the Internet

Internet Access	Online survey	Paper survey
No Internet	0.1%	10.5%
Limited Internet	1.5%	6.6%
Home Access	30.3%	43.9%
Home and Mobile Access	64.2%	32.8%
Mobile Access	3.9%	6.2%

As shown in Tables 17 - 19, Internet access increases with income and decreases with age. Even in the lowest income and highest age categories, over 60% of respondents had home or mobile-device based Internet access suggesting that it would be feasible to reach Vermonters in these demographic groups with a web-based survey.

Table 17. Internet Access by Household Income (LRTPS)

Household Income	None	Limited	Home No Mobile	Home and Mobile	Mobile No Home
Less than \$15,000	16.5%	14.1%	42.1%	13.3%	14.1%
\$15,000 to \$24,999	12.9%	9.3%	40.2%	30.5%	7.2%
\$25,000 to \$34,999	5.0%	3.1%	42.5%	41.6%	7.8%
\$35,000 to \$49,999	3.6%	3.4%	38.3%	50.9%	3.8%
\$50,000 to \$74,999	2.0%	1.2%	36.7%	54.0%	6.1%
\$75,000 to \$99,999	0.4%	2.0%	38.0%	58.1%	1.5%
\$100,000 to \$149,999	0.2%	0.0%	27.5%	70.1%	2.2%
\$150,000 to \$199,999	0.0%	0.0%	26.1%	73.9%	0.0%
\$200,000 or more	0.0%	0.0%	18.8%	80.5%	0.7%

Table 18. Internet Access by Income - Age 75 + years (LRTPS)

Income Category	None	Limited	Home No mobile	Home and Mobile	Mobile No Home
Less than \$15,000	32.0%	16.2%	48.1%	0.0%	3.7%
\$15,000 to \$24,999	43.6%	15.3%	41.1%	0.0%	0.0%
\$25,000 to \$34,999	23.7%	3.3%	69.2%	1.9%	1.9%
\$35,000 to \$49,999	22.0%	5.8%	58.7%	13.6%	0.0%
\$50,000 to \$74,999	16.6%	6.5%	66.0%	11.0%	0.0%
\$75,000 to \$99,999	8.4%	18.7%	68.8%	4.1%	0.0%
\$100,000 to \$149,999	11.4%	0.0%	72.9%	15.8%	0.0%
\$150,000 or more	0.0%	0.0%	100.0%	0.0%	0.0%

Table 19. Internet Access by Age Group (LRTPS)

Age Category	None	Limited	Home No mobile	Home and Mobile	Mobile No Home
18-24 years	0.0%	9.6%	21.6%	50.3%	18.6%
25-34 years	0.0%	2.1%	21.4%	68.5%	8.0%
35-44 years	1.3%	1.4%	23.1%	69.3%	4.9%
45-54 years	2.5%	3.2%	38.5%	50.5%	5.4%
55-64 years	6.7%	3.8%	46.3%	40.3%	2.9%
65-74 years	9.6%	5.7%	59.2%	24.6%	0.9%
75 years or older	25.4%	9.3%	58.0%	6.1%	1.1%

4.3.3. Access to Smartphones

The annual Vermonter Poll survey conducted by the UVM Center for Rural Studies in February, 2017 included the following question at the request of this project team: “How many adults (including yourself) in your household have a data-enabled cell phone, that is a cell phone that can access the Internet?”

Information about data enabled cell phone ownership for 590 respondents was collected. Of these respondents, 79% of individuals reported that a least one adult in their household owned a data enabled cell phone. Tables 20 and 21 show the household cellphone penetration levels by region and household income respectively. Household smartphone penetration is considered to be full if there are at least as many data enabled cell phones as adults in the household and partial if the household has fewer cell phones than adults. Cell penetration is lowest in the Central and Southwest regions and highest in the Champlain Valley. It is also highly correlated to income with nearly 60% of households with income below \$25,000 having no data enabled cellphones.

Table 20. Household Smartphone Penetration by Region (Vermonter Poll)

Region	HH Smartphone Penetration (%)			Total Respondents
	None	Partial*	Full	
Central	26.9%	15.7%	57.4%	108
Champlain Valley	17.2%	14.6%	68.2%	261
Northeast	24.6%	22.8%	52.6%	57
Southeast	20.7%	16.3%	63.0%	92
Southwest	26.4%	15.3%	58.3%	72
Total	126	94	370	590

* Cell penetration is considered to be full if there are at least as many data enabled cell phones as adults in the household and partial if the household has fewer cell phones than adults.

Table 21. Household Smartphone Penetration by income group (Vermonter Poll)

Household Income	HH Smartphone Penetration			Total Respondents
	None	Partial	Full	
Less than \$25,000	57.9%	10.5%	31.6%	76
Between \$25,000 and \$50,000	27.0%	23.5%	49.6%	115
Between \$50,000 and \$75,000	15.7%	17.7%	66.7%	102
Between \$75,000 and \$100,000	8.5%	15.9%	75.6%	82
More than \$100,000	2.3%	9.1%	88.6%	132
Total	101	78	328	507

Tables 22 and 23 show the breakdown of data enabled cellphone ownership by educational attainment and age. Because these variables are only collected for the individual respondent and cellphone ownership is collected at the household level these tables only include respondents with full cellphone

penetration or with no cellphone penetration (n = 496). Smartphones are more prevalent for younger and more educated individuals as might be expected. A smartphone-based survey might systematically limit data from older and/or less educated Vermonters. The barriers to access to a smartphone-based travel and transportation survey is considered to be more significant than access to an Internet-based survey based on the data in this section.

Table 22. Data enabled cellphone ownership by education (Vermonters Poll)

Educational Attainment	HH Smartphone Penetration		Total Respondents
	None	Full	
Less than High School (no diploma)	70.0%	30.0%	10
High School graduate (incl. GED)	36.7%	63.3%	98
Some college (no degree)	35.7%	64.3%	98
Associates/technical	14.3%	85.7%	42
Bachelor	14.5%	85.5%	138
Post graduate/professional	14.7%	85.3%	102
Total	119	369	488

Table 23. Data enabled cellphone ownership by age (Vermonters Poll)

Age (years)	HH Smartphone Penetration		Total Respondents
	None	Full	
18-24	0.0%	100.0%	14
25-34	6.5%	93.5%	46
35-44	1.9%	98.1%	53
45-54	8.3%	91.8%	97
55-64	20.8%	79.2%	130
65-74	50.0%	50.0%	92
75+	61.5%	38.5%	52
Total	117	367	484

4.4. Sampling Unit

SAMPLING UNIT

Recommended Sampling Unit:

- Household
- Retain data from partially completed households as part of a supplemental person-based dataset

Key Considerations:

- Supports travel modeling by VTrans and CCRPC
- Increases the sample size for analysis of the customer satisfaction and attitudinal variables (modules 1-4)

Transportation surveys can be conducted with either an individual or a household as the basic sampling unit. Surveys with an individual as the sampling unit are referred to as “person-based” or personal surveys and information is collected from a single household member regardless of the household size. These surveys may collect information about the demographics of the respondent’s household but generally the level of detail is much lower than in surveys that use a household sampling unit and little

or no data are collected about other household members’ travel behavior or activities. Surveys that collect information about the travel behaviors of *all* members of the household are known as “household-based.” Travel surveys have more typically been recruited at the household unit in an address-based sampling frame, but newer survey methods, involving GPS tracking, mobile devices and Internet-based response, are more efficiently carried out in person-based units. Some practitioners are eager to move toward person-based travel surveys due to the efficiency of data collection using GPS enabled mobile devices (Safi et al. 2015) but full household participation for surveys conducted in this way is more challenging than getting full household participation using other retrieval methods.

The unit of observation for travel surveys has traditionally been, and still is, the household. The household or residential location is considered a base from which people travel and is the persistent modeling framework. Moreover, the specific make-up and location of the household tends to have a significant impact on travel behavior (Inbakaran and Kroen 2011). Traditional four-step transportation demand models are based on trip generation rates per household. More advanced activity-based models have reinforced this household-based structure because members of a household do not act independently - they share resources including vehicles, adjust travel patterns to suit other member’s schedules, and make decisions about home ownership based on all household members’ needs. Therefore, it may not be methodologically sound to treat the travel behaviors of an individual as independent data points for statistical analysis of regional travel behaviors. All weighting efforts found in the travel survey literature were oriented to the household. Person-level data is most often summed by household in order to proceed with the development of household-level weighting (Cambridge Systematics 2011).

Complete data collection from all household members is a challenging task and has negative impacts on the response rate (Sharp and Murakami 2005). In many travel surveys, data collected from a household is considered incomplete and discarded if it does not include responses from all adults in the household (or in other cases half of the adult household members or all persons over 5 years of age). For example, the design of the 2017 NHTS requires that all members of the household have complete travel log

information, or the observation is not accepted (Westat, Inc. 2015). The cost of re-contacting survey recruits in order to achieve complete household participation can be significant.

The team is recommending a household-based survey for the All-in-One program with the understanding that data from incomplete households would not be discarded but rather maintained and recorded in a separate person-based set of tables. Person-based data are adequate for many analyses and use of all data is appropriately respectful of the participants who volunteered their time. Only a reasonable effort at completely full households is recommended in order to manage costs. We recommend only reasonable effort to ensure complete household representation, with development of both household-level and person-level datasets and associated weights. The use of person-level data from incomplete households will increase the cost-effectiveness of the survey efforts, as opposed to discarding the data from households without travel diary information for every adult member of the household. Incomplete households are useful for non-travel diary questions and also for many aspects of travel modeling. Therefore, our sample size recommendations ensure adequate households for trip rate models for the CCRPC and VTrans model but we assume more in-depth travel analysis as well as the customer satisfaction considerations would be performed using individual level data from both complete and incomplete households

While there has been relatively little research on the matter, the goal to simulate full households based on travel data from an individual has been the subject of many discussions. From an NCHRP Research Needs Statement from 2007 (Sampling Persons within Households for Travel Surveys (NM) - ABJ40, Travel Survey Methods), there is a stated need for better methods of replicating data for an entire household when travel logs were not completed for every member of the household. In particular, the interaction between household composition and vehicle availability is of interest. A person-based survey process would be viable if an effective replication scheme was available. However, some argue that generating a synthetic population without knowledge of every individual agent’s household structure would lead to inaccuracies (Pritchard and Miller 2012). If surveys collect person-based information including all household members information, the objective is to simulate the full household’s travel behavior based on the travel of the one individual as well as that of similar households in the region. This simulation process is not recommended for the Vermont All-in-One program because the methods are not mature, it would increase costs and our sample size will undoubtedly be too small.

4.5. Sample Size

There is little consensus about the appropriate sample size for travel surveys (Stopher et al. 2008; Richardson, Ampt,

SAMPLE SIZE

Recommended Sample Size:

- 2,5000 total households statewide over a 5 year survey cycle including:
- 1,200 total households in Chittenden County over a 5 year survey cycle
- Utilize data from household with partially completed data to augment the analysis of customer satisfaction and attitudinal variables

Key Considerations:

Sample size is sufficient to:

- Conduct *statewide* analysis of trends related to customer satisfaction and attitudes on an annual basis
- Conduct *regional* analysis of trends related to customer satisfaction and attitudes every 5 years
- Support VTrans and CCRPC model updates every 5 years with similar accuracy to the NHTS
- Enable weighting based on key demographic variables such as age and income

and Meyburg 1995). Larger sample sizes reduce sampling error but increase the survey program cost. Larger sample sizes also tend to reduce the variance in the sample weights resulting in lower margins of error in the estimation of travel behaviors from the dataset. Sample size selection must balance multiple issues including survey cost, acceptable level of error as well as, in some cases political considerations related to the representation of specific regions (Stopher et al. 2008). Sample size selection should not be highly dependent on population size (except in cases where the population size is very small) but instead should reflect the *underlying variability* of the data measures being collected and the desired precision for the estimation of that variable (Richardson, Ampt, and Meyburg 1995). For example, estimating average trip length with similar levels of accuracy will require a larger sample in a region where trip lengths are highly variable than in a region where household trips lengths are less variable. This is true even if the population in the more variable region is smaller than in the more homogenous region. As detailed in Appendix F, in the 2009 NHTS Chittenden County had a more variable trip length than areas in Vermont outside of Chittenden County. Sample size calculation methods are mathematically well-define but require assumptions about inputs (the true underlying variance of the measure within the whole population) and the confidence level of the output (typically 95%). In practice, the existing literature and the research team's discussions with survey managers both indicate that an agency's available budget typically dictates sample size. Some sources suggest a minimum of 1,000 households in any jurisdiction.

Two criteria were applied in this project in order to estimate appropriate sample sizes for the All-in-One program. First, we assumed the total sample size at the end of the 5-year survey cycle should be sufficient to provide average surface trip generation rates and trip lengths within 5% at a 95% level of confidence for both Chittenden County and statewide Vermont (excluding Chittenden County). Second, we assumed the annual sample size should have a minimum of 20 individuals statewide in each income, age and mode use categories to facilitate sample weighting. We relied on the U.S. Census data and the travel characteristics from the 2009 NHTS data for Vermont to approximate sample sizes. Sample size estimates using standard sample size calculations based on the variance observed in the NHTS for different travel variables are included in Appendix F, as well as the expected number of respondents from various mode users groups. Note for these calculations we are considering sample size in terms of number of households not persons.

We recommend a total sample size of 2,500 households – 1,200 households in Chittenden County and 1,300 households in the remainder of the state with data from 500 households collected each year. This sample size is expected to be sufficient to match household trip rates and trip lengths as found in the 2009 NHTS within 5% for both Chittenden County and the state outside of Chittenden County over the five year survey cycle (see Appendix F). Given the random address-based recruitment, this sample size is also likely to produce a sample that captures a sufficient number of residents in low income and older age groups on an annual basis to ensure adequate weighting of the sample is possible.

Erring on the side of larger sample sizes increases the likelihood of capturing an adequate subsample of travelers of special interest such as users of active transportation and transit modes. Given the low proportion of Vermonters who bicycle (approximately 2%) and use transit (approximately 1%), however, an annual sample size an annual sample of 1,000 to 2,000 Vermonters would be required to capture at least 20 people in each of these mode user groups. This is not deemed feasible for the All-in-One. Additional efforts to capture these user groups is discussed in Chapter 5.

As discussed in Section 4.4, household level data remains the best practice for travel modeling but is not necessary for other applications. The 2,500 household sample size recommendations ensure adequate households for trip rate models for the CCRPC and VTrans. Retaining data from incomplete households and developing a person-level dataset and weights will effectively increase the sample size for the Transportation Planning modules and improve the cost-effectiveness of the survey.

4.6. Estimated Survey Costs

Survey costs are highly variable and are influenced by a number of factors including recruiting strategies, response rates and the length and/or complexity of the survey. Thus it is challenging to meaningfully compare the costs across travel surveys given variability in the number and types of questions used, recruitment strategies, and target sample sizes. Hartgen and San Jose (2009) report an average cost per travel survey of almost \$500,000 with smaller sample surveys typically having higher per unit costs. On a household basis, Hartgen and San Jose found an average of \$150 per completed survey. This remains broadly consistent with estimates provided by agencies and survey managers that participated in informal interviews for this project. The NHTS 2016 was on the higher end of the cost spectrum (\$225) due to its scope and scale. Note that \$225 was the cost paid per household by each add-on agency and is not the full survey cost as some costs were subsidized by the FHWA.

Conversations with current survey managers nationwide indicate recent costs of \$145-\$225 per completed household for a typical travel survey with a travel diary. Most of these survey efforts included some GPS or mobile app data collection. Costs per completion for the CCRPC 2016 survey came in at the higher end of this spectrum reflecting in part a short-turnaround time and challenges to the planned recruitment process that resulted in a comparatively small sample size.

Person-based surveys, similar to the LRTPS, could be administered to collect the Transportation Planning modules from the Question Bank and have lower costs per completion than household travel diary surveys. Estimates for the cost of these surveys range from \$40 - \$85 per completion. At \$40 per completed survey, the LRTPS was one of the lowest cost surveys administered. The low per complete cost of this survey reflects a higher than typical response rate (over 18%) is likely not indicative of typical costs for a survey of this type. Note these costs are per person not per household.

ESTIMATED SURVEY COSTS

Best Survey Cost Estimates:

- \$75 per person for an online survey covering the Transportation Planning Modules in the Question Bank
- \$135 per household for an online survey cover all Question Bank Module include the Travel Diary
- \$69,000 per year for the recommended survey program

Key Considerations:

- Survey costs are highly variable based on factors including survey length, response rate, recruitment strategy, and retrieval method.
- On a per capita basis, best estimate household surveys cost that include a Travel Diary are cost competitive with more limited personal surveys.
- Given the goal of collecting customer service data every year, it is more cost effective to administer the full Question Bank (including travel diary) on an annual basis is than it is to collect travel diary data separately once every 5 years.

Common components that influence survey costs are summarized in Table 24. Best estimates for the cost of person-based and household-based surveys are provided in Table 25. Given that streamlined survey content already designed in the Question Bank, a web-based data retrieval method that does not include GPS or another geo-locating tool to facilitate trip logging, we estimate a minimum cost of \$135 per completed household for a survey using all modules of the Question Bank (this excludes recruitment costs, incentives and analysis). Based on the length and assuming multiple recruit modes, we are estimating \$70 per individual for conducting only modules 1-4 (this excludes recruitment costs, incentives and analysis). Note that the \$135 per household for the full “travel survey” also includes the general survey that would have cost approximately \$70 per completed individual. If one assumes there are on average 2 individuals per household conducting the full survey appears to have cost advantages. Note that these rates are higher per unit than previously discussed at meetings with the project TAC to account for the invariable base costs associated with a survey and the small samples sizes.

Table 24. Typical Determinants of Survey Costs

Cost Type	Cost Characteristics
Upfront Costs	Fixed costs for survey design and program; Independent of sample size
Recruiting Costs	Proportional to sample size for postcard or mail invitations; Independent of sample size for web/email based invitations; Incentives may be an additional recruiting cost
Data Retrieval Costs	Proportional to sample size for phone or paper based surveys; Independent of sample size for web or mobile device-based survey
Technical Support	Largely independent of sample size but proportional to the duration of data collection
Data Cleaning/Tabulation	Proportional to sample size but varies by survey retrieval method

Table 25. Range of Survey Costs

Survey Type	Estimated Cost per Completion*		
	Low from Existing Surveys	High from Existing Surveys	Best Estimate for All-in-One
Person-based, Transportation Planning Modules Only	\$40	\$85	\$75
Household-based, All Modules including Travel Diary	\$145	\$225	\$135

* Single individual for person-based survey, all household members for household-based survey

The total cost for the recommended, five-year survey cycle with the full Question Bank and a sample size of 2,500 households is estimated to be \$337,500 or \$67,500 per year. These cost are calculated as follows:

Cost per completed household – All modules including a travel diary:

	\$135
Number of households per year:	500
Number of years:	<u> </u> x 5
Total Cost:	\$337,500

An additional \$1,500 would be required annually for recruitment postcard printing and mailing. This would result in a totally annual cost of \$69,000 excluding incentives and analysis.

The total cost for the alternative schedule, in which the and the full Question Bank is administered to a sample of 2,500 household in year one and the Transportation Planning component of the Question Bank (modules 1-4) are administered to 500 individuals in years 2 through 5 is 4 \$487,500 or \$97,500 per year excluding mailings, incentives and analysis.

Cost per completed household – All modules including a travel diary:

	\$135
Number of households per year:	2,500
Number of years:	<u> </u> x 1
Cost for Year 1:	\$337,500

Cost per completed individual – Modules 1 - 4:	\$75
Number of individuals per year:	500
Number of years:	<u> </u> x 4
Cost for Years 2 - 5:	\$150,000

Total Cost (Years 1 – 5): **\$487,500**

The recommended schedule (full survey yearly with one fifth of the total sample) provides modest cost savings as well as two additional benefits relative to the alternative schedule. First, since the recommended schedule only requires one survey be programmed there are likely cost savings that are not captured in these calculations. Second, as discussed in section 4.1, conducting the travel diary on an annual basis will address potential single-year travel anomalies in travel behavior caused by severe weather or other external factors.

4.7. Other Survey Program Design Factors

4.7.1. 2-day Travel Diary Duration

The state of the practice is to use a one-day travel diary for each household/respondent. In 2009, Hartgen and San Jose reported in their overview of 91 travel surveys that 87% were 1-day weekday surveys. The limitations of one-day diaries are widely recognized and multi-day surveys are considered the state of the art. As smartphone Apps designed to facilitate trip logging evolve, multi-day surveys are becoming more common as the user's daily burden is decreased. Multi-day travel diaries can reveal important characteristics of a household's weekly travel patterns, and confirm differences in weekday/weekend travel behaviors. Multi-day travel diaries are also more important for rural areas, where fewer trips are taken each day but the trip lengths tend to be longer. For these types of

households, the true range of trip types may not be represented by a single day of travel. To our knowledge no concerns were raised during the CCRPC two-day rMove survey in the fall of 2016. No significant attrition was noted on day two of the survey. We recommend a two-day travel diary be considered for each respondent regardless of the survey mode. This is expected to increase costs only slightly.

4.7.2. Travel by External Visitors to Vermont

Visitors and pass-through traffic are also important non-resident travelers in Vermont. As an add-on, VTrans and CCRPC could consider a special version of the survey conducted on non-resident travelers including tourists. Information on the origin of the visitors is the only potential application of “big data” we recommend as appropriate for Vermont at this time. Current limitations of these data sources are discussed in Section 4.8. For example, an external OD matrix of visitors to Vermont (in 5 zones) for those with residences in 20 origins zones in the United States outside of Vermont may not be cost prohibitive. Note that we are concerned that most of these purchased aggregate data sources do not include international visitors including Canadians.

4.8. Technical Advantages and Limitations of Direct or Secondary Mobile-Device Data Collection

Providing a review of the most up-to-date and appropriate technology available for travel surveys in the Vermont context was an important component of this project. Most of the pilot tests of technology-based data collection whether direct or purchased from third party providers have been conducted in areas with much larger populations and higher population densities. To test the technical viability of mobile device-based data collection, original GPS and cell signal strength data were collected in the fall 2016 for four routes selected in conjunction with the project TAC. These routes, shown in Figure 4, were selected to cover areas known to have gaps in cellular coverage.

The data collection was conducted by driving routes with an Android smartphone with cell service from T-Mobile in the vehicle. The Android was equipped with RF Signal Tracker, a free App that records the GPS coordinates and the received cell signal strength indication (RSSI) as logged by the smartphone. Table 26 shows the length of each route as well as the percent of the route length that had GPS and cell coverage. A gap in GPS coverage was recorded anytime two records were more than 1,000 feet apart. A gap in cell service was recorded anytime the RSSI was below -110 dbm. GPS coverage was over 98% for all four routes (coverage gaps existed on Route 2 between Montpelier and East Montpelier and on Route 100 in Moretown). Cell service was considerably more limited, ranging from 72 – 89% coverage across the four routes. These tests suggest that any future mobile device based data collection should rely on GPS location data rather than location information derived from cell towers. All data should be capable of being logged on the mobile device for an extended period in the event that cell service is not available for data upload.

Table 26. GPS and Cell Coverage

Route	Test Date	Length (Miles)	GPS Coverage	Cell Service
Burlington – Hardwick	11/17/16	179	98.2%	88.6%
Burlington – Warren	12/3/16	153	99.7%	81.9%
Burlington – Belvidere	12/6/16	128	100%	71.8%
Burlington - Addison	12/8/16	139	100%	72.8%

Third party data (from cell phone companies, credit card information or similar) could potentially be used to replace the travel diary component of the All-in-One survey, reducing survey burden and survey costs. Interviews with two external data providers during this project suggest a number of problems for use of these data for Vermont travel demand estimation. First, the limited number of observations captured in the rural parts of the state necessitate spatial aggregation of origins and destinations into zones that are too large to be effective as inputs for the Vermont Statewide Model and other modeling applications. The current Vermont statewide model zones would have to be aggregated. Second, Canadian travelers are included in only a limited number of datasets but not others. Third, our results above indicate that GPS location is more appropriate for Vermont than cell phone tower-derived location. Many of the most common datasets available at this time use cell tower location processes. Finally, these datasets lack the ability to capture trip purpose, mode and other variables contained in the travel diary component of the Question Bank and we therefore do not recommend third party cell-based data for data collection from Vermont residents.

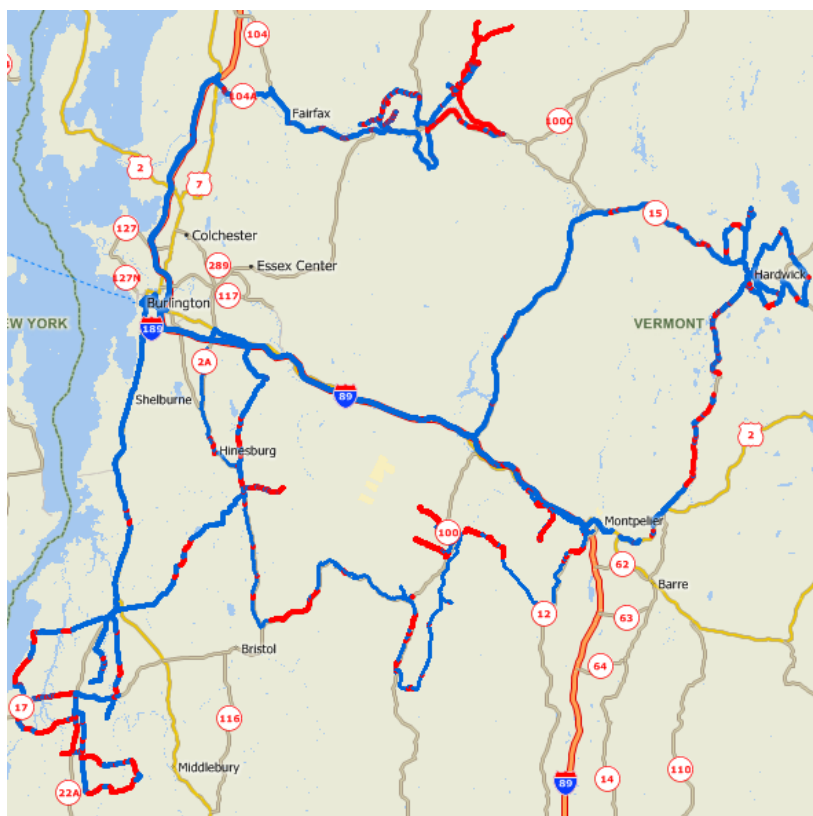


Figure 4. GPS and Cell Coverage Test Routes

There is one part of the modeling and policy interests related to travel patterns for which third party data may be useful: external travel. Very large external zones would be required to meet cost requirements. The use of large zones would not be as problematic for the external traffic and could be disaggregated to destinations and origins within Vermont for model use.

5. Program Launch and Future Research

Based on detailed analysis of existing recent travel survey data as well as original data collection, this project has provided a realistic and timely proposal for a robust travel and transportation survey program in Vermont over the next 5-years. The recommendations in this report provide the structure necessary to implement All-in-One survey program for Vermont. This program would produce data to support annual, statewide performance measurement based on modules 1 – 4 of the Question Bank and travel model updates for CCRPC and VTrans on a 5 year cycle based on module 5, the travel diary.

The recommended survey structure consists of the following attributes:

- Survey Schedule and Content - a yearly survey schedule with full Question Bank content conducted in September to October for both weekdays and weekends
- Recruitment Strategy - Address-based, random recruitment with 2-contact postcards and random prize drawing incentives
- Data Retrieval Method - web-based
- Sample Unit – households (but retain incomplete households for a separate person-based database)
- Sample Size - A five-year, total sample size of 2,500 households – 500 per year with 240 per year in Chittenden County to ensure valid data for the CCRPC model
- Cost Estimate - annual cost of \$69,000 excluding incentives and analysis
- 2-day travel diary duration
- External third-party data sources should be considered for travel by external visitors to Vermont and external flow calibration in demand models.

This project has reconfirmed the results of prior analysis that Vermont agency needs could likely be met more cost effectively than with the thorough, but very large, NHTS. Assuming the NHTS is \$235 per household and the add-on covered 2,500 households, the total cost of \$587,500 is more than the 5-year cycle cost of the All-in-One program, estimated at \$337,500.

At the close of the 5-year survey cycle, it would be appropriate to conduct a program review covering the following items:

1. Revisiting mobile-device based data collection. If smartphone penetration rates continue to increase, it may be viable to collect a representative sample using this data retrieval method in the future.
2. Reviewing the required sample size in light of the variance found in the All-in-One data and the adequacy of the actual (rather than expected) number of respondents in each weighting category.
3. Reviewing the Question Bank for potential additions/deletions especially related to attitudes and timely policy issues.

Several future questions remain for Vermont transportation planners and researchers as they jointly pursue quality travel and transportation data for the state. First, the analysis of several real-world Vermont datasets in this project suggested that a better method and more appropriate variables for accurate weighting of survey observations should be pursued. It is unclear how to address this challenge especially for the small but diverse population. This might be a subject for future research projects.

Second, technology-based transportation surveys including those conducted by smartphones are increasing in number and decreasing in price over time. Near the end of the first 5-year All-in-One survey program period we recommend a basic program review and consideration of the feasibility of moving to a smart phone-based data program. Finally, there are important groups of Vermonters that will be very limited or missed in the sample size recommended here. These groups include bicyclists, the disabled, those without Internet access and transit riders. Additional special focused programs aimed at understanding these travelers in Vermont would be appropriate as it is not practical to increase sample size or design a stratified method to obtain these survey respondents in this effort. Moreover, issues related to these travelers might be better addressed in a targeted effort that may not be survey-based.

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Appendix A –All-in-One VT Transportation Survey Question Bank

Note: Text in brackets, [], indicates a programming note or dynamically generated text.

[Automatically record date survey completed or received.]

Module 1: Socio-Demographics & Transportation Context

Household

1. [Question wording assumes web--based data collection] What is your approximate home location? If you do not want to provide your street address, you may provide a nearby street intersection. [Interactive Map]
2. Which of the following best describes the place where you live?
 - a) City, downtown with a mix of offices, apartments, and shops
 - b) City, residential neighborhood
 - c) Suburban neighborhood, with a mix of houses, shops, and businesses
 - d) Suburban neighborhood with houses only
 - e) Small town or village
 - f) Rural area
3. How many months of the year do you live in at this location? [Numeric]
4. [If #3 <12] What is the zip code of your other alternative home location? [Numeric]
5. How many people live in your household? [If household based survey and electronic data collection, collect nicknames for all household members]
6. How many people in your household have a physical or mental impairment that restricts their ability to make trips outside of the home (e.g., for work, school, shopping, socializing, etc.)? [Numeric]
7. How many registered motorized vehicles (passenger cars, pick-up trucks, sport utility vehicles, vans/minivans, and motorcycles) do you have in your household? [Numeric]
8. Which of the following categories best describes your household income last year before taxes? Please include income from all sources for all persons living in your household.
 - a) Less than \$15,000
 - b) \$15,000 to \$24,999
 - c) \$25,000 to \$34,999
 - d) \$35,000 to \$49,999

- e) \$50,000 to \$74,999
- f) \$75,000 to \$99,999
- g) \$100,000 to \$149,999
- h) \$150,000 to \$199,999
- i) \$200,000 or more
- j) Prefer not to answer

9. What type of telephone service do you have in your home? (Select all that apply)
- a) Landline telephone
 - b) A cell phone without data or Internet access
 - c) A cell phone with data and Internet access
 - d) None

Include as final questions after completing survey:

10. Would you be willing to be contacted in the future to discuss transportation surveys in Vermont?
- a) Yes
 - b) No
11. Would your household be interested in participating in future surveys?
- a) Yes [If yes, provide email address.]
 - b) No
 - c)

Personal

Note: These questions will be repeated for each member of the household rather than only for the first survey respondent. Location questions should include a map-based selection option.

1. What is your gender?
- a) Male
 - b) Female
 - c) Another
2. In what year were you born? [Numeric, check for <current year-10 and >1912]
3. What is your employment and student status? Please select all that apply.
- a) Employed full-time
 - b) Employed part-time
 - c) Self-employed
 - d) Homemaker
 - e) Retired
 - f) Not currently employed
 - g) Student – K-12th Grade including GED

- h) Student – Vocational/Technical/Trade School
 - i) Student – Part-time college/University
 - j) Student – Full time college/University
 - k) Student – Other
 - l) Not currently a student
 - m) I don't know
 - n) I prefer not to answer
4. [If worker] Which best describes your primary job?
- a) Sales or service
 - b) Clerical or administrative support
 - c) Manufacturing, construction, maintenance, or farming
 - d) Professional, managerial, or technical
 - e) Something else
 - f) I don't know
 - g) I prefer not to answer
5. [If employed full-time, part-time, or self-employed] Do you leave your home to travel to a typical workplace on a regular basis?
- a) Yes
 - b) No
6. [If work outside the home] What is your approximate work location? If you do not want to provide your street address, you may provide a nearby street intersection. [Interactive Map]
- [If address refused] *Approximately how many miles do you live from your typical workplace?*
[Numeric]
7. [If student] What is your approximate school location? If you do not want to provide your street address, you may provide a nearby street intersection. [Interactive Map]
8. Are you a licensed driver?
- a) Yes
 - b) No
9. What is your highest level of education?
- a) 0-11 years, no diploma
 - b) High school graduate or GED
 - c) Some college, no degree
 - d) Associate's degree
 - e) Bachelor's degree
 - f) Graduate degree or higher

10. What is your race?
- a) White
 - b) Black or African American
 - c) American Indian or Alaska Native
 - d) Asian
 - e) Native Hawaiian or Pacific Islander
 - f) Two or more races
 - g) Some other race
 - h) Prefer not to answer
11. Are you of Hispanic, Latino, or Spanish origin?
- a) Yes
 - b) No
 - c) Prefer not to answer
12. [Repeat for all members of Household] What is [HH member name] relationship to you?
Relationships include biological, adopted and step.
- d) Self
 - e) Spouse/Unmarried partner
 - f) Child
 - g) Parent
 - h) Brother/Sister
 - i) Other relative
 - j) Non-relative
 - k) I don't know
 - l) I prefer not to answer
13. Is your first language something other than English?
- a) No (English is my first language)
 - b) Yes
14. How do you access the Internet? Please select ALL that apply.
- a) Internet service at home
 - b) Internet service at school
 - c) Internet service at work
 - d) Public Internet service (e.g., at the library, community center)
 - e) Mobile device with a cellular data plan (e.g., smartphone, Internet-enabled tablet)
 - f) Other, please specify
 - g) I do not have access to the Internet

Vehicles [Repeated for number of vehicles in household]

1. What are the make, model and year of this vehicle?
Year [Numeric] Make [Text] Model [Text]

2. Who drives this vehicle most of the time?
[Options include household member nicknames or relationship based descriptions collected above.]

3. What fuel does this vehicle use?
 - a) Gas
 - b) Diesel
 - c) Biodiesel
 - d) Plug-in Hybrid (gas/electric e.g. Chevy Volt)
 - e) Electricity (e.g. Nissan Leaf)
 - f) Hybrid (gas/electric, not plug-in, e.g. Toyota Prius)
 - g) Some other fuel
 - h) I don't know
 - i) I prefer not to answer

Module 2: General Travel Behavior

1. [If worker who leaves home to work] Thinking about the entire year (past 12 months), how have you traveled to work? Please select the transportation option you use the most often.
 - a) Drive alone
 - b) Carpool
 - c) Passenger in a private vehicle
 - d) Walk
 - e) Bicycle
 - f) Public transit bus
 - g) Specialized bus or van service
 - h) Ferry
 - i) Taxi
 - j) Ride share service (e.g., Uber)
 - k) Vanpool
 - l) Other, please specify
 - m) None of the above

2. [If student] Thinking about the entire year (past 12 months), how have you traveled TO school? Please select the transportation option you use the most often.
 - a) Drive alone
 - b) Carpool
 - c) Passenger in a private vehicle
 - d) Walk

- e) Bicycle
- f) Public transit bus
- g) Specialized bus or van service
- h) Ferry
- i) Taxi
- j) Ride share service (e.g., Uber)
- k) Vanpool
- l) Other, please specify
- m) None of the above

3. [If student] Thinking about the entire year (past 12 months), how have you traveled FROM school? Please select the transportation option you use the most often.

- a) Drive alone
- b) Carpool
- c) Passenger in a private vehicle
- d) Walk
- e) Bicycle
- f) Public transit bus
- g) Specialized bus or van service
- h) Ferry
- i) Taxi
- j) Ride share service (e.g., Uber)
- k) Vanpool
- l) Other, please specify
- m) None of the above

4. How often do you use the following transportation options or services? Please include all activities such as commuting, running errands, leisure travel, etc.

[Show options on a 7-point scale: Once per week, Multiple times per week, Once per Month, Multiple times per month, Multiple times per year, One time per year or less, or Never]

- a) Drive a personal vehicle
- b) Travel as a passenger in a personal vehicle
- c) Walk outside including walking the dog and walks for exercise along roads, sidewalks or trails.
- d) Bicycle for transportation or leisure including exercise
- e) Commercial airline
- f) Private aircraft
- g) Amtrak Greyhound, Megabus, or other intercity bus
- h) Public transit bus
- i) Park-and-ride lots
- j) Taxi
- k) Rideshare service (e.g. Uber, Lyft, etc.)
- l) Car share

5. How often do you make a trip that has a destination outside the United States or Canada?

[Show options on a 7-point scale: Once per week, Multiple times per week, Once per Month, Multiple times per month, Multiple times per year, One time per year or less, or Never]

6. How often do you make an OUT OF TOWN trip?

[Show options on a 7-point scale: Once per week, Multiple times per week, Once per Month, Multiple times per month, Multiple times per year, One time per year or less, or Never]

7. Check how often do you WANT or NEED to travel to an OUT OF TOWN destination but cannot...

- a. Due to cost?
- b. Due to limited time?
- c. Because you had too much prior travel?
- d. Due to lack of transportation options (car, bus, rail or air availability)?

- e. Because the travel would be too tiring?
- f. Other (specify)

[Show options on a 7-point scale: Once per week, Multiple times per week, Once per Month, Multiple times per month, Multiple times per year, One time per year or less, or Never]

8. How often do you WANT or NEED to travel to a destination INSIDE your home community but cannot..

- a. Due to cost?
- b. Due to limited time?
- c. Because you had too much prior travel?
- d. Due to lack of transportation options (car, bus, rail or air availability)?

- e. Because the travel would be too tiring?
- f. Other (specify)

[Show options on a 7-point scale: Once per week, Multiple times per week, Once per Month, Multiple times per month, Multiple times per year, One time per year or less, or Never]

9. Which of the following sources do you use to obtain real-time (up-to-the-minute) traffic and travel information? Please select all that apply.

- a) Television
- b) Radio

- c) Electronic highway message signs
- d) VT 511 website
- e) GPS or navigation device
- f) Live traffic from a website (e.g., Google Maps or MapQuest)
- g) Live traffic from a smartphone application (e.g., Waze, Google Maps, etc.)
- h) Social media such as Twitter, Facebook, or YouTube
- i) None of the above

10. [If worker] How many minutes did it usually take you to get from home to work last week?
[Numeric]

11. How far do you typically travel from your home to shop for your routine household needs (e.g. groceries, clothing, or other household supplies)?
- a. Less than a mile
 - b. Between 1 to 5 miles
 - c. Between 5 to 10 miles
 - d. Between 10 to 15 miles
 - e. More than 15 miles
 - f. I don't know
 - g. I prefer not to answer

12. In the past 30 days, approximately how many times did you purchase something online and have it delivered? [Numeric]

Module 3: Attitudes

1. When considering how VTrans should focus its transportation planning and financial resources, how important are the following services/issues to you?

[Show on a 5-point scale: Not at All Important, Slightly Important, Moderately Important, Very Important, and Extremely Important. Include 'Don't know' option.]

- a) Minimize cost to taxpayers
- b) Support job creation and retention
- c) Support Vermont's downtowns and village centers
- d) Protect the environment
- e) Ensuring the safety of the traveling public
- f) Reduce traffic congestion
- g) A transportation system that can withstand extreme weather events
- h) Roadway/ pavement conditions
- i) Winter snow and ice removal
- j) Bicycle and pedestrian facilities

- k) Public Transit services
- l) Passenger Rail (Amtrak) services

2. The gas tax is becoming a less reliable revenue source that states can use to pay for transportation projects. Here are some other ways to pay for transportation projects such as highways, bridges, sidewalks, bicycle facilities, and transit. Please indicate how acceptable you find the following as a way to fund such projects.

[Show on a 5-point scale: Not At All Acceptable, Slightly Acceptable, Moderately Acceptable, Very Acceptable, Completely Acceptable. Include 'Don't know' option.]

- a) A fee based on how many miles a vehicle is driven
- b) A tax based on vehicle carbon emissions
- c) Raising the general sales tax
- d) An annual registration fee tied to the value of a vehicle
- e) Raising the Vermont gas tax

3. What might encourage you to drive your car less in Vermont? [Text]

4. Which of the following keeps you from walking more? Please select all that apply.

- a) No nearby paths or trails
- b) No nearby parks
- c) No sidewalks
- d) Sidewalks are in poor condition
- e) Street crossings are unsafe
- f) Heavy traffic with too many cars
- g) Not enough lighting at night
- h) None of the above
- i) I don't want to walk more
- j) I don't know
- k) I prefer not to answer

5. Which of the following keeps you from bicycling more? Please select all that apply.

- a) No nearby paths or trails
- b) No nearby parks
- c) No sidewalks or sidewalks are in poor condition
- d) Street crossings are unsafe
- e) Heavy traffic with too many cars
- f) Not enough lighting at night
- g) None of the above
- h) I don't want to bike more
- i) I don't know
- j) I prefer not to answer

6. What keeps you from taking transit (or taking transit more often) to your destination(s)? Please select the top three reasons:
- a) Service not frequent enough/does not run early or late enough
 - b) Service not reliable
 - c) Service too expensive
 - d) No stops near destination
 - e) Street crossings are unsafe
 - f) Weather
 - g) Safety concerns
 - h) Prefer to drive
 - i) No other choices apply
 - j) Something else
 - k) I don't know
 - l) I prefer not to answer

Module 4: Customer Satisfaction

1. How satisfied are you with the following transportation services or infrastructure in Vermont?

[Show options on a 5-point scale: Very dissatisfied, Dissatisfied, Neither Satisfied nor Dissatisfied, Satisfied, Very Satisfied. Include 'Don't Know' option]

- a) Safety of the transportation system
 - b) Physical condition of highways
 - c) The availability of sidewalks
 - d) The availability of biking facilities (e.g., on-street bike lanes, road shoulders, and bike paths)
 - e) Amtrak service
 - f) The availability of park-and-ride lots
 - g) Winter highway maintenance such as removing snow and ice
 - h) Convenience of public bus service
 - i) Specialized bus or van service
 - j) Traveler information about weather, construction, road closures, etc.
 - k) Department of Motor Vehicles (DMV) services (e.g., licensing, vehicle registration, etc.)
2. How often do you experience traffic congestion in Vermont?
- a) Daily
 - b) Weekly
 - c) Monthly
 - d) A few times a year
 - e) Never
3. How much does experiencing traffic congestion affect your overall quality of life?

[Show options on a 5-point scale: No Negative Effect, Slight Negative Effect, Moderate Negative Effect, Strong Negative Effect, Very Strong Negative Effect. Include 'Don't Know' option]

Module 5: Travel Diary

1. Are you [respondent] or are you filling out this survey on [respondent's] behalf?
 - a) [Respondent]
 - b) I am answering the survey for [respondent] and [respondent] is here with me to provide the answers.
 - c) I am answering the survey for [respondent] and [respondent] is NOT here with me to provide the answers.

2. Where were you at 3 AM on [date of travel day], when the travel day began?
 - a) Home
 - b) Work
 - c) In-transit (driving or flying for example)
 - d) Another place, please specify – city and state or zipcode

3. Where were you at 3 AM on [date of day after travel day], when the travel day ended?
 - a) Home
 - b) Work
 - c) In-transit (driving or flying for example)
 - d) Another place, please specify – city and state or zipcode

4. Did you go anywhere on [travel day] even if it was just a short trip such as a walk or bicycle ride?

5. Please list, in order, all the places you went between 3 AM [date of travel day] and 3AM [date of day after travel day].
[Questions 6 – 15 will be repeated in sequence for each destination specified in Question 5]

6. Please locate [trip destinations] on the map

7. Time departed from [start location]

8. Time arrived at [destination location]

9. Household members who traveled on the trip to [DESTINATION] [Select household members from list]

[Respondents would be prompted to select household member based on the nicknames collected in the Socio-Demographics section.]

10. Number of other people (e.g. friends or co-workers) who travel on this trip

11. Main purpose of this trip
 - a. Went home
 - b. Went to work/work-related
 - c. Dine out/get coffee or take-out
 - d. Appointment/shopping/errands
 - e. Social/leisure/vacation activity
 - f. Exercise (e.g., gym, jog, bike, walk dog)
 - g. Attended school/class
 - h. Drop off/pick up/accompany person
 - i. Change/transfer mode (e.g., wait for bus, change planes)
 - j. Other reason, please specify

12. Please select the primary transportation mode used on this trip
 - a) In a household vehicle (or motorcycle, moped)
 - b) In other personal vehicle (e.g., rental, carshare, work car)
 - c) Any taxi (regular or Uber/Lyft)
 - d) Any bus or vanpool (e.g., public, school, shuttle)
 - e) Any rail (e.g., train, subway, trolley)
 - f) Walk (or jog/wheelchair)
 - g) Bicycle
 - h) Private or commercial airplane
 - i) Other, specify:
 - j) I don't know
 - k) I prefer not to answer

13. [If mode is household vehicle or other personal vehicle] How far, in minutes, was your parking location from your destination?

14. [If mode is transit or air] How did you access [selected mode]?
 - a. In a household vehicle (or motorcycle, moped)
 - b. In other personal vehicle (e.g., rental, carshare, work car)
 - c. Any taxi (regular or Uber/Lyft)
 - d. Walk (or jog/wheelchair)
 - e. Bicycle
 - f. Other, specify:
 - g. I don't know
 - h. I prefer not to answer

15. [If mode is household vehicle] Which vehicle was used on the trip [Select from list]?

16. Was this a typical [travel day of week]?
 - a) Yes
 - b) No, it was not a typical [day of week]. Please specify reasons:

Appendix B – Question Sources

This Appendix consists of set of tables that document the questions included from each of the resources used to develop this Question Bank. To facilitate comparisons across these resources, questions with similar content were combined into single items. For example, the 2009 NHTS asked respondents about the number of phone lines in their households while the 2016 NHTS asks respondents whether or not their household has a landline telephone. In Table 1A, these questions are combined into a single entry: “Number/type of household telephones.” Entries for the NHTS are generally limited to questions asked of the full national sample. That is, the six “add-on” questions sponsored by specific states are only included in instances where they are recommended for inclusion in the Question Bank.

Source questions included in the Question Bank are marked with corresponding question number used Appendix A while those that were not recommended for the Question Bank are marked with a dash (-). Notes about how/why questions were or were not incorporated into the Question Bank are included when these decisions differ from the LRTPS or from the majority of other sources.

Appendix B Tables:

1. Socio-demographics and transportation context
 - a. Household
 - b. Personal
 - c. Vehicle
2. General travel behavior
3. Attitudes about transportation issues
4. Customer satisfaction
5. Travel log/diary

Sources:

1. NCHRP 2008 – NCHRP Report 571: Standardized Procedures for Personal Travel Surveys
2. NHTS 2009 – The National Household Travel Survey for 2009
3. NHTS 2016 – The National Household Travel Survey for 2016
4. CTDOT 2016 – The Connecticut DOT Statewide Transportation Survey for 2016
5. CCRPC 2016 – The Chittenden County 2016 Regional Transportation Survey.
6. VTrans LRTPS – The VTrans Long Range Transportation Plan Public Opinion Survey for 2016.

Table B1. Socio-Demographics Module – Household Question Selection

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CTDOT 2016	CCRPC 2016	VTrans LRTPS	Question Bank Question Number and Notes
Home location	✓	✓	✓	✓		✓	H1
Type of neighborhood						✓	H2 Neighborhood type categories are from the LRTPS and reflect Vermont context
Months/year at home location						✓	H3 Included because part-year residents are deemed important in Vermont.
Zip code of alternative home location							H4 New question added for respondent who live in home locations for less than 12 months since this is of importance to Vermont
Household size	✓	✓	✓	✓	✓	✓	H5
Household relationship structure						✓	H6 Question developed for the LRTPS to reflect changing household types in Vermont. Household relationship options modified from LRTPS based on UVM TRC pilot testing.
Number of household members with physical/mental impairments						✓	H7 Disability status is collected here for the household but at the individual level for other survey sources.
Number of motorized vehicles	✓	✓	✓	✓	✓	✓	H8
Household income		✓		✓	✓	✓	H9 Household income categories are from the LRTPS
Number/type of household telephones		✓	✓				H10 New question developed to capture all types of household telephone service
Willingness to participate or be contacted about this /future surveys	✓	✓		✓	✓		H11/12 Important for research with human subject procedures, experimental survey modes and possible long distance and other follow-ups.
Type of residence	✓	✓		✓			- Poor travel predictor: omitted to minimize burden
Home ownership status	✓	✓	✓	✓			- Poor travel predictor: omitted to minimize burden
Number of household bicycles				✓			- Omitted but question about bicycling frequency remains
Considering moving within 5 years						✓	- Omitted for space/burden
Internet access in home			✓				- Duplicates question P14 "methods of Internet access"

Table B2. Socio-Demographics Module – Personal Question Selection

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CT DOT 2016	CCRPC 2016	VTrans LRTP	Question Bank Question Number and Notes
Gender	✓	✓	✓	✓	✓	✓	P1 .
Age/Year of birth	✓	✓	✓	✓	✓	✓	P2 (Year of Birth) maintains analytical flexibility
Employment Status, Number of Jobs/Hours worked	✓	✓	✓	✓		✓	P3 Combined LRTPS employment status question with NHTS 2016 student status questions
Job Classification	✓	✓	✓	✓			P4 Job classification options from NHTS 2016
Work from home/Travel to work			✓	✓		✓	P5
Work location		✓	✓	✓		✓	P6
School location			✓	✓			P7 Additional student/school questions have been added in parallel to the employment/work questions following the practice in NHTS 2016 and CTDOT 2016
Driver’s license status	✓	✓	✓	✓		✓	P8
Education	✓	✓	✓	✓		✓	P9
Race	✓	✓	✓			✓	P10
Hispanic/Latino origin	✓	✓	✓			✓	P11
Relationship of household member to respondent	✓	✓	✓	✓			P12
Non-English first language						✓	P13 In some areas, surveys are offered in other languages
Methods/frequency of accessing the Internet			✓			✓	P14 Access method options from LRTPS
Disability history	✓	✓					- Collected at the household, not individual, level
Past license status		✓					- Omitted for space/burden
Student status/type			✓	✓			- Captured in combined employment/student status question P3
Distance from home to work		✓				✓	- Included in question P6 if retrieval method does not allow geocoding (paper/phone)
Internet use/purchase frequency		✓					-
Smartphone ownership/type					✓		- Incorporated into question H10.

Table B3. Socio-Demographics Module – Vehicle Question Selection

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CTDOT 2016	CCRPC 2016	VTrans LRTPS	Question Bank Question Number and Notes
Year	✓	✓	✓	✓			V1
Make		✓	✓	✓			V1
Model		✓	✓	✓			V1
Body Type	✓	✓	✓				V2 Body type options from the 2016 NHTS
Main vehicle driver	✓	✓	✓				V3
Fuel Type		✓	✓				V4 Fuel type options from 2016 NHTS
Vehicle ownership status	✓						-
License plate type		✓					-
Annual VMT		✓					-
Odometer reading		✓	✓				-
Odometer reading date			✓				-
Toll transponder in vehicle				✓			-

Table B4. General Travel Behavior Module – Question Selection

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CTDOT 2016	CCRPC 2016	VTrans LRTPS	Question Bank Question Number and Notes
Primary commute mode		✓	✓	✓		✓	G1
Typical mode for travel to/from school			✓	✓			G2-3 Added from NHTS 2016 using LRTPS mode options
Frequency of using various modes		✓	✓	✓	✓	✓	G4 Combine two existing LRTPS question to reduce survey burden.
Frequency of travel to various destinations						✓	G5-7
Inability to travel to various destinations		✓				✓	G8-9 Response options revised based on user feedback. New options will be piloted in UVM TRC survey in January, 2017.
Methods of accessing traffic/travel info						✓	G12
Number of walking trips in past week		✓	✓				G11 Added from NHTS 2016
Number of bicycling trips in past week		✓	✓				G12 Added from NHTS 2016
Typical commute duration		✓	✓				G13 Added from NHTS 2016
Typical shopping travel distance			✓				G14 Added from NHTS 2016 MD Add-on
Number of online purchases			✓				G15 Added from NHTS 2016
Estimated VMT		✓	✓			✓	- Question excluded since estimated VMT value have questionable accuracy.
Change in number of vehicles						✓	-
Plans to purchase/lease a vehicle						✓	-
Methods of accessing transit info						✓	-
Number of walking/biking trips for exercise			✓				-
Times using a bike share program			✓				-
Typical commute vehicle occupancy		✓	✓				-
Typical work arrival time		✓	✓				-
Flexibility of work arrival time		✓	✓	✓			-
Work from home frequency		✓	✓				-
Travel options if vehicle is unavailable			✓				-
Number of times using a rideshare app			✓				- Included in mode frequency question G4
Number of times using carshare			✓				- Included in mode frequency question G4
Commuter duration with no traffic			✓				-
Transfer time during transit commutes			✓				-

Table B5. Travel Attitudes Model – Question Selection

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CTDOT 2016	CCRPC 2016	VTrans LRTPS	Question Bank Question Number and Notes
Preferred neighborhood type						✓	A1 May be important given aging population
Most important transportation issues/funding priorities		✓				✓	A2
Acceptance of alternative fee structures						✓	A3
Likelihood of purchasing an AFV						✓	A4
Obstacles to HEV/EV purchase						✓	A5
Barriers to walking more		✓	✓				A7 Added from NHTS 2016
Barriers to bicycling more		✓	✓				A8 Added from NHTS 2016
Barriers to using transit more			✓				A9 Added from NHTS 2016
Attitudes toward biking and walking		✓					-
Impact of cost on travel decisions			✓				-
Reasons for choosing home location		✓	✓				-

Table B6. Customer Satisfaction Module - Question Selection

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CTDOT 2016	CCRPC 2016	VTrans LRTPS	Question Bank Question Number and Notes
Satisfaction with transportation infrastructure/services						✓	CS1
Congestion frequency						✓	CS2
Congestion impact on quality of life						✓	CS3

Table B7. Travel Diary Module

Questions	NCHRP 2008	NHTS 2009	NHTS 2016	CTDOT 2016	CCRPC 2016	VTrans LRTPS	Question Bank Question Number and Notes
Person completing survey (self/proxy)		✓	✓	✓	✓		D1
Location at start of travel day		✓	✓	✓	✓		D2
Location at end of travel day				✓			D3
Did travel day include any trips		✓	✓	✓	✓		D4
Trip destination	✓	✓	✓	✓	✓		D5-6
Trip start and end times	✓	✓	✓	✓	✓		D7-8
Household members on trip	✓		✓	✓	✓		D9
Number of travelers on trip	✓		✓	✓	✓		D10
Trip purpose	✓	✓	✓	✓	✓		D11
Trip Mode	✓	✓	✓	✓	✓		D12-14 Covers primary mode and access modes for transit trips
Household vehicle used		✓	✓	✓	✓		D15
If no trips why not/Was travel day typical	✓		✓	✓	✓		D16
Mode Sequence	✓						
Toll/fare costs/payment methods	✓	✓		✓	✓		
Parking costs/payment methods	✓			✓	✓		
Type of parking facility					✓		
Not in town/country on travel day		✓					
Trip Duration		✓					
Did travel day include transit trip		✓	✓				
Mode to transit terminal		✓	✓				
Trip used of turnpike/HOV lane/other		✓		✓			
If no trips when was last trip		✓	✓				
Purpose and distance of loop trips			✓				
Time to get to transit station			✓				
Wait time for transit/ Number of transfers			✓				
Mode from transit station to destination			✓				
Time from transit station to destination			✓				
Identity of drive on multi-person trips			✓		✓		
Time online telecommuting/shopping			✓		✓		
Number of deliveries/home service visits			✓		✓		

Appendix C – Comparison of Online and Paper Respondents LRTPS

Since the raw paper and online samples from LRTPS 2016 differed substantially in terms of demographic makeup, we weighted the online sample to match the paper sample in terms of gender, age, income and regional distribution. The purpose of this weighting process was to facilitate comparisons between paper and online respondents while controlling for these important demographic variables. Unlike the LRTPS weights, these weights were *not* intended to replicate the demographics of the state at large.

The weighting process resulted in essentially identical distributions for gender, age, income and region, but statistically significant differences remained in several other socio-demographic variables, summarized in Table 27. Relative to the paper sample, the weighted online sample has fewer one person households and more two person households, is more highly educated, has higher rates of Internet access (especially smartphone access), and more likely to live in a rural area than a small town/village.

Table 27 Overview of socio-demographic differences between paper sample and weight online sample

Variable	Paper Sample vs. Weighted Online Sample
Household Size	**
Education	***
Employed	--
Distance to work	--
Neighborhood Type	***
Registered Vehicles	--
Internet Access Type	***

* Significant at P = .1, ** Significant at P = .05, *** Significant at P = .01

Table 28 shows the differences in the customer satisfaction between paper and online respondents, weighted to account for difference in gender, age, income and region. The responses of paper and online respondents are significantly different for 7 of the 11 customer services questions. The responses for these 7 questions are show in Table 31 through Table 40.

Table 28. Difference in Customer Satisfaction Rating by Retrieval Method

Variable	Paper Sample vs. Weighted Online Sample
Highway condition	***
Sidewalks	--
Biking Facilities	--
Amtrak Service	***
Park & Ride	--
Winter maintenance	--
Bus service	***
Specialized bus/van	***
Traveler info	***
DMV	***
Real ID	***

* Significant at P = .1, ** Significant at P = .05, *** Significant at P = .01

Table 29 shows the difference in issue importance ratings between paper and online respondents, weighted to account for difference in gender, age, income and region. The responses of paper and online respondents differ with high statistical significance for 10 of the 13 customer services questions. The responses for these questions are show in Table 41 through Table 48.

Table 29. Difference in Issue Importance Rating by Retrieval Method

Variable	Paper Sample vs. Weighted Online Sample
Minimize cost	*
Job creation	--
Support downtowns	*
Environment	***
Safety	***
Congestion	***
Withstand extreme weather	--
Roadway conditions	***
Winter maintenance	***
Bike/ped facilities	**
Transit	***
Amtrak	***

* Significant @ .1, ** Significant @ .05, *** Significant @ .01

Table 30 summarizes differences in the travel behaviors between paper and online respondents, weighted to account for difference in gender, age, income and region. Online respondents are more likely to commute by every non-SOV mode more frequently than their paper counterparts and are more likely to express an inability to travel to destinations inside Vermont.

Table 30. Overview of difference in travel behavior by retrieval method

Variable	Test	Paper Sample vs. Weighted Online Sample
Primary commute mode	Chi-square	**
Estimated weekday VMT	Wilcoxon-Mann-Whitney	--
Mode Use Frequency	Chi-square	Mixed
Inability to travel in Vermont	Chi-square	**
Inability to travel out of VT	Chi-square	--
Frequency of Trips Outside VT	Chi-square	***

* Significant at P = .1, ** Significant at P = .05, *** Significant at P = .01

Table 31. Satisfaction levels with the condition of Vermont highways

How satisfied are you with the physical condition of VT highways?	Online survey	Paper survey
Very dissatisfied	6.4	8.1
Dissatisfied	23.7	22.9
Neither satisfied nor dissatisfied	19.7	23.8
Satisfied	36.1	36.3
Very satisfied	14.1	9.0

Table 32. Satisfaction levels with Amtrak service

How satisfied are you with Amtrak service?	Online survey	Paper survey
Very dissatisfied	7.6	8.2
Dissatisfied	27.6	17.0
Neither satisfied nor dissatisfied	43.6	50.3
Satisfied	16.8	20.9
Very satisfied	4.5	3.6

Table 33. Satisfaction levels with public bus service

How satisfied are you with the convenience of public bus service?	Online survey	Paper survey
Very dissatisfied	11.4	9.5
Dissatisfied	21.4	16.7
Neither satisfied nor dissatisfied	44.3	45.4
Satisfied	16.0	22.0
Very satisfied	7.2	6.3

Table 34. Satisfaction levels with dedicated bus or van service

How satisfied are you with specialized dedicated bus or van service?	Online survey	Paper survey
Very dissatisfied	6.3	5.7
Dissatisfied	5.6	7.8
Neither satisfied nor dissatisfied	72.3	63.5
Satisfied	10.9	18.8
Very satisfied	4.9	4.2

Table 35. Satisfaction levels with traveler information

How satisfied are you with traveler information about weather, construction, road closures, etc.?	Online survey	Paper survey
Very dissatisfied	2.0	1.8
Dissatisfied	5.5	7.1
Neither satisfied nor dissatisfied	24.9	28.7
Satisfied	48.1	49.7
Very satisfied	19.6	12.7

Table 36. Satisfaction levels with DMV services

How satisfied are you with the Department of Motor Vehicles (DMV) services (e.g., licensing, vehicle registration, etc.)?	Online survey	Paper survey
Very dissatisfied	2.8	3.3
Dissatisfied	8.1	11.0
Neither satisfied nor dissatisfied	19.0	22.2
Satisfied	50.0	49.6
Very satisfied	20.2	13.9

Table 37. Satisfaction levels with Real ID instructions

If you renewed your driver's license in the last 2 years, how satisfied are you with the DMV's instructions concerning Real ID?	Online survey	Paper survey
Very dissatisfied	4.9	5.8
Dissatisfied	13.3	12.6
Neither satisfied nor dissatisfied	25.8	30.0
Satisfied	39.3	41.8
Very satisfied	16.7	10.3

Table 38. Satisfaction levels with traveler information

How satisfied are you with traveler information about weather, construction, road closures, etc.?	Online survey	Paper survey
Very dissatisfied	1.96	1.81
Dissatisfied	5.5	7.14
Neither satisfied nor dissatisfied	24.91	28.73
Satisfied	48.06	49.68
Very satisfied	19.56	12.65

Table 39. Satisfaction levels with DMV services

How satisfied are you with the Department of Motor Vehicles (DMV) services (e.g., licensing, vehicle registration, etc.)?	Online survey	Paper survey
Very dissatisfied	2.78	3.29
Dissatisfied	8.08	11.02
Neither satisfied nor dissatisfied	19.01	22.2
Satisfied	49.96	49.59
Very satisfied	20.16	13.9

Table 40. Satisfaction levels with Real ID instructions

If you renewed your driver's license in the last 2 years, how satisfied are you with the DMV's instructions concerning Real ID?	Online survey	Paper survey
Very dissatisfied	4.91	5.75
Dissatisfied	13.27	12.61
Neither satisfied nor dissatisfied	25.8	29.97
Satisfied	39.31	41.37
Very satisfied	16.71	10.29

Table 41. Issue: Minimize Cost

How important are is it to minimize cost to taxpayers?	Online survey	Paper survey
Not at all important	2.7	3.0
Slightly important	12.5	11.5
Moderately important	34.3	29.8
Very important	28.6	33.3
Extremely important	21.9	22.4

Table 42. Issue: Support downtowns

How important is it to support Vermont's downtowns and village centers?	Online survey	Paper survey
Not at all important	3.3	4.7
Slightly important	8.1	8.9
Moderately important	24.3	26.3
Very important	41.2	40.5
Extremely important	23.0	19.6

How important is to protect the environment?	Online survey	Paper survey
Not at all important	2.1	2.5
Slightly important	5.9	6.5
Moderately important	14.1	20.7
Very important	35.8	37.9
Extremely important	42.1	32.5

Table 43. Issue Safety

How important is ensuring the safety of the traveling public?	Online survey	Paper survey
Not at all important	0.2	0.9
Slightly important	2.5	3.5
Moderately important	9.7	11.5
Very important	41.6	43.3
Extremely important	46.0	40.7

Table 44. Issue: Withstand Weather

How important is a transportation system that can withstand extreme weather events?	Online survey	Paper survey
Not at all important	2.6	2.2
Slightly important	6.5	8.6
Moderately important	26.3	24.5
Very important	37.9	40.3
Extremely important	26.7	24.4

Table 45. Issue: Pavement Condition

How important is roadway/pavement condition?	Online survey	Paper survey
Not at all important	1.1	0.7
Slightly important	1.5	2.1
Moderately important	14.1	12.4
Very important	41.3	47.8
Extremely important	42.3	37.1

Table 46. Issue: Snow & Ice Removal

How important is winter snow and ice removal?	Online survey	Paper survey
Not at all important	1.2	0.2
Slightly important	1.5	2.2
Moderately important	10.4	10.3
Very important	38.1	46.3
Extremely important	48.7	40.9

Table 47. Issue: Bike/Ped Facilities

How important are bicycle and pedestrian facilities?	Online survey	Paper survey
Not at all important	8.5	11.1
Slightly important	15.7	15.4
Moderately important	26.5	29.3
Very important	28.7	27.0
Extremely important	20.7	17.2

Table 48. Issue: Public Transit

How important are public transit services?	Online survey	Paper survey
Not at all important	6.5	9.4
Slightly important	14.0	15.0
Moderately important	26.2	28.6
Very important	29.7	28.6
Extremely important	23.6	18.3

Table 49. Primary Commute Mode

Primary Commute Mode (last 12 months)	Online survey	Paper survey
Drive alone	83.1%	90.5%
Carpool	3.6%	2.8%
Passenger in a private vehicle	1.9%	1.2%
Walk	3.1%	2.4%
Bicycle	1.5%	0.7%
Public transit bus	2.4%	1.4%
Specialized bus or van service	0.2%	0.0%
Ferry	0.2%	0.0%
Ride share service (e.g., Uber)	0.1%	0.0%
Vanpool	0.4%	0.2%
Other	3.6%	0.9%

Table 50. Inability to Travel in VT

How often do you need to travel to a destination INSIDE Vermont but cannot due to lack of transportation options)	Online survey	Paper survey
Never	82.8%	87.7%
Very infrequently (one time per year or less)	9.8%	5.7%
Infrequently (a few times per year)	3.4%	3.9%
Frequently (multiple times per month)	2.0%	1.8%
Very frequently (multiple times per week)	2.0%	1.0%

Table 51. Frequency of Travel Outside VT

How often do you make a trip that has a destination outside Vermont but in the US?	Online survey	Paper survey
Never	3.4%	7.8%
Very infrequently (one time per year or less)	12.7%	21.9%
Infrequently (a few times per year)	61.1%	43.4%
Frequently (multiple times per month)	18.3%	21.2%
Very frequently (multiple times per week)	4.5%	5.8%

Appendix D – Comparison of CCRPC 2016 Respondents by Recruit Source

The demographics and travel behavior of CCRPC 2016 participants varied with recruitment source. Most notably, participants recruited through Local Motion were younger, lower income and more likely to be male than respondents recruit through other means (see Table 52 through Table 54). These recruits also completed the highest proportion of walking and bicycling trips (Table 55). Front Porch Forum recruits had the highest proportion of older and female respondents and were the most likely to report that they never walked or biked (Table 56 and Table 57). The CCPRC newsletter recruits had the highest proportion of respondents with incomes in excess of \$150,000.

Table 52. Age of CCPRC 2016 Respondents by Recruit Source

Age Category	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
18 - 24 years	5.3%	9.5%	0.8%
25 - 34 years	30.3%	28.6%	17.7%
35 - 44 years	21.1%	28.6%	30.8%
45 - 54 years	19.7%	19.1%	22.3%
55 - 64 years	18.4%	9.5%	18.5%
65 - 74 years	4.0%	4.8%	9.2%
75 - 84 years	1.3%	0.0%	0.8%
Total	76	21	130

Table 53. Gender of CCPRC 2016 Respondents by Recruit Source

Gender	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
Male	46.1%	76.2%	43.9%
Female	54.0%	23.8%	56.2%
Total	76	21	130

Table 54. CCRPC 2016 Respondents' Household income by Recruit Source

Household Income	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
\$10,000-\$24,999	1.3%	9.5%	1.5%
\$25,000-\$34,999	2.6%	4.8%	2.3%
\$35,000-\$49,999	4.0%	4.8%	7.7%
\$50,000-\$74,999	13.2%	28.6%	15.4%
\$75,000-\$99,999	21.1%	9.5%	20.0%
\$100,000-\$149,999	30.3%	19.1%	27.7%
\$150,000-\$199,999	15.8%	9.5%	6.9%
\$200,000-\$249,999	4.0%	0.0%	3.9%
\$250,000 or more	4.0%	0.0%	4.6%
Did not answer	4.0%	14.3%	10.0%
Total	76	21	130

Table 55. CCRPC 2016 Primary Trip Mode by Recruit Source

Primary Mode	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
Walk	24.5%	25.3%	15.8%
Bike	8.2%	42.0%	10.0%
Other/Don't Know	0.4%	0.0%	1.0%
Private Vehicle	63.9%	30.0%	71.1%
Bus/Train	2.9%	2.7%	2.1%
Total Trips	681	150	1180

Table 56. Self-reported Walking Frequency in CCRPC 2016 by Recruit Source

Walking Frequency	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
Daily	26.3%	23.8%	27.7%
A few times a week	25.0%	38.1%	25.4%
About once a week	11.8%	19.1%	13.1%
A few times a month	21.1%	9.5%	13.9%
Once a month or less	5.3%	4.8%	7.7%
Never	10.5%	4.8%	12.3%
Total Respondents	76	21	130

Table 57. Self-reported Biking Frequency in CCRPC 2016 by Recruit Source

Bicycle Use Frequency	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
Daily	13.2%	57.1%	10.8%
A few times a week	10.5%	38.1%	10.0%
About once a week	7.9%	4.8%	8.5%
A few times a month	23.7%	0.0%	11.5%
Once a month or less	21.1%	0.0%	20.8%
Never	23.7%	0.0%	38.5%
Total Respondents	76	21	130

Table 58. Self-reported Transit Use in CCRPC 2016 by Recruit Source

Transit Use Frequency	Survey Link Distribution		
	CCRPC Outreach	Local Motion	Front Porch
Daily	2.6%	9.5%	3.1%
A few times a week	15.8%	4.8%	6.2%
About once a week	1.3%	4.8%	3.9%
A few times a month	6.6%	0.0%	5.4%
Once a month or less	35.5%	23.8%	29.2%
Never	38.2%	57.1%	52.3%
Total Respondents	76	21	130

Appendix E – Tabulations from the CCRPC rMove Dataset

The analysis here of the 2016 CCRPC data is provided for interest because the innovative mobile approach to data collection is important. However, the reader is cautioned that the dataset is very small and that recruiting was limited when a recruiting partner withdrew at the last minutes.

CCRPC 2016 had a higher average trip rate (Table 59) and lower average trip length (Table 60 and Figure 5) than the 2009 NHTS respondents from Chittenden County. In addition the CCRPC 2016 sample included a higher percentage of walk, bike and transit trips (Figure 6). It is likely that these differences in travel behavior reflect of combination of differing demographics between the two groups due to recruit methods (see Appendix D) as well as improved recall of shorter trips as a result of the automatic data capture and reminders sent by the rMoves App.

Table 59. Average Trip Rate CCRPC 2016 and Chittenden County NHTS 2009

	CCRPC 2016	NHTS 2009
N	226	934
Mean Trip Rate (per day)	6.0	4.6
Std Dev	3.2	2.6

Table 60. Average Trip Length CCRPC 2016 and Chittenden County NHTS 2009

	CCRPC 2016	NHTS 2009
N	2733	4379
Mean (miles)	7.1	10.0
Std Error of Mean	0.87	0.97
95% CI Lower Bound	5.4	8.1
95% CI Upper Bound	8.8	11.9

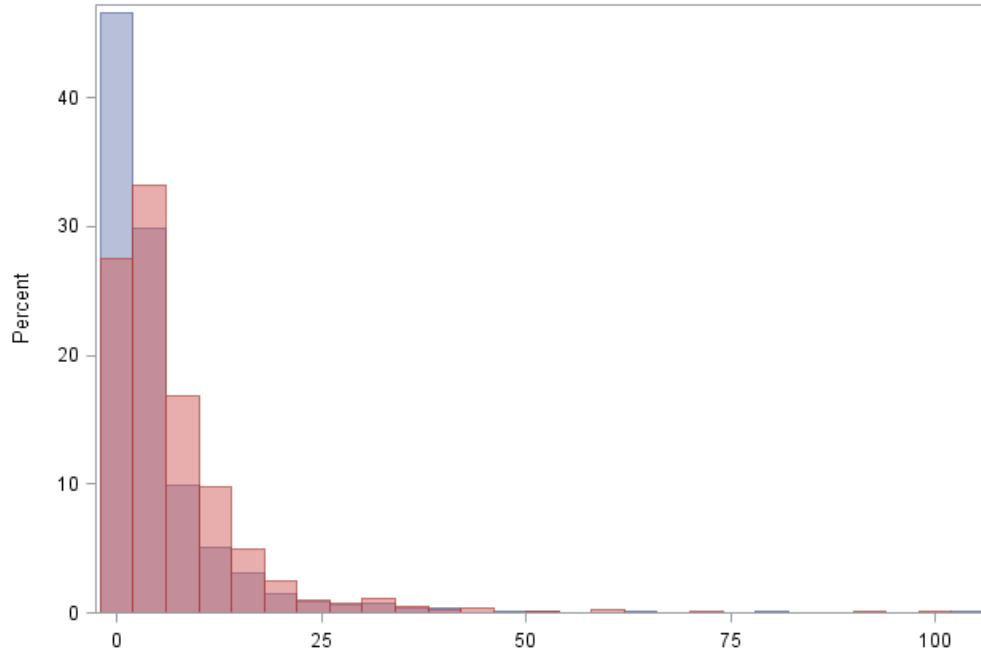


Figure 5. Histogram of trip lengths in miles for CCRPC 2016 (blue) and Chittenden County Sample of NHTS 2009 (red)

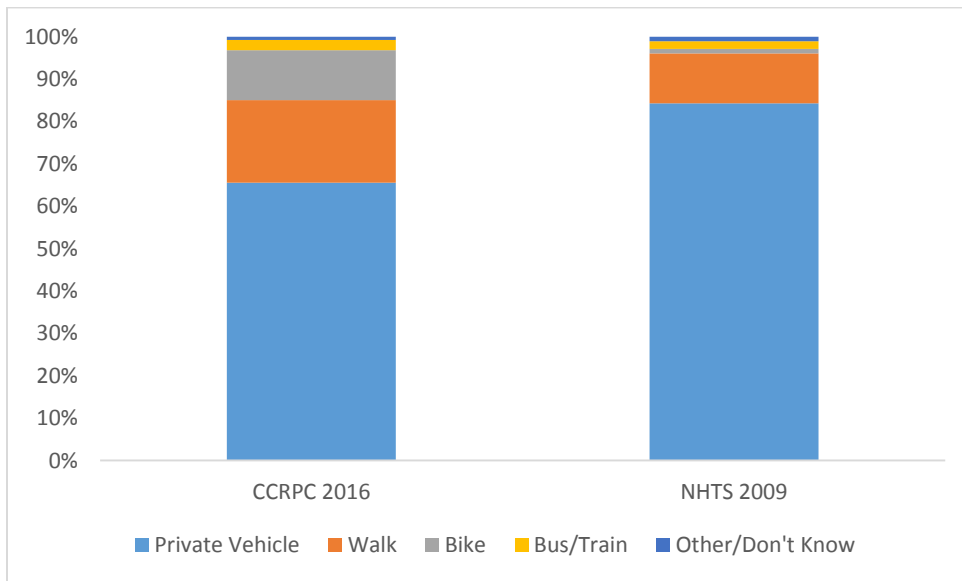


Figure 6. Mode Distribution CCRPC 2016 and Chittenden County NHTS 2009

Participants in the CCRPC study were automatically provided with a short survey whenever they were detected as having taken a trip. Errors in the trip details could be corrected at this time. Participants were also given “end of day” surveys when trips missed by the device could be added. Contrary to our expectation, the sub-set of participants who completed all surveys added fewer trips (9.7%) than did the sample as a whole (33.7%). This may indicate that respondents who needed to add many missed trips

became tired of adding trips and stopped fully completing daily and trip surveys because of higher survey burden. The reason for the App missing so many of the trips is unknown.

Table 61. Trip Capture Rate among All Respondents

Trip Capture Rate	All Participants		Participants Completing All Surveys	
	Number of Trips	%	Number of Trips	%
No Error	1715	62.8%	1461	85.3%
Trip Merged	9	0.3%	8	0.5%
Trip Split	6	0.2%	4	0.2%
Trip Added	922	33.7%	166	9.7%
Other Error (e.g. wrong route)	81	3.0%	73	4.3%
Total	2733		1712	

Appendix F – Sample Size Calculations

Sample Sizes Calculated Using NHTS 2009 Results

Sample sizes based on the NHTS surface trip data are calculated independently for household trip rates, average trip length and mode share. Separate sample sizes are estimated for Chittenden County and the rest of Vermont in order to ensure an adequate sample for modeling efforts by both VTrans and CCRPC. For each variable of interest, estimates are calculated for a standard error 5%, 10%, and 20%. Where appropriate, sample sizes are converted from trip to household sample sizes using a rate of 8.83 household-trips per day and assuming one day of data collection. These calculations make several assumptions: that means/proportions and variance from the NHTS match the true population means/variances and that the desired level of confidence is 95%. Note that the mode share calculations are provided for additional context but are not part of the criteria imposed for the sample size recommendations for the All-in-One program.

Results for Chittenden County are provided in Table 62 through Table 64. Replicating the average trip length found in NHTS 2009 for Chittenden County within 5% requires a sample size of approximately 1,200 households. This relatively large sample size, reflects high variability in trip length in the Chittenden County NHTS 2009 subsample. This sample size is also sufficient to replicate household trip rates. Results for Vermont outside of Chittenden County are provided in Table 65 through Table 67. Because the variance in trip length is smaller in this NHTS sub-sample, a sample of 718 households is sufficient to replicate the average trip length and household trip rate found in NHTS 2009 within 5%.

Table 62. Sample Size Required to Replicated NHTS Household Trip Rates for Chittenden County

	NHTS Average (Trips/Day)	Std Dev	Acceptable Error (%)	Required Sample Size (Households)
HH Trip Rate	8.9	6.5	5%	812
			10%	203
			20%	51

Table 63 Sample Size Required to Replicated Average NHTS Trip Length for Chittenden County

	NHTS Average (Miles)	Std Dev	Acceptable Error (%)	Required Sample Size (Trips)	Required Sample Size (HHs)
Trip Length	8.1	21.2	5%	10,478	1,278
			10%	2,619	319
			20%	654	80

Table 64. Sample Size Required to Replicated NHTS Mode Share for Chittenden County

	NHTS Proportion	Std Dev	Acceptable Error (%)	Required Sample Size (Trips)	Required Sample Size (HHs)
Walk Trip Rate	0.118	0.32	5%	11,453	1,297
			10%	2,863	324
			20%	716	81
Transit Trip Rate	0.006	0.08	5%	237,710	26,923
			10%	59,427	6,731
			20%	14,856	1,683
Bike Trip Rate	0.010	0.10	5%	148,335	16,800
			10%	37,083	4,200
			20%	9,270	1,050
Vehicle Trip Rate	0.845	0.36	5%	282	32
			10%	71	8
			20%	18	2

Table 65. Sample Size Required to Replicated NHTS Household Trip Rates Outside of Chittenden County

	NHTS Average (Trips/Day)	Std Dev	Acceptable Error (%)	Required Sample Size (HHs)
HH Trip Rate	8.2	5.96	5%	806
			10%	202
			20%	50

Table 66. Sample Size Required to Replicated Average NHTS Trip Length Outside of Chittenden County

	NHTS Average (Miles)	Std Dev	Acceptable Error (%)	Required Sample Size (Trips)	Required Sample Size (HHs)
Trip Length	9.7	19.0	5%	5,888	718
			10%	1,472	180
			20%	368	45

Table 67. Sample Size Required to Replicated Average NHTS Trip Length Outside of Chittenden County

	NHTS Proportion	Std Dev	Acceptable Error (%)	Required Sample Size (Trips)	Required Sample Size (HHs)
Walk Trip Rate	0.104	0.31	5%	13,143	1,488
			10%	3,285	372
			20%	821	93
Transit Trip Rate	0.005	0.07	5%	289,786	32,818
			10%	72,446	8,205
			20%	18,111	2,051
Bike Trip Rate	0.013	0.11	5%	120,540	13,651
			10%	30,135	3,413
			20%	7,533	853
Vehicle Trip Rate	0.85	0.38	5%	271	31
			10%	68	8
			20%	17	2

Expected Number of Users by Age & Income Group

Another way to consider sample size is to look at the number of respondents by demographic group or mode use that would be expected for a given sample size. We assumed that ensuring at least 20 respondents annually in each subgroup would facilitate adequate sample weighting. Table 68 and Table 69 show the breakdown of Vermont's population by age and income level (expressed relative to the poverty level for a particular household size) based on Census ACS data². Note that the sample size calculations here are in individuals rather than households.

Table 68. Number of Vermonters by Age and Percent of Poverty Level

Income as a Ratio to Poverty Level	18 to 34 years	35 – 65 years	65+ years
Less than twice the poverty level	46,372	56,699	29,092
Two to three times the poverty level	23,737	40,841	19,209
Three to five times the poverty level	29,585	76,067	25,308
Five or more times the poverty level	20,773	88,331	25,250

² Age By Ratio Of Income To Poverty Level In The Past 12 Month, U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates.
https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_5YR_B17024&prodType=table

Table 69. Proportion Vermont Population by Age and Percent of Poverty Level

Income as a Ratio to Poverty Level	18 to 34 years	35 – 65 years	65+ years
Less than twice the poverty level	9.6%	11.8%	6.0%
Two to three times the poverty level	4.9%	8.5%	4.0%
Three to five times the poverty level	6.1%	15.8%	5.3%
Five or more times the poverty level	4.3%	18.4%	5.2%

Table 70 shows the expected number of Vermonters in each age and income bracket give a random sample of 500 Vermonters. Table 71 shows the number of users of various modes that would be expected in Chittenden County and the rest of Vermont give a sample size of 240 in Chittenden County and 260 outside of Chittenden County (total n=500). Walkers, bikers and transit riders are defined as individuals who completed at least one trip on their NHTS travel day using that particular mode. A sample size of 500 would produce an adequate number of Vermonters to support demographic weighting by age and income but not by mode use on an annual basis.

Table 70. Expected Number of Respondents Given a Random Sample of 500 Vermonters

Income as a Ratio to Poverty Level	18 to 34 years	35 – 65 years	65+ years
Less than twice the poverty level	48	59	30
Two to three times the poverty level	25	42	20
Three to five times the poverty level	31	79	26
Five or more times the poverty level	22	92	26

Table 71. Expected Users by Mode Given a Random Sample of 500 Vermonters

User Group	Chittenden County		Rest of Vermont		Statewide Total
	Rate	Sample	Rate	Sample	
All Respondents	N/A	240	N/A	260	500
Walkers	0.24	58	0.19	49	107
Bikers	0.02	5	0.02	6	11
Transit Riders	0.02	5	0.01	3	8