Massachusetts Department of Transportation

Massachusetts Travel Survey

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massDOT
Massachusetts Department of Transportation

Massachusetts Travel Survey
2010 - 2011

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Acknowledgments

All available report documents can be accessed on the MassDOT web site at:

www.mass.gov/massdot/travelsurvey

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Executive Summary

The Massachusetts Department of Transportation (MassDOT) and the Commonwealth's metropolitan planning organizations (MPOs) contracted with NuStats to conduct the Massachusetts Travel Survey (MTS), a comprehensive study of the demographic and travel behavior characteristics of residents within the Commonwealth of Massachusetts. The survey data obtained through this effort will provide substantially updated information on travel and mobility patterns, enable updates for state and regional travel demand models, and ultimately assist planners and decision makers in better understanding the needs of the traveling public – all of which will support making the best investments in transportation.

The MTS targets included demographic and trip data collected from a minimum of 15,000 households, including a sub-sample of at least 500 households that would also provide global positioning system (GPS) data. As summarized in Table 1, the data collection goal was met. The final data set contains information for 15,033 households, of which 611 households also provided GPS data. The project was conducted by NuStats, in association with GeoStats, with a portion of the Computer-Assisted-Telephone-Interviewing conducted by Wilkins Research Services.

Table 1: Overall Completed Survey Summary

MPO (with associated regional planning commission)	Retrieval Target	Recruits	Retrievals	% of Target	Retrieval Rate
Boston MPO (MAPC)	7,200	12,688	7,661	106.4%	60.4%
Southeastern Massachusetts MPO (SRPEDD)	1,400	2,120	1,181	84.4%	55.7%
Pioneer Valley MPO (PVPC)	1,400	2,537	1,488	106.3%	58.7%
Central Massachusetts MPO (CMRPC)	1,200	1,956	1,148	95.7%	58.7%
Old Colony MPO (OCPC)	725	1,048	554	76.4%	52.9%
Merrimack Valley MPO (MVPC)	725	1,304	711	98.1%	54.5%
Northern Middlesex MPO (NMCOG)	625	1,081	640	102.4%	59.2%
Cape Cod MPO (CCC)	600	788	498	83.0%	63.2%
Montachusett MPO (MRPC)	525	855	529	100.8%	61.9%
Berkshire MPO (BRPC)	300	490	303	101.0%	61.8%
Franklin Transportation Planning Organization (FRCOG)	200	372	262	131.0%	70.4%
Martha's Vineyard MPO (MVC)	50	48	35	70.0%	72.9%
Nantucket MPO (NPEDC)	50	44	23	46.0%	52.7%
Statewide Total	15,000	25,331	15,033	100.2%	59.3%

The survey design employed a generally accepted research method for household travel surveys that included a subsample of households equipped with global positioning system (GPS) equipment to provide an independent measure of travel. Household members (age 14 and older) recorded all trips for a specified 24-hour period using a specially designed diary. After an in-depth review of data needs, a specific set of data elements aimed at collecting household level, person level, and trip level data were identified. The final questionnaire was administered by telephone or mail.

A stratified sampling approach was used where the survey universe was divided into smaller groups and a random sample was chosen within each group. The approach allowed NuStats to oversample at the certain geographic and demographic strata to capture the diversity of the population according to specific factors affecting travel behavior in the study area, while meeting the MPO distribution goals.

The pretest, designed to test the materials, processes, and procedures for the full study, was conducted from September to December 2009 and included sample from each MPO in the study area. In total, demographic and travel data were collected and completed for 574 households. The results of the pretest provided information used to refine the survey procedures, programs, and materials.

Data collection activities for the full-study began in May 2010 and continued through October 2011, with a break during the summer, and included seven main stages; (1) advance notification, (2) reminder postcard, (3) recruitment, (4) placement of materials, (5) reminder call, (6) travel data retrieval, (7) data processing. Sampled households were initially contact by an advance letter that introduced the household to the survey and invited them to participate in the recruitment survey, either by phone or mail, where key household and person level information was collected.

A total of 25,331 households were recruited for the full study. Once a GPS household was recruited, GeoStats managed the deployment and recovery of the GPS devices as well as the GPS data processing. All recruited households, including those participating in the GPS portion of the survey, were then mailed personalized diaries to report their travel for an assigned 24-hour period. NuStats retrieved the travel information by mail (52.5 percent) or by telephone (47.5 percent).

Once retrieved, household travel details were processed, and then subjected to quality control checks. Data Processing took place on a daily basis throughout the study, beginning with the release of sample for recruitment, to processing recruitment data for the respondent mailout, to appending the retrieval data to the master tables, and to performing initial quality control measures on the data. All trip-ends and habitual addresses were geocoded during the retrieval through the TripTracer software.

Results

General

- Achieved 15,033 completed households with an overall recruitment rate of 58.4 percent and retrieval rate[1] of 59.3 percent. These households yielded information for 37,023 persons, 26,488 vehicles, and 190,215 places.

- The average interview length for recruitment was (17.1 minutes); the retrieval interview averaged 28.1 minutes.

- Travel days were evenly distributed among each weekday: Monday (20.1 percent), Tuesday (20.1 percent), Wednesday (20.0 percent), Thursday (19.4 percent), and Friday (20.2 percent).

Person Data (n = 37,023)

- Twenty-nine percent of respondents were aged 35 to 54 years of age; forty-five percent were younger than 35 years of age.

- Thirty-eight percent of respondents reported being unemployed.

- Workers in the study area average 1.11 jobs each.

- Eighty-five percent of respondents reported having a valid driver's license.

- Twenty-nine percent of respondents reported being a student.

Household Data (n = 15,033)

- The average household size is 2.5 household members.

- On average, households reported 1.8 vehicles, with 37.1 percent of households reporting two vehicles and 35.7 percent of household reporting one vehicle.

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[1] Total number of retrieved households divided by the total number of recruited households

- Households reported having an average of 1.3 household workers. Zero-worker households constituted 25.5 percent, one-worker households constituted 36.4 percent, and two-person households constituted 30.2 percent.

- The average household income category with the highest percentage of respondents (16.4 percent) was between $50,000 and $74,999.

Place Data (n = 190,215)

- Households reported an average of 10.2 daily household trips and 4.1 daily person trips.

- Sixty-nine percent of all trips were made by automobile, either as the driver or passenger.

- The non-motorized transportation mode for all trips included walk (19 percent) and bike (1.1 percent).

- Transit transportation mode for all trips included Public Bus (3.6 percent), Train (4.0 percent), and Ferry/Boat (0.1 percent).

Survey Methods

Objectives and Approach

The Massachusetts Travel Survey (MTS) is a comprehensive study of the demographic and travel behavior characteristics of residents of the Commonwealth of Massachusetts. Sponsored by MassDOT and the Commonwealth's MPOs, the survey data obtained through this effort will support updates for travel demand models and assist public decision-makers in better understanding how well the transportation system is functioning under the demands placed upon it.

The MTS had three phases: design, pretest, and full study data collection. The design phase took place in early 2009 and included the development of the work plan and sampling plan, the identification of data elements, materials design, and database programming. The pretest effort took place between September and December 2009 and served as a dress rehearsal of all processes required of the full study. A survey of non-respondents was conducted following the pretest to help inform the design of the survey materials for the full study. The full study data collection effort took place from June 2010 and concluded in November 2011. The study area is presented in Figure 1 on the next page.

The project design called for a traditional household travel survey with a subsample of households equipped with global positioning system (GPS) equipment to provide an independent measure of travel. Sampled households were contacted by telephone to secure their participation in the study; then they were mailed personalized diaries to report their travel for an assigned 24-hour period. Their travel details were retrieved by telephone, processed, and then subjected to standard quality control checks. The GPS subsample followed the same protocol: they were also contacted by telephone to secure their participation, they received their diaries and GPS units via mail, and then they reported their travel details by phone while they mailed back their GPS units. A subsequent review of the GPS data included a comparison of what was reported by telephone versus what trips were detected in the GPS data streams. Following quality control checks and the compilation of the final dataset, weighting factors were created to adjust the data with regard to geographic and demographic distribution.

This section of the report provides details about the methodology used to conduct the survey through the stages described above. It concludes with documentation on the development of the weights for use with the final dataset. Within each section, the methods used, as well as the outcomes from those methods, are discussed.

2009 Statewide Household Survey Sample Groups
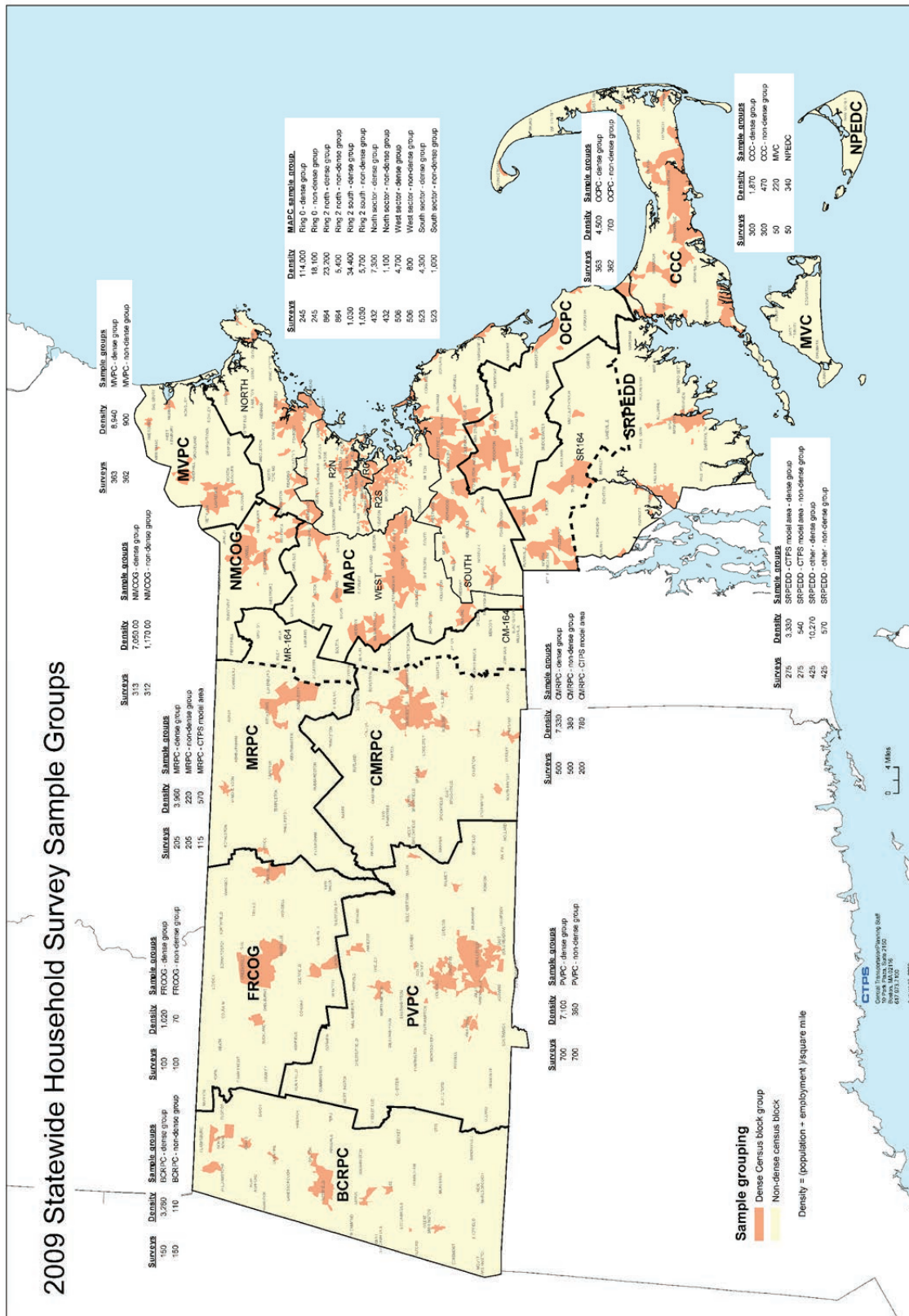
Survey Design

The goal of the study was to collect data from a minimum of 15,000 regional households. Demographic information (obtained during the recruitment interview) and detailed travel information (obtained during the retrieval interview) were collected for all household members. The final dataset contains demographic and trip information for 15,033 households.

The survey employed a generally accepted research method for household travel behavior research, in which household members age 14 and older recorded all trips for a specified 24-hour period (from 3:00 a.m. to 2:59 a.m.) using a specially designed travel diary. Travel for children younger than 14 were collected via proxy reporting from an adult in the household. In the survey materials and interview scripts, respondents were assured that their responses would be kept confidential and that their responses would be analyzed in the aggregate only. As a result, the data files were structured such that a 7-digit unique identifier ("sample number") would be used to link each household's data together and documentation prepared to ensure the public use data files would be stripped of all identifying information prior to its release. Households were randomly assigned to non-Federal Holiday weekdays for recording their travel (Monday–Friday). The final distribution of households by day of week is shown in Table 2, which shows roughly equal distribution of completed households among the days of the week.

Table 2: Distribution of Households by Day of Week

Day of Week	Frequency	Percent
Monday	3040	20.2%
Tuesday	3029	20.1%
Wednesday	3005	20.0%
Thursday	2919	19.4%
Friday	3040	20.2%
Total	15033	100.0%

The study began with an in-depth review of data needs that would satisfy the modeling requirements and analysis plans that would be relying on the survey data. This resulted in the identification of the following data items identified in Table 3, listed in order of their appearance in each data file.

Table 3: Data Items in Household, Person, Vehicle and Travel/Location Files

Household Level	Person Level	Vehicle Level	Trip Level
GPS Participation Status	Gender	Year	Primary Trip Purpose
NRFU Flag	Age	Make	Secondary Trip Purpose
Advance Letter Sent	Age Category	Model	Mode of Trip
Retrieval Mode	Driver License Status	Body Type	Total Traveling in Travel Party
Area of Residence	Has Transit Pass	Fuel Type	Household Members on Trip
MPO of Residence	Type of Transit Pass (Multiple Response)	Main User of Vehicle	Non-Household Members on Trip
County of Residence	Employment Status	Vehicle Used on Travel Day	Vehicle Number used on Trip

Household Level	Person Level	Vehicle Level	Trip Level
Travel Date	Unemployment Status	Reason Vehicle not Used	Parking Location
Travel Day of Week	Hours Worked per Day		Location of Where Person Parked
Transit Use on Regular Basis	Work Name		Paid to Park
Household Size	Days Worked per Week		Parking Cost/Unit
Household Bicycles	Typical Mode to Work		Amount Paid out of Pocket
Household Vehicles	Transit Service Used to Travel to Work		Toll Road Used
Hispanic or Latino Status	Telecommute		Which Toll Road Used
Ethnicity	Flexible Work Schedule		Entrance to Toll Road
Residence Type	Flexible Programs Offered		Exit from Toll Road
Home Ownership Status	Participation in Flex Programs		Toll Road Amount
Number of Cell Phones	Disabled License Plate		HOV Lane Use
Number of Landline Phone Lines	Disabled Transit Registration		Transit Mode Type
Number of Dedicated Fax Lines	Level of Education Completed		Fare Paid
Household Income	Student Enrollment		Transit Route Used
Willing to Participate in Future Studies	Full or Part-Time Student		Arrival Hour/Minute
Household Trips	Student Grade Level		Departure Hour/Minute
Household Workers	School Name		Trip Duration
Household Students	Typical Mode to School		Activity Duration
Number of Licensed Drivers in Household	Transit Service Used to Travel to School		Place Name
Home Address	Transit Trips in Past Week		Place Address
Home X/Y Coordinates	Bike Facilities Available at Work/School		Place X/Y Coordinates
	Days Used Bike for Recreation last week		
	Days Used Bike for Transportation last week		
	Bike Trails and Lanes Used		
	Internet Used in Place of Trips on Travel Day		
	Person Trips		
	Completed Travel Log		
	Interviewed in Person		
	Household Member Serving as Proxy		
	Travel Day Typical		
	Travel Activities Planned in Advance		
	Reason for No Travel		
	Work Address		
	Work X/Y Coordinates		
	School Address		
	School X/Y Coordinates		

Sample Design

Equally important as the decision of what to obtain during the survey is from whom to obtain that data. The objective was to provide a dataset representative of the region's population and travel patterns. As such, the sample design for the study needed to guide the collection of data such that the resultant dataset would include adequate representation of households by geography, as well as the key demographics of household size and household vehicles.

This section discusses the sample design used for the full study. The key issues considered while developing the sampling plan were identification of the survey universe, selection of the sampling frame(s), selection of the sampling method, and calculation of the sample size. The following subsections discuss these key issues in detail, including: (1) Survey Universe, (2) Sampling Frame, (3) Sample Method, (4) Stratification Scheme, and (5) Sample size.

Sampling Plan Goals and Survey Universe

The survey population represents all households residing in the thirteen MPO regions in the Commonwealth of Massachusetts (see Figure 2). The population, or the study universe, comprises 2,547,075 households. Table 4 provides the distribution of households by MPO region. The goal was to obtain travel data from over 15,000 households.

Table 4: Distribution of Households in Study Area

MPO Region	2010 Census	
	All Households	Percent of All Households
Boston MPO (MAPC)	1,226,596	48.2%
Southeastern Massachusetts MPO (SRPEDD)	240,223	9.4%
Pioneer Valley MPO (PVPC)	238,629	9.4%
Central Massachusetts MPO (CMRPC)	210,870	8.3%
Old Colony MPO (OCPC)	119,437	4.7%
Merrimack Valley MPO (MVPC)	123,577	4.9%
Northern Middlesex MPO (NMCOG)	104,022	4.1%
Cape Cod MPO (CCC)	95,755	3.8%
Montachusett MPO (MRPC)	89,816	3.5%
Berkshire MPO (BRPC)	56,091	2.2%
Franklin Transportation Planning Organization (FRCOG)	30,462	1.2%
Martha's Vineyard MPO (MVC)	7,368	0.3%
Nantucket MPO (NPEDC)	4,229	0.2%
Statewide Total	2,547,075	100.0%

Figure 2: Sampled Household Locations (Map of Massachusetts)
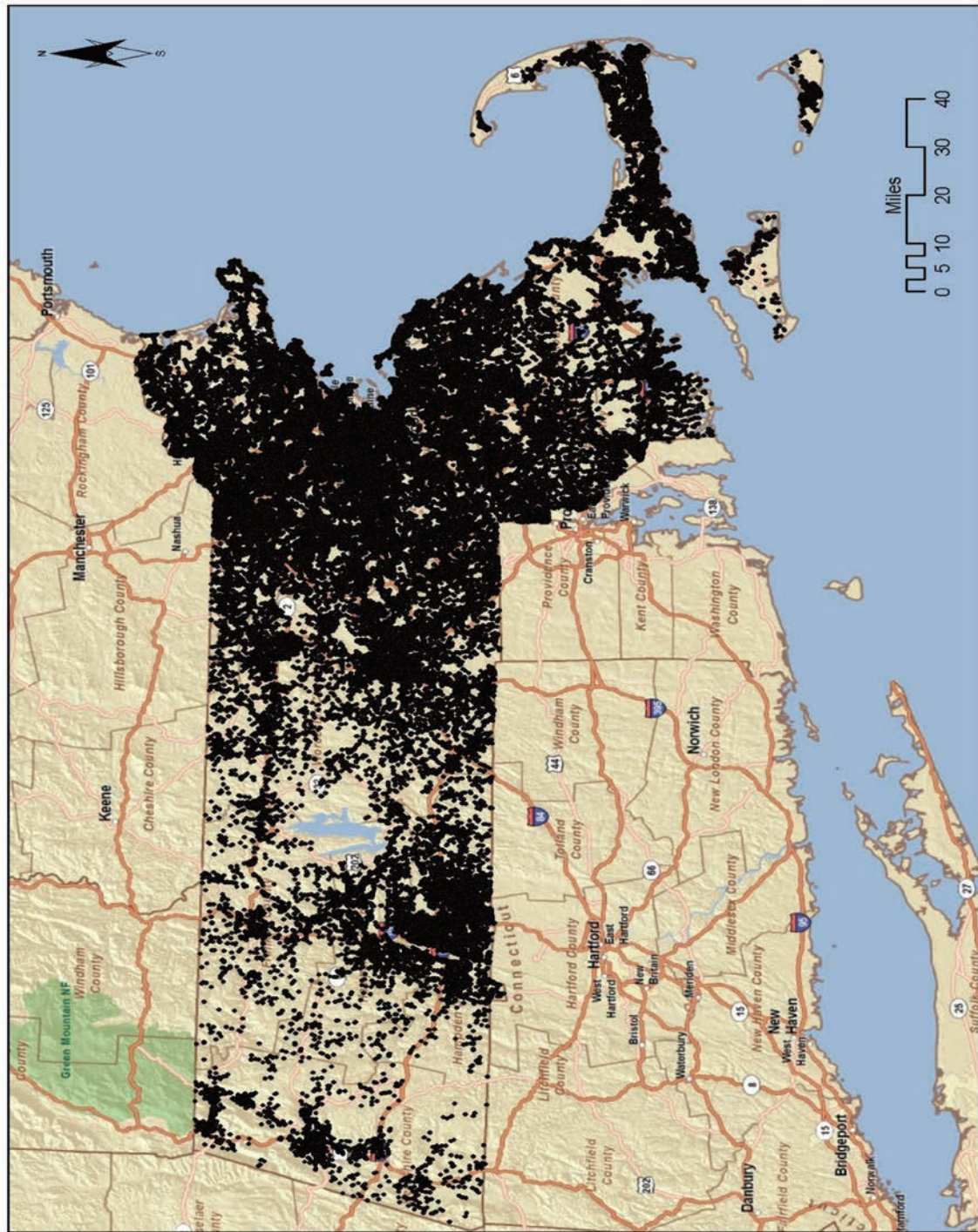
Sampling Frame

A dual sampling frame approach was used that combines the strengths of two sampling frames—Address-based frame and Listed Residential frame. An address-based frame includes all residential addresses that receive U.S. Mail delivery. Its main advantage is its reach into population groups that typically participate at lower-than-average levels, largely due to coverage bias (such as households with no phones or cell phone-only households). For efficiency of data collection, the addresses were matched to telephone numbers and had a listed name of the household appended to it. Addresses were generated and matched by MSG, a third-party vendor. This sampling frame ensured coverage of all types of households irrespective of their telephone ownership status, including households with no telephones (estimated at less than 3 percent of households in the U.S.).

The Listed Residential frame, on the other hand, included listed telephone numbers from working blocks of numbers in the U.S. for which the name and address associated with the telephone number are known. The Listed Residential frame was used to strengthen the coverage of households with listed landlines. The advantage of drawing sample from this frame is its efficiency in conducting the survey effort—being able to directly reach households and secure their participation in the survey in a direct and active approach.

Based on findings from the pretest, appropriate targeted samples were drawn from the dual sampling frames to capture the following hard-to-reach populations groups.

- Large Households: Listed large household sample and young household sample
- Low-income Households: Listed low-income sample
- Young Households: Listed young household sample
- 1-person Worker Households: Listed 1-person earning more than $50,000 annually
- Hispanic Households: Listed Hispanic Surname sample
- African-American Households: Listed African American sample
- New Residents to the study area: Listed New Mover sample
- High Probability Zero-vehicle Households: Listed low-income sample
- Transit Using Households: Listed and Unmatched sample pulled from census tracts with dense populations and near transit

The sample was procured from the sample provider, Marketing Systems Group (MSG), based in Fort Washington, PA. Using Census data, census tracts/blocks are identified having higher than average percentages of households bearing the target characteristics. Because the sample frame is addressed-based, households are randomly selected from these targeted areas. Although there is no guarantee that each household within these targeted areas will actually have the targeted characteristic(s), it does increase the likelihood more than a pure random sample of the study area households.

Sample Method

The selection of an appropriate sampling method is critical for an effective sample design that guards against unplanned selectiveness and produces a robust dataset that is representative of the population. To ensure adequate representation, a sample needs to be drawn scientifically so that each person in the population has a measurable chance of selection. This way, the results can be reliably projected from the sample to the larger population with known levels of certainty and precision.

In this study, we employed a stratified probability sample of households. Stratified sampling is a type of random or probability sampling, the methods of which are well grounded in statistical theory and the theory of probability. Specifically, stratified sampling is a probability sampling method where the survey universe is divided into smaller groups and a random sample is chosen within each group (i.e., every

sampling unit has some non-zero probability of being selected into the sample). This method resulted in oversampling for some strata to ensure we captured the diversity of the population according to specific factors affecting travel behavior in the study area. Thus, within strata, households were selected randomly (i.e., with equal probabilities), but the combined sample (across strata) comprised an unequal probability sample of households.

Stratification Scheme

Based on the recommendations provided by the MPO regions in the study area, we used a geographic stratification scheme that ensured adequate representation of households by MPO regions and municipal density groups. The sample was drawn proportionate to the distribution of households by the geographic strata. The percent of households within the study area (2008 ACS) is compared with the final dataset (MTS) in Table 5.

Table 5: Distribution of MPO Density Stratification

MPO Region	Density Group	2008 ACS	Massachusetts Travel Survey (MTS)
Boston MPO – Ring 0	Dense	1.6%	1.6%
	Non-Dense	1.6%	1.8%
Boston MPO – Ring 2 north	Dense	5.8%	5.8%
	Non-Dense	5.8%	5.9%
Boston MPO – Ring 2 south	Dense	6.9%	6.7%
	Non-Dense	6.9%	7.0%
Boston MPO – North sector	Dense	2.9%	2.9%
	Non-Dense	2.9%	2.8%
Boston MPO – West sector	Dense	3.4%	4.4%
	Non-Dense	3.4%	4.9%
Boston MPO – South sector	Dense	3.5%	3.6%
	Non-Dense	3.5%	3.6%
Merrimack Valley MPO (MVPC)	Dense	2.4%	2.0%
	Non-Dense	2.4%	2.7%
Northern Middlesex MPO (NMCOG)	Dense	2.1%	1.6%
	Non-Dense	2.1%	2.6%
Montachusett MPO (MRPC)	Dense	1.4%	1.4%
	Non-Dense	1.4%	1.3%
	CTPS model area	0.8%	0.9%
Franklin Transportation Planning Organization (FRCOG)	Dense	0.7%	1.0%
	Non-Dense	0.7%	0.8%
Berkshire MPO (BRPC)	Dense	1.0%	1.1%
	Non-Dense	1.0%	1.0%
Pioneer Valley MPO (PVPC)	Dense	4.7%	4.7%
	Non-Dense	4.7%	5.2%
Central Massachusetts MPO (CMRPC)	Dense	3.3%	3.0%
	Non-Dense	3.3%	3.2%
	CTPS model area	1.3%	1.5%
Southeastern Massachusetts MPO (SRPEDD) - CTPS model area	Dense	1.8%	1.7%
	Non-Dense	1.8%	1.6%
Southeastern Massachusetts MPO (SRPEDD) – Other	Dense	2.8%	2.3%
	Non-Dense	2.8%	2.3%
Cape Cod MPO (CCC)	Dense	2.0%	1.6%

MPO Region	Density Group	2008 ACS	Massachusetts Travel Survey (MTS)
	Non-Dense	2.0%	1.7%
Martha's Vineyard MPO (MVC)		0.3%	0.2%
Nantucket MPO (NPEDC)		0.3%	0.2%
Old Colony MPO (OCPC)	Dense	2.4%	1.7%
	Non-Dense	2.4%	2.0%
Statewide Total		100.0%	100.0%

We also used a demographic stratification to set demographic controls and monitor the performance of the sample against these controls. In particular, the study area was stratified by household size, number of workers, and vehicle ownership, translating to 37 demographic cells formed by the cross-tabulation of the three key variables with the following categories.

- Household size – one-person, two-person, three-person, four-person, and five-or-more persons

- Number of workers – zero, one, two, and three-or-more workers

- Vehicle ownership – zero, one, two, and three-or-more vehicles.

Table 6 presents the census distribution of the households in the study area by the 37 demographic cells using 2008 American Community Survey (ACS) data. The table also presents the distribution of completed surveys by demographic stratification.

Table 6: Stratification Scheme

Household Size	Number of Workers	Vehicle Ownership	ACS 2008		Survey Results	
			Count	Percent	Count	Percent
1-person	0	0	102,405	4.2%	756	5.03%
		1	132,839	5.4%	1257	8.36%
		2 or more	2,382	0.5%	116	0.77%
	1	1 or less	428,620	17.4%	1792	11.92%
		2	42,403	1.7%	149	0.99%
		3 or more	1,710	0.5%	53	0.35%
2-person	0	0	2,846	0.5%	146	0.97%
		1	48,928	2.0%	365	2.43%
		2 or more	42,913	1.7%	621	4.13%
	1	1 or less	102,452	4.2%	535	3.56%
		2	81,776	3.3%	813	5.41%
		3 or more	13,212	0.5%	222	1.48%
	2	2 or less	430,272	17.4%	1702	11.32%
		3 or more	49,704	2.0%	425	2.83%
3-person	0	1 or less	8,456	0.3%	107	0.71%
		2 or more	2,418	0.1%	74	0.49%
	1	1 or less	7,084	1.9%	255	1.70%
		2	18,416	0.7%	298	1.98%
		3 or more	6,943	0.3%	147	0.98%
	2	2 or less	160,012	6.5%	787	5.24%
		3 or more	34,929	1.4%	405	2.69%
	3	All	116,748	4.7%	465	3.09%

Household Size	Number of Workers	Vehicle Ownership	ACS 2008		Survey Results	
			Count	Percent	Count	Percent
4-person	0	All	5,400	0.2%	65	0.43%
	1	0	5,326	0.2%	20	0.13%
		1	18,077	0.7%	111	0.74%
		2 or more	25,863	1.0%	502	3.34%
	2	2 or less	169,837	6.9%	968	6.44%
		3 or more	26,802	1.1%	315	2.10%
	3+	1 or less	11,673	0.5%	15	0.10%
		2 or more	96,911	3.9%	428	2.85%
5+person	0	All	1,535	0.1%	33	0.22%
	1	2 or less	25,318	1.0%	279	1.86%
		3 or more	3,021	0.1%	62	0.41%
	2	1 or less	15,064	0.6%	47	0.31%
		2	49,182	2.0%	299	1.99%
		3 or more	17,384	0.7%	147	0.98%
	3+	All	88,468	3.6%	252	1.68%
Total			2,467,329	100.0%	15033	100.00%

The geographic and demographic distributions of participating households were monitored on a regular basis, and areas/demographic cells that were underrepresented were targeted during the course of the full study, as and when needed. In order to facilitate this, the sample was ordered in several waves. The first sample order included a disproportionate draw of sample from the two frames wherein targeted samples were drawn from the frames with higher oversampling percentages. The oversampling percentages used in the pretest were revised to reflect the observed percentages needed to meet the geographic and demographic goals.

Sample Size

The expected sample size for the full study was 15,000 completed surveys. NuStats recruited 25,331 households and retrieved information from 15,033 households. Table 7 shows expected and completed surveys by MPO of residence, with recruitment and retrieval rates.

Table 7: Distribution of Participating Households by MPO

MPO Region	Recruited Households	Recruitment Rate	Retrieved Households	Retrieval Rate	All Households (2010 Census)
Boston MPO (MAPC)	12688	60.1%	7661	60.4%	48.2%
Southeastern Massachusetts MPO (SRPEDD)	2120	55.6%	1181	55.7%	9.4%
Pioneer Valley MPO (PVPC)	2537	58.5%	1488	58.7%	9.4%
Central Massachusetts MPO (CMRPC)	1956	58.5%	1148	58.7%	8.3%
Old Colony MPO (OCPC)	1048	52.5%	554	52.9%	4.7%
Merrimack Valley MPO (MVPC)	1304	54.4%	711	54.5%	4.9%
Northern Middlesex MPO (NMCOG)	1081	59.0%	640	59.2%	4.1%
Cape Cod MPO (CCC)	788	63.0%	498	63.2%	3.8%
Montachusett MPO (MRPC)	855	61.7%	529	61.9%	3.5%
Berkshire MPO (BRPC)	490	61.4%	303	61.8%	2.2%
Franklin Transportation Planning Organization (FRCOG)	372	70.2%	262	70.4%	1.2%
Martha's Vineyard MPO (MVC)	48	72.9%	35	72.9%	0.3%
Nantucket MPO (NPEDC)	44	52.3%	23	52.3%	0.2%
Statewide Total	25331	58.4%	15033	59.3%	100.0%

The locations of all recruited households are shown in Figure 3.

Figure 3: Recruitment Household Locations (Map of Massachusetts)
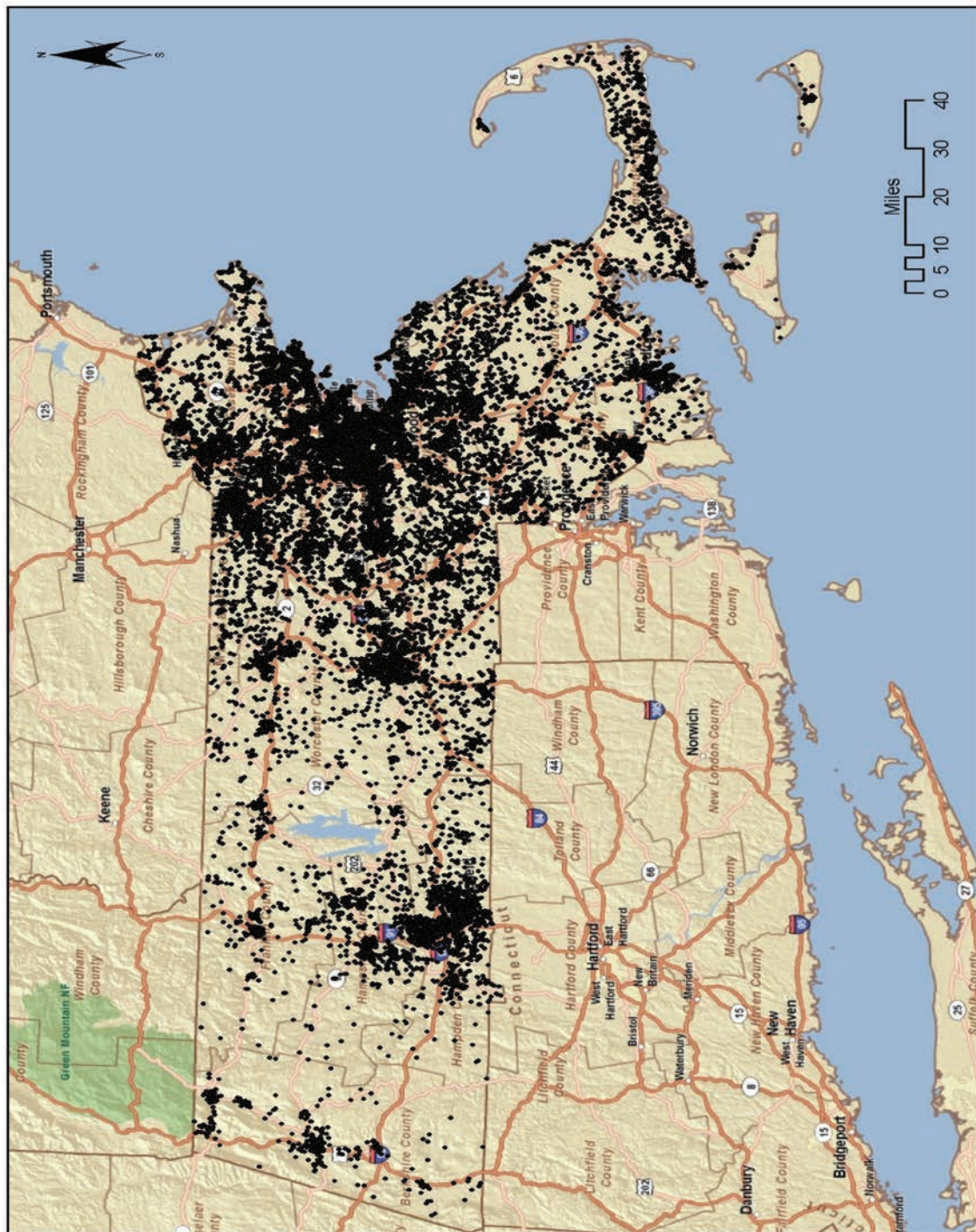
Effect of Multi-Modal Data Collection on Sampling

Multi-modal data collection does not have significant consideration in sampling. For recruitment, Computer-Assisted Telephone Interviewing (CATI) was available for data collection. For retrieval, CATI and mail-back options were available. Multi-modal data collection helps reach a diversified, and representative, sample not possible though one survey mode. For example, unmatched sample do not have a phone number. We mailed advance letters to 100 percent of the unmatched sample inviting them to participate in the study and encouraged them to call the survey hotline or to request a household questionnaire to complete the survey.

Sample Generation and Processing

The planned sampling approach for the MTS combined the strengths of address-based sampling frame and listed residential frame. The address-based frame permitted differential sampling rates by census tract and the listed residential frame strengthened the coverage and enhanced the efficiency of data collection from hard-to-reach population groups. With the address-based sampling frame, the randomly sampled addresses were divided into two categories: (a) those with telephone numbers ('matched') and (b) those without telephone numbers (unmatched). The address-based sampling frame consists of a current listing of city- and rural-route residential postal addresses for the study area from the delivery sequence file (DSF) of the United States Postal Service. Its main advantage is its reach into population groups that typically participate at lower-than-average levels, largely due to coverage bias (such as households with no phones or cell-phone-only households). The listed residential frame, on the other hand, includes listed telephone numbers from working blocks of numbers for which the name and address associated with the telephone number are known. The advantage of drawing sample from this frame is its efficiency in conducting the survey effort—being able to directly reach households and secure their participation in the survey in a direct and active approach.

The sample from both frames was ordered from a private supplier, Marketing Systems Group (MSG). The address-based sample was systematically drawn from the ADVO frame. ADVO is a direct mail media company that has a proprietary database of up-to-date and deliverable resident/occupant mailing address lists based on the DSF. MSG matched the sampled residential addresses to obtain landline telephone numbers; then, the sample file was forwarded to Direct List for name matching.

A total of 319,187 sample pieces were ordered for the study area. Sample orders were placed in different waves (phases) and specification based on sample analysis and performance. The following table shows the distribution of the overall sample order by sample type for the full study.

Table 8: Summary of Sample by Sample Type

Sample Type	Count	Percent
Address Based Matched	54,322	17.0%
Address Based Unmatched	25,489	8.0%
Listed General	47,679	14.9%
Listed Large HH	40,398	12.7%
Listed Low-Income HH	25,417	8.0%
Listed Young HH	22,208	7.0%
Client-Provided Sample	6	<0.1%
Listed 1-person earning >$50k	10,359	3.2%
Listed Spanish Surname	17,133	5.4%
Listed African-American	8,537	2.7%
Listed New-Mover	31,833	10.0%
Listed High Probability Zero-Vehicle	2,843	0.9%
Listed residing in densely populated census tracts	19,478	6.1%
Listed residing in census tracts near transit	13,485	4.2%
Total	319,187	100.0%

Data Collection

Pretest

The purpose of the pretest phase of the study was to test survey instruments and materials planned for the full study in order to assess respondent reaction, data collection processes, and budget assumptions. The main objectives of the pretest phase were:

1) To test the respondent materials to ensure they were applicable and understood by all respondent groups, despite differences in geography and demographics;

2) To program and test the core programs and processes;

3) To program and test the GPS processes and to ensure that the GPS component was properly designed to yield the desired data; and

4) To evaluate project team performance and respondent participation rates in light of original cost assumptions.

The pretest survey was designed to test the materials, processes, and procedures for the full study. To do so, the data collection goal was to recruit a sufficient number of households in order to obtain complete and usable data from 600 households. The MTS pretest consisted of all necessary data collection activities required to produce a dataset. These activities included sample generation, advance notification, recruitment, placement of respondent materials, reminder calls, retrieval, quality assurance, and data delivery. The pretest focused on all MPOs within the full study area. In total, 860 households were recruited into the pretest study; complete and usable data were obtained from 574 households.

Throughout all pretest activities, the focus was to target areas for improvement prior to the start of the full study. The role of the pretest was critical in the study—it was not designed to make everyone "comfortable," as that approach would have resulted in inadequate and insufficient evaluation of the process. The pretest was referred to as a "dress rehearsal" specifically for this reason; it was a road test of all systems and respondent materials to ensure everything was in place and ready for full implementation. As such, the pretest households were not included as part of the final dataset.

Recruitment

Recruitment for the Massachusetts pretest occurred between September 24 and November 12, 2009. Contact was made with 6,352 households, of which 867 agreed to participate in the study (14 percent recruitment rate). In addition, 203 of the 867 households agreed to participate in the GPS portion of the study (23 percent of all recruited households).

The use of advanced letters is recommended to inform respondents of the purpose of the study, as well as to legitimize the survey effort. Letters were mailed to approximately 56 percent of the total pretest sample. A total of 17,776 records were dialed during the pretest, of which 9,923 received an advanced letter.

The mean call attempt for non-contact sample (answering machines, no answers, and busy signals) was approximately 4.14. Of the 4,187 non-contacted records, 54 percent required over five call attempts. During the pretest, 867 households were recruited with a final recruitment completes per hour rate (CPH) of 0.82. This was slightly lower than the budgeted 0.95 completes per hour rate (CPH). The average interview length was just under 20 minutes.

Retrieval

Pretest retrieval occurred from October 6 through December 23, 2009. Of the 867 recruited households who agreed to participate, 574 actually completed their diaries and were retrieved, representing a 67 percent retrieval rate, which is in line with the budgeted estimate. Of the 203 households who agreed to partake in

the GPS study, 153 were retrieved, representing a 75 percent retrieval rate. The difference in rates can be attributed, in large part, to the monetary incentive offered for GPS participation. A total of 149 households refused to participate, which represents a 17 percent refusal rate. The final retrieval completes per hour rate (CPH) was 0.91, which is in line with budgeted expectations.

The average retrieval interview was just over 40 minutes and includes time needed to research addresses and finalize diaries received by mail. This does not represent total time spent on the phone with the respondent.

Dialing hours

A total of 1,053 interviewer dialing hours were used to secure 860 recruits in the pretest, and 629 hours were used to collect the 574 retrieval completes. This is a total of 1,682 total dialing hours throughout the course of the pretest.

Mailback Processing

During pretest retrieval, 302 respondents chose to mail in their completed diaries rather than complete the survey by phone (35 percent of the total recruits). Of those that opted to mail in their materials, 269 actually did so (89 percent). NuStats was able to complete 255 of the 269 diaries received, which represents a 95 percent completion percentage. The remaining 14 cases were missing data and needed respondent follow-up in order to be considered complete. Calls were placed to these cases throughout the remaining shifts, and contact was not established. Approximately 44 percent of the total retrieval completes were derived from mail back (255/574).

Methods and Design

The pretest was a dress rehearsal of the full study and included 1) drawing a statewide sample, 2) an advance letter mailout, 3) data collection, 4) data cleaning, and 5) data file creation. However, the first major task was the survey instrument design—identifying the required data elements that meet MassDOT's statewide modeling needs as well as the area MPOs' local modeling needs.

The survey was designed to capture the required data elements for MassDOT's regional and travel demand modeling needs. In addition to collecting the standard data variables as inputs to the model, the survey attempted to capture non-auto travel modes such as walk, transit, and bicycle.

The survey instruments, both recruitment and retrieval, were programmed into a CATI environment. The recruitment program is designed to capture household-, person-, and vehicle-level characteristics for each household, to recruit randomly selected households for the GPS component of the study, and to assign households a travel date.

The retrieval program, which is designed to capture all the elements of each person's travel, is supplemented by TripTracer, a customized program used to capture geographic details about each trip. TripTracer is a data quality tool embedded with the road network, public transit layers, place names, and major landmarks for ease of reference to assist the respondent in providing as much trip detail as possible.

Evaluation

The pretest sample design was effective in ensuring an adequate representation of the surveys by geography. However, there was a moderate under-representation of hard-to-reach population groups including large households, zero-vehicle households, low-income households, African Americans, Hispanics, and young households. The sample types targeted towards capturing these population groups were effective. However, the inability to meet the demographic goals of these hard-to-reach population groups

suggests that our assumptions on the oversampling percentages used to draw sample from different sample types needed to be revisited prior to the full study.

NuStats recommended increasing the oversampling percentages for the hard-to-reach population segments based on the findings from the pretest and using targeted sample types more effectively to capture these households, including employing the targeted sample in the beginning of recruitment, monitoring its progress, and offering an incentive to these households. NuStats also recommended offering an incentive to the unmatched (i.e., no landline or cell-only) households, as these households are presumably younger, minority, and/or low-income. Key demographics of pretest participants are shown in Table 11.

Recruitment and retrieval interview lengths by household size are shown in Tables 9 and 10.

Table 9: Pretest: Recruitment Interview Length by Household Size

Household Size	N	Interview Length (min)
1 person	231	13.52
2 persons	325	17.33
3 persons	120	21.58
4+ persons	191	26.38
Total	867	19.70

Table 10: Pretest: Retrieval Interview Length by Household Size

Household Size	N	Interview Length (min)
1 person	173	21.37
2 persons	228	35.02
3 persons	76	52.95
4+ persons	97	51.92
Total	574	40.32

Table 11: Pretest: Distribution of Demographic Characteristics

Key Demographic Variables		Recruited Households	Retrieved Households	2008 ACS	Retrieval Rate
Household size	1	26.6%	30.1%	29.6%	74.9%
	2	37.5%	39.7%	31.7%	70.2%
	3	13.8%	13.2%	16.0%	63.3%
	4+	22.0%	16.9%	22.7%	50.8%
Household vehicles	0	8.4%	8.0%	11.7%	63.0%
	1	31.6%	32.6%	36.0%	68.2%
	2	41.2%	42.0%	37.4%	67.5%
	3+	18.8%	17.4%	14.6 %	61.3%
Household Income	Less than $25,000	15.6%	15.0%	20.2%	64.3%
	$25,000 to $50,000	17.3%	16.3%	19.0%	62.9%
	$50,000 to $75,000	16.4%	18.0%	17.5%	72.9%
	$75,000 or more	50.7%	50.6%	43.2%	66.4%
	Income Refusals	6.6%	6.1%	--	--
Respondent Ethnicity	White	89.2%	93.7%	82.7%	68.5%
	African American	2.3%	0.5%	6.2%	27.8%
	Other	8.4%	5.8%	11.1%	49.2%
Respondent Hispanic Status	Yes	5.0%	3.0%	8.6%	39.4%
	No	95.0%	97.0%	91.4%	67.3%
Respondent Age	<20 years old	22.2%	20.1%	25.0%	56.2%
	20–24	4.1%	2.6%	6.7%	40.5%
	25–34	6.3%	5.2%	12.9%	51.5%
	35–54	30.3%	29.7%	30.8%	60.9%
	55–64	16.4%	19.1%	11.8%	72.3%
	65+	19.0%	21.5%	12.8%	70.2%
	Age Refusals	1.8%	1.9%	--	--
Workers Per Household	0	29.8%	29.6%	14.9%	65.9%
	1	32.2%	33.6%	33.6%	69.2%
	2	31.1%	31.5%	38.7%	67.0%
	3+	6.9%	5.2%	12.8%	50.0%

Non-Response Follow-Up Study

A secondary focus of the pretest was to evaluate who did and did not participate in the survey so as to understand how to better reach out to or recruit those non-responders in the full study. To that end, a non-response follow-up (NRFU) study was designed. This type of study is concerned with unit non-response—that is, entire sample units (households) that may be under-represented in the final survey dataset because of lack of participation.

The purpose of the NRFU was to contact a sub-sample of households who did not participate in the pretest. The goal was to document demographic and travel characteristics among these non-responsive households in an effort to identify differences between those who participate in household travel surveys and those who do not. In October 2009, with direction from the MassDOT, NuStats executed the NRFU effort by

collecting data on the non-responsive households through in-person interviews and observation forms, when in-person interviews could not be conducted.

Specifically, the Massachusetts NRFU approach consisted of the following steps: (1) sample non-contacts and soft refusals, (2) attempt to contact the household three times to complete an in-person interview, (3) complete an observational questionnaire (an external assessment of the household based on the home location and characteristics), and (4) compare these findings to those achieved in the pretest study.

NRFU Study Area Selection

During the design phase of the pretest, the NuStats project team prepared a memorandum outlining the recommended study areas for the NRFU study. This memorandum was provided to the MassDOT for review and comment. Upon review and consideration of favorable study area options, it was decided that Brookline, MA; New Bedford, MA; and Springfield, MA would be targeted as study areas for the NRFU study.

NRFU Sample Selection

The NRFU study methodology called for a sample of 50 household to be selected in each study area. The sample used in the pretest was closely monitored during the recruitment phase in order to generate and identify eligible sample for the NRFU study. To be eligible, sample needed to receive three call attempts and have a specified disposition. These call attempts occurred over a two-week period and at various times of day. Furthermore, sample with the following dispositions were eligible for inclusion in the non-response follow-up sample: Soft Refusals, Specific callback not leading to a complete, General callback not leading to a complete, Hang-Up, Disconnect, Caller ID, Answering Machine, Busy, No Answer, and Households without a telephone match that did not respond by mail.

Overall, 185 household were selected for the NRFU study. Each study area contained the minimum target of 50 household. Available sample above the 50 household minimum was included as contingency and to keep the fieldwork teams as productive as possible.

NRFU Fieldwork Team

NuStats hired a professional staffing agency, Adecco, to organize the fieldwork team of three surveyors. As residents of the study area, these surveyors provided valuable knowledge of the study area. A two-hour training session, moderated and managed by NuStats, was organized and conducted in each study area. The field manager traveled to Massachusetts to conduct these training sessions in person with the purpose of educating the survey teams on the project background, goals, logistics, etc. A training manual distributed to all surveyors included an introduction to the MTS and explained how the NRFU contributes to the overall goal of the study. In addition, specific instructions for executing the fieldwork were clearly outlined so that each surveyor understood their responsibilities and was educated on all survey materials and protocols.

Furthermore, guidelines for the more subjective questions included in the observational questionnaire were discussed in order to achieve consistency between surveyors. All materials necessary for fieldwork were distributed at the training session. These materials included in-person questionnaires, observational questionnaires, sample sheets, clipboards, and writing utensils. At the conclusion of the training session, the field manager answered any questions the surveyors had and provided each surveyor with the list of households they were responsible for contacting. The surveyors worked independently of one another, with each being responsible for conducting interviews and observations for a portion of the households identified within the study area. Overall, the surveyors operated as a team to ensure all households are contacted during the allotted timeframe.

NRFU Fieldwork Hours

Surveyors provided their own transportation or took public transit. Surveyors were available to work eight hours on weekdays (between the hours of 8:00 a.m. and 8:00 p.m.) and on weekends (between the hours of 9:00 a.m. to 12:00 p.m. and 3:00 p.m. to 8:00 p.m.) and were given a three-hour break in the afternoon for lunch. Daily hours were charged when a surveyor arrived at the first household and ended when they left the last household.

NRFU Fieldwork Visits

Surveyors attempted a maximum of three visits to each household. The priority was to complete the in-person questionnaire. If there was no one present in the household, then the second step was to complete the observational questionnaire to make key observations about the residence from clues or indicators about the household and/or neighborhood. A second attempt was made to complete the in-person questionnaire, preferably at a different time of day. Finally, on the third visit, if the surveyor was unable to make contact with the household, they left a short door-knocker questionnaire, along with business-reply mail envelope for mail-back to NuStats.

A total of 175 households resulted in a data collection outcome. Surveyors completed in-person interviews with 28 percent of the households and left a door-knocker with 35 percent of households. Two scenarios resulted in a door-knocker being left at the residence: (1) if the respondent was home, refused to participated but accepted receipt of the door-knocker, and (2) if no contact was made upon the third visit, a door-knocker was left either in the mailbox or on the door knob.

When contact was made with an adult at the sampled household, the interviewer administered the in-person questionnaire. This instrument included 15 questions, three of which were recorded based on interviewer observation; the remainder was asked of the respondent. Forty-eight of these forms were completed.

Recorded by Observation
- Housing Type
- Gender
- Language

Asked of Respondent
- Number of Household Vehicles
- Type(s) of Telephone Service (is the telephone number listed in the phone book?)
- Home Ownership Status
- Number of Household Members
- Licensed Driver Status for respondent and all Household members
- Employment Status for Respondent and all Household members
- Number of places visited yesterday
- Age
- Income
- Race
- Best means to contact respondent (email, phone, mail, etc.)

In addition to the in-person questionnaire, the interviewers completed an observational questionnaire for each household. If the home was visited more than once and the interviewer noted new details, these were noted on the same form. A total of 139 observation questionnaires were completed for the 185 sampled households. The missing cases consisted of "Missing Address" or sample the survey field staff did not attempt to contact because of time constraints.

The observation questionnaire was designed to obtain the following data elements:

- Housing Type: single-family (detached and attached), mobile home, duplex, building with three or more apartments, and "other".

- Neighborhood Type: inner city very dense multi-family, inner city dense one-family and multi-family, traditional suburban (with and without cul-de-sacs), rural, mixed-use, and "other".

- Presence of a driveway

- Number of vehicles in driveway

- Assumptions regarding residence

  ✓ Does it appear like a single person lives here?

  ✓ Does it appear like children live here?

  ✓ Does household income appear to be: low, medium, high?

  ✓ Does it appear like seniors or retired persons live here?

  ✓ Does it appear like a Hispanic/Latino neighborhood?

  ✓ Is it the type of building/neighborhood where young adults (18–24) live?

- Other observations about the home

All visits were noted on the sample form, including date of visit, day of week of visit, the visit outcome, and any interviewer comments.

NRFU Results

In sum, the NRFU study consisted of field staff making a total of 342 visits to the 185 sampled households, distributed across the three study areas and three sample types, resulting in 48 in-person interviews and 139 observational surveys. The purpose was to contact a sub-sample of households that did not participate in the pretest. The goal was to document demographic and travel characteristics among these non-responsive households in an effort to identify differences between those who participate in household travel surveys and those who do not. In addition, it served to provide insights regarding the best way to contact these non-participants for inclusion in the full study.

Non-respondents. The traditional non-response approach (comparing survey demographics to census) identified the non-respondents as large households, Hispanic households, and "young adult" households. The in-person NRFU survey confirmed these are the missing population subgroups. Thus, for the full study, tracking demographics against these census parameters will be necessary. Furthermore, the NRFU survey results suggest that non-responsive household have fewer number of vehicles and thus, it is assumed, make fewer trips and fewer long distance trips. Non-responders appear to be more transient, with only 54 percent of the NRFU sample owning their home. Eighty percent of the pretest sample reported owning their home. Young adults continue to be under represented in travel surveys. This is shown in the pretest and NRFU results, which both trend toward an older demographic. The NRFU results seem counterintuitive to the idea that young adults are non-responsive. However, over half of the NRFU observation questionnaire indicated the households had characteristics of a young-adult household. It was reported through the observation questionnaires that 71 percent of households in New Bedford to have evidence of a young-adult residents.

Methods. The NRFU effort in general was a success. The field team met the overall goal of obtaining at least 30 completed in-person interviews. However, they fell short of the secondary goals of completing ten in-person interviews within each study area. The fieldwork team would have benefited from additional time in the field. In the future, the methodology could be revised in order to take advantage of the face-to-face time with the respondent to investigate why they did not participate, whether or not they received the materials, and how to entice them to respond in the future. Unmatched sample could be shown the advance letter and asked if they recall receiving it, and what it should look like to encourage them to read it. For the matched sample, they could be shown the dates and times the team tried to reach them by phone and ask when would be better or what the team could say to keep them from hanging up. These details would help to finalize the full study survey design.

Overall, the NRFU effort confirmed that the non-participants in this study included large households, minority households, young adult households, low-income households, and high-income household. The various sample types, matches versus unmatched, could be leveraged to increase response rates to these non-responsive sample. More aggressive advance mailing and promotion in or around the college campus can help target young adults. Demographics are contained in Table 12.

Table 12: Pretest: Comparison of NRFU Demographic Characteristics with Pretest Results

Demographic		2008 ACS	Pretest	NRFU
Household Size	1	29.6%	30.5%	19.2%
	2	31.7%	39.4%	25.5%
	3	16.0%	13.4%	29.8%
	4+	22.7%	16.7%	25.5%
Household Vehicles	0	11.7%	8.0%	14.6%
	1	36.0%	32.6%	47.9%
	2	37.4%	42.0%	29.2%
	3+	14.6%	17.4%	8.3%
Age	< 24	32.4%	23.0%	0.0%
	25-34	12.6%	5.1%	16.7%
	35-54	30.1%	30.4%	32.1%
	55-64	16.4%	19.5%	12.8%
	65+	23.4%	21.8%	31.6%
Home Ownership Status	Own Residence	64.5%	80.1%	54.2%
	Rent Residence	35.5%	19.9%	45.8%
Household Ethnicity	White	82.7%	93.6%	55.6%
	African Amer., Black	6.2%	0.9%	8.9%
	Hispanic	8.6%	1.3%	28.9%
	Asian	5.0%	1.9%	2.2%
	Other/Refused	6.1%	2.3%	4.4%
Household Income	Less than $25,000	20.2%	14.1%	
	$25,000 to $50,000	19.0%	32.2%	
	$50,000 to $75,000	17.4%	32.2%	
	$75,000 or more	43.2%	15.4%	

Impact of Pretest on Final Survey Design

Processes and Procedures

Overall, the pretest was successful in terms of the procedures and collection of necessary data.

1) The targeted sample was fairly successful in finding under-performing demographic groups; however, it was closely monitored during the full study because some cells in the pretest were too small from which to draw conclusions.

2) The use of advance letters was found to be very beneficial as demonstrated by the significant improvement in recruitment productivity.

3) Despite not achieving the budgeted recruitment completes per hour rate (CPH), 67 percent of the recruited respondents successfully completed the retrieval portion, which was in line with the budgeted rate of 68 percent. NuStats expected that this rate would improve slightly for the full study with a greater understanding of the study area and the demands of the project.

4) The pretest dataset was skewed to older respondents. This was monitored carefully in the full study, and households with all retired members were randomly terminated from participation.

5) Based on the results of the Pilot NRFU effort, in lieu of conducting a full study NRFU survey, NuStats and MassDOT agreed that the implementation of a "Rest and Recycle" sample effort would have greater benefit on project participation. More detail on the rest and recycle effort can be found in the Response Rates section of this report.

Advance Notification

Maximizing response rate is vital to the success of any household travel survey for two specific reasons. Primarily, maximizing response rate ensures that the survey data is representative of a wide range of socioeconomic factors that are characteristic of Massachusetts households. Secondly, maximizing response rates minimizes the cost associated with the purchase of excess survey sample.

During the pretest, NuStats tested the efficacy of five different advance-mailing methods to gauge the effectiveness of survey communications in the overall participation rates. The pretest provided a mechanism to quantifiably compare each mailing method and, ultimately, make a recommendation for the full study. The sample frame for this study, as previously discussed, was a database containing all households in Massachusetts with a mailing address.

Sample records were either matched (address and landline telephone number) or unmatched (address only). The four primary contact methodologies implemented during the pretest are described below. All advance-mailing materials can be found in Appendix H.

1) ***Matched – Cold Call:*** These households were not mailed any advance notification materials at all prior to being called for recruitment.

2) ***Matched – Letter and Brochure:*** These households were mailed an advance letter and a brochure. Shortly after the letter and brochure mailing, these households were called for recruitment.

3) ***Matched – Self-Mailer Brochure Only:*** These households were mailed a self-mailer brochure that explained the purpose of the study and respondent participation. Shortly after mailing the self-mailer brochures, these households were called for recruitment.

4) ***Unmatched – Household Questionnaire:*** These households were mailed a letter, brochure, and a household questionnaire that contained the same questions as the telephone recruitment survey. The questionnaire asked questions about the household, each person in the household, and about each vehicle, and asked for contact information (e.g., cell phone number, work number)

so that the remainder of the survey (assigning a travel date and trip data) could be conducted via phone rather than mail. A pre-paid postage return envelope was provided for those who cared to participate by mail. Prior to receipt of this completed questionnaire by NuStats, there was no means of making telephone contact with the household, as a landline telephone number could not be initially matched to these addresses.

5) ***Unmatched – Contact Card:*** These households were mailed a letter, brochure, and a contact card (return postage paid) that simply asked for contact information so that the remainder of the survey (assigning a travel date and trip data) could be conducted via phone rather than mail. The contact card also provided the project website, which was another means for respondents to submit their contact information. Prior to receipt of this completed contact card by NuStats, there was no means of making telephone contact with the household, as a landline telephone number could not be initially matched to these addresses.

These methods provided a wide range of sample statistics for each of the four sample types (unmatched households receiving either the household questionnaire or contact card were aggregated because insufficient samples were collected to conduct separate analysis for each of these two groups) and provided the statistics at the aggregate level. There were several key points of interest that helped to inform the full study advance notification method:

- ▪ ***Regarding the ratio of recruited households to contacted households,*** the unmatched sample performed best. However, this ratio is based on the number of respondents that took it upon themselves to make initial contact with NuStats. Of the 2,225 records that were sent advance letters, 20 households responded, of which 15 were recruited for participation. When the matched sample are analyzed, the data suggest that the matched records that were mailed a letter and brochure performed best.

- ▪ ***Regarding recruited households,*** the matched sample that were mailed a letter and brochure performed best.

- ▪ ***Regarding retrieved households,*** the matched sample that were mailed a letter and brochure yielded the highest number of (1) retrieved households, (2) the highest ratio of retrieved households to households that were mailed, and (3) the highest ratio of retrieved households to households that were dialed.

- ▪ ***Regarding retrieval response rate,*** the matched sample that were cold-called slightly outperformed the matched sample that were mailed a letter and brochure. However, these differences are negligible.

- ▪ ***Regarding overall response rates,*** the product of the recruitment response rate and the retrieval response rate, the matched sample that were mailed a letter and brochure outperformed all other sample types. NuStats recommended this method for the matched sample households for the full study.

Incentives

Although a very poor response was obtained from the unmatched sample, research has shown that the households that either do not have a telephone at all or only have a cell phone are an important market segment. These may be younger, more mobile, or lower-income households, all of which are historically more difficult to survey. For the full study, NuStats recommended offering a $25 incentive to these households, via letter and contact card, to solicit participation. These households were mailed the incentive only if they participated in the entire survey effort (i.e., both recruitment and retrieval).

Recruitment Questionnaire

No significant changes to the recruitment survey instrument were suggested. The survey flow worked well, as did the content. However, there were suggestions to shorten the introduction (too long) as well as to

move the mention of the GPS component after the initial contact introduction. The introduction was slightly shorter in the full study, but still described the survey process and purpose.

Retrieval Questionnaire

More recommendations were made to the retrieval questionnaire than the recruitment questionnaire. These included modifications to ensure all places visited during the travel day were recorded (i.e., additional emphasis on script text probing for missed trips), additional text to ensure capture of access/egress non-motorized trips, the additional capture of toll road entry and exit points, "Charlie Ticket" was added to the transit fare payment list, personal garage/driveway was added to the parking location list, and "Pick Up" and "Drop Off" passenger were added to the Activities list.

Full Study Survey Process

Full Study data collection activities began in June 2010 and continued through November 2011. These activities centered around seven main stages: advance notification, reminder postcard, recruitment, placement of materials, reminder call, travel data retrieval, and data processing. The details regarding each stage are provided in this section and illustrated in the following figure.

Figure 4: Continuous Data Flow (CDF) Process
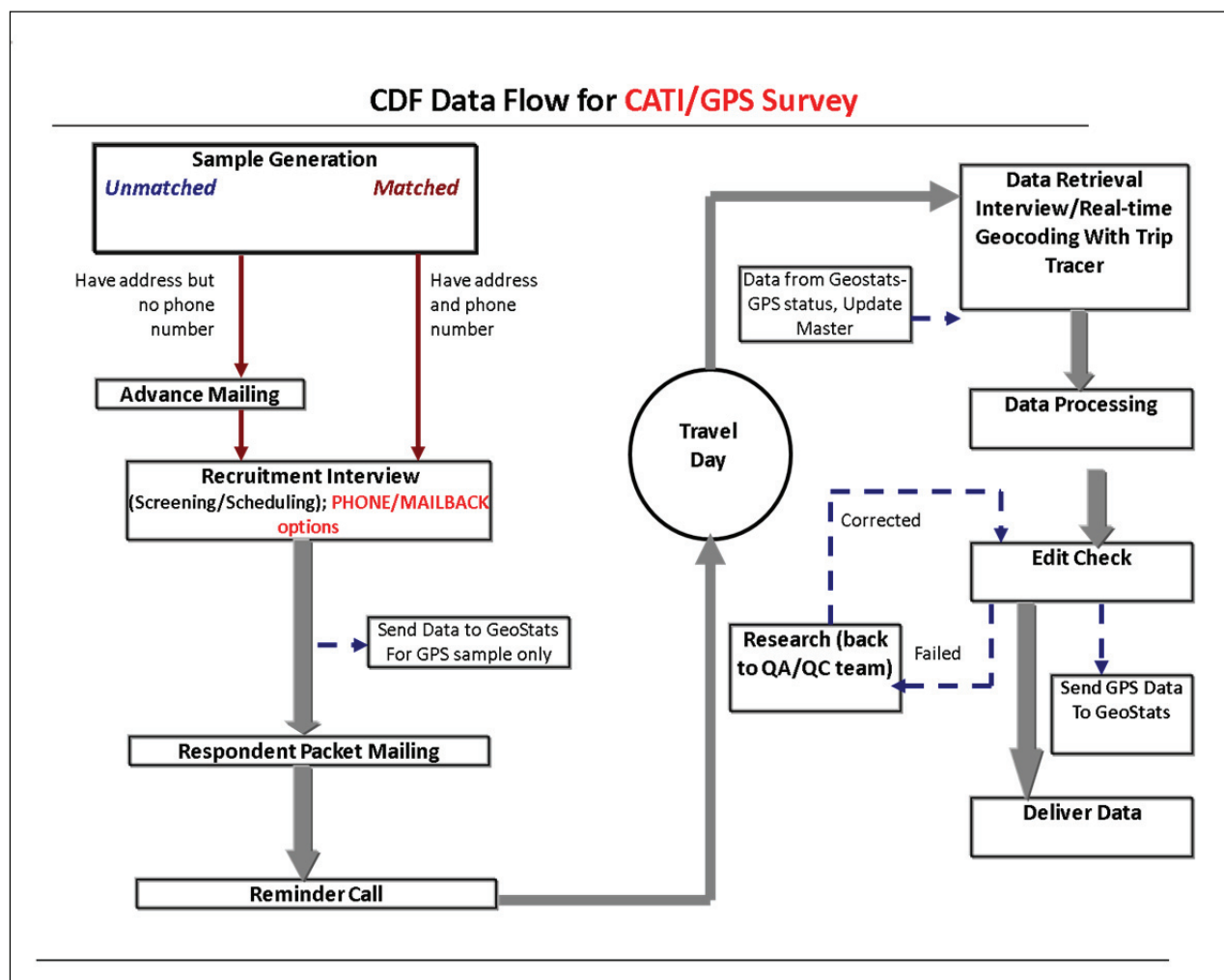
Advance Mailing

The advance mailing served as advance notification to the household that it had been randomly selected and would be receiving a call regarding the study, or were given the option of calling NuStats to participate in the study. The mailing also provided information about the study sponsor, introduced NuStats as the company that would be contacting them, and provided the Web site address and a telephone number where additional information could be obtained.

A study letter and brochure were mailed to a portion of households for which a name and address were known (i.e., matched) prior to the recruitment call, as well as to households with no phone number (i.e., unmatched); however, contact cards were mailed to unmatched households in addition to the letter and brochure in hopes that households would mail the card back with completed contact information. If they preferred, unmatched households could also request a household questionnaire to complete via mail. The household questionnaire contained all recruitment data elements.

Recruitment

The recruitment interview was administered using a Computer-Assisted Telephone-Interviewing (CATI) program. At that time, each household was telephoned by an interviewer to determine if they would participate in the study. If the household did agree to participate, demographic information was collected including income, household size, vehicle ownership, and other household characteristics. In addition, demographic characteristics were obtained for each member of the household, including age, gender, employment, and school status (see Appendix A for the recruitment questionnaire).

Over the course of the recruitment effort, 271,660 telephone numbers were called. Of these:

- 43,351 (16.0 percent) resulted in contact with <u>eligible</u> households,
- 41,755 (15.4 percent) were determined to be <u>ineligible</u> (non-working, non-household, or non-voice lines, and
- 186,554 (68.7 percent) were unable to be classified as eligible or ineligible.

Of the <u>eligible</u> households reached, 25,331 of the 43,351 agreed to participate in the full study (58.4 percent). The average length of the recruitment call was 17.1 minutes. It took an average of 3.7 call attempts to reach a household for recruitment. Table 14 shows the average interview length and the average number of call attempts required to reach each household based on household size. As indicated, the larger the household, the longer the interview length. The table also shows that it took fewer call attempts to reach households with fewer members.

Table 13: Recruitment Interview Length and Average Call Attempts/Household, by Household Size

Household Size	N	Average Call Duration (in min.)	Average Call Attempts
1	5,615	11.6	3.5
2	7,477	15.2	3.6
3	4,729	18.7	3.7
4+	7,510	22.2	3.9
Overall	25,331	17.1	3.7

The recruitment instrument performed well as item non-response was marginal, as evidenced by the unweighted frequency of responses to the recruitment questionnaire contained in Appendix F. The following is list of questions for which respondents did not all provide answers:

- Household Ethnicity (1.1% refused)
- Hispanic/Latino Household (0.6% refused)
- Household Residence Type (0.1% refused)
- Home Ownership (0.1% refused)
- Cell Phone Lines (0.2% refused)
- Landlines (0.1% refused)
- Fax Lines (1.1% refused)
- Household Income (6.8% refused)
- Gender (0.1% refused)
- Age (2.2% refused)
- Valid Driver's License (<0.1% refused)
- Respondent has Transit Pass (<0.1% refused)
- Transit Pass Type (0.7% refused)
- Non-Worker Employment Status (0.5% refused)
- Hours Worked per Day (0.4% refused)
- Days Worked per Week (0.1% refused)
- Typical Mode to Work (0.2% refused)
- Worker Telecommutes (0.1% refused)
- Flexible Work Program Offered (0.2% refused)
- Type of Flexible Work Program Offered (2.5% refused)
- Respondent Participates in Flexible Work Program (0.1% refused)
- Disabled License Plate (0.1% refused)
- Disabled Transit Registration (0.1% refused)
- Level of Education Completed (0.1% refused)
- School Enrollment Status (<0.1% refused)
- Full-Time/Part-Time Student Status (<0.1% refused)
- Student Grade Level (0.3% refused)
- Typical Mode to School (0.1% refused)
- Transit Trips Made in Past week (0.1% refused)
- Bike Facilities Available at Work/School (1.3% refused)
- Days used Bike for Recreation in Past Week (6.0% refused)
- Days used Bike for Transportation in Past Week (6.0% refused)
- Bike Lanes/Trails Used for Non-Recreational Purposes (9.5% refused)
- Vehicle Year (0.2% refused)
- Vehicle Make (0.2% refused)
- Vehicle Body (5.5% refused)
- Vehicle Fuel Type (0.1% refused)

Respondent Packet Mailing

The day following recruitment, the demographic information was processed into the master dataset, and packets were assembled for each recruited household. These packets included a cover letter, travel diary with instructions and an example, and a postage-paid envelope to return the completed diaries after the retrieval interview (see Appendix H). Travel days were scheduled 7–10 days after recruitment to allow for sufficient time for packets to reach the households using First-Class mail.

Reminder Message

The night prior to the assigned travel day, reminder calls were made to the households. This reminder call served three key purposes:

1) Confirm that the household received the packet and answer any questions respondents might have about using the travel diary to track their travel,

2) Schedule an appointment to conduct the retrieval interview, and

3) Increase the likelihood that the household will follow through with recording their travel by re-iterating the importance of the study and the household's commitment to participate.

For those instances where an answering machine was reached, the interviewers left brief messages that referenced a toll-free number for respondents to call if they had questions.

Data Retrieval

The day after an assigned travel day or at an agreed-upon time, telephone calls were made to retrieve the travel data recorded by each eligible household member in his/her travel diary. The interviews were guided using CATI programs of the retrieval instrument (see Appendix B). Overall, 47 percent of households retrieved via CATI interviewer. Fifty-two percent of households mailed back their travel diaries, as seen in Table 14.

Table 14: Retrieval Mode

Phase	% CATI	% MAIL	TOTAL
Retrieval	47.5%	52.5%	15,033

Shown in Table 15, the average interview length was 28.1 minutes, and it took 8.5 call attempts to complete retrieval, on average.

Table 15: Retrieval Interview Length and Average Call Attempts/Household, by Household Size

Household Size	N	Average Call Duration (in min.)	Average Call Attempts
1	4,123	19.1	6.9
2	4,829	25.1	7.9
3	2,538	32.2	9.3
4+	3,543	39.2	10.4
Overall	15,033	28.1	8.5

The retrieval instrument had minimal item non-response. As indicated in the unweighted frequencies contained in Appendices G of this report, the variable that experienced the highest item non-response was

the question that asked drivers whether they paid to park, with just under 9 percent of respondents refusing to answer this question.

Data Processing, Coding, and Correction

Data processing took place throughout the study, beginning with the creation of the advance notification mailout, continuing with the release of sample for recruitment, processing recruitment data for the respondent mailout, appending the retrieval data to the master tables, and performing initial quality control measures on the data. This process is summarized in Figure 5 on the following page. A master control file tracked the progress of each household through the various survey stages, with codes to allow immediate identification of problem cases that were not progressing according to schedule as well as confirmation that cleared cases moved along as appropriate. Routine data checks included the following:

- Data range checks to ensure data were inside the expected ranges for each variable and that there was agreement across data files (for example, if the household had four persons and two vehicles, there should be four records in the person file and two records in the vehicle file).

- Confirmation that travel data were collected from all household members.

- If a person reported no travel, the household was flagged for manual review to confirm the reason for non-travel was appropriate based on the demographic characteristics of the household member. Those cases where the reason for non-travel was suspect or did not make sense within the context of the available demographic information were flagged and returned for confirmation or replacement.

- Within the travel data itself, several items were checked. The following are examples of conditions researched within the trip data:

  - ✓ Did each trip begin and end at a different location? Were loop trips (those that have the same origin and destination) coded correctly?

  - ✓ Did each person return home at the end of the travel day? If not, did the final recorded destination make sense within the context of the household and person characteristics?

  - ✓ For all instances where a respondent reported traveling with other household members, was the shared trip reported for all other household members?

  - ✓ For all trips with "auto-driver" as the reported mode, was the respondent a licensed driver?

  - ✓ For all trips reported as "auto-passenger", did another household member report the same trip as an auto-driver? If not, did the passenger report riding in a non-household vehicle with at least one other person making the trip?

Figure 5: Data Processing Flow Chart

Household Data Quality Control Process

Daily CDF Processing is complete (Receive email)

WORKING Database
(Where all the data tables are stored for cleaning, research, reporting)
-Update STATUS for every household
-Clean errors using Check Queries
-Flag and append research cases

Import working files

Export new working files and Errors List

EDIT CHECK Database
1. PRECLEAN
-Appends new retrievals, remakes all tables according to STRUC tables
-Overwrites records based on STATUS
-Runs summaries for all records

2. EDIT CHECK
-Finds and flags errors from EditCode Table, automatically appends to research if CATICODE > 0.
-Makes cumulative Errors to be Corrected

DS Research
Email summary of current research cases - CATI/TB/TT

Fully cleaned records are prepared for delivery

Real-Time Geocoding with Trip Tracer

All trip-ends and habitual addresses were geocoded during the retrieval telephone interview with the TripTracer software. The TripTracer software was designed to provide interviewers with study area details (road names, landmark references, etc.). Interviewers used this additional detail to confirm respondent-reported locations in real time. An additional benefit of the use of the TripTracer software was that once the interview was completed, full address information, with matching X/Y coordinates, for 100 percent of the locations, was immediately available.

Assessment of Survey Quality

For the full study, the survey quality was improved when compared to the pretest. Non-response for Household, Person, Vehicle, and Place items had a decreased non-response rate for the key variable compared to pretest. During the rigorous quality control process for regional household travel surveys, NuStats generally expects that up to 3 percent of retrieved households will not be included in the final dataset due to unresolved data inconsistencies. MTS full study exceeded that benchmark with very high quality survey data—while 15,281 households completed both the recruitment and retrieval interviews, 15,033 households passed all quality checks and were included in the final data file, a loss of only 1.6 percent.

Edit Checks

The Edit Check module is used by analysts to check data for consistency and accuracy, as well as to transform data to the final delivery format and perform summaries on this data. For the Edit Check section, there are a number of queries that are run to check the quality of the data and update the status flags for any existing data and other queries. The following table details the automated edit checks performed on the full study dataset.

Table 16: Edit Checks

EDITCODE	MESSAGE	TREATMENT	FILE
1	TOP PRIORITY--Arrival before departure (TRIP)	Check to see if TRPDU is >0, If not there is a time error between this row and the previous row	TRIP
2	TOP PRIORITY--Departure before arrival (TRIP)	Check to see if ACTDU is >0, If not there is a time error between ARRIVAL and DEPATURE	TRIP
3	TOP PRIORITY--First place does not start at 3am (TRIP)	Check the ARRIVAL time of PLANO=1, it should be 300, if not maybe the first trip is missing or there is a reporting error	TRIP
4	TOP PRIORITY--Last place does not end at 2:59am (TRIP)	Check the DEPART time of the last trip, it should be 259, if not maybe there is a numbering error between trips or the last trip has a reporting error	TRIP
5	TOP PRIORITY--Last place not home- confirm (TRIP)	Confirm with last place description	TRIP
6	TOP PRIORITY--Day Time Totals <> 1439 (TRIP)	One of the TRPDUR/ACTDUR's is false	TRIP
7	TOP PRIORITY--Need reason for no travel/filled in and should not be (PER)	Check NOGO/TRAVL	PER
8	HHSIZ (HH) not equal to person count (PER)	Check PER data to see if everyone is a valid person , then modify HHSIZ	HH/PER
9	HHVEH (HH) not equal to vehicle count (VEH)	Check VEH data to see if vehicle is a valid vehicle , then modify HHVEH	HH
10	HHWRK (HH) not equal to workers count (PER)	Check PER data to see if everyone >15 has a valid EMPLY code, then modify HHWRK	HH/PER
11	HTRIPS (HH) does not match number of household trips (TRIP)	RERUN PRECLEAN	HH/TRIP

EDITCODE	MESSAGE	TREATMENT	FILE
12	INCOM is missing or is out of range (HH)	Check INCOM, look in REC data	HH
13	ASSN or DAY is missing or invalid (HH)	Check ASSN, make sure it is a valid number, look in REC data	HH
14	OWN missing or is out of range (Including OWNO)	Check OWN and OWNO, look in REC data	HH
15	RESTY missing or is out of range (Including RESTO)	Check RESTY and RESTO, look in REC data	HH
16	HHSTU does not match number of HHSTU	RERUN PRECLEAN	HH
17	TRIP - Person without Drivers License Driving	Check Person Roster	PER
18	TRIP - Person Making Trips not in PER file (PER/TRIP)	Check Trip file or Person Roster for inconsistency	TRIP
19	RELATION of "self" is duplicated or missing (PER)	Two People in HH have relation as "SELF" check age gender and PERNO to see who should be the respondent, generally PERNO 1 is the respondent, and should have the relation of self	PER
20	Person is missing from trip file (PER/TRIP)	This person is missing from the trip file, look in RET data and if unresolved send to research (this person may have been deleted RET)	PER/TRIP
21	TRIP-person traveling together (TRIP)	Intra-household travel inconsistencies	TRIP
22	AGE and/or GENDER is missing or out of range (PER)	Check AGE and GENDER, one could be missing, RET (add per) and REC data	PER
23	PERSON not in HH file	There is no HH in the HH table for this PERSON, check REC and RET or send to RESEARCH	HH/PER
24	Unemployed person working or work related on travel day (PER/TRIP)	Check to see if work is valid activity, if no work is in PER, update PER with WORK information (add per)	PER/TRIP
25	School info missing (PER) - Part1	Check PER school enrollment data, update from RET (add per)	PER
26	School info missing (PER) - Part 2	Check PER school location data, update from RET (add per)	PER
27	School info missing (PER) - Part 3	Check PER school data, update from RET (add per)	PER
28	Activities do not match PTYPE (TRIP)	Check place type, address, and place name	TRIP
29	Trip duration (TRPDU) is out of range or does not agree with PLANO (TRIP)	Check Arrival time of current place and departure time of previous place, PLANO=1 should have a null TRPDU	TRIP
30	Travel in (TRIP) file does not correspond to a person (PER)	Extra TRIP data, this person is not in per. Check to see if PERNO's changed in RET (add per and del per)	PER/TRIP
31	PTRIPS (PER) does not match number of person trips (TRIP)	RERUN PRECLEAN	PER/TRIP
32	PTRIPS (PER) does not match number of person trips (TRIP)	RERUN PRECLEAN	PER/TRIP
33	PTRIPS (PER) does not match number of person trips (TRIP)	RERUN PRECLEAN	PER/TRIP
34	MODE does not agree with PLANO or is a refusal (TRIP)	PLANO 1 should not have a mode, there should be a MODE for all other PLANO's	TRIP
35	Non-student doing school activities on travel day (PER/TRIP)	Check ACT1/ACT2 in TRIP, Check AGE, if a student add student variables to PER, if not, change activity to match place	PER/TRIP
36	Number of household members traveling together is larger than household size (	Check HHMEM in TRIP it is too large	TRIP
37	ACTIVITY DURATION =0	All activities should have a duration; RERUN PRECLEAN and check trip times	TRIP
38	LOOPTRIP	Review loop trip and confirm if valid	TRIP
39	VEH YEAR is missing or is out of range (VEH)	Check rec data	VEH
40	PER - Employment Verification (EMPLY,VOLUN,WORKS) - Part 1	Review person data and send for research if missing	PER

EDITCODE	MESSAGE	TREATMENT	FILE
41	PER - STUDENT (SMODE,O_SMODE,SLOC)	Review person data and send for research if missing	PER
42	TRIP - Transit section - Route Name missing or transfer not selected - (MODE1)	Get Route Name or Check Transit Roster	TRIP
43	PER - GEND = 9	Check rec data	PER
44	PER - AGEB is NOT NULL	Null out AGEB if AGE is not refused	PER
45	PER - WKSTAT is not null	Review WKSTAT and null out if worker	PER
46	HH - Zero-trip household	Obtain travel info from day where trips were made	TRIP
47	PER - School-aged person not a student	Obtain school information, or reason not in school	PER
48	TRIP - Auto passenger riding alone	Include driver in PARTY or change to driver	TRIP
49	PER - Person under 14 years old is INTRV=1	Change INTRV=2 and get actual PROXY for that person	PER
50	Worker has no Work Address in HOTLIST	Send for research to collect work address	HOTLIST
51	Student has no School Address in HOTLIST	Send for research to collect school address	HOTLIST
52	Speed of Trip is too fast for mode	Review address, coordinates, mode, and travel times	TRIPS
53	Cati Trips are not equal to TripTracer Trips on a HH Level	Send to research to review within trip tracer	TRIPS
54	Cati Trips are not equal to TripTracer Trips on a Person Level	Send to research to review within trip tracer	TRIPS
55	Cati Trip is not in TripTracer	Send to research to review within trip tracer	TRIPS
56	Middle waypoint that has no Dummy Name or the name is null	Send to research to review within trip tracer	WAYPOINTS
57	Sequential waypoints don't have equal end/start locations	Send to research to review within trip tracer	WAYPOINTS
58	Sequential waypoints don't have equal end/start locations	Send to research to review within trip tracer	WAYPOINTS
59	Sequential waypoints don't have equal end/start locations	Send to research to review within trip tracer	WAYPOINTS
60	Record has rows with PTYPE=Home and differing x/y coords	Send to research to review within trip tracer	TRIP/WAYPOINTS
61	Record Home address in hotlist	Send to research to review within trip tracer	HOTLIST
62	Transit Trip - Missing Access and/or Egress Trip.	Send to research to review within trip tracer	TRIP/WAYPOINTS
63	NOGO=Out of Area but person has waypoint within study area	Send to research to collect out of area location if possible	PER/WAYPOINTS

Geographic Coverage

Overall geographic distribution of the final (unweighted) data file was roughly proportionate to the 2010 Census distribution by MPO Region as shown in Table 22. While Boston, PVPC, NMCOG, MRPC, NPEDC, and FRCOG were slightly over-represented, some others were slightly under-represented in the final MTS data file.

Table 17: MPO Distribution

MPO Region	Massachusetts Travel Survey (Final Unweighted data file)		All Households (2010 Census)
	Count	Percent	
Boston MPO (MAPC)	7661	51.0%	48.2%
Southeastern Massachusetts MPO (SRPEDD)	1181	7.9%	9.4%
Pioneer Valley MPO (PVPC)	1488	9.9%	9.4%
Central Massachusetts MPO (CMRPC)	1148	7.6%	8.3%
Old Colony MPO (OCPC)	554	3.7%	4.7%
Merrimack Valley MPO (MVPC)	711	4.7%	4.9%
Northern Middlesex MPO (NMCOG)	640	4.3%	4.1%
Cape Cod MPO (CCC)	498	3.3%	3.8%
Montachusett MPO (MRPC)	529	3.5%	3.5%
Berkshire MPO (BRPC)	303	2.0%	2.2%
Franklin Transportation Planning Organization (FRCOG)	262	1.7%	1.2%
Martha's Vineyard MPO (MVC)	35	0.2%	0.3%
Nantucket MPO (NPEDC)	23	0.2%	0.2%
Statewide Total	15033	100.0%	100.0%

Figure 6 displays the geocoded home location of all households that participated in the full study and were contained in the final weighted data file.

Figure 6: Retrieval Household Locations (Map of Massachusetts)
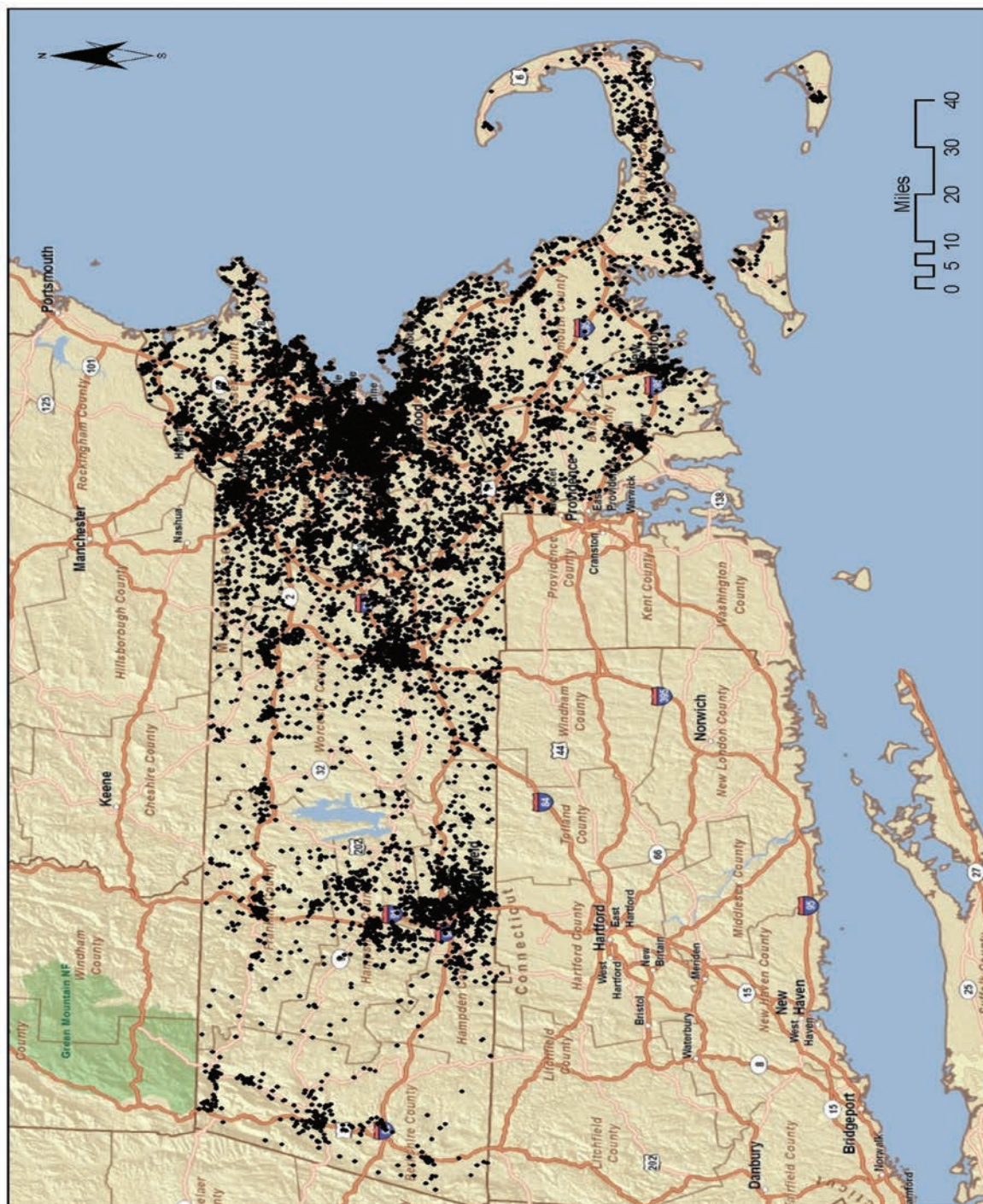
Demographic Coverage

The full study effort continually tracked the demographic representation to inform sampling procedures in an effort to reach a representative sample. Table 18 shows the unweighted distribution of demographic characteristics of participating households as compared to 2006–2010 five-year estimates from the American Community Survey (ACS) data. The sampling approach resulted in a household distribution that varied from the ACS in some areas, while matching in others.

Table 18: Demographic Results Compared to ACS

Demographic		Massachusetts Travel Survey (unweighted)	State of Massachusetts 2006-2010 ACS
Total Households		15,033	2,512,552
Household size	1	27.4%	28.9%
	2	32.1%	32.1%
	3	16.9%	16.1%
	4+	23.6%	22.8%
Household workers	0	23.5%	25.5%
	1	34.8%	36.4%
	2	33.9%	30.2%
	3+	7.7%	7.8%
Household vehicles	0	10.2%	12.2%
	1	31.4%	35.7%
	2	39.1%	37.1%
	3+	19.3%	15.0%
Household Income	Less than $25000	17%	20.4%
	$25,000–$49,999	16%	19.2%
	$50,000–$99,999	29%	30.5%
	$100,000-$149,999	17%	16.4%
	$150,000 or more	14%	13.4%
	Income Refusals	7%	NA
Ethnicity	Hispanic	4.9%	9.3%
	Non-Hispanic White	85.5%	76.8%
	Non-Hispanic Other	8.5%	13.8%
	Refused	1.1%	NA
Respondent Age	Under 20 years	24.7%	25.2%
	20–34 years	10.7%	19.9%
	35–54 years	31.6%	29.6%
	55–64 years	19.1%	11.7%
	65 years and over	11.7%	13.5%
	Age Refusals	2.2%	NA

Response Rates

The response rate calculation is itself a calculation of two rates, which are multiplied together to form a third rate. The first rate is the recruitment rate, which reflects the proportion of the sample that was recruited into the study. There are two approaches to calculating recruitment rates: 1) that which is prescribed by the Council of American Survey Research Organizations (referred to herein as the recruitment rate), which tends to underestimate the real response rate, and 2) the simpler estimation of participation rate, which is the ratio of all recruited households to all sample eligible for recruitment, which tends to over-estimate the recruitment rate. The true recruitment rate lies somewhere in between. The second rate is the retrieval rate, calculated as the proportion of all retrieved households to all recruited households. The final response rate is derived by multiplying the recruitment rate (or participation rate) by the retrieval rate.

Data were collected from all household members for the 15,033 households that completed the full study. This is a retrieval rate of 59.3 percent (15,033 retrieved / 25,331 recruited). The overall response rate for the study is determined by multiplying the recruitment rate (58.4 percent) by the retrieval rate (59.3 percent). For this study, the response rate is 34.6 percent. This means that slightly more than one out of three eligible households contacted about participation in the Massachusetts Travel Survey completed all activities associated with the project.

The response rates for the MTS full study effort are shown in Table 19, along with those from other recent studies. The MTS full study response and participating rates are similar to other studies.

Table 19: Response Rate Comparison to Other Surveys

Study	Year	Final Response and Participation Rate
Massachusetts Travel Survey	2010–2011	34.6%
ARC Regional Travel Survey	2011	5.9%–34%
CALTRANS HH Travel Survey	2011	5.5%
ARC Regional Travel Survey Pre-Test	2010	11%–31%
Central Indiana Full Study	2010	41%
Oregon Full Study – Region 4	2009	39%
Oregon Full Study – Region 2	2009	44%
Central Indiana Pre-Test	2008	10%–36%
Oregon 1-day Pre-Test	2008	15%–46%
Chicago Full Study	2007–2008	10%–31%
Chicago Pre-Test	2006	9%–29%

In lieu of a full study NRFU effort and in order to increase full study participation rates, a "Rest and Recycle" strategy was implemented. With this strategy, households are mailed the advance letter and called for the recruitment interview as normal. When NuStats was not able to contact a household (busy signals, no answer, answering machines, etc.), the telephone numbers were rested and not called for a period of one month. Following that rest period, the sample was "recycled", and additional recruitment calls were made to attempt to gain participation from those households.

GPS Subsample

In early 2009, the MassDOT contracted NuStats to conduct the MTS, the first step of which was the pretest study with a GPS subcomponent. GeoStats, as a subcontractor to NuStats, was responsible for implementing the GPS component. The full study portion of the survey began on June 14, 2010. The GPS portion of the full study concluded on July 18, 2011. This section documents the GPS data collection and processing methods used and describes the findings of the GPS component of the full study.

The objective of the GPS component was to obtain at least 500 GPS/CATI complete households in the full study effort. GeoStats projected that approximately 770 households would need to be deployed with GPS devices to meet this goal. In all, wearable GPS devices were deployed to 780 households (with 1649 household members receiving GPS devices) of the households recruited into the full study.

The purpose of the GPS component was to collect very detailed information about all trips made by the GPS subsample and to estimate levels of trip underreporting in this subsample that could be applied to the larger, non-GPS sample. The GPS devices were to be used for two consecutive weekdays, with the first weekday coinciding with the assigned diary/travel day. For Friday travel dates, GPS participants were asked to wear the device for four days, to collect GPS data from Friday through Monday.

A wearable (or person-based) GPS approach was implemented to capture all trips made by all travel modes within the GPS households. In this approach, all household members between the ages of 16 and 75 (inclusive) were provided with a wearable GPS data logger. Local deployment personnel shipped and received returned equipment from their home. As GPS devices were returned by GPS households, the data collected on the devices were downloaded and posted to the GPS Project Management Website. From there, the data were imported into the project database at GeoStats and processed by analysts to review and confirm trip end locations and mode assignments. A $25 incentive was offered for each household member who carried their GPS device and successfully reported their travel data; however, this was only paid if everyone in the household participated as requested.

Deployment Methods and Results

In the GPS component of this study, battery-powered GPS devices were provided to all deployed households for all household members between the ages of 16 and 75 (as reported during the recruit call). This section of the report will describe the GPS equipment used, will review the methods employed to distribute and collect the GPS devices, and will present the results of the deployment effort.

GPS Equipment

The GlobalSat GPS Data Logger is a rugged yet simple GPS data logging device (see Figure 7) that has been deployed by GeoStats in seven household travel studies and physical activity studies conducted since 2007. The GlobalSat device is lightweight (6 oz.) and small (2.75" x 3.15" x .7"). It can be worn on the waist, clipped to a purse or backpack, or dropped in a suit jacket pocket.

This device can log at various frequencies, can log all valid GPS points or only those valid points for which the speed is greater than one MPH (to screen out non-movement events), and has a 60,000 GPS point storage capacity. For the purpose of this study, the planned logging frequency was 4-second intervals with the speed screen activated. The standard GPS data stream elements recorded by the GlobalSat include date, time, latitude, longitude and speed. These elements are stored in the logger in standard NMEA units and are converted into user-specified units and formats upon download.

Figure 7: GlobalSat DG-100 GPS Data Logger

At the start of the study, 150 GlobalSat devices were provided to support deployment of 770 households over the planned year-long study period. An additional 62 devices were provided throughout the course of the study due to delayed returns and equipment losses (non-returns) from some households.

Deployment Procedures

Households were recruited into the travel survey at least 10 days prior to their assigned travel date. As GPS households were recruited, GeoStats pulled recruit details (such as names, addresses, phone numbers, and person rosters) daily. GeoStats imported this recruit information into its database. This recruit information was then available on the GPS Study Management website, where the GeoStats field deployment staff accessed the recruit information for their zone.

The deployment team member signed onto the password-protected website on a daily basis to review upcoming deployments. The lead time between the posting of recruited households to the website and the assigned travel date was at least seven days, allowing sufficient time to prepare the necessary documents, diaries, and equipment, and to ship them to arrive prior to the assigned travel date.

Simple printed instructions were shipped with the devices; these instructions also listed the assignment of each logger to each household member based on the logger identification number as well as a color-coded sticker. Households were reminded of the importance of using their diaries to record their travel for the assigned travel date. A return device sheet was also provided on which the household members were asked to record if they used the devices, and if not, to list the reason(s) why. Examples of the GPS device instructions and return sheets can be seen in Appendix I following the cover letter (these three pages were sent as a set with the equipment and diaries).

Shipping was conducted via FedEx. Participant instructions, equipment, diaries and a pre-paid return FedEx Pak were placed in a cardboard box and secured with packing material. The equipment was delivered to the household one to two business days prior to the assigned travel day. After the travel day, the participant was asked (in the instructions) to place all of the equipment and the return device sheet in the original box, to insert that box in the FedEx Pak, and to either put the package into a FedEx drop box or call 1-800-GoFedEx to schedule a pick-up at their home. Equipment was tracked on the FedEx website, with tracking information recorded on the GPS Study Management website. The participants were requested to hold onto their diaries, either reporting travel over the phone or returning the diaries in the pre-paid envelope provided with the diaries.

The deployment team member was instructed to prepare and ship equipment packages for each household listed. They were instructed to update the household deployment status on the website as the statuses changed. The default status for deployment when recruit information was first loaded was 'Recruit'. They could then change this status to reflect the current state of the deployment process; here is a list of all household deployment status codes:

- Recruited

- Shipped
- Deployed
- Complete (deployed and retrieved)
- Invalid Address
- Returned Refused (elected not to participate)
- Not Returned / Lost
- Over-recruit

The first four statuses reflect the natural progression of a successful deployment, whereas the final four statuses reflect GPS recruits that did not result in a useful deployment. The last status, Over-recruit, was used only if the address provided by the participant was non-deliverable (according to FedEx), and the participant could not be contacted for an alternative address. Three households were set to over-recruit in the full study, and therefore were not included in the data deliverable.

After receiving the returned equipment, the deployment staff downloaded the GPS data from the loggers and then cleared the device memory for redeployment. The downloaded, zipped GPS file was then posted to the project website and imported into the project database at the GeoStats office, where all further GPS data processing occurred. Deployment personnel were also responsible for updating the person-level equipment usage status fields as reported by each household and for recording any household or person-level comments on the website.

Deployment Results

Equipment was deployed (i.e., successfully delivered) to 780 households of the 784 households recruited into the study. GeoStats implemented an equipment retrieval management system in Microsoft Access and used this to coordinate follow up with all GPS households that did not immediately return their GPS equipment as instructed. First, a phone call was placed to the home telephone number for all households that did not return their GPS devices within one week after the last GPS travel date. When a person answered or an answering machine picked up, a message was delivered thanking the household for their participation and requesting that the GPS equipment be returned in the pre-paid FedEx envelope. A toll-free call back number was left if the household had any questions. If no person or answering machine was reached, additional calls were attempted.

 If equipment still had not been returned by three weeks after the last GPS travel day, a letter was sent to the home. A second equipment retrieval letter was mailed to the household if equipment was still outstanding after five weeks. During the final week of the study, phone calls were made and letters were mailed simultaneously in an attempt to retrieve as much equipment as possible. An example of the letter sent as a reminder to households that did not return equipment after phone calls can be seen in Appendix I.

There were 49 households that did not return the GPS devices sent to them. In total, 102 GPS devices remain unreturned and are considered lost, which represents an equipment loss of 48 percent of the equipment inventory provided (212 total devices). (Some equipment loss was expected due to the mail-out/ship-back method, which was one reason for offering the $25 incentive.) Table 20 shows the final totals for each deployment disposition category once the study was complete.

Table 20: Recruitment and Deployment Statistics

Travel Week	Total Recruited	Deployed, Returned	Returned Refused	Returned Undeliverable	Not Returned Refused	Lost	Not Deployed
Total	784	695	32	4	9	40	3

Participation Results

Table 21 shows the results of the GPS component with respect to collecting both CATI and GPS data on the assigned travel date. CM stands for complete data collected from household.

Table 21: Participation Statistics

GPS Statistics					CATI Statistics		GPS & CATI Combined	
Recruited	Deployed	Returned	GPS CM	% CM	CATI CM	% CM	GPS & CATI CM	% GPS & CATI CM
784	780	695	605	78%	611	78%	506	65%

As seen in these tables, complete GPS and CATI data were collected from 506 households out of the 780 households deployed in this study; which is a 65 percent completion rate. A complete (GPS + CATI) household is defined as one in which CATI data was retrieved and GPS data were either collected from each instrumented person or, if not collected from a given person on the assigned travel date, then the CATI data confirmed no travel for that person.

Table 22 contains the overall data collection disposition of all households participating (deployed) in the GPS component. As seen in this table, there are other categories (or levels) of participation that are also useful for analysis. In fact, beyond the 506 GPS/CATI complete households, an additional 149 households collected complete or partial GPS data. Here is the breakdown of these households:

▪ 99 households collected complete GPS data but did not report their trips via CATI (therefore a total of 605 GPS Completes as listed in Table 21).

▪ 50 households collected GPS data for a subset of all instrumented persons, and all persons reported their trips via CATI.

Table 22: Disposition of GPS and Diary Retrieval Outcomes

Participation Outcome	Frequency	Percent
Complete (GPS + CATI)	506	64.8%
Full GPS data but no CATI data	99	12.8
Partial GPS data but no CATI data	0	0%
No GPS data but full CATI data*	54	6.9 %
Partial GPS and full CATI	50	6.4 %
No GPS data and no CATI data	71	9.1%
Total	780	100.0%
* There was one household which reported travel (CATI), but was not deployed with GPS. Therefore, the CATI total here is 610 (506+54+50), while the CATI Complete total in Table 21 is 611.		

If the GPS/CATI complete total and the GPS complete/No CATI total are combined, this yields a 77.6 percent GPS data collection completion rate. The original target goal of 65 percent for GPS/CATI completes was also met.

GPS / Diary Processing Methods and Results

Of the 506 GPS / CATI complete households, 482 households had all members collect both GPS and CATI data on their assigned travel date. The 998 persons in those 482 households were used for the missed trip analysis and matching results. These persons reported a total of 5477 trips on the assigned travel day. The

GPS devices collected a total of 5899 trips from these same persons. All information contained in this section pertains to these 482 households only.

Reporting Exceptions

In some household travel surveys, work-related trips (i.e., commercial use of personal auto) and external to external trips (i.e., those that have origins and destinations outside of the planning regions) are not reported in the travel diary and not collected during the retrieval call. These were the instructions for this pretest study as well. However, of the 187 external to external GPS trips GeoStats detected in the GPS/CATI complete households, 147 of these trips was reported. Similarly, of the 447 work-related GPS trips GeoStats found in these households, 268 had been reported. This left a total of 40 external-external trips and 179 work-related trips found in the GPS data that had not been reported (and were not required to be reported).

GeoStats flagged GPS trips as loop trips whenever a GPS trip was detected in which the origin and destination were the same location. According to the rules of this study, loop trips should have reported whenever their purpose (e.g., exercise or walk the dog) was not tied to the purpose of the previous trip. This means that a loop trip made from home is a valid trip whereas a loop walk trip in a park preceded by a drive to the park for exercise purposes should not have been reported. GeoStats found a total of 150 loop trips, 95 of which were reported by participants. Furthermore, GeoStats found 293 other non-transportation or on-site trips that were not required to be reported.

To account for these reporting rules and discrepancies, GeoStats provided two versions of the missed trip analysis at the end of this section – one that includes all reporting exceptions and one that excludes these exceptions.

Matching Results – Wearable GPS Households

The results of the trip matching process fell into the following three categories:

100 Percent Matched Trips. Any person instrumented with GPS that captured the same GPS trips as reported in CATI were considered to be a perfect match. This category also includes 61 persons who reported no travel and for which there were no GPS trips recorded.

Of all trips made by the 998 instrumented persons included in this analysis, 402 persons had perfect matches between the CATI and GPS trip data. The breakdown of this number includes the 61 persons who did not travel and 341 persons who made at least one trip. This represents a perfect match (or reporting rate) for 40.3 percent of all instrumented persons and 1758 of the 5477 CATI-reported trips (32.1 percent). Table 23 contains the trip frequency statistics for the persons included in this category.

Table 23: Trip Frequencies for Perfect Matches at Person Level

# Trips	Frequency	Percent	Cumulative Percent
0	61	15.2%	15.2%
1	2	0.5%	15.7%
2	63	15.7%	31.3%
3	41	10.2%	41.5%
4	63	15.7%	57.2%
5	46	11.4%	68.7%
6	40	10.0%	78.6%
7	32	8.0%	86.6%

# Trips	Frequency	Percent	Cumulative Percent
8	12	3.0%	89.6%
9	10	2.5%	92.0%
10	12	3.0%	95.0%
11	10	2.5%	97.5%
12	2	0.5%	98.0%
13	3	0.7%	98.8%
14	0	0.0%	98.8%
15	2	0.5%	99.3%
16	1	0.2%	99.5%
17	0	0.0%	99.5%
18	2	0.5%	100.0%
Totals	402	100.0%	100.0%

GPS Trip Not Detected but CATI Trip Reported. The second comparison identifies CATI trips that had no corresponding GPS trips. During the matching process, 702 CATI trips were identified that had no corresponding GPS trip (or 10.6 percent of all GPS trips). This typically happens when respondents place the GlobalSat device in a position in which it cannot receive GPS satellite signals (such as in a purse or backpack) or forget to confirm that it is powered on. A few participants noted that the device may not have been powered throughout the travel day (e.g., they forgot to check to see if the power light was on).

GPS Trip Detected but No CATI Trip Reported. The last category in the matching process contains those cases where trips were identified within the GPS data stream but not within the CATI data. There were 1125 "missing" CATI trips identified as a result of the trip matching process (for a missing diary (or CATI) trip rate of 17.0 percent. If we exclude any reporting exceptions detected during GPS data processing, this number reduces to 724 missing trips, for a 11.7 percent missing trip rate. The section on the missed trip research process and results provides additional information about these missing trips.

Table 24 shows the frequency of missing GPS trip counts and CATI trip counts detected for the 596 persons who were not perfect matches. For example, there were 139 persons missing one GPS trip and 185 persons missing one CATI trip (172 if reporting exceptions are excluded). On the higher end of the spectrum, there was one participant missing 12 GPS trips and two persons missing 24 CATI trips. Once reporting exceptions are excluded, the highest number of missing CATI trips decreased to 12. It should also be noted that some participants could be missing both GPS and CATI trips.

Table 24: Trip Frequencies for Missing GPS and Missing Diary Trips

# Missing Trips	GPS Frequency	CATI Frequency (with exceptions)	CATI Frequency (without exceptions)
0	692	587	650
1	138	182	171
2	82	87	82
3	31	58	46
4	17	30	21
5	18	19	15
6	9	10	6
7	3	4	5

# Missing Trips	GPS Frequency	CATI Frequency (with exceptions)	CATI Frequency (without exceptions)
8	3	7	0
9	3	2	1
10	0	2	0
11	1	2	0
12	1	2	1
13	0	0	0
14	0	0	0
18	0	1	0
19	0	2	0
24	0	2	0

Overall Matching Results

As reported previously, the CATI data contained 5477 person trips while the GPS equipment captured 5899 trips. However, at the individual person level, a total of 1125 missing CATI trips were detected (724 trips when reporting exceptions are excluded). The overall adjusted missed trip rate is 11.7 percent for the GPS / CATI complete sample (724 missing CATI trips divided by the sum of the 724 missing trips and the 5477 reported trips).

The overall missed trip rate of 11.7 percent is very consistent with findings in other recent studies, including Baltimore, Washington DC, Chicago, Indianapolis, Denver, and Atlanta. Additional analyses of unreported trips should be performed to gain insight into the types of trips that are typically unreported (as shown in the Missed Trip Research Section) as well as of the person-level and household-level demographics and travel patterns that contribute to trip under-reporting. It is important to note that these analyses are needed to generate targeted trip rate correction factors; it is not advisable to use the overall missed trip rate as a correction factor for an entire sample.

Link Matching

Another task included in the GPS component of this study was link matching the GPS points confirmed as valid trips to GIS spatial layers. Consequently, upon completion of the GPS trip review process, the files were run though a link matching routine. This routine compared GPS point sequences with linear spatial databases representing different elements from the study area's transportation infrastructure.

Process Description

The algorithm used to perform the matching was based on the one proposed by Marshal, Hackney, and Axhausen,[2] with the added feature of performing shortest network path on gaps found in the final routes.[3] The spatial layers used in this process were obtained from MassDOT in ESRI Shapefile format, prior to processing they were imported into PostGIS for more efficient access by the matching routine. The layers were stored using the NAD83(HARN) / Massachusetts Mainland projection. Table 25 lists the layers to which GPS points were matched based on the travel modes they were associated with in TIAS. Note that a given set of points can be matched to more than one layer.

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[2] F. Marchal, J. Hackney, K. W. Axhausen, Efficient Map Matching of Large Global Positioning System Datasets: Tests on Speed-Monitoring Experiment in Zürich, Transportation Research Record: Journal of the Transportation Research Board, Transportation Research Board of the National Academies, 2006.

[3] Shortest path computations were only performed on routes built using the Navteq street network layer, which was provided by the client.

Table 25: List of Travel Modes included in Matching Process

Layer Name	Label Field	Travel Mode (Mode ID)
navteq_streets_topo	link_uid	Walk (1), Auto / Van / Truck Driver (3), Auto / Van / Truck Passenger (4), Dial-a-Ride / Paratransit (6), Taxi (7), School Bus (8), Motorcycle Driver (9), Motorcycle Passenger (10), Local Bus (81), Express Bus (82), Shuttle Bus (83)
bike_trails	gid*	Bike (2)
transit_routes	gid	Local Bus (81)
silver_line	gid	Express Bus (82)
mta_rapid_transit_rail_line_subway, rapid_transit_lines	gid	Subway (84)
passenger_trains_lines	gid	Commuter Rail (85)

Spatial operations were performed in the layer's original local projection with GPS coordinates projected on the fly. The match tolerance was set at 25 meters for the Navteq street layer and 75 meters for all other layers to account for the fact that non-auto modes tend have poorer positional quality. The result of this process is a set of two tables, GPSLINKS and GPSLINKSNAPS. The first one has one record for each link matched to a given trip, while the second one contains the resulting snapped coordinates.

Snapped coordinates were computed by intersecting a line perpendicular to the point's trajectory with the route's links. The resulting intersection's coordinates were un-projected to WGS84 decimal degrees and saved to the database. Linear referencing measurements were computed by measuring the distance along the routes' individually matched segments to the point snaps, results were saved in the local projection's measurement unit (meters).

Data Weighting and Expansion

As discussed earlier, the sample design was crafted to enable the collection of data from a representative and randomly selected sample of households from the region. Demographic and geographic targets were used to guide data collection with the goal of having a final dataset that reflected the ACS 2006–2010 population proportions. Although the sample was randomly selected, not all sampled households agreed to participate, nor did all households that agreed to participate actually complete the study. This resulted in a non-response bias in the dataset.

To correct for this, the final dataset includes two analytical weights, computed at the household and person levels. These weights;

1) Adjust the relative importance of responses to reflect the different probabilities of selection of respondents,

2) Adjust for bias associated with the high probability of selection associated with cell phone sample households that have more than one cell phone,

3) Adjust for households that do not own landlines, and

4) Align the sample distributions to population distributions, thereby improving coverage and precision.

From a finite population sampling theory perspective, analytic weights are needed to develop estimates of population parameters and, more generally, to draw inferences about the population that was sampled. Without the use of analytic weights, population estimates are subject to biases of unknown (and possibly large) magnitude. Consequently, analytic weights are crucial to obtain survey estimates with minimal bias.

The weighting approach used in this study accounts for the biases associated with sampling, telephone ownership, and robustness of the data collected. Specifically, the components of the analytic weights generated are as follows:

- Sampling weights,
- Raking adjustments.

The analytic weights were computed at the household and person level. These weights adjusted the relative importance of responses to reflect the different probabilities of selection of respondents, and align the sample distributions to population distributions.

Household Weight

Sampling Weight

The sampling weight reflects the probability of selection of a telephone number or an address from the sampling frame. Considering the dual-frame sampling framework employed in this study, separate sampling weights were calculated for the listed residential and address-based sampling frames. Specifically, the sampling weight for a sampling unit j in the sampling frame, denoted as $W_{j,SampFr}$, is simply the reciprocal of the selection probability of the sampling unit.

$$W_{j,SampFr} = \frac{1}{\text{Prob}_{j,SampFr}}$$

where,

- ✓ Sampling unit j is a landline number in the listed residential frame and an address in the address-based sampling frame.
- ✓ Sampling frame $_{SampFr}$ is listed residential or address-based sampling frame.

The sampling weights also adjusted for oversampling of specific geographies or demographic groups of interest, for which we had implemented controls to make sure that we had adequate observations in these groups. To illustrate, the sampling weight associated with address-based sample was simply computed as the number of addresses in the address-based frame divided by number of sample pieces ordered from the frame for the study area. It is important to note that the adjustments for oversampling were made at the aggregate level of the sampling frame type (instead of a specific geography).

Raking Adjustment

Raking improves the reliability of the survey estimates; hence, raking adjustments were used to align the weighted sample to population statistics from 2006–2010 ACS data. These adjustments were made using raking variables. In particular, the aforementioned weights were adjusted so that the sums of the adjusted weights were equal to known population totals for certain subgroups of the population defined by demographic characteristics and geographic variables. The variables used for raking at the household level are as follows:

- Household size,
- Household income,
- Total number of workers in the household,
- Total number of vehicles in the household, and
- MPO of residence.

These variables were chosen as the raking variables due to significant differences in the coverage by categories of these variables. Therefore, it is reasonable to expect that maximum bias reduction would be achieved using these variables. It is important to note that the missing values in the raking variables were imputed to calculate the raking adjustments.

The raking procedure is based on an iterative proportional fitting (IPF) procedure and involves simultaneous ratio adjustments to two or more marginal distributions of the population counts. The raking procedure is undertaken in a sequence of adjustments. First, the base weights are adjusted to one marginal distribution and then to the second marginal distribution, and so on. One sequence of adjustments to the marginal distributions is known as a cycle or iteration. The procedure is repeated until convergence is achieved. Following the raking procedure, the inordinately large weights, a by-product of raking, were capped. In particular, the "very large" weights were capped to equal a maximum of five times the mean weight.

Table 26 shows the sample and population distribution by demographic and geographic raking variables for the study area. A comparison of the unweighted difference and weighted difference between the survey data and the ACS indicates that the raking procedure has aligned the sample statistics to the population statistics. Note that the table uses the imputed recoded data where households refused one of the raking variables.

Table 26: Raking Adjustment at Household Level

Raking Variable	2006-2010 ACS	Weighted Data		Difference (% pts)	
		Before Raking	After Raking	Before Raking	After Raking
Household Size					
1	28.9%	27.4%	28.9%	-1.50%	0.00%
2	32.1%	32.1%	32.1%	0.00%	0.00%
3	16.1%	16.9%	16.1%	0.80%	0.00%
4 or more	22.8%	23.6%	22.8%	0.80%	0.00%
Household Vehicles					
0	12.2%	10.2%	12.2%	-2.00%	0.00%
1	35.7%	31.4%	35.7%	-4.30%	0.00%
2	37.1%	39.1%	37.1%	2.00%	0.00%
3 or more	15.0%	19.3%	15.0%	4.30%	0.00%
Workers in Household					
0	25.5%	23.5%	25.5%	-2.00%	0.00%
1	36.4%	34.8%	36.4%	-1.60%	0.00%
2	30.2%	33.9%	30.2%	3.70%	0.00%
3 or more	7.8%	7.7%	7.8%	-0.10%	0.00%
Household Income					
Less than $25000	20.4%	16.9%	20.4%	-3.50%	0.00%
$25,000–$49,999	19.2%	16.0%	19.2%	-3.20%	0.00%
$50,000–$99,999	30.5%	29.5%	30.5%	-1.00%	0.00%
$100,000-$149,999	16.4%	23.6%	16.4%	7.20%	0.00%
$150,000 or more	13.4%	14.1%	13.4%	0.70%	0.00%
MPO of Residence					
Berkshire	2.2%	2.0%	2.2%	-0.20%	0.00%
Cape Cod	3.9%	3.3%	3.9%	-0.60%	0.00%
Central Mass.	8.5%	7.6%	8.5%	-0.90%	0.00%
Franklin	1.2%	1.7%	1.2%	0.50%	0.00%
Boston	48.0%	51.0%	48.0%	3.00%	0.00%

Raking Variable	2006-2010 ACS	Weighted Data		Difference (% pts)	
		Before Raking	After Raking	Before Raking	After Raking
Montachusett	3.3%	3.5%	3.3%	0.20%	0.00%
Martha's Vineyard	0.2%	0.2%	0.2%	0.00%	0.00%
Merrimack	4.9%	4.7%	4.9%	-0.20%	0.00%
Northern Middlesex	4.0%	4.3%	4.0%	0.30%	0.00%
Nantucket	0.1%	0.2%	0.1%	0.10%	0.00%
Old Colony	4.9%	3.7%	4.9%	-1.20%	0.00%
Pioneer Valley	9.4%	9.9%	9.4%	0.50%	0.00%
Southeastern Mass.	9.4%	7.9%	9.4%	-1.50%	0.00%
Total	2,512,552	15033	15033	-1.50%	0.00%

Final Household Weight

The final analytic weight is simply the product of sampling weight and raking adjustment. Following the computation of this weight, an expansion procedure was undertaken to get the final 'expanded' analytic weight. The expansion process simply takes the weighted total households and multiplies each household by a factor, when applied, expands the data to represent the universe of households in the study area. To derive the expansion factor, a simple division was used: Expansion Factor = N(Universe)/ N(Surveyed).

Person Weight

The person weight is a product of the final household weight and the person-level raking weight. Specifically, the person data weighted by the 'final household weight' was raked to align it to the population statistics from 2006–2010 ACS data. The raking procedure is based on an iterative proportional fitting procedure. The variables used for raking at the person level are Hispanic Status/Ethnicity and Age.

Following the raking procedure, the very large weights were capped. The weights were then expanded to reflect the total number of persons residing in the study area. The final person weight is the product of household weight and raking adjustment at the person level.

Table 27 shows the sample and population distribution by the aforementioned raking variables. A comparison of the unweighted difference and weighted difference between the survey data and the 2006–2010 ACS indicates that the raking procedure has aligned the sample statistics to the population statistics. This weight was expanded to represent the total population in the study area.

Table 27: Raking Adjustment at Person Level

Raking Variable	2006-2010 ACS	Weighted Data		Difference (% pts)	
		Before Raking	After Raking	Before Raking	After Raking
Hispanic Status/Ethnicity					
Hispanic	9.3%	5.2%	9.3%	-4.10%	0.00%
Non-Hispanic-white	76.8%	86.3%	76.8%	9.50%	0.00%
Non-Hispanic Other	13.8%	8.5%	13.8%	-5.30%	0.00%
Age					
Under 20 years	25.2%	25.3%	25.2%	0.10%	0.00%
20–34 years	19.9%	10.8%	19.9%	-9.10%	0.00%
35–54 years	29.6%	32.6%	29.6%	3.00%	0.00%
55–64 years	11.7%	19.6%	11.7%	7.90%	0.00%
65 years and over	13.5%	11.7%	13.5%	-1.80%	0.00%
Total	6,470,619	37023	37023		

Limitations of the Survey

Limitations and Impact on Data

Response Rate and Survey Non-Response. Some level of non-response occurs in every voluntary survey. Low response rates are attributable to a variety of factors, including growing resistance among U.S. householders to surveys in general and telephone surveys in particular; the changing patterns of telephone access in American households; and the growing number of households in which English is not a first language—making telephone communication for survey respondents who are not native English speakers difficult.[4] Household travel surveys are particularly susceptible to non-response. These surveys are complex, requiring a two-stage interview process plus the completion of a travel diary by all household members. Since each interview stage has an accompanying level of non-response, the overall response rate is the product of a recruitment rate and a retrieval rate.

Under-Reporting of Trips. An important determinant of data quality is the accuracy of the reported trips. To enhance reporting accuracy, most household travel surveys rely on travel diaries, in which respondents are asked to record each trip for a specific time period (e.g., 24 hours). Yet even with the use of diaries, under-reporting of trips by survey respondents is a well-documented occurrence. Memory decay, failure to understand or to follow survey instructions, unwillingness to report full details of travel, and simple carelessness all contribute to the incomplete collection of travel data. After the data have been weighted and expanded, the trip rates are assessed relative to prior surveys and other metropolitan areas.

Response Bias. Surveys are prone to non-response errors because certain types of households selected in a sample do not participate in surveys or individual household members fail to answer an item in an interview.

Recommendations for Study Improvement

Travel behavior study innovations are in continuous development by various research organizations. Sponsors typically focus concerns on multiple elements relevant to their existing or planned models. Future studies should consider each element and weigh the importance by priority and financial investment. The indexing of priority, innovation, value, and cost is a difficult task, even for experienced model coordinators.

Hispanic Outreach: Despite targeted sampling, response from Hispanic households was low. Based on recent household travel survey experience in large metropolitan areas, it is believed that robust public outreach efforts involving the sponsoring agency and the research firm are necessary in order to effectively communicate and generate interest with Hispanic communities. Public outreach efforts should include press releases through community new media and messaging efforts through community leaders, with the sponsoring agency providing the local presence and expertise.

Non-Response Follow-Up. Conducting in-person non-response efforts can increase the quality of the study and decrease coverage bias. In-person interviews tend to be more expensive in cost. However, conducting a limited non-response effort can allow for bias correction, through weighting the difference in travel behavior from those that originally participate.

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[4] The survey was designed to include English and Spanish speakers only.

Survey Results

The 15,033 households that participated in the Massachusetts Travel Survey had many characteristics in common. All were willing to take the time to record their travel and provide demographic information about their households. These households provided data about their household composition, housing type and ownership, and income. They provided details about their 37,023 household members, including age, gender, disability status, and employment and student status. They divulged the year, make, and model for each of their 26,488 vehicles. In addition, they willingly provided trip destinations, travel times, travel modes, and the reasons for visiting 190,215 places during their respective 24-hour period. In all, the households reported an average of 10.2 daily household trips and 4.1 daily person trips.

The purpose of this section is to summarize the characteristics of participating households and understand the ways in which they are similar and how they vary, at both the person and the household level. These differences are important in understanding their travel behavior, which is presented in the second section of this chapter. Details about their trip characteristics comprise the third section, followed by a more detailed look at mode choice and travel times reported by respondents, including travel destinations during specific time periods.

Household Characteristics

As shown in Table 28, Nearly one-third of all households surveyed reported having two household members; another 29 percent of households reported only one household member.

Table 28: Household Size (Weighted)

Household Size	Count	Percent
1	727048	28.9%
2	807743	32.1%
3	403832	16.1%
4	389256	15.5%
5	142149	5.7%
6	32534	1.3%
7	6753	0.3%
8 or more	3237	0.1%
Total	2512552	100.0%

The majority of households (72 percent) reported they do not use transit on a regular basis, as shown in Table 29.

Table 29: Transit Used on Regular Basis (Weighted)

Transit Used on Regular Basis	Count	Percent
Yes	710060	28.3%
No	1801000	71.7%
DK	1491	0.1%
Total	2512552	100.0%

Overall, just over half of all households (56 percent) reported having at least one household bicycle; of those, 18 percent reported having two bicycles available to the household, and 16 percent reported one bicycle. On the other hand, 44 percent of households reported not having a household bicycle. See Table 30 for more detail.

Table 30: Household Bicycles (Weighted)

Household Bicycles	Count	Percent
0	1092463	43.5%
1	410116	16.3%
2	448577	17.9%
3	221518	8.8%
4	193676	7.7%
5	80431	3.2%
6	37033	1.5%
7	11570	0.5%
8	14887	0.6%
DK	2281	0.1%
Total	2512552	100.0%

Thirty-seven percent of households reported having two vehicles available to the household, 36 percent reported having one vehicle available, while 12 percent reported having no vehicles (see Table 31).

Table 31: Household Number of Vehicles (Weighted)

Household Vehicles	Count	Percent
0	307472	12.2%
1	895898	35.7%
2	931730	37.1%
3	256939	10.2%
4	80755	3.2%
5	27223	1.1%
6	8677	0.3%
7	1896	0.1%
8 or More	1961	0.1%
Total	2512552	100.0%

Regarding ethnicity of the participating households (Table 32), the majority (86 percent) reported White Alone, nearly 5 percent reported Black or African American Alone, while 4 percent reported Some Other Race Alone.

Table 32: Household Ethnicity (Weighted)

Household Ethnicity	Count	Percent
White Alone	2160929	86.0%
Black or African American Alone	114230	4.5%
American Indian or Alaskan Native Alone	6784	0.3%
Asian Alone	46785	1.9%
Native Hawaiian, Pacific Islander Alone	1626	0.1%
Some Other Race Alone	105500	4.2%
Two or More Races	50292	2.0%
Refused	26405	1.1%
Total	2512552	100.0%

Overall participation of Hispanic or Latino households in the survey was nearly 6 percent, as shown in Table 33.

Table 33: Hispanic or Latino Households (Weighted)

Hispanic or Latino Household	Count	Percent
Yes	137733	5.5%
No	2360496	93.9%
RF	14323	0.6%
Total	2512552	100.0%

Shown in Table 34, 63 percent of all households reported living in a Single Family Detached Dwelling, followed by a Building with 2–4 Units (nearly 20 percent), a Building with 5–19 Units (8 percent), and a Building with 20 or More Units (also at 8 percent).

Table 34: Household Residence Type (Weighted)

Household Residence Type	Count	Percent
Single Family Detached Dwelling	1591042	63.3%
Building with 2-4 Units	489639	19.5%
Building with 5-19 Units	212156	8.4%
Building with 20 or More Units	209147	8.3%
Something Else	5671	0.2%
DK	1683	0.1%
RF	3213	0.1%
Total	2512552	100.0%

Seventy-three percent of households reported they own their homes, while 27 percent reported that they rent. See Table 35 for more detail.

Table 35: Ownership of Household Residence (Weighted)

Home Ownership	Count	Percent
Own/Mortgaged	1839664	73.2%
Renter	667080	26.5%
Other, Specify	2536	0.1%
DK	1778	0.1%
RF	1494	0.1%
Total	2512552	100.0%

Thirty-six percent of households have two cell phones in the household, 31 percent have one cell phone, while another 14 percent have three cell phones. Also shown in Table 36, nearly 9 percent reported having no cell phones.

Table 36: Cell phone lines in Household (Weighted)

Cell Phones in Household	Count	Percent
0	222006	8.8%
1	779823	31.0%
2	892893	35.5%
3	345062	13.7%
4	207193	8.2%
5	50157	2.0%
6	7323	0.3%
7	1117	0.0%
8	1160	0.0%
9	107	0.0%
DK	2268	0.1%
RF	3441	0.1%
Total	2512552	100.0%

As shown in Table 37, 99 percent of participating households have landline telephone service. Less than 1 percent reported not having a landline connection.

Table 37: Landlines in Household (Weighted)

Landlines in Household	Count	Percent
0	21295	0.8%
1	2307534	91.8%
2	145370	5.8%
3	26571	1.1%
4	5343	0.2%
5	1787	0.1%
6	975	0.0%
8	208	0.0%
10	184	0.0%
DK	1425	0.1%
RF	1861	0.1%
Total	2512552	100.0%

Regarding household income distribution, 16 percent reported making $15,000–$34,999 annually, another 16 percent reported making $50,000–$74,999 annually, while 14 percent report making $75,000–$99,999 annually. Thirteen percent of households fall within the highest income category ($150,000 or more) while a comparative 12 percent fall within the lowest income category (less than $15,000). See Table 38 for more information.

Table 38: Household Income (Weighted)

Household Income	Count	Percent
Less than $15,000	299314	11.9%
$15,000-$24,999	213980	8.5%
$25,000-$34,999	195841	7.8%
$35,000-$49,999	286397	11.4%
$50,000-$74,999	412466	16.4%
$75,000-$99,999	354862	14.1%
$100,000-$149,999	290100	11.5%
$150,000 or more	337531	13.4%
Don't Know/Refused	122062	4.9%
Total	2512552	100.0%

As shown in Table 39, on their travel day, 29 percent of households made 6–10 trips, while another 29 percent made fewer (1–5) trips. Seventeen percent made 11–15 trips, 10 percent made 16–20 trips, and another 10 percent of households made at least 21 trips on their travel day. Nearly 5 percent of household reported making no trips.

Table 39: Trips Made by Household on Travel Day (Weighted)

Trips Made by Household on Travel Day	Count	Percent
None	117549	4.7%
1 to 5	721970	28.7%
6 to 10	734918	29.2%
11 to 15	428671	17.1%
16 to 20	251205	10.0%
21 to 30	202945	8.1%
31 to 50	52714	2.1%
50+	2581	0.1%
Total	2512552	100.0%

As summarized in Table 40, the majority of households (63 percent) reported having no students in the household. Of those households that did, 17 percent reported 1 student, 13 percent reported 2 students, and 5 percent reported 3 students.

Table 40: Household Students (Weighted)

Household Students	Count	Percent
0	1589998	63.3%
1	423061	16.8%
2	336048	13.4%
3	130475	5.2%
4	26781	1.1%
5	5830	0.2%
6	360	0.0%
Total	2512552	100.0%

Two-thirds of all households reported having one or two workers in the household, while 6 percent reported having at least three workers. Conversely, 26 percent of households reported having no workers within the household. See Table 41 for more information.

Table 41: Household Workers (Weighted)

Household Workers	Count	Percent
0	641650	25.5%
1	915403	36.4%
2	759429	30.2%
3	155176	6.2%
4	35133	1.4%
5	5423	0.2%
6	337	0.0%
Total	2512552	100.0%

Table 42 summarizes that nearly half of all households reported having two licensed drivers in the household, while another 33 percent reported having one licensed driver. Seven percent reported having no licensed drivers.

Table 42: Licensed Drivers in Household (Weighted)

Licensed Drivers in Household	Count	Percent
0	178392	7.1%
1	821724	32.7%
2	1201859	47.8%
3	233449	9.3%
4	65762	2.6%
5	9641	0.4%
6	1582	0.1%
7	143	0.0%
Total	2512552	100.0%

Table 43 shows the final distribution of households across the days of the week. As is shown, households were distributed nearly equally across the days of the week.

Table 43: Distribution of Households by Day of Week of Travel (Weighted)

Day of Week of Travel	Count	Percent
Monday	524703	20.9%
Tuesday	500912	19.9%
Wednesday	494735	19.7%
Thursday	482082	19.2%
Friday	510120	20.3%
Total	2512552	100.0%

As Table 44 indicates, overall, distribution by day of week of travel was roughly even, even across the multiple years of data collection. Friday travel days were over-recruited in 2011 in order to compensate for lower response rates of Friday travelers in 2010.

Table 44: Distribution of Households by Day of Week of Year of Travel (Weighted)

Year	Day of Week of Travel	Count	Percent
2010	Monday	274451	10.9%
	Tuesday	256973	10.2%
	Wednesday	249816	9.9%
	Thursday	243299	9.7%
	Friday	240566	9.6%
	Monday	250253	10.0%
	Tuesday	243939	9.7%
	Wednesday	244918	9.7%
	Thursday	238783	9.5%
	Friday	269553	10.7%
Total		2512552	100.0%

Distribution by month of year of travel is shown in Table 45. Due to the occurrence of two fall data collection phases, there are more households from those months.

Table 45: Distribution of Households by Month of Year of Travel (Weighted)

Year	Month of Year of Travel	Count	Percent
2010	June	125251	5.0%
	July	244190	9.7%
	August	258163	10.3%
	September	218371	8.7%
	October	178178	7.1%
	November	123601	4.9%
	December	117353	4.7%
2011	January	127609	5.1%
	February	98825	3.9%
	March	162577	6.5%
	April	186356	7.4%
	May	168924	6.7%
	June	208199	8.3%
	July	64491	2.6%
	September	134313	5.3%
	October	96151	3.8%
Total		2512552	100.0%

Person Characteristics

The majority of survey respondents (53 percent) are female, as shown in Table 46.

Table 46: Respondent Gender (Weighted)

Respondent Gender	Count	Percent
Male	3056017	47.2%
Female	3411842	52.7%
Refused	2760	0.0%
Total	6470619	100.0%

The overall age distribution is presented in Table 47. As is shown, 29 percent of respondents are between the ages of 35 and 54, 25 percent are younger than 20 years of age, while 20 percent are between the ages of 20 and 34. Fourteen percent are at least 65 years of age, while 11 percent are between the ages of 55 and 64.

Table 47: Age Distribution (Weighted)

Age Distribution	Count	Percent
Younger than 20	1601580	24.8%
20 to 34 years	1278683	19.8%
35 to 54 years	1865589	28.8%
55 to 64 years	735931	11.4%
65 years or older	872768	13.5%
Refused Age	116068	1.8%
Total	6470619	100.0%

As indicated in Table 48, the majority of survey respondents (85 percent) reported having a valid driver's license.

Table 48: Valid Driver's License (Weighted)

Valid Driver's License	Count	Percent
Yes	4400916	85.1%
No	764421	14.8%
Don't Know	3557	0.1%
Refused	2399	0.0%
Total	5171293	100.0%

Only one-quarter of all respondents reported having a transit pass; the remaining 75 percent reported not having a transit pass. The distribution is reported in Table 49.

Table 49: Respondent has Transit Pass (Weighted)

Respondent has Transit Pass	Count	Percent
Yes	1266763	24.5%
No	3878327	75.0%
Don't Know	25040	0.5%
Refused	1162	0.0%
Total	5171293	100.0%

Table 50 presents the type of transit pass that respondents reported having. Of those who reported having a transit pass, 56 percent use the Charlie Card, 13 percent use some other, unspecified, type of transit pass, 10 percent use the Link Pass, 10 percent use a Local Bus Pass, while 8 percent use the Commuter Rail Pass. The least common types of passes are the Inner and Outer Express Bus Passes and the Ferry/Board Pass (all less than 1 percent).

Table 50: Transit Pass Type (Weighted)

Transit Pass Type, Multiple Response	Count	Percent
Local Bus Pass	121656	9.6%
Link Pass	129118	10.2%
Inner Express Bus Pass	3920	0.3%
Outer Express Bus Pass	714	0.1%
Commuter Rail Pass	95805	7.6%
Ferry / Board Pass	3047	0.2%
Charlie Card	704902	55.6%
Other, specify	168296	13.3%
Don't Know	31194	2.5%
Refused	10178	0.8%
Total	1268830	100.0%

Table 51 summarizes worker status. Of the respondents within the study area, 62 percent reported being employed.

Table 51: Worker Status, Computed (Weighted)

Worker Status, Computed	Count	Percent
Yes	3224601	62.4%
No	1946692	37.6%
Total	5171293	100.0%

Of the 38 percent of respondents within the study area who reported being unemployed (see Table 51), 38 percent are retired, 16 percent are students, 16 percent are disabled, 14 percent are looking for work, while 13 percent are homemakers, as indicated in Table 52.

Table 52: Employment Status, Non-workers (Weighted)

Employment Status, Non workers	Count	Percent
Retired	740937	38.1%
Disabled/On Disability Status	301901	15.5%
Homemaker	245729	12.6%
Unemployed but looking for work	270349	13.9%
Unemployed and not looking for work	49721	2.6%
Student	317361	16.3%
Other, specify	9765	0.5%
Refused	10929	0.6%
Total	1946692	100.0%

As summarized in Table 53, respondents within the study area average working 1.11 jobs each.

Table 53: Average Number of Jobs (Weighted)

Jobs	Average
Average Number of Jobs	1.11

Regarding the number of hours workers average per day, 43 percent work eight hours a day. Eleven percent work ten hours a day, while 10 percent work nine hours a day. Refer to Table 54 for more detail.

Table 54: Hours Worked per Day (Weighted)

Hours Worked per Day	Count	Percent
1	21506	0.7%
2	48136	1.5%
3	79283	2.5%
4	172651	5.4%
5	172784	5.4%
6	206260	6.4%
7	200631	6.2%
8	1399643	43.4%
9	330899	10.3%
10	353648	11.0%
11	32679	1.0%

Hours Worked per Day		Count		Percent
12		107188		3.3%
13		6873		0.2%
14		11431		0.4%
15		4921		0.2%
16		7339		0.2%
17		517		0.0%
18		626		0.0%
20		3465		0.1%
22		81		0.0%
23		137		0.0%
24		5554		0.2%
Don't Know		45108		1.4%
Refused		13242		0.4%
Total		3224601		100.0%

As shown in Table 55, the majority of respondents (68 percent) work a typical five-day work week, while 10 percent average working four days a week. Eight percent work three days a week, and 7 percent work six days a week.

Table 55: Respondent Average Number of Days Worked Per Week (Weighted)

Days Worked Per Week		Count		Percent
1		50519		1.6%
2		116144		3.6%
3		242915		7.5%
4		319291		9.9%
5		2194908		68.1%
6		214203		6.6%
7		77370		2.4%
Don't Know		6971		0.2%
Refused		2280		0.1%
Total		3224601		100.0%

Table 56 summarizes telecommute status of workers. Of the respondents who work, 22 percent telecommute.

Table 56: Telecommute Status (Weighted)

Worker Telecommutes	Count	Percent
Yes	694912	21.6%
No	2473252	76.7%
Don't Know	52388	1.6%
Refused	4048	0.1%
Total	3224601	100.0%

As shown in Table 57, of those who work, 23 percent are offered a flexible work program at work, 72 percent are not offered a flexible work schedule, while 5 percent do not know if this is an option for them or not.

Table 57: Flexible Work Program Offered at Work (Weighted)

Flexible Work Program Offered at Work	Count	Percent
Yes	738870	22.9%
No	2313130	71.7%
Don't Know	168175	5.2%
Refused	4425	0.1%
Total	3224601	100.0%

For those who are offered a flexible work program at work, 35 percent are offered early arrival/departure, 22 percent are offered flexible hours, 15 percent are offered some other type of program, 8 percent are offered the 4/40 work week, and 6 percent are offered the 9/80 work period. Refer to Table 58 for more detail on flexible work programs offered.

Table 58: Type of Flexible Work Programs Offered, Multiple Response (Weighted)

Type of Flexible Work Programs Offered, Multiple Response	Count	Percent
9/80 Work Period	47241	6.1%
Early Arrival/Departure	268127	34.7%
4/40 Work Week	63992	8.3%
Flexible Hours	167448	21.7%
Other, Specify	115041	14.9%
Don't Know	90677	11.7%
Refused	19210	2.5%
Total	771735	100.0%

Table 59 summarizes whether workers participate in flexible work programs. For those who are offered a flexible work program at work, 81 percent participate in one of the programs offered to them; 17 percent do not participate.

Table 59: Respondent Participates in Flexible Work Program (Weighted)

Respondent Participates in Flexible Work Program	Count	Percent
Yes	598287	81.0%
No	122739	16.6%
Don't Know	17227	2.3%
Refused	618	0.1%
Total	738870	100.0%

Ninety-four percent of respondents reported not having a disabled license plate, while 5 percent reported having a disabled license plate. See Table 60 for this summary.

Table 60: Disabled License Plate (Weighted)

Disabled License Plate	Count	Percent
Yes	310996	5.1%
No	5757190	94.4%
Don't Know	20316	0.3%
Refused	8412	0.1%
Total	6096914	100.0%

Similar to disabled license plate status, Table 61 indicates that the majority of respondents (96 percent) reported not having disabled transit registration, while 3 percent did report having this type of registration.

Table 61: Disabled Transit Registration (Weighted)

Disabled Transit Registration	Count	Percent
Yes	196138	3.2%
No	5876828	96.4%
Don't Know	15700	0.3%
Refused	8249	0.1%
Total	6096914	100.0%

Just over half of all respondents (56 percent) reported having some level of college education or some type of college degree, while Table 62 confirms that 27 percent (including young children) reported not having attained a high school degree.

Table 62: Level of Education Completed (Weighted)

Level of Education Completed	Count	Percent
Not a high school graduate, 12th grade or less. (Includes very young children)	1745045	27.0%
High school graduate (high school diploma or GED)	1090490	16.9%
Some college credit but no degree	616711	9.5%
Associate or technical school degree	430733	6.7%
Bachelor's or undergraduate degree	1290818	19.9%
Graduate Degree (includes professional degrees, MD, DDs, JD)	1261299	19.5%
Other, specify	2743	0.0%
Don't Know	27493	0.4%
Refused	5288	0.1%
Total	6470619	100.0%

Shown in Table 63, the majority of all respondents (71 percent) reported not being enrolled in school; 29 percent reported being a student of some kind.

Table 63: School Enrollment Status (Weighted)

School Enrollment Status	Count	Percent
Yes	1855592	28.7%
No	4611647	71.3%
Don't Know	2917	0.0%
Refused	463	0.0%
Total	6470619	100.0%

Of those who reported being a student, 81 percent are full-time students, while 19 percent attend school on a part-time basis (Table 64).

Table 64: Full-Time/Part-Time Student Status (Weighted)

Full-time / Part-time Student Status	Count	Percent
Part-time	358296	19.3%
Full-time	1496240	80.6%
Don't Know	986	0.1%
Refused	71	0.0%
Total	1855592	100.0%

Summarized in Table 65 in more detail, of all students, 43 percent attend Kindergarten to Grade 8, 22 percent attend Grade 9 to 12, 11 percent attend a 4-year college or university, 6 percent attend graduate

school, 5 percent attend Nursery School or Preschool, and 3 percent attend Daycare. An additional 2 percent attend Technical/Vocational School.

Table 65: Student Grade Level Attends (Weighted)

Student Grade Level	Count	Percent
Daycare	59095	3.2%
Nursery School, Preschool	100109	5.4%
Kindergarten to Grade 8	804495	43.4%
Grade 9 to 12	408884	22.0%
Technical/Vocational School	33694	1.8%
Two-year college (community college)	121052	6.5%
4-year college or university	201577	10.9%
Graduate School/Professional	117272	6.3%
Other, SPECIFY	2076	0.1%
Don't Know/Refused	7338	0.4%
Total	1855592	100.0%

Table 66 reports on recent transit trips. The majority of respondents made no transit trips in the week prior to their travel day. Six percent reported making two transit trips, while 5 percent reported making ten transit trips.

Table 66: Transit Trips Made in Past Week (Weighted)

Transit Trips Made in Past Week	Count	Percent
0	4678756	72.3%
1	122474	1.9%
2	355034	5.5%
3	77922	1.2%
4	187264	2.9%
5	103867	1.6%
6	119787	1.9%
7	31231	0.5%
8	94527	1.5%
9	6203	0.1%
10	334186	5.2%
11	2817	0.0%
12	60275	0.9%
13	3082	0.0%
14	87860	1.4%
15	18598	0.3%

Transit Trips Made in Past Week	Count	Percent
16	18017	0.3%
17	1493	0.0%
18	5942	0.1%
19	500	0.0%
20	31983	0.5%
21	3259	0.1%
22	1255	0.0%
23	1032	0.0%
24	3016	0.0%
25	5789	0.1%
26	698	0.0%
28	7100	0.1%
30	11343	0.2%
32	403	0.0%
34	152	0.0%
35	422	0.0%
40	2430	0.0%
42	1398	0.0%
45	84	0.0%
48	156	0.0%
50	1152	0.0%
52	124	0.0%
56	170	0.0%
58	213	0.0%
60	523	0.0%
70	282	0.0%
75	162	0.0%
87	81	0.0%
Don't Know	82347	1.3%
Refused	5212	0.1%
Total	6470619	100.0%

For those respondents who work or attend school, Table 67 indicates there was an almost even split between those for whom bicycle facilities are available (43 percent) and for whom bicycle facilities are not available (42 percent) at work or school.

Table 67: Bike Facilities Available at Work/School (Weighted)

Bike Facilities Available at Work/School	Count	Percent
Yes	2019087	42.8%
No	1998235	42.4%
Don't Know	624817	13.3%
Refused	71539	1.5%
Total	4713678	100.0%

Overall, the majority of respondents (68 percent) had not used a bicycle for recreational purposes during the week prior to their travel day. Of those who had biked recreationally, Table 68 shows that 6 percent did so on one day only, 4 percent did so on two days, and 2 percent did so on three days.

Table 68: Days Used Bike for Recreation in Past Week (Weighted)

Days Used Bike for Recreation in Past Week	Count	Percent
0	2928168	68.3%
1	259910	6.1%
2	187141	4.4%
3	95291	2.2%
4	48097	1.1%
5	32611	0.8%
6	9783	0.2%
7	29423	0.7%
Don't Know	427588	10.0%
Refused	271227	6.3%
Total	4289241	100.0%

Similar to recreational biking, the majority of respondents (77 percent) reported not using a bicycle for transportation in the week prior to their travel day. Of those who did, 2 percent used a bicycle for transportation for one day only, while another 2 percent used a bicycle on two days. See Table 69 for more information on bicycle use.

Table 69: Days Used Bike for Transportation in Past Week (Weighted)

Days Used Bike for Transportation in Past Week	Count	Percent
0	3290741	76.7%
1	75857	1.8%
2	67059	1.6%
3	40402	0.9%
4	31082	0.7%
5	37581	0.9%
6	10063	0.2%
7	18763	0.4%
Don't Know	443834	10.3%
Refused	273860	6.4%
Total	4289241	100.0%

As summarized in Table 70, for those who did use a bicycle in the week prior to their travel day, 23 percent used on-road bike lanes, 22 percent used on and off-road bike lanes and trails, while 10 percent used off-road trails.

Table 70: Bike Lanes/Trails Used (Weighted)

Bike Lanes/Trails Used for Non-Recreational Purposes	Count	Percent
Off-Road	443132	10.3%
On-Road	965122	22.5%
Both	945162	22.0%
Don't Know	1511407	35.2%
Refused	424418	9.9%
Total	4289241	100.0%

The majority of respondents (90 percent) reported that they did not use the Internet in place of making a shopping trip on their travel day; only 5 percent of respondents replaced a trip by shopping on the Internet. See Table 71 for more information on internet use in place of travel.

Table 71: Internet was Used on Travel Day in Place of Trips (Weighted)

Internet was used on Travel Day in Place of Trips	Count	Percent
Yes	324959	5.0%
No	5791581	89.5%
Don't Know	335795	5.2%
Refused	18284	0.3%
Total	6470619	100.0%

As Table 72 presents, for those respondents who reported not traveling on their travel day, 30 percent did not travel because they worked around their home (not for pay), 15 percent reported being sick, while 14 percent are homebound, elderly, or disabled. An additional 6 percent worked at home for pay on their travel day.

Table 72: Reason for Non-Travel (Weighted)

Reason for Non-Travel	Count	Percent
Personally Sick	125232	14.9%
Caretaking Sick Kids	10057	1.2%
Caretaking Sick Other	7847	0.9%
Homebound Elderly or Disabled	114131	13.6%
Worked at Home for Pay	47366	5.7%
Worked Around Home (Not for Pay)	251283	30.0%
Out of Area	47736	5.7%
Other	234034	27.9%
Total	837685	100.0%

Vehicle Characteristics

About half of all reported vehicles (49.6 percent) had a vehicle year between 2000 and 2006, as shown in Table 73.

Table 73: Vehicle Year (Weighted)

Vehicle Year	Count	Percent
1964 or older	9631	.2%
1965-1979	29936	.7%
1980-1989	63802	1.6%
1990-1999	735118	18.1%
2000-2003	1046962	25.7%
2004-2006	972548	23.9%
2007	305702	7.5%
2008	276134	6.8%
2009	233884	5.7%
2010	246766	6.1%
2011	57478	1.4%
Refused	92377	2.3%
Total	4070336	100.0%

Regarding the make of respondent vehicles, the most commonly reported vehicle make is Toyota (18 percent), followed by Honda (12 percent), and Ford (11 percent). See Table 74 for more detail on common vehicle makes.

Table 74: Vehicle Make (Weighted)

Vehicle Make	Count	Percent
Acura	55192	1.4%
Audi	40547	1.0%
BMW	67785	1.7%
Buick	79825	2.0%
Cadillac	31564	0.8%
Chevrolet	296379	7.3%
Chrysler	88366	2.2%
Dodge	164591	4.0%
Ford	443006	10.9%
Geo	5616	0.1%
GMC	60582	1.5%
Harley Davidson	33874	0.8%
Honda	499071	12.3%

Vehicle Make	Count	Percent
Hummer	1395	0.0%
Hyundai	109202	2.7%
Infiniti	20373	0.5%
Isuzu	7156	0.2%
Jaguar	5014	0.1%
Jeep	109549	2.7%
Kawasaki	8146	0.2%
Kia	40954	1.0%
Lexus	56970	1.4%
Lincoln	24302	0.6%
Mazda	74969	1.8%
Mercedes	41741	1.0%
Mercury	67129	1.6%
Mitsubishi	23362	0.6%
Nissan	174456	4.3%
Oldsmobile	24029	0.6%
Plymouth	13622	0.3%
Pontiac	54672	1.3%
Porsche	7858	0.2%
Range Rover	2374	0.1%
Saab	39324	1.0%
Saturn	68176	1.7%
Scion	9055	0.2%
Subaru	168576	4.1%
Suzuki	13093	0.3%
Toyota	741929	18.2%
Volkswagen	105728	2.6%
Volvo	104612	2.6%
Yamaha	10728	0.3%
Other	48892	1.2%
Don't Know	19476	0.5%
Refused	7078	0.2%
Total	4070336	100.0%

Displayed in Table 75 regarding vehicle body type, over half of all respondent vehicles (53 percent) were reported as being a car/station wagon, 23 percent were reported as being a SUV, followed by van (any type) and pickup truck (both at 9 percent), and motorcycle (2 percent).

Table 75: Vehicle Body Type (Weighted)

Vehicle Body Type	Count	Percent
Car/Station Wagon	2144300	52.7%
Van (any type)	344912	8.5%
SUV	926701	22.8%
Pickup Truck	352083	8.6%
Other type of truck	7429	0.2%
RV	5196	0.1%
Motorcycle	67313	1.7%
Other, specify	7025	0.2%
Refused	215378	5.3%
Total	4070336	100.0%

Table 76 presents distribution of vehicle fuel type. The vast majority of all respondent vehicles (97 percent) run using traditional gasoline; 2 percent of respondent vehicles are hybrid vehicles, while 1 percent use diesel fuel.

Table 76: Vehicle Fuel Type (Weighted)

Vehicle Fuel Type	Count	Percent
Gas	3935927	96.7%
Diesel	40423	1.0%
Hybrid	76789	1.9%
Flex Fuel	9101	0.2%
Other, specify	1893	0.0%
Don't Know	2846	0.1%
Refused	3357	0.1%
Total	4070336	100.0%

Place Characteristics

Overall, 43 percent of all trips made were to return home for non-work-related activities, shown in Table 77. Other frequently reported reasons for traveling included change mode of transportation (12 percent), work/job (8 percent), and routine shopping (7 percent).

Table 77: Primary Trip Purpose (Weighted)

Primary Trip Purpose	Count	Percent
All other home activities	14160381	42.8%
Changed type of transportation	3958467	12.0%
Work/Job	2498750	7.6%
Routine shopping (groceries, clothing, convenience store, HH maintenance)	2153878	6.5%
Attending Class	1092376	3.3%
Eat meal outside of home	1027752	3.1%
Visit friends/relatives	962137	2.9%
Drop off passenger from car	948537	2.9%
Pick up passenger from car	825329	2.5%
Household errands (bank, dry cleaning, etc.)	818617	2.5%
Indoor recreation/entertainment	813596	2.5%
Work Business Related	759734	2.3%
Personal business (visit government office, attorney, accountant)	694983	2.1%
Health care (doctor, dentist)	587056	1.8%
Outdoor recreation/entertainment	543700	1.6%
Service private vehicle (gas, oil lube, etc.)	296377	0.9%
Working at home (for pay)	262083	0.8%
Civic/Religious activities	203042	0.6%
Shopping for major purchases or specialty items (appliance, electronics, new vehicle, major HH repairs)	161818	0.5%
All other School Activities	111917	0.3%
All other activities at work	83827	0.3%
Loop trip	79280	0.2%
Other, specify	25371	0.1%
Volunteer Work/Activities	5483	0.0%
While Traveling -- Other, Specify	0	0.0%
Total	33074491	100.0%

Summarized in Table 78, the majority of trips (59 percent) were made with only one person in the travel party; 25 percent of trips were made with two people in the travel party, and another 10 percent of trips were made with three people in the travel party.

Table 78: Total People Traveling in Travel Party, Including Respondent (Weighted)

Total People Traveling	Count	Percent
1 person	15230786	59.2%
2 persons	6342061	24.6%
3 persons	2615175	10.2%
4 persons	1022344	4.0%
5 persons	534009	2.1%
Total	25744375	100.0%

Table 79 indicates that at 45 percent of all places visited where the respondent drove a personal vehicle, respondents parked in a parking lot, while a driveway/personal garage was used at 34 percent of all places reported.

Table 79: Parking Location (Weighted)

Parking Location	Count	Percent
Parking Lot	8183180	44.8%
Parking Garage	365947	2.0%
Street	1688269	9.2%
Driveway/personal garage	6175911	33.8%
Did not park	1627338	8.9%
Other, specify	44063	0.2%
Don't Know	143450	0.8%
Refused	24242	0.1%
Total	18252400	100.0%

For the majority of places visited in a personal vehicle (89 percent), Table 80 indicates that respondents were not required to pay for parking.

Table 80: Paid to Park (Weighted)

Paid to Park	Count	Percent
Did not Pay	16249013	89.0%
Did Pay, record amount	287449	1.6%
Don't Know	92194	0.5%
Refused	1623744	8.9%
Total	18252400	100.0%

For those who paid to park, 76 percent paid for parking via cash/credit/debit card, 18 percent paid with a pre-paid parking pass, while 6 percent paid using an employer-provided parking pass. See Table 81 for more detail on how parking fares were paid.

Table 81: How Parking Fare was Paid (Weighted)

How Parking Fare was Paid	Count	Percent
Cash/Credit/Debit Card	218889	76.1%
Pre-Paid parking Pass	50840	17.7%
Employer-Provided Parking Pass	16391	5.7%
Don't Know	74	0.0%
Refused	1254	0.4%
Total	287449	100.0%

As shown in Table 82, for the majority of trips (96 percent), a toll road was not used.

Table 82: Toll Road Used on Trip (Weighted)

Use a Toll Road	Count	Percent
Yes	288635	1.6%
No	17533685	96.1%
Don't Know	405083	2.2%
Refused	24996	0.1%
Total	18252400	100.0%

For those who did use a toll road on their trip, Table 83 summarizes that the majority (87 percent) used the Massachusetts Turnpike; in addition, 6 percent used the Tobin Bridge, 4 percent used the Sumner Tunnel, and 3 percent used the Ted Williams Tunnel.

Table 83: Toll Road Used (Weighted)

Which Toll Road was Used	Count	Percent
Massachusetts Turnpike	250114	86.7%
Ted Williams Tunnel	8760	3.0%
Sumner Tunnel	11310	3.9%
Tobin Bridge	18451	6.4%
Total	288635	100.0%

Travel Behavior

The purpose of this section is to review the travel behavior reported by the 15,033 participating households in order to document the extent to which the travel behavior does vary. This section includes summaries of trip rates by the different household and person characteristics in the total study area. As is shown in Table 84, the overall trip rate by household is 10.2 trips, whereas the overall trip rate per person is 4.1 trips.

Table 84: Average Household and Person Trip Rates (Weighted)

	Average Trip Rate
Household	10.2
Person	4.1

As one may expect, the larger the household, the more trips they report. This trend is summarized in Table 85. The larger households (8 or more members) reported the highest trip rate—29.8. One-person households reported 4.5 trips, two-person households reported 8.3 trips, three-person households reported 13.6 trips, four-person households reported 17.5 trips, five-person households reported 22.2 trips, while six-person households reported 26.6 trips. Finally, seven-person households reported 24.8 trips.

Table 85: Trip Rates by Household Size (Weighted)

Household Size	Trip Rate
1	4.5
2	8.3
3	13.6
4	17.5
5	22.2
6	26.6
7	24.8
8 or more	29.8
Total	10.2

Households with five workers reported the highest trip rate, at 27.2. Similar to the correlation between household size and trip rates, Table 86 reveals that the fewer the household workers, the fewer the trips that households report. In this case, households with no workers made the fewest trips (6.6), households with one worker made 9.7 trips, households with two workers make 13.1 trips, and households with three workers make 16.8 trips, while household with four workers made 22 trips. Conversely, households with the most workers (six) did not make the most trips, rather they made 22.7 trips.

Table 86: Trip Rates by Number of Household Workers (Weighted)

Household Workers	Trip Rate
0	6.6
1	9.7
2	13.1
3	16.8
4	22.0
5	27.2
6	22.7
Total	10.2

Table 87 shows trip rates by household income. Overall, higher-income households reported more trips than lower-income households. For example, households with an annual income of $150,000 or more made the most trips (13.3), followed closely by households within the $100,000–$149,999 range at 13.2 trips. Households in the lowest income category (less than $15,000) reported the fewest trips, 8.3.

Table 87: Trip Rates by Household Income (Weighted)

Household Income	Trip Rate
Less than $15,000	8.3
$15,000-$24,999	9.2
$25,000-$34,999	8.4
$35,000-$49,999	9.4
$50,000-$74,999	10.2
$75,000-$99,999	11.4
$100,000-$149,999	13.2
$150,000 or more	13.3
Don't Know/Refused	9.8
Total	10.2

Of all trips, half were reported as being made by auto/van/truck driver, 19 percent were reported as walk trips, while another 19 percent were reported as being made as an auto/van/truck passenger. Nearly 8 percent of trips were made via transit and 3 percent made by school bus. See Table 88 for more information on travel mode.

Table 88: All Trip Modes (Weighted)

Transportation Mode	Count	Percent
Walk	5044082	19.0%
Bike	292894	1.1%
Auto/Van/Truck Driver	13207297	49.6%
Auto/Van/Truck Passenger	5029508	18.9%
Public Bus	951866	3.6%
Train	1053782	4.0%
Ferry/boat	14539	0.1%
Dial-A-Ride/Paratransit	66570	0.3%
Taxi	107497	0.4%
School bus	752930	2.8%
Motorcycle Driver	14314	0.1%
Motorcycle Passenger	1281	0.0%
Other, SPECIFY	68242	0.3%
Total	26604802	100.0%

Table 89 summarizes mode to work information. For those trips made to work, 68 percent were reported as being made by auto/van/truck driver, 13 percent were reported as being made by bus/public transit, 5 percent were reported as walk trips, while 4 percent were reported as being made as an auto/van/truck passenger. Seven percent of those who work do so from home and therefore require no transportation.

Table 89: Mode to Work (Weighted)

Mode to Work	Count	Percent
Works from home	211178	6.5%
Walk	153289	4.8%
Bike	55937	1.7%
Auto/Van/Truck Driver	2196773	68.1%
Auto/Van/Truck Passenger	122804	3.8%
Bus / Public Transit	405145	12.6%
Dial-A-Ride/Paratransit	4025	0.1%
Taxi	6149	0.2%
Motorcycle Driver	1592	0.0%
Motorcycle Passenger	181	0.0%
Other, SPECIFY	51416	1.6%
Don't Know	10208	0.3%
Refused	5904	0.2%
Total	3224601	100.0%

Table 90 summarizes typical mode to school. For those trips made to school, 30 percent were reported as being made via school bus, 28 percent were reported as being made as an auto/van/truck passenger, 15 percent were reported as being made by auto/van/truck driver, while 12 percent of trips were reported as walk trips.

Table 90: Mode to School (Weighted)

Mode to School	Count	Percent
Home schooled	44231	2.4%
Walk	230441	12.4%
Bike	21235	1.1%
Auto/Van/Truck Driver	271077	14.6%
Auto/Van/Truck Passenger	520597	28.1%
Bus / Public Transit	168672	9.1%
Dial-A-Ride/Paratransit	1887	0.1%
Taxi	749	0.0%
School Bus	550310	29.7%
Motorcycle Driver	216	0.0%
Other, SPECIFY	25972	1.4%
Don't Know	18637	1.0%
Refused	1568	0.1%
Total	1855592	100.0%

Respondents were asked to record the arrival and departure times for all locations visited during their designated 24-hour travel period, as summarized in Table 91. All travel days began at 3:00 a.m. and ended at 2:59 a.m. the following day. As shown in Table 91, travel in the state peaks in the afternoon (p.m. peak), with 32 percent of trips made at this time; 30 percent of trips are made during mid-day, while 26 percent of trips are made during the a.m. peak.

Table 91: Trip Departure Times (Weighted)

Trip Departure Time	Count	Percent
AM Peak (6:00 a.m. to 9:59 a.m.)	6868633	25.8%
Mid-Day (10 a.m. to 2:59 p.m.)	7986897	30.0%
PM Peak (3:00 p.m. to 6:59 p.m.)	8490535	31.9%
Evening (7:00 p.m. to 10:59 p.m.)	2725689	10.2%
Late Night / Early Morning (11 p.m. to 5:59 a.m.)	533048	2.0%
Total	26604802	100.0%