University of Vermont

ScholarWorks @ UVM

Transportation Research Center Research Reports

6-20-2015

Modeling Travel Choices to Assess Potential Greenhouse Gas Emissions Reductions

Jonathan Dowds
University of Vermont, jdowds@uvm.edu

Brian Lee
University of Vermont

Lisa Aultman-Hall
University of Vermont

Richard Nam
University of Vermont

Alyssa Johnson
University of Vermont

Follow this and additional works at: https://scholarworks.uvm.edu/trc

Recommended Citation

Dowds, Jonathan; Lee, Brian; Aultman-Hall, Lisa; Nam, Richard; and Johnson, Alyssa, "Modeling Travel Choices to Assess Potential Greenhouse Gas Emissions Reductions" (2015). *Transportation Research Center Research Reports*. 193.
https://scholarworks.uvm.edu/trc/193

This Report is brought to you for free and open access by ScholarWorks @ UVM. It has been accepted for inclusion in Transportation Research Center Research Reports by an authorized administrator of ScholarWorks @ UVM. For more information, please contact donna.omalley@uvm.edu.

A Report from the University of Vermont Transportation Research Center

Modeling Travel Choices to Assess Potential Greenhouse Gas Emissions Reductions

TRC Report 13-001

Nam, Dowds, Lee, Aultman-Hall, Johnson

Modeling Travel Choices to Assess Potential Greenhouse Gas Emissions Reductions

UVM Transportation Research Center

Report 13-001

June 20, 2015

Prepared by:

Richard Nam, Graduate Research Assistant

Jonathan Dowds, Research Specialist, Transportation Research Center

Brian H. Y. Lee, Assistant Professor, Transportation Research Center & School of Engineering

Lisa Aultman-Hall, Professor, Transportation Research Center & School of Engineering

Alyssa Johnson, Undergraduate Research Assistant

Transportation Research Center
Farrell Hall
210 Colchester Ave
Burlington, VT 05405

Phone: (802) 656-1312
Website: http://www.uvm.edu/trc

Table of Contents

Acknowledgments

This research was funded by the United States Department of Transportation through the University Transportation Center program at the University of Vermont. Work summarized in this report benefited from the travel survey expertise of Resource Systems Groups (RSG Inc.). Project conception originated with Matthew Coogan and contributions by Thomas Adler and others is gratefully acknowledged. Additional funding from provided for this study to the New England Transportation Institute (NETI) from the Green Mountain Coffee Roasters.

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the US DOT or the UVM Transportation Research Center. This report does not constitute a standard, specification, or regulation.

1. Introduction

The transportation sector is the source of approximately 27% of total U.S. greenhouse gas (GHG) emissions (EPA, 2015), and these emissions are projected to increase in the future (NHTSA, 2011). Given the potentially severe impacts of climate change, policy makers are looking at methods to reduce GHG emissions from all transportation sources. Three broad approaches have been identified to reduce passenger vehicle emissions: improving vehicle technology to increase fuel efficiency, switching to low or no carbon fuels, and changing travel choices such as mode and vehicle choice, destination and trip chaining choices, and vehicle occupancy rates. Changes in these behaviors can lead to reductions in overall GHG emissions through reductions in vehicle miles traveled (VMT) and GHG intensity per passenger mile of travel.

While improved vehicle and alternative fuel technologies offer considerable promise for GHG reductions, these technologies take years or decades to penetrate the market at significant rates and may have unforeseen consequences that reduces the GHG benefits that they provide. In contrast, many changes in travel behavior are feasible with the current vehicle fleet and thus could potentially be implemented immediately. Travel behavior refers to the choices that individuals and households make to meet their travel needs and it includes destination choices, trip chaining choices, and the methods that individuals select to transport themselves from one location to another. Transport methods encompass travel group size, as well as mode and route choices. Cumulatively, travel choices determine total VMT, the fuel consumed to travel those miles, and the resultant GHG emissions. This report summarizes a set of projects that examine different aspects of travel behavior that influence fuel consumption and GHG emissions.

Two of these projects, described in Sections 2 and 3, examined how households choose to allocate vehicles among drivers and the potential for alternative vehicle allocations among household members to reduce fuel consumption. These two projects drew on data from the National Household Travel Survey (NHTS) to estimate the potential fuel savings from intra-household vehicle reallocations that ensure that the relative usage of each vehicle in the household corresponds to that vehicle's relative fuel efficiency among all vehicles in the household. In Section 2, this analysis assumes that all vehicles can be substituted for one another regardless of their passenger and cargo capacities. Section 3 builds on this analysis by limiting potential reallocation to vehicles with similar passenger and cargo capacities. Section 4 of this report describes the execution the Northeast Travel Choice Survey (NTCS), which asked respondents a range of questions related to travel behavior, demographics, vehicle ownership, as well as about commute, home and work location characteristics. The results of the NTCS provided the basis for the final two projects summarized in this report. One of these projects, described in Section 5, examined the commuters' willingness to use ridesharing, one method for reducing overall VMT. Section 6 describes an analysis of the impact of workplace and commute-corridor accessibility on annual VMT. Finally, additional exploratory analysis of the factors related to vehicle choice from the NTCS are included in Appendix E and descriptive statistics for survey data collected specifically with employees of the Green Mountain Coffee Roasters (GMCR) is provided in Appendix F.

Collectively, these projects support the idea that travel choices have an important role to play in GHG reductions. As discussed in Section 2, something as simple as reallocating household vehicles so that more fuel efficient vehicles are used more frequently can result in significant fuel consumption and GHG emissions reductions. Ridesharing, which increases vehicle occupancy rates, may be a desirable commute mode for many individuals if the option to drive alone is restricted. Destination accessibility at the home, at the worksite and along the commute corridor all influence annual VMT. The projects also indicate that additional research is needed to fully understand what factors drive the travel choices that individuals make as the models presented here explain only a relative small proportion of the variability in travel choices. Without a better understanding of behavioral factors, policy interventions geared toward changing behavior are less likely to be effective. Continued refinement and expansion of travel behavior data collection efforts will be needed to support research in this vein.

2. Optimizing Intra-household Vehicle Allocation by Fuel Economy

This section summarizes the work published in:

Nam, R., Lee, B. H. Y., Aultman-Hall, L., and Sears, J., (2013). Allocation of Household Motorized Vehicles: Exploration with the 2009 National Household Travel Survey. *Transportation Research Record.* No. 2382, 63-73.

Reallocating household vehicles such that the annual VMT of each vehicle corresponds to that vehicle's fuel efficiency (e.g. that vehicle with the highest VMT is the most fuel efficient vehicle in the household) is a reasonable short-term action to reduce fuel use and GHG emissions. This study analyzed households in the 2009 NHTS to determine whether a household had an optimized household fleet (OHF), was a high-potential saver (HPS) that could save at least 50 gallons of fuel by vehicle reallocation, and estimated the total fuel saving that could be realized by intra-household vehicle reallocation. Regression models were used to examine predictors of OHF and HPS households as well as the potential gallons saved (PGS) by vehicle reallocation. Modeling was conducted at the national and regional level. Two major assumptions were made for this study – that all household vehicles were substitutable for one another and that each vehicle was used by only one driver.

Within the NHTS sample, approximately 41% of households with two or more vehicles had an OHF. The remaining 59% of households showed the potential to reduce fuel use by 5.2% through household vehicle reallocation. Figure 1 shows the PGS among NHTS households. On a national scale, this would equate to approximately 5 billion gallons of avoided fuel use. Among households at least two vehicles, 31% were classified as HPS.

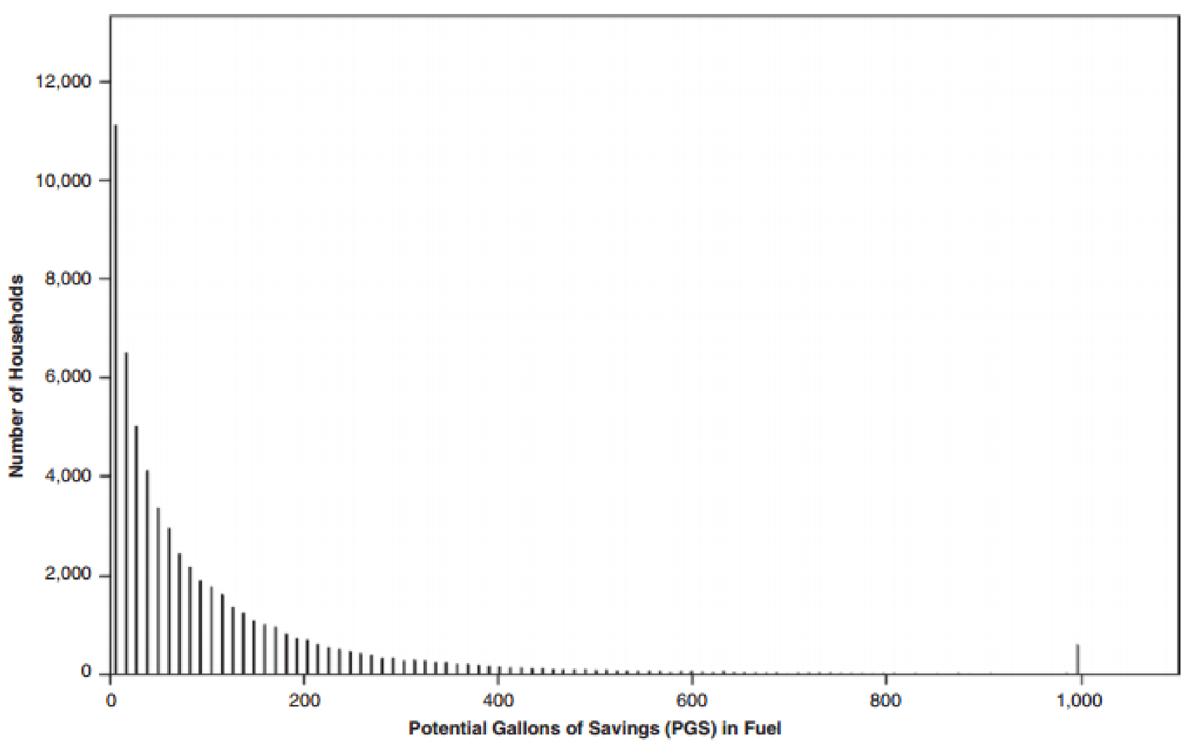

Figure 1. Potential fuel savings from intra-household vehicle reallocation (in gallons)

Household size and life-cycle, travel behavior, and fleet composition were significant predicts of optimized household vehicle allocations. Similar variables were significant predictors of potential gallons of savings and whether or not a household was an HPS. These models were consistent across regions with minor exceptions with rural areas exhibiting differences from more urban areas.

This study demonstrated that appreciable savings in fuel consumption and associated GHG emissions are plausible through vehicle reallocation, and the ability to pursue this countermeasure in the short-term motivates further research to provide fuller understanding of the causal mechanisms and target households for intervention.

3. Optimizing Intra-household Vehicle Allocation among Vehicles of Similar Types

One major assumption of the work summarized in Section 2, was that vehicles could be reallocated without consideration of seating capacity and cargo space. Due to the variability in these and other vehicle attributes, reallocation of household vehicles may not always be feasible. In this section, this issue is addressed by isolating a subset of the NHTS households with two drivers and two vehicles of similar types. The purpose of modeling this subset is to examine the environment in which the reallocation of vehicles is most feasible. In addition, the analysis presented here further segments these households based on vehicles type (automobiles, vans, sport utility vehicles, and trucks). The methods and study variables used here replicate to those found in the Section 2 in order to provide a consistent basis for a comparison between the two sets of results.

3.1. Data

The households selected for this analysis consisted of the subset of NHTS households with two drivers and two vehicles of the same vehicle type. Vehicle types that were used in this analysis include automobiles, vans, SUVs, and trucks. In total, 15,562 households met these criteria. This subset included 12,132 households with two automobiles, 386 with two vans, 2,390 with two SUVs, and 654 with two trucks.

When comparing descriptive statistics of the households in this subset to the larger national sample, a number of variables differed. Households that only owned SUVs had, on average, higher incomes and lower average household age than other households. In addition, these households drove more miles than households with other vehicle types in their fleet. Not surprisingly, households with vans were found to have a larger number of members in the home. Van only households also had a higher number of trips in the day travel diary than other households. The percent of households with a graduate school education was consistent with national percentages, except for fleets with only trucks. Only 5% of truck only households had at least one person with a graduate degree. This percent is much smaller than those found in other households, which ranged from 25% to 35%. Further, households with a fleet comprised of trucks spent a higher percent of their income on fuel. Rural households made up a larger percent of household with trucks. The percent of OHF households is consistent throughout all four vehicle types. Potential gallons saved (PGS), while consistent in its value, was lower than the national average for all four vehicle segments. Similarly, the percent of households that were classified as high potential savers was lower than the national average. Table 1provides more detailed information on these comparisons.

Table 1 Descriptive Statistics –Two Vehicle, Two Driver Households, by Vehicle Type

			Vehicle Fleet Type			
		National	Automobile	Van	SUV	Truck
Income (dollars)	Mean	65,500	$65,085	$52,401	$78,026	$50,183
	Median	52,500	$67,500	$47,500	$90,000	$47,500
Household Size	Mean	2.6	2.3	3.2	2.7	2.4
	Median	2	2.0	2.0	2.0	2.0
Average HH Age	Mean	54	56	50	47	50
	Median	57	60	56	50	53
Annual VMT	Mean	28,147	20,925	22,669	25,670	23,351
	Median	19,078	18,750	20,064	23,364	20,565
Average Number of Trip per Day	Mean	9.65	8.5	10.7	9.8	7.5
	Median	7.0	8.0	9.0	9.0	6.0
Max Fuel Efficiency Difference in Fleet	Mean	7.6	5.7	3.0	4.1	3.3
	Median	4.4	3.7	1.9	3.3	2.1
Percent of HH with Graduate Education		25.0%	35.7%	35.3%	33.6%	5.2%
Percent of HH with Children Present		34%	19.0%	41.4%	40.0%	24.4%
Percent of Income Spent on Fuel		7.7%	5.1%	8.3%	5.8%	11.6%
Percent of HH in Rural Area		33%	17.8%	27.7%	26.7%	50.4%
Percent of HH with OHF		41%	54.1%	57.2%	54.8%	55.5%
PGS		75	20.0	21.4	30.3	31.6
Percent of HH that are a HPS		31%	11.1%	11.1%	17.8%	14.6%
N		129,184	11,527	386	2,237	582

3.2. Methods

The methods used here replicate those in Section 2. Households were modeled to determine their likelihood of fleet optimization, potential gallons savings, and HPS designation. A logistic regression is used to model OHF, an OLS linear regression is used for modeling PGS, and a logistic regression is used to model HPS. Model fit is determined using a pseudo McFadden r-square, r-square, and pseudo McFadden r-square, respectively. The set of three regressions were repeated for each vehicle type category. Van and SUV households were aggregated to create a single category due to the small number of households in the van category. While there may be small differences between vehicle types their general purpose is considered similar in this analysis. Both provide households with vehicles with large enclosed spaces. The aggregated segments represent households with vehicles that provide a high level of seating capacity and cargo space. The following results use the aggregation of vans and SUVs into a single category.

3.3. Results

The results of the three regressions models are shown in Table 2 through Table 4. Table 2 details the likelihood of a household to optimize its fleet. Table 3 gives the results from a linear regression modeling potential gallons savings. Lastly, Table 4 shows the results from the regression that models the likelihood of a household to be classified as an HPS. Note that results using the new subset do not include all variables listed in the national analysis. Vehicle count and driver count variables were removed since all households in the subset have both two drivers and two vehicles.

Table 2 Model One – Optimized Household Fleet, Logit Regression – by Vehicle Type

Segment	National	Automobile	Van & SUV	Truck
Model ID	C1-0	C1-a	C1-vs	C1-t
Model Type	Binomial Logistic	Binomial Logistic	Binomial Logistic	Binomial Logistic
N	78,899	9,178	2,312	425
McFadden's R^2	0.0893	0.054	0.126	0.182
	Estimate(t-stat)	Estimate(t-stat)	Estimate(t-stat)	Estimate(t-stat)
AVEAGE	-0.0123(-473)	-0.00384(-60.9)	-0.00935(-55.9)	-0.0164(34.1)
LOGINC	-0.0414(-57.9)	0.0993(52.2)	-0.5473(92.7)	0.0532(4.54)
HHSIZE	-0.0739(-158)	-0.0737(-38.5)	-0.4268(136)	0.1691(15.9)
GRAD	-0.0518(-72)	-0.1035(-54.1)	-0.3504(89.3)	0.2454(8.52)
FUELEXP	-0.904(-1312)	-2.4384(-537)	-2.8621(371)	-2.2459(124)
FELPER	0.148(39.6)	0.3125(26.2)	-1.963(41.5)	0.4357(8.802)
VEHAGEDIF	-0.0146(-310)	0.0406(208)	-0.0149(30.7)	-0.0109(16.7)
AVEMPG	-0.0439(-562)	-0.1114(-375)	-0.3438(312)	-0.516(152)
AVEGAS	1.04(432)	2.1023(287)	3.3494(206)	4.0464(100)
TPOCCM	0.146(386)	0.1243(97.8)	0.0894(49.6)	-0.1598(21.8)
TRSTPS	0.149(251)	-0.00751(-4.31)	-0.3494(95.4)	-0.2122(24.2)
TRTIM	-0.000750(-106)	0.000396(15.2)	-0.00091(18.5)	-0.00185(11.4)
ANNUAL_VMT	0.0679(780)	0.2367(468)	0.454(375)	0.2423(86.2)
VMTHH	0.0572(560)	0.0305(53.2)	-0.1178(105)	0.287(93.4)
HHBKTP	0.0228(253)	0.013(35.2)	0.0569(94.6)	0.03(30.2)
HHWWTP	-0.00193(-83.9)	0.000374	-0.00613(-37.3)	0.0117(35.5)
INTPUR	-0.00697(-145)	0.00703	0.00718(35.5)	-0.0242(-13.9)
NUMT	-0.0147(-267)	-0.0119	-0.0165(52.38)	0.016(13.9)
RURAL	0.117(164)	0.00493	0.071(17.2)	-0.7313(74.09)
VPERD	-0.522(-616)			
TRUCKINHH	0.0719(104)			

Table 3 Model Two – Potential Gallons Savings, OLS Regression – by Vehicle Type

Segment	National	Automobile	Van & SUV	Truck
Model ID	C2-0	C2-a	C2-vs	C2-t
Model Type	OLS	OLS	OLS	OLS
N	52,687	4,706	1,093	249
R^2	0.217	0.132	0.155	0.208
	Estimate(t-stat)	Estimate(t-stat)	Estimate(t-stat)	Estimate(t-stat)
AVEAGE	-0.00209(-3.85)	-0.00304(-1.908)	-0.0003(0.0650)	0.00772(1.04)
LOGINC	-0.0782(-6.67)	-0.0308(-0759)	-0.06233(0.622)	0.0527(0.437)
HHSIZE	0.0369(4.17)	0.255(5.66)	0.354(4.89)	-0.353(1.705)
GRAD	0.0327(2.04)	-0.0364(0.716)	-0.217(2.098)	0.162(0.248)
FUELEXP	0.177(38.2)	0.239(4.42)	0.322(3.49)	0.628(3.63)
VEHAAGE	0.00587(4.03)	0.0142(2.508)	-0.0891(5.81)	0.0693(3.78)
AVEGAS	-0.107(-2.09)	-0.243(1.39)	-1.08(2.58)	-1.86(2.69)
TRTIM	0.000297(2.12)	0.000499(0.841)	-0.00387(3.02)	0.00162(0.466)
ANNUAL_VMT	-0.00031(-0.347)	-0.03107(3.92)	-0.0586(3.14)	-0.0244(0.627)
VMTHH	0.00751(4.73)	0.115(8.49)	0.118(4.50)	-0.0937(-1.72)
RURAL	-0.115(-7.65)	-0.1104(1.61)	0.2707(2.4003)	-0.117(0.711)
TRUCKINHH	-0.0390(-2.55)			
HHVEHCNT	0.0986(13.8)			
AUTO	-0.604(-30.1)			

Table 4 Model Three – High Potential Savers, Logit Regression – by Vehicle Type

Segment	National	Automobile	Van & SUV	Truck
Model ID	C3-0	C3-a	C3-vs	C3-t
Model Type	Binomial Logistic	Binomial Logistic	Binomial Logistic	Binomial Logistic
N	79,010	9,187	2,313	428
McFadden's R^2	0.171	0.0762	0.0926	0.189
	Estimate(t-stat)	Estimate(t-stat)	Estimate(t-stat)	Estimate(t-stat)
AVEAGE	-0.000390(-14.4)	-0.00714(-72.8)	0.00299(14.1)	0.0184(31.8)
LOGINC	-0.149(-176)	-0.00871(-131)	0.00506(36.1)	-0.00834(22.7)
HOMEOWN	-0.087(-91.7)	-0.047(-15.0)	0.706(82.4)	-0.878(54.2)
GRAD	0.082(101)	0.132(43.5)	0.255(47.5)	-0.365(8.97)
FUELEXP	0.810(1540)	0.906(280)	0.747(166)	0.157(14.4)
FELPER	-0.557(-156)	-2.03(-79.06)	3.54(82.1)	-5.34(46.5)
VEHAAGE	-0.00567(-71.7)	0.00343(10.5)	0.111(117)	-0.0562(46.8)
TPOCCM	-0.0492(-122)	-0.0178(-10.3)	0.108(42.1)	-0.517(47.9)
TRDIS	-0.0004(-40.0)	-0.00464(-53.3)	-0.00618(31.2)	-0.0328(58.5)
TRSTPS	0.00696(10.8)	-0.0183(-7.06)	0.644	0.911(101)
ANNUAL_VMT	-0.0738(-1025)	-0.0704(-175)	-0.124(169)	0.0405(21.5)
VMTHH	0.00967(112)	0.0551(116)	0.0664(78.8)	-0.0476(21.9)
INTPUR	0.00629(125)	0.0184(80.7)	0.00878(33.1)	0.00896(4.66)
RURAL	-0.173(-221)	0.0703(19.2)	0.242(42.3)	0.819(66.1)
TRUCKINHH	-0.181(-230)			
HHVEHCNT	0.471(1032)			
AUTO	-0.298(-268)			
DRVRCNT	0.285(440)			

3.4. Discussion

The first set of regressions model households on their likelihood to allocate their vehicles in an optimal manner. Coefficients from average age, fuel expenditure, fleet fuel efficiency, fuel price, and annual VMT have the same signs to those found in the full national results. Note though, that the magnitude is much larger than full national values for variables fuel expenditure and fuel price. These larger coefficients may be due to the smaller differences in fuel efficiency within fleets of the same vehicle type.

Coefficients with inverse signs include income, household size, fuel expenditure, percent of income spent on fuel, difference in the number of years between the oldest and newest vehicle, trip occupancy, number of stops on tour, tour travel time, VMT per person, bike trips, walk trip, internet purchase, trip count, and households that reside in a rural area.

The change in these coefficients may be a result of households owning similar vehicles types. Households with larger incomes may also have a higher number of employed members. Since the average difference in fuel efficiency amongst vehicles in the fleet is less than the national average, along with the predominance of single occupancy travel during commute trips, the household may choose to minimize the fuel consumption by optimizing the fleet.

Estimates for trip occupancy for truck fleets were the inverse of those from other vehicle type categories. One explanation for this event may be the limited seating capacity of trucks. When households with only trucks in their fleet travel with high occupancy rates, the distances traveled by the household may increase. In addition, since the cost per trip, per person decreases, these households lower the priority of fleet optimization.

Rural households with only trucks in their fleet were less likely to optimize their fleet than rural households found in the national sample. This result may be attributed to the high percent of rural households found among fleets with only trucks. In addition, households with trucks are observed with lower VMT, compared to the national average. Since households in rural areas, on average, take fewer trips and those with trucks travel fewer miles annually, the optimization of a fleet with trucks may be less dependent on the built environment.

In the second set of regressions, households, by vehicle type, are modeled to determine what characteristics are related to potential gallons savings. Fuel expenditure had a significant positive relationship throughout the set of three regressions. Furthermore, the signs of the coefficients were similar to the one found in chapter 3. The estimates found in the regression were, though, higher than those found in the national analysis. The coefficients for the average fleet age were constant with national estimates, except for households with either a van or SUV in their fleet. In this category, the average age of the fleet had a negative relationship with PGS. One theory for this effect is that as fleets become newer, the overall fuel efficiency may become better. Therefore, households that have large vehicles (vans, SUVs) may be more likely to use them with no regard to potential gallons savings, since fuel consumption rates are relatively better. In addition, since vans and SUVs are likely to be used for trips with multiple occupants or large amounts of cargo, the amount of miles traveled may be higher, thus resulting in high PGS.

It should also be noted that the model two regressions for households with only trucks in their fleet had a sample size of 249. This may affect the relevance of the estimates in the model, though its model fit is denoted with an r-square value of 0.20. In addition, a number of insignificant variables were found in this regression. For the purposes of comparison they were kept in the model.

In the third set of regressions, households were modeled to determine their likelihood of association with the high potential savers classification. A logistic regression is used in this model. Fuel expenditure, income, tour distance, and internet purchases had similar coefficient signs to those found in the national results.

Parameter estimates that differed in comparison to national estimates include average household age, home owner, graduate degree, percent of income spent of fuel, average fleet age, trip occupancy, stops per tour, VMT per member, and rural households. The percent of income spent on fuel had a positive coefficient for households with a van or SUV in their fleet. This was an inverse effect of the result found in the national regression. One explanation may be due to the fuel efficiency of vans and SUVs. Households that spend a higher percent of their income on fuel may also be traveling more miles. Therefore, since these vehicles can be characterized as having lower fuel efficiency ratings, the probability of becoming categorized as a high potential saver increases.

One surprising result is the sign of the coefficients for households that reside in a rural area. In all three regressions, the sign is the inverse of the estimate found in the national results. Since consumption of fuel is a function of VMT and vehicle fuel efficiency, households that reside in a rural area may have to travel longer distance to reach their destination. Since the degree of difference between the fuel efficiencies of their vehicles is smaller than the national average, the combination of the two (longer distances and similar fuel consumption levels) may result in the rural household being more likely to fall into the high potential saver category.

Rural households also make up the highest percentage of households with fleets containing only trucks. In model one and three, the regressions for households with trucks were denoted with parameter estimates that differ from estimates from non-truck segments. In model one, trip occupancy and rural variables had the opposite effect of non-truck segments. In model three, graduate education, and annual VMT had inverse signs. Truck only households may also allocate their vehicles in a different manner due to their limited enclosed space.

3.5. Conclusion

In this analysis, the assumption of vehicle homogeneity is addressed. To control for the variability amongst vehicle types a subset sample of the NHTS is used. This subset includes households with two vehicles, two drivers, and a fleet comprised of a similar vehicle type. Furthermore, a market segmentation is completed in the analysis using the vehicle type found in the fleet.

Fuel expenditure, in all three sets of regression, had a similar sign to those found in the national analysis. Therefore, households with different fleet compositions, with respect to vehicle type, may factor fuel expenditure into their allocation scheme. Annual VMT had similar results, except for the parameter estimate found for truck fleets in model three. One reason for this departure may be due to the lower number of miles traveled by fleets with trucks. With the exception of this last regression, this variable may lead to a theory that while households with different fleet characteristics may allocate vehicles using a unique decision criterion, fuel expenditure and mile travelled are consistently included.

Among the market segmentations, the automobile category may have the largest variability, with regard to seating capacity and cargo space. Within the group, two and four door autos, along with station wagons are included. The result of the difference in vehicle ages for the OHF regression for this group (model C1-a) may signal the effect of the variation within this vehicle category. Households in this market were less likely to optimize their fleet if the age between vehicles increased. This is a departure from the national level results and those found in other vehicle type markets. The allocation scheme for automobile households may, therefore, not depend on the age of the vehicles or their corresponding fuel efficiency.

Rural households produce similar coefficients throughout all three markets in TABLE 20. These estimates were in contrast to the one found in the national analysis. There was an inverse effect found in the national analysis and should be explored further. One theory for this difference may be derived from the relatively similar fuel efficiency ratings found within the fleet of these households. By combining this average, with the high percent of rural households who travel more miles, the likelihood for a HPS event to occur increases. Another perspective is that rural households base their allocation on the variability in fuel efficiency of vehicles in the fleet. Since the national average of this difference was found to be higher, it may incentivize rural households to more optimally allocate their vehicles.

Truck only fleets also displayed estimates that differed from other segments. Due to the characteristics of the vehicle, these households may be allocating their trucks based on a different decision process. Further, the parameter estimates may be further compounded by the high percent of rural households found in this segmentation.

Further research into the variability among the automobile categories and truck only fleets may help better define the effect of vehicle characteristics in the intra-household vehicle allocation behavior. In addition, exploring the contribution of fuel expenditure and VMT may also add to the understanding of the intra-household vehicle allocation behavior.

4. The Northeast Travel Choice Survey

The Northeast Travel Choices Survey (NTCS) was sponsored the University of Vermont's Transportation Research Center (UVM TRC) and the New England Transportation Institute (NETI). It was conducted by Resource Systems Group, Inc. (RSG) in 2012. The goal of this survey was to provide data on the travel choices, behavior, and attitudes about travel to non-home workplaces in northern rural areas. The full NTCS questionnaire can be found in Appendix A.

The NTCS was administered in two waves to residents of Maine, New Hampshire, Vermont, and "upstate" New York as shown in Figure 2. The survey area did not include the Boston or New York City commuter sheds since travel behavior around major metropolitan areas can be expected to differ from that in more rural regions. The counties included in the NTCS study area are listed in Appendix B. The survey was administered separately to Vermont-based employees of Green Mountain Coffee Roasters (GMCR). A subset of the survey responses by GMCR employees are included in Appendix F. Table 5 summarizes the data collection for the two waves of resident surveys and the GMCR survey.

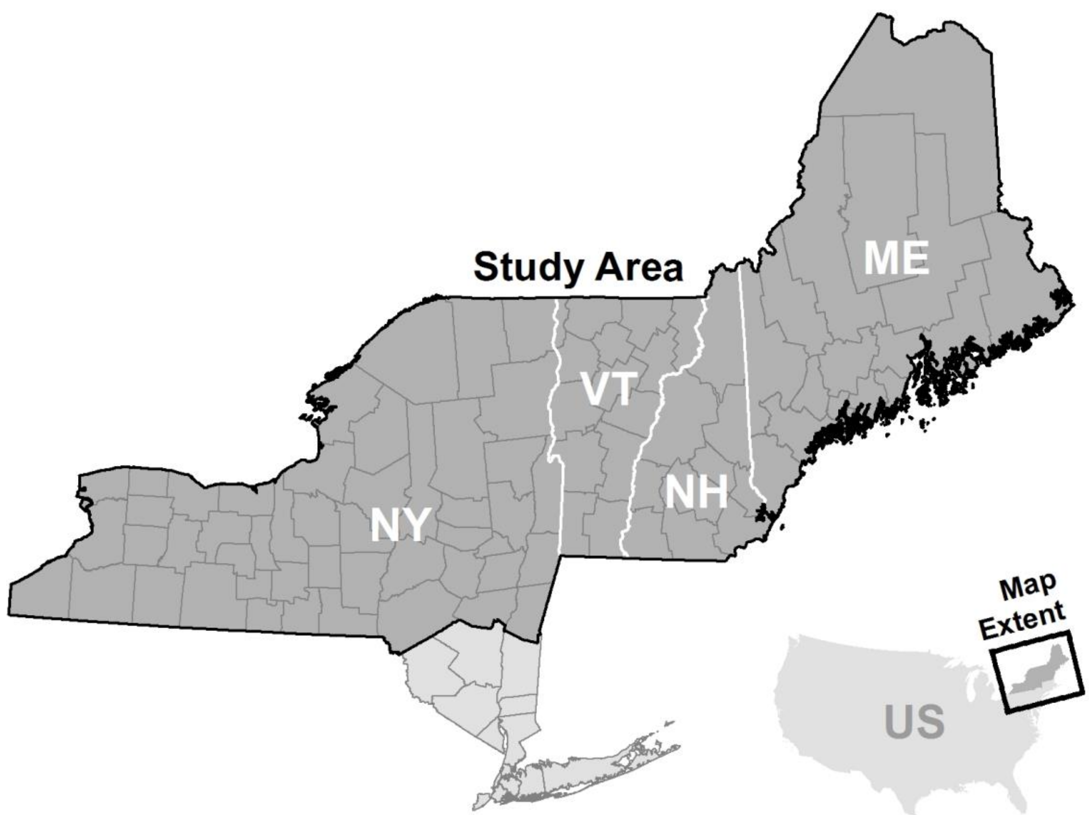

Figure 2. NTCS study area

Table 5 NTCS Administration Details

	Resident Survey		GMCR Survey
Wave	One	Two	n/a
Sample frame	Address Based Sample	Online Research Panel	Vermont-based GMCR employees
How respondents were contacted	First-class mail	Email from Research Panel	Email from GMCR contact
Study area	Residents from ME, NH, VT, or "upstate" NY	Residents from ME, NH, VT, or "upstate" NY	Primarily VT
Survey launch	12 July 2012	19 November 2012	14 August 2012
Survey close	16 August 2012	5 December 2012	30 August 2012
Completes	393	1444	459

For Wave One, the survey invitation was disseminated using address-based random sampling with the geographic strata to a total 20,000 potential respondents. Geographic stratification by state and county aimed to achieve a robust rural sample as well as a reasonable urban sample. Five thousand invitations were sent to each of the four states in the study area. Each urban county in the study area (defined as counties with a population density of at least 250 people per square mile) was targeted with twice as many invitations as the non-urban counties in the same state. This was intended to ensure that a reasonably-sized urban sample was obtained. This stratification, as opposed to a land area-based scheme, would allow for weighting using standard county-based Census data. Invitees received a pre-invitation postcard followed by an invitation letter that that described the survey, provided directions for how to complete the survey online or over the phone using a toll-free number, and notified potential respondents of the survey incentive (one iPad or three $100 Amazon gift cards).

Given the lower-than-expected response rate from wave one (2%), the project team decided to administer the survey again in the fall of 2012 using a new recruitment method. Members of an online panel, maintained by ResearchNow, were invited to participate in the same survey. This effort was entirely electronic and covered the same study area states as Wave One but did not include any stratification at the sub state level.

At the conclusion of Wave Two data collection, Wave One and Wave Two were merged. The online research panel data for quality, which involved removing 118 respondents for either speeding through the survey or "straight-lining" (e.g. select "somewhat agree" for all attitude questions). An additional 41 individuals were removed from the sample because they indicated a home location outside the four-state study area and one respondent was dropped for providing inconsistent answers. The final sample sizes for Waves One and Two are summarized in Table 6.

Table 6 NTCS Sample Details

Wave	One	Two
Sample frame	Address-based sample	Online research panel
Contact method	First-class mail	Email from research panel
Study area	ME, NH, VT, and "Upstate" NY	ME, NH, VT, and "Upstate" NY
Survey launch	12 July 2012	19 November 2012
Survey close	16 August 2012	5 December 2012
Total participants (1795)	392	1403
Maine	81	405
New Hampshire	97	377
New York	79	389
Vermont	135	232

In addition, all Vermont-based GMCR employees were invited to participate in the GMCR survey. This included employees at the four primary locations within Vermont: South Burlington, Waterbury, Essex, and Williston. A vice president at GMCR was responsible for emailing survey invitations to employees. This invitation email contained a hyperlink to participate in the online survey.

After the conclusion of the survey, a range of built environmental variables were calculated around the home and work locations of Wave One and Wave two respondents. These built environment variables include various measures of residential and retail density, road mileage and Rural-Urban Commuting Area codes (RUCA2) and were calculated in ArcGIS. These types of variables have been shown to impact mode choice and VMT. A table with a complete set of the built environment variables calculated for NTCS respondents can be found in Appendix C.

5. Rideshare Potential in Non-metropolitan areas of the Northeast

This chapter summarizes the work published in:

Lee, B. H. Y., L. Aultman-Hall, M. A. Coogan, & T. J. Adler. (forthcoming) Rideshare Mode Potential in Non-metropolitan Areas of the Northeastern United States. *Journal of Transport and Land Use*.

This study focused on the potential for rideshare as a commute mode in the four-state NTCS study area. A better understanding of topics related to work travel choices, behavior, and attitudes in northern non-metropolitan and rural areas is needed to inform the design of more sustainable transportation systems in the non-metropolitan context where longer distances create challenges for frequent biking and walking, and lower land use density creates challenges for transit services. Three discrete choice models were created and the results of these model are summarized in Table 7. Model One examined factors related to current rideshare commuters. Model Two investigated factors related to potential rideshare commuters (individuals who indicated they would likely rideshare if they could not drive alone) and Model Three looked at factors related to willingness to rideshare with a member of a rideshare program.

Table 7 Summary of Modeling Findings

Variable	Model 1	Model 2	Model 3
Household/demographic			
Female	+	+	–
Younger than 55	+	+	n/a
Younger than 45	n/a	n/a	–
Male and older than 55 (derived from interaction)	–	n/a	n/a
No education degree	+	n/a	n/a
Associate degree or less	n/a	n/a	–
Multi-person household	+	+	n/a
More drivers than vehicles in household	+	n/a	n/a
Annual household income ($10,000/person)	n/a	n/a	–
Employment/commute			
Work less than 4 days/week	–	n/a	n/a
Work 3 to 5 days/week	n/a	n/a	+
Work requires midday vehicle trips	–	n/a	n/a
Reported travel time to work (minutes)	+	+	n/a
Have work schedule flexibility	n/a	–	n/a
Built environment			
Home in dense tract (≥420 HH/km^2)	+	–	n/a
Home near Central Business District (≤2¼km)	+	n/a	n/a
No transit available in neighborhood	n/a	+	n/a
Count of retail business within 10km radius of home	n/a	n/a	+
Count of retail business within 1km of work	n/a	–	n/a
Work area ruralness (RUCA2; 1 through 10)	+	n/a	n/a
Work near Central Business District (≤2¼km)	n/a	n/a	–
Attitudes			
Prefer to be driver over passenger	–	n/a	n/a
Not important to live close to work, school, friends	–	n/a	n/a
Important to have private home location	–	n/a	n/a
Not concerned about need to come and go	n/a	n/a	+

Note: n/a = not statistically significant

While the socio-demographic characteristics of rideshare commuters and potential rideshare commuters were similar, those indicating a willingness to use rideshare services were dissimilar, specifically women and younger individuals were uninterested in these programs. Those who live in denser areas were more likely to rideshare now, but less likely to indicate rideshare as their alternative to drive alone. Having a rural workplace corresponded to more ridesharing and being willing to use rideshare services, but less likely to indicate rideshare in place of drive alone. Many attitudinal variables were examined in the models; but interestingly most were not useful in explaining potential ridesharers or potential rideshare program participants. This analysis indicates that potential rideshare commuters may be demographically similar to existing rideshare commuters, but live and work in more rural areas. Those that would participate in rideshare programs are a different set and should be further defined and targeted separately.

6. Impacts of Work Place and Commute-corridor Accessibility on Annual Vehicle Miles Traveled

The relationship between VMT and land use patterns has been studied for several decades (see e.g., Newman and Kenworthy 1989; Wachs, 1989; Krizek 2003; Cervero and Duncan, 2006; and Ewing and Cervero, 2010). Understanding the relationships between land use, accessibility and VMT could facilitate more effective policy interventions to influence travel choices, VMT and GHG emissions. However, as summarized in Cervero and Duncan (2006), research into the relationship between VMT and land use has yielded mixed results. Generally research in this area has focused either on the effect of home location accessibility (frequently measured by residential/retail mixed) on VMT or on the impact of jobs-housing balance on VMT (Cevero and Duncan 2006). Considerably fewer studies have been conducted that look at accessibility characteristics around work locations or about the potential for trip chaining along the commute to impact VMT. One of the few works to consider accessibility in relations to work locations is Lee et al. (2010). As with other areas of travel research, many of these studies have focused on large urban areas such as San Francisco (Cervero and Duncan 2006) and Seattle (Krizek, 2003; Lee et al. 2010). This project expands on prior work in this area studying VMT with an expanded focus on workplace and commute corridor accessibility variables in the context of the more rural study area covered by the NTCS. If particular spatial/accessibility variables can be demonstrated to influence transportation energy use, zoning and other policy tools could be employed to promote development that was consistent with reducing transportation GHG emissions.

6.1. Data

This project analyzed VMT data and potential explanatory variables from the NTCS. For the NTCS, respondents estimated the annual VMT for each vehicle in their household. Mileage was estimated in 2,500 mile increments for vehicles with between 0 and 5,000 miles and in 5,000 mile increments for vehicles with between 5,000 and 50,000 miles. These binned values were converted to continuous values by assigning each estimate a random value within the estimated bin. For each respondent, personal annual VMT was calculated as the cumulative VMT of all vehicles for which the respondent was the primary driver. Twenty respondents with a personal annual VMT in excess of 40,000 miles were excluded from the model. These values were more than three standard deviations from mean VMT and were considered to be outliers.

Household and demographic variables as well as the home and work location built environment variables described in Section 4 and Appendix C were used as baseline explanatory variables. In addition, a series of built environment variables were calculated along the respondents presumed commute corridor. Since NTCS respondents reported the duration of their commutes but not specific commute routes, the shortest-path routes between respondents home and work locations were calculated in ArcGIS using ESRI streets data and used as a proxy for their commute routes. Shortest-path routes were successfully calculated for all but 7 of the 1795 valid responses. Once these routes were calculated, the shortest-path travel time was compared to the respondents' self-reported travel time in order to ensure that the shortest-path route was a reasonable approximation of actual commute route. The shortest-path was rejected as an approximation of the commute route if the reported commute time was significantly shorter than the shortest-path travel time or if the reported commute time was time significantly longer than the reported commute time for very short commutes. The reported commute time was considered to be significantly shorter the shortest path travel time if it was at least 10 minutes and 25% shorter than the shortest-path travel time. Reported commute times were considered to be significantly longer then the shortest-path travel time if they exceeded the shortest path travel time by 10 minutes or more for single occupancy vehicle commutes of less than half a mile. Since the NTCS capped self-reported commute times at 60 minutes it was not possible to specifically compare these responses the shortest-path travel times so commutes reported at 60 minutes or more were eliminated from the dataset. A total of 1,512 valid commute routes remained after this screening process. Figure 3 shows the correlation between self-reported and shortest-path travel times for these 1,512 respondents.

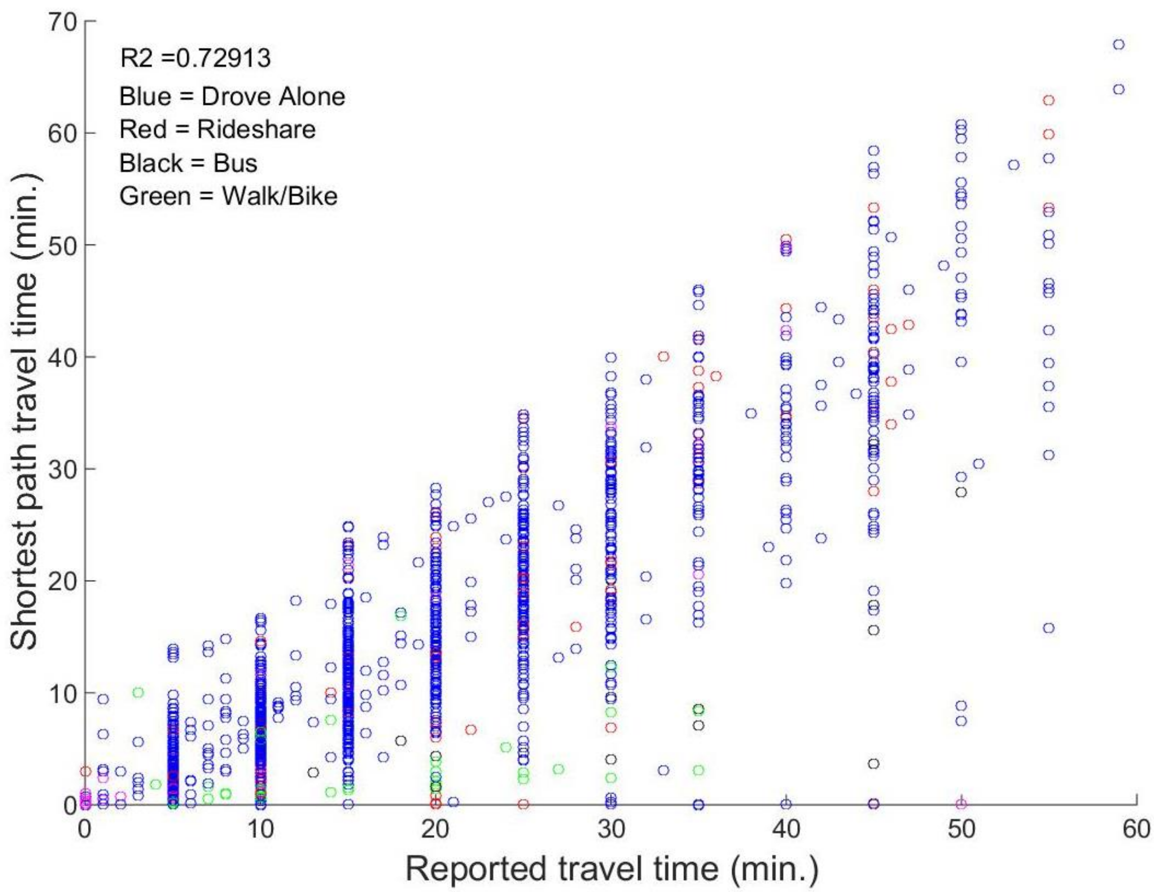

Figure 3 Shorted path travel time versus self-reported commute time

Prior research on commute-based trip chaining by McGuckin et al. (2005) indicated that commuters who trip chained on the way from home-to-work or from work-to-home traveled approximately 6 miles (9.6 km) farther than commuters who made direct home-to-work or from work-to-home trips. Castro et al. (2011) showed workers who included non-work activities on home-to-work and work-to-home tours added average of 6.1 and 7.1 miles respectively. Based on these estimates, commute-corridor accessibility variables were calculated using a 10km buffer around the shortest-path commute route. These same variables were also calculated using a 5km buffer. A complete list of the commute corridor variables calculated is provided in Appendix D.

6.2. Methods

A linear least squares regression model was developed with personal annual VMT as the dependent variable. Explanatory variables were selected based on those previously identified in the literature and by creating parallel variables that measured accessibility along the commute corridor. These variable include household and demographic characteristics, employment and commute attributes, built environment variables calculated at home and work locations and along the commute corridor. The full set of variables consider in this analysis are presented in

6.3. Results and Discussion

The majority of the household/demographic and employment/commute variables had a significant relationship to personal annual VMT when modeled individually. Education, household size and number of licensed drivers were not significant and were eliminated prior to the stepwise model selection process. Employment status, working days per week and telecommute frequency were not significant at the 0.10 level but were within the 0.11 threshold and were retained in the modeling building process. Among the home accessibility variables, distance to the nearest city center was the only variable that was not significant. Half of the work accessibility variable (residential density, retail count within 1 km, distance to nearest retail and distance to nearest city center) were eliminated at this stage. Of the commute accessibility variables, retail count with 10 km of the commute route and distance to the nearest city were eliminated.

Overall, 29 variables were retained for the stepwise model selection procedure. Of these 29 variables, 11 were included in the final model which had an r-squared of 0.25. Five of the variables in the final model came from the household/demographic and employment/commute categories. Two variables from each of the home accessibility, workplace accessibility, and commute corridor accessibility categories were included in the final model. These modeling results are presented in Table 9. Note that for categorical variables with multiple levels, only those levels which are significant are presented in this Table.

Table 8. As a preliminary analytic step, the relationship between each variable and personal annual VMT was modeled in isolation. Variables with individual p-values <0.11 were included in a stepwise model selection procedure implement in SAS.

6.3. Results and Discussion

The majority of the household/demographic and employment/commute variables had a significant relationship to personal annual VMT when modeled individually. Education, household size and number of licensed drivers were not significant and were eliminated prior to the stepwise model selection process. Employment status, working days per week and telecommute frequency were not significant at the 0.10 level but were within the 0.11 threshold and were retained in the modeling building process. Among the home accessibility variables, distance to the nearest city center was the only variable that was not significant. Half of the work accessibility variable (residential density, retail count within 1 km, distance to nearest retail and distance to nearest city center) were eliminated at this stage. Of the commute accessibility variables, retail count with 10 km of the commute route and distance to the nearest city were eliminated.

Overall, 29 variables were retained for the stepwise model selection procedure. Of these 29 variables, 11 were included in the final model which had an r-squared of 0.25. Five of the variables in the final model came from the household/demographic and employment/ commute categories. Two variables from each of the home accessibility, workplace accessibility, and commute corridor accessibility categories were included in the final model. These modeling results are presented in Table 9. Note that for categorical variables with multiple levels, only those levels which are significant are presented in this Table.

Table 8 Explanatory variables examined

	Variable	Measure
Household/Demographic	Age (years)	<18, 18-24, 25-34, 45-54, 55-64, 75-84, >85
	Gender	Male, female
	Education	<High school (HS), HS diploma, Some college, Associate degree, bachelor's degree, graduate degree
	Annual HH income ($1,000)	<25, 25-49, 50-74, 75-99, 100-149, 150-199, 200-249, >250
	Household size	1, 2, 3, 4, 5, 6, >7
	No. of licensed drivers	0, 1, 2, 3, >4
	No. of vehicles available	0, 1, 2, 3, 4, >5
	No. of vehicles primarily driven by the respondent	Continuous
Employment/ Commute	Employment status	Full-time, Part-time, Self-employed (FT or PT), Student & employed
	Days/week worked outside home	<3, 3, 4, 5, >5
	Work requires midday veh. trips	Yes, No
	Telecommute frequency	Never, <1/mo., 1-3/mo., 1day/wk, 2 days/wk, 3 days/wk, >3 days/wk
	Shortest-path commute distance	Continuous in km
Home & Work Built Environment	Neighborhood type	City, downtown with a mix of offices, apartments, and shops; City, residential neighborhood; Suburban neighborhood, with a mix of houses, shops, and businesses; Suburban neighborhood, with houses only; Small town or rural village; Rural area, outside of a town or village
	Residential density*	Continuous in HH/km^2, for census block group at home & work locations
	Retail location counts*	Continuous, within 1km & 10km radii of home & work locations
	Distance to nearest retail*	Continuous in km, for home & work locations
	Distance to nearest city*	Continuous in km, for home & work locations
	Level of Ruralness: Rural-Urban Commuting Area codes ver. 2 (RUCA2)*	Census tract-based classification scheme that uses Urbanized Area and Urban Cluster definitions with work commuting information to characterize all Census tracts regarding their rural and urban status (http://depts.washington.edu/uwruca/), codes 1 through 10 in increasing ruralness, for home & work locations
	Length of road*	Continuous in km, within 1km & 10km radii, for home & work locations
Commute Corridor Built Environment	Max. Residential density*	Continuous in HH/km^2, for densest census block along commute route
	Retail location counts*	Continuous within 5km & 10km buffers of shortest-path commute route
	Distance to nearest retail*	Continuous in km from shortest-path commute route
	Distance to nearest city*	Continuous in km from shortest-path commute route
	Lowest RUCA2 code	Lowest (most urban) RUCA 2 code interested by the shortest-path commute
	Length of road*	Continuous in km, within 5km buffer of shortest-path commute route

* Variables calculated in GIS

Table 9 Least squares regression model for Personal Annual VMT

Group	Parameter	Estimate	Standard Error	t Value	Pr > |t|
	Intercept	6860.62	905.79	7.57	<.0001
	Gender (Female vs. Male)	-604.40	379.30	-1.59	0.1113
	Income (Under $25,000 vs. $100,000 - $149,000)	-2031.67	1022.15	-1.99	0.0470
	Income ($25,000 - $49,999 vs. $100,000 - $149,000)	-1739.37	611.53	-2.84	0.0045
	Household Vehicles. (3 versus 2 vehicles)	903.14	470.09	1.92	0.0549
	Number of vehicles primarily driven by respondent	2812.28	480.62	5.85	<.0001
	Work requires midday vehicle trips (Yes vs. No)	1753.56	420.75	4.17	<.0001
	Commute Length	117.28	13.40	8.75	<.0001
	Home location place type (Mixed downtown vs. suburban neighborhood, with houses only)	-2809.91	1023.76	-2.74	0.0061
	Home location place type (Mixed suburban neighborhood vs. suburban neighborhood, with houses only)	-1545.04	618.79	-2.5	0.0126
Home RUCA 2 Code*	Metropolitan area with low commuting	5607.91	1529.51	3.67	0.0003
	Micropolitan core	3389.44	1601.80	2.12	0.0345
	Micropolitan core with flow to an urban area	2713.92	1367.28	1.98	0.0474
	Micropolitan area with low commuting	7986.74	2663.66	3	0.0028
	Micropolitan area with flow to an urban area	8537.78	3058.09	2.79	0.0053
	Small town core	5199.43	1971.46	2.64	0.0084
	Small town core with flow to an urban area	9815.66	4733.60	2.07	0.0383
	Small town high commuting	6242.61	3146.43	1.98	0.0474
	Small town, high commuting and flow to an urban area	9773.24	4058.93	2.41	0.0162
Work RUCA 2*	Micropolitan core	5985.27	1886.57	3.17	0.0015
	Micropolitan area with high commuting	5249.47	2220.40	2.36	0.0182
	Small town, high commuting and flow to an urban core	8336.09	3731.65	2.23	0.0256
	Small town low commuting	39136.53	10043.81	3.9	0.0001
	Rural area	6721.95	1930.43	3.48	0.0005
	Rural area with flow to an urban area	17414.61	8125.47	2.14	0.0323
	Rural area with flow to a large urban core	4644.03	2366.88	1.96	0.0500
	Rural area with flow to a small urban core	7014.56	3181.08	2.21	0.0276
Commute RUCA 2*	Metropolitan area with low commuting	-6477.47	2942.09	-2.2	0.0279
	Micropolitan core	-8160.60	2361.45	-3.46	0.0006
	Miropolitan area with high commuting	-7794.64	2861.23	-2.72	0.0065
	Micropolitan area with low commuting	-11935.09	4351.38	-2.74	0.0062
	Small town core	-9072.49	3270.34	-2.77	0.0056
	Rural area	-9993.78	3651.34	-2.74	0.0063
	Rural area with flow to a large urban core	-12142.77	4164.82	-2.92	0.0036
	Distance from commute path to nearest city center	-23.38	9.01	-2.59	0.0096
	Number of observations: 1492				
	R-square: 0.25				
	* All RUCA coefficients are estimated against the metropolitan core and listed in order of increasing ruralness				

Generally speaking, the coefficients for the non-RUCA variables have the expected sign. The most highly significant variables are the number of vehicles driven primarily by the respondent, work requiring midday trips and commute length. As would be expected, personal annual VMT increases when the respondent drives multiple vehicle, has to drive for work outside of the commute, and with commute length. Consistent with prior research, home locations that have mixed land use are significant predictors of decreased personal annual VMT relative to home locations in exclusively residential suburban neighborhoods. Respondents from households in the lowest two income bracket have lower personal annual VMT which could reflect the effects of long distance travel for recreational purposes. The trends for both the home location and work locations RUCA codes are also consistent with prior finding that individuals in metropolitan areas have lower VMT than those living in more rural regions. The coefficients for the RUCA codes along the commute corridor, however, show the opposite pattern and it is not clear why this would be true or if this reflects a misspecification of the model. Many of the variables initially considered for this model were highly correlated with one another resulting in a wide range of model specifications with similar fit and number of significant variables. Additional work is needed to determine the optimal combination of these variables.

6.5. Conclusion

The results here suggest that home, workplace, and commute corridor accessibility are all factors that influence VMT. However, the exact relationship between these variables and VMT remains difficult to quantify. This research is needed because it has important implications for managing transportation energy use and may also have important equity implications as outlying areas with lower home costs may have especially low transportation energy efficiency, counteracting the perceived financial benefits of lower housing costs.

Multiple avenues for future work are possible. The data collected in the NTCS and the accessibility variables calculated from it could be parsed farther. Currently, many of the accessibility variables are highly correlated because the home, work and commute buffers are overlapping. Adjusting these variables to be exclusive of another could make model specification more straightforward. These variables could also be looked at terms of the ratio of home, workplace, and commute corridor accessibility to see if the relative accessibility levels at each of the locations differ across the urban-rural spectrum. Finally, additional data collection efforts that would advance this work include collecting actual commute route data, actual (rather than binned) VMT, and information about individual long distance travel habits.

References:

Castro, M., Eluru, N., Bhat, C., and R. Pendyala, (2011). Joint model of participation in nonwork activities and time-of-day choice set formation for workers. *Transportation Research Record: Journal of the Transportation Research Board*. (2254): p. 140-150.

Cervero, R. and M. Duncan (2006). Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing? *Journal of the American Planning Association*. 72(4): p. 475-490.

Ewing, R. and R. Cervero (2010). Travel and the Built Environment. *Journal of the American Planning Association*. 76(3): p. 265-294.

EPA (2015). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2013*. U.S. Environmental Protection Agency, Washington, D.C.

Krizek, K. (2003). Neighborhood services, trip purpose, and tour-based travel. *Transportation*. 30(4): p. 387-410.

Lee, B.H.Y., Waddell, P., Wang, L., and R. M. Pendyala (2010). Reexamining the influence of work and nonwork accessibility on residential location choices with a microanalytic framework. *Environment and Planning A*. 42(4): p. 913-930.

McGuckin, N., Zmud, J., and Y. Nakamoto (2005). Trip-chaining trends in the United States: understanding travel behavior for policy making. *Transportation Research Record: Journal of the Transportation Research Board*. (1917): p. 199-204.

National Highway Traffic Safety Administration (2011). *Summary of Fuel Economy Performance*. U.S. Department of Transportation, Washington, D.C.

Newman, P.W.G. and J.R. Kenworthy (1989), Gasoline Consumption and Cities. *Journal of the American Planning Association*. 55(1): p. 24-37.

Wachs, M. (1989). Regulating traffic by controlling land use: The Southern California experience. *Transportation*. 16(3): p. 241-256.

Appendix A – NTCS Questionnaire

The NTCS questionnaire text for the Wave Two respondents is included below. GMCR employees took the same core survey; however, they were asked a few additional questions at the beginning of the survey: employment status, work field, and primary work location. Residents from the Wave One survey were not asked for their home location because it was already known from the mailing address.

SCREENING

1. [A05_intro]

Welcome and thank you for your participation!

The purpose of the Northeast Travel Choices Study is to understand travel behavior and attitudes about travel to and from workplaces around northern New England and New York. The New England Transportation Institute (NETI) is sponsoring this study along with the University of Vermont Transportation Research Center and Resource Systems Group, Inc.

2. Your privacy will be protected. Please click here to review our privacy policy. If you have any questions or concerns, please email us at NETI@rsgsurvey.com. [A06_instructions]

Instructions
Here are some tips:
- If at any time you have to stop, you can always return to the website and begin again where you left off. All your answers will have been saved for you.
- After you have answered all questions on a page, use the "Next" button at the bottom of the screen to advance.
- We recommend that your web browser (Internet Explorer, Firefox, Safari, etc.) is set to allow javascript. This is done by default for most web browsers.

If you have any questions please feel free to email us at NETI@rsgsurvey.com.
Answering all the questions should take about 15 minutes.
Now, let's get started!

3. [A07_home]

Where is your home located?

Please locate your primary residence.
- Search for an intersection, cross street, or nearby address by typing in the box below
- OR you can click on the map with the hand icon to zoom to a location. Once you are zoomed in enough you can click to place the marker.

4. [A08_employment]

What is your employment status?
- Employed full-time
- Employed part-time
- Self-employed (full or part-time)
- Student, not employed or employed less than 25 hrs/week
- Student, employed 25+ hrs/week
- Homemaker
- Retired

- Not currently employed

5. [A09_lastchance] *[If student and not employed, homemaker, retired, not currently employed]* Is there another member of your household that is currently employed?
- Yes
- No [terminate]

6. [disqualified] [*If no other members of household are currently employed*] Thank you for your interest. Unfortunately, this study focuses on the travel patterns of Northeast residents who work outside their home. If you believe you are seeing this page in error, please contact the survey administrator at neti@rsgsurvey.com. [terminate]

7. [A11_employment2]Please have that household member fill out the rest of the survey, starting now.

What is your employment status?
- Employed full-time
- Employed part-time
- Self-employed (full or part-time)
- Student, employed 25+ hrs/week
- Other [terminate]

8. [A12_occupation] In what occupation or industry are you employed?
- Agriculture, farming, forestry, mining
- Professional services/managerial
- Manufacturing/transportation
- Construction, carpentry
- Professional assistant/administrative
- Sales, retail
- Education
- Other, please specify:

9. [A13_daysatwork] How many days each week do you usually work <u>outside</u> your home (e.g. a jobsite, the office, a retail store)?
- More than 5 days a week
- 5 days a week
- 4 days a week
- 3 days a week
- Fewer than 3 days a week

10. [A14_workloc] Please locate your primary workplace.
- Search for an address or business by typing in the box below
- OR you can click on the map with the hand icon to zoom to a location. Once you are zoomed in enough you can click to place the marker.

{Note: record gtime and gdist based on home and work locations }

RESIDENTIAL LOCATION AND INCENTIVES

11. [B15_restype] How would you describe your residence?
- Single-family house (detached house)

- Townhouse (attached house)
- Building with 3 or fewer apartments or condos
- Building with 4 or more apartments or condos
- Mobile home or trailer
- Dormitory or other institutional housing
- Other (including boat, RV, van, etc.)

12. [B16_lotsize] *[if detached residence]* Approximately what size is the lot on which your house is located?
- Less than 1/4 acre
- Between 1/4 acre and 2 acres
- More than 2 acres

13. [B17_placetype] Which of the following best describes where you live?
- City, downtown with a mix of offices, apartments, and shops
- City, residential neighborhood
- Suburban neighborhood, with a mix of houses, shops, and businesses
- Suburban neighborhood, with houses only
- Small town or rural village
- Rural area, outside of a town or village

14. [B18_rent] Do you own or rent your current home?
- Rent
- Own
- Other
- Prefer not to answer

15. [B19_numyears] How long have you lived in your current home?
- Less than 1 year
- 1-5 years
- 6-10 years
- More than 10 years

16. [B20_hhsize] How many people live in your household?

Please include everyone who normally resides in your home, including yourself, any relatives, boarders, and live-in household employees. Please do not include people away at school or in the military.
- ____ Children under 12 years old
- ____ Children 12-16 years old
- ____ Persons 17-24 years old
- ____ Persons 25-50 years old
- ____ Persons over 50 years
- ______ Total household members: [calculated for respondent]

{Note: store total HHsize as its own variable}

17. [B21_licensed] How many licensed drivers are there in your household?
- None

- 1 licensed driver
- 2 licensed drivers
- 3 licensed drivers
- 4 or more licensed drivers

{*Note: only display answer options less than the total HH size*}

18. [B22_movelikelihood] How likely are you to move to a different home in the next five years?

- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely

19. [B23_resconsid] When you think of the next place you would like to live, how important would each of the following be to you?

- Not important at all
- Not very important
- Neutral
- Somewhat important
- Extremely important
- Not applicable

{Note: The statements are shown in random order to minimize any statement order bias.}

- A home location that is closed to work, school, and friends
- A home with a large lot
- A garage for two or more vehicles
- Services that are nearby
- A neighborhood where you could walk to a village or commercial center
- A private home location with adequate separation from others

20. [B24_instruct2] Next, you will see two scenarios about choosing a new home location. For each question, please look closely at the details and tell us how likely you would be to make that decision.

Please click "Next" to continue.

21. [B25_scenario1] Assume that you were offered <$5,000/10,000/15,000/20,000> to cover part of the down payment for the purchase of a house or condominium under the condition that you live within 5 miles of your workplace or within a village center (you would have to pay this back only if you move out of that house or change employers within 5 years). Also assume that everything about this house is otherwise the same as your current home or any other home you might consider.

How likely would you be to accept the <$5,000/10,000/15,000/20,000> and choose to buy a house that is close to your current workplace or in a village center?

- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely
- I already live within 5 miles of my workplace

22. [B26_scenario2] Assume that you were offered a property tax reduction of <5/10/15/20%> for the purchase of a house or condominium under the condition that you live within 5 miles of your workplace or within a village center. Also assume that everything about this house is otherwise the same as your current home or any other home you might consider.

How likely would you be to take advantage of this <5/10/15/20%> property tax reduction and choose to buy a house that is close to your current workplace or in a village center?
- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely
- I already live within 5 miles of my workplace

AUTO OWNERSHIP AND INCENTIVES

23. [C27_numbikes] We would now like to ask you a question about the vehicles and bicycles in your household.

How many bicycles (in working order) are there in your household?

Please include all bicycles (e.g. road or mountain bikes, tandem bikes, etc).
- 0 (none)
- 1 bicycle
- 2 bicycles
- 3 bicycles
- 4 bicycles
- 5 bicycles
- 6 or more bicycles

24. [C28_numvehs] How many total vehicles (in working order) are there in your household?

Please include all cars, pickup trucks, minivans and motorcycles/scooters to which your household <u>regularly uses</u>, whether owned, leased, or a company vehicle.
- 0 (no vehicles)
- 1 vehicle
- 2 vehicles
- 3 vehicles
- 4 vehicles
- 5 or more vehicles

25. [C29_vehicledetails] *[if num-vehicles > 0]* Please tell us about the vehicles in your household.

Viewing <X of Y> total vehicle(s).
- Year: <drop-down>
- Make: <drop-down>
- Model: <drop-down>
- Miles driven in past 12 months: <drop-down>
- Primary driver: <drop-down>
- How much longer do you plan to have this vehicle?:
- {Note: the following answer categories will be used for the drop-down lists
- Year

   - 2012 to 1986 in 1 year increments. Last entry is '1985 or older'
- Make
   - Based on year, makes are dynamically populated from vehicle database
   - "Other" option is always first. "Motorcycle/scooter" is always second. Then list auto makes alphabetically.
- Model
   - All models associated with year and make are dynamically populated from vehicle database
   - "Other" option is always first. If "Other" or "Motorcycle/scooter" is selected as Make, then dropdown is disabled (or there's some indication that it doesn't need to be answered).
- Miles driven by this vehicle in past 12 months
   - 0 – 50,000 or more in 2,500 mile increments
   - I don't know
- Primary driver
   - Me
   - Someone else
- For how long do you plan on having this car
- <drop-down: 1 year, 2 years, 3-4 years, 5-10 years, more than 10 years>

26. [C30_vehattitude] [*If number of vehicles > 1*] Please think about the multiple vehicles in your household and how you make vehicle-related decisions when answering these questions.

How strongly do you agree or disagree with each of the following statements?
- Strongly disagree
- Somewhat disagree
- Neutral
- Somewhat agree
- Strongly agree
- Not applicable

{Note: The statements are shown in random order to minimize any statement order bias.}
- When I take longer trips, I prefer the bigger vehicle
- I prefer to use "my car"
- If I have cargo it affects my choice of vehicle
- I typically use a different vehicle for work and non-work trips
- The number of people traveling is a big factor in selecting which vehicle to use
- The choice of vehicle is based on who is going to drive
- The weather and road conditions affect my choice of vehicle
- We often discuss who will use which vehicle in our household

27. [C31_example1] [*if num-vehicles > 0*] Assume that a more efficient vehicle costs $4,000 more than a similar-sized less efficient vehicle.

If you were offered <$500/1,000/2,000/3,000> as an incentive to buy a vehicle that gets 35 miles per gallon (MPG) or higher, how likely would you be to purchase such a vehicle when the time comes to replace your primary vehicle?
- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely

- My primary vehicle already gets 35 miles per gallon (MPG)

28. [C32_example2] *[if num-vehicles > 0]* If gasoline prices were to increase to <$5/6/7/8>/gallon how likely would you be to purchase such a vehicle that gets 35 miles per gallon (MPG) or greater when the time comes to replace your primary vehicle?
- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely
- My primary vehicle already gets 35 miles per gallon (MPG)

29. [C33_example3] *[if num-vehicles > 0]* If you were offered <$500/1,000/2,000/3,000> as an incentive to buy a hybrid electric vehicle, how likely would you be to purchase such a vehicle when the time comes to replace your primary vehicle?
- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely
- My primary vehicle is a hybrid electric.

WORK COMMUTING AND INCENTIVES

30. [D34_middaytrips]We'd now like to ask you about your work and commute.

Does your work require you to have a vehicle for regularly making trips other than between home and work?
- Yes
- No

31. [D35_transitavail] What types of public transit are currently offered in your neighborhood?

Please select all that apply.
- Large bus
- Small bus
- Bus for special purposes, like medical or senior citizen service
- Taxi
- Other, please specify:
- No public transit currently available in my neighborhood
- I do not know

32. [D36_telecomfreq] How frequently do you work from home or telecommute instead of traveling to work?
- More than 3 days a week
- 3 days a week
- 2 days a week
- 1 day a week
- 1–3 times per month
- Less than once per month
- Never

33. [D37_workflex] How flexible are your work hours?
- I have no flexibility in my schedule
- I have some flexibility to adjust my schedule, within about 30 minutes
- I am pretty much free to adjust my schedule as I like

34. [C38_inflex_reason] *[if no flexibility]* Why don't you have flexibility in your work schedule?

Please select all that apply.
- My work schedule requires me to be present for specific hours each day
- My personal situation requires me to arrive and leave at specific times each day
- Other

35. [D39_mode] How did you get from home to your work location on your most recent workday?

Please select all that apply.
- Drove alone
- Dropped off
- Carpool/rode with others
- Vanpool
- Bus/public transit
- Bike
- Taxi
- Walk
- Other, please specify:

36. [D40_occ] [*If carpool, vanpool, or dropped off*] Please continue to think about your trip from home to work on your most recent workday.

How many total people, including yourself, were in the vehicle on your trip to work?
- 2 people
- 3 people
- 4 or more people

37. [D41_livewitha] [*If carpool, vanpool, or dropped off AND occ = 2*] Do you live with the people who you carpooled with on your trip to work?
- Yes
- No

38. [D41_livewithb] [*If carpool, vanpool, or dropped off AND occ > 2*] Do you live with the people who you carpooled with on your trip to work?
- Yes, I live with everyone that was in the car
- Yes I live with some of the people that were in the car
- No, I don't live with anyone that was in the car

39. [D42_transitstop] [*If used transit*] Please continue to think about your trip from home to work on your most recent workday.

How many miles is the transit stop you used from your home?

- Miles from home: Please slide the gray box to select a value

[Interactive slider will record the access miles in 1 mile increments]

40. [D43_arrtime] When did you arrive at your workplace?

- Time arrived: Please slide the gray box to select a value

  [Interactive slider will record the arrival time in 15 minute increments]

41. [D44_travtime] Please continue to think about your trip from home to work on your most recent workday.

How long did it take you to travel from home to work?

- Travel time: Please slide the gray box to select a value

  [An interactive slider will record travel times in 5 minute increments from 0-60 minutes or more]

42. [D45_deptime] Please continue to think about your trip from home to work on your most recent workday.

When did you leave your workplace?

- Time departed: Please slide the gray box to select a value

  [Interactive slider will record the departure time in 15 minute increments]

43. [D46_toworkstops] Please continue to think about your trip from home to work on your most recent workday.

On the way TO work, how many stops did you make?
- None
- 1 stop
- 2 stops
- 3 or more stops

44. [D47_toworkreasons] [*If number of stops > 0*] Why did you stop on the way to work?

Please select all that apply.
- Food or coffee
- Child care or school drop-off/pick-up
- To drop someone else off
- To pick someone up
- Personal errand including shopping
- Meeting or other work-related task
- Visit or assist a friend or family member
- Other, please specify:

45. [D48_fromworkstops] Please continue to think about your trip from home to work on your most recent workday.

On the way home FROM work, how many stops did you make?
- None

- 1 stop
- 2 stops
- 3 or more stops

46. [D49_fromworkreasons] [*If number of stops > 0*] Why did you stop on the way home FROM work?

Please select all that apply.

- Food or coffee
- Child care or school drop-off/pick-up
- To drop someone else off
- To pick someone up
- Personal errand including shopping
- Meeting or other work-related task
- Visit or assist a friend or family member
- Other, please specify:

47. [D50_altmode] [*If mode was "drove alone"*] If you could not drive alone to work, how would you most likely get there?

- Get dropped off
- Carpool
- Vanpool
- Bus/public transit
- Taxi
- Bike
- Walk
- Telecommute
- Other, please specify:
- I don't know

{Note: multiple selections allowed, though "Please select all that apply" is not shown}

48. [D51_longestcommute] What is the longest one-way commute distance to work or school of anyone in your household?

- Miles: ______
- Not Applicable

49. [D52_shuttle] Assume for a moment that a special shuttle service could pick you up at home, and take you to work every day, with you paying just a small portion of the cost of the gas for the trip. The service includes an occasional taxi home for working late. The service also includes a shared car (like a "Zipcar") for errands in the middle of the day.

Keeping these services in mind, how strongly do you agree or disagree with the following statements?

- I am concerned about traveling with people that I do not know
- It would be easier for me to take the shuttle service if I were not so concerned about getting to and from work in the shortest amount of time
- It would be easier for me to take the shuttle service if I were not so concerned about my need to come and go when I want to
- I prefer to be the driver, not a passenger
- I use the most convenient form of transportation regardless of cost
- How I get to work is really up to me, and I could do this if I chose to

- It is important to me to control the radio and the air conditioning in the vehicle

50. [D53_incentivecar] [*If commute mode is drive alone*] If you were offered <$100/150/200/250> per month as an incentive not to drive by yourself to work, how likely would you be to accept this payment and find an alternative way to get to work?

- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely

51. [D54_incentiveshuttleA] If a free door-to-door shuttle service were provided that took <5/10/15/20> minutes longer than driving alone, how likely would you be to use such a service?

- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely

52. [D55_incentiveshuttleB] If gasoline prices were to increase to <$5/6/7/8> gallon how likely would you be to use a free door-to-door shuttle service that took <5/10/15/20 minutes> longer than driving alone?

- Extremely unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Extremely likely

INTERCITY TRAVEL

53. [E56_cities] We would now like to ask you a few questions about long distance travel.

Which of the following cities have you visited in the last year?

- New York City
- Boston
- Montreal
- Toronto
- Philadelphia
- Washington D.C.
- None of the above [Branch to next section]
- {Note: multiple selections are allowed though "Please select all that apply" is not shown}

54. [E57_cityrecent] [*If more than one city selected*] Which city did you visit most recently?

- [*selected city from q53*]
- [*selected city from q53*]

55. [E58_LDmode] How did you travel to/from <most recent city>?

- Auto/car
- Intercity bus (e.g. Greyhound, Megabus, etc.)
- Intercity rail (e.g. Amtrak, Metro-North, etc.)
- Airplane
- Other, please specify:
- {Note: multiple selections are allowed though "Please select all that apply" is not shown}

56. [E59_considbus] [*If not bus or rail*] For your most recent trip to <most recent city>, did you consider taking a train or intercity bus?
- Yes
- No

57. [E60_LDocc] How many people were in your travel party on your most recent trip to <most recent city>?
- 1 (I traveled alone)
- 2 people
- 3 people
- 4 people
- 5 or more people

58. [E61_schedinfo] In general, do you know where to find schedule information about the following travel options?
- Yes
- No
- Not sure

{Note: The statements are shown in random order to minimize any statement order bias.}
- Intercity bus (e.g. Greyhound, Megabus, etc.)
- Intercity rail (e.g. Amtrak, Metro-North, etc.)
- Airplane

59. [E62_carpoolknowledge] If you wanted to find someone to carpool with on one of these long-distance trips, would you know where to go find such a person?
- Yes
- No

SMARTPHONE/TECHNOLOGY USE AND TRANSPORTATION DECISIONS

60. [F63_access] Where can you access the Internet?

Please select all that apply.
- At home
- At work
- On my mobile phone
- None of the above

61. [F64_infofreq] Approximately how often do you use travel information (traffic congestion, flight delays, etc.) from the Internet and/or a smart phone?
- Daily
- Weekly
- Monthly
- Rarely
- Never

62. [F65_alerts] Would you be interested in a service that provided an alert message (a text message) to your phone for transportation information about weather (snow, storms, etc.) or incidents (crashes, congestions, etc.)?
- Yes
- No

63. [F66_rideshare] Should the situation arise, would you be willing to ride with someone you did not know personally but who was registered with a ride share program?
- Yes
- No

DEMOGRAPHICS

64. [G67_age] I am…
- Under 18 years old
- 18 - 24 years old
- 25 - 34 years old
- 35 - 44 years old
- 45 - 54 years old
- 55 - 64 years old
- 65 - 74 years old
- 75 - 84 years old
- 85 or older

65. [G68_gender] I am…
- Male
- Female

66. [G69_education] What is your highest completed level of education?
- Less than a high school diploma
- High school diploma or equivalency
- Some college, no degree
- Associate degree
- Bachelor's degree
- Graduate or professional degree

67. [G70_income] What is your annual household income?

If you are unsure of the answer, please give your best estimate.

Under $25,000
$25,000 - $49,999

$50,000 - $74,999
$75,000 - $99,999
$100,000 - $149,999
$150,000 - $199,999
$200,000 - $249,999
$250,000 or more
Prefer not to answer

[end] Thank you for completing this survey! All your answers have been saved. You may now close this window.

Appendix B – NTCS Study Area

Table B-1 Counties included in the NTCS Study Area

ME	NH	VT	NY	
Androscoggin	Belknap	Addison	Albany	Monroe
Aroostook	Carroll	Bennington	Allegany	Montgomery
Cumberland	Cheshire	Caledonia	Broome	Niagara
Franklin	Coos	Chittenden	Cattaraugus	Oneida
Hancock	Grafton	Essex	Cayuga	Onondaga
Kennebec	Hillsborough	Franklin	Chautauqua	Ontario
Knox	Merrimack	Grand Isle	Chemung	Orleans
Lincoln	Rockingham	Lamoille	Chenango	Oswego
Oxford	Strafford	Orange	Clinton	Otsego
Penobscot	Sullivan	Orleans	Columbia	Rensselaer
Piscataquis		Rutland	Cortland	Saint Lawrence
Sagadahoc		Washington	Delaware	Saratoga
Somerset		Windham	Erie	Schenectady
Waldo		Windsor	Essex	Schoharie
Washington			Franklin	Schuyler
York			Fulton	Seneca
			Genesee	Steuben
			Greene	Tioga
			Hamilton	Tompkins
			Herkimer	Warren
			Jefferson	Washington
			Lewis	Wayne
			Livingston	Wyoming
			Madison	Yates

Appendix C – NTCS Home and Work Built Environment Variables

Numerous built environment variables were calculated for both respondents' home and work locations to provide an indication of the destination accessibility near these locations. These variables were calculated in ArcGIS using road network, census and other data provided by ESRI, retail location and classification data collected by Neilson, data from the National Elevation Dataset, and zip-code level Rural-Urban Commuting Area Codes (RUCA2) data from the University of Washington. These variables were calculated for all 1795 valid Wave One and Wave Two NTCS respondents.

Table C-1 Home and Workplace Built Environment Variables

Variable Name	Variable Description
NEARESTBIZ & W_NEARESTBIZ	North American Industry Classification System code of the retail location closest to the home and work locations respectively
KM2BIZ & W_KM2BIZ	Distance from the home and work locations respectively to the nearest retail location in kilometers
NEARESTCITY & W_NEARESTCITY	City center closest to the home and work locations respectively
KM2CITY & W_KM2CITY	Distance from the home and work locations respectively to the nearest city center in kilometers
RUCA2 & W_RUCA2	The RUCA v2.0 code corresponding to the zip codes of the home and work locations respectively
RUCA2_INT & W_RUCA2_INT	The integer value of the RUCA v2.0 corresponding to the zip codes of the home and work locations respectively
RESID_BLKG_KM & W_RESID_BLKG_KM	The residential density for the census block group in which the household and work site respectively are located in households per km^2
RESID_TRAC_KM & W_RESID_TRAC_KM	The residential density for the census tract in which the household and work site respectively are located in households per km^2
BIZ_1KM & W_BIZ_1KM	Count of retail locations within 1km radius of the home and work locations respectively
BIZ_10KM & W_BIZ_10KM	Count of retail locations within 10km radius of the home and work locations respectively
INVDSQx1M & W_INVDSQx1M	Sum of 1,000,000,000/$distance^2$ to each retail establishment within 30km of the home and work locations respectively
INTRSCT_1KM	Number of intersections within 1 km of the home location
INTRSCT_10KM	Number of intersections within 10 km of the home location
RDKM_1KM & W_RDKM_1KM	Total length of roadway, in km, within 1 km of the home and work locations respectively
RDKM_10KM & W_RDKM_10KM	Total length of roadway, in km, within 10 km of the home and work locations respectively
BIZCNT_1KM & W_BIZCNT_1KM	Total number of retail trade locations within 1 km of network distance of the of home and work locations respectively
BIZCNT_10KM & W_BIZCNT_10KM	Total number of retail trade locations within 1 km of network distance of the of home and work locations respectively
Z_STD_1KM	Standard deviation of DEM elevations within 1km of the home location
Z_STD_10KM	Standard deviation of DEM elevations within 10km of the home location

Appendix D – NTCS Commute Corridor Built Environment Variables

Built environment variables were also calculated along the shortest-path route between respondents home and work locations to provide an indication of the destination accessibility along the respondents' commute corridors. These variables were calculated in ArcGIS using road network, census and other data provided by ESRI, retail location and classification data collected by Neilson, and zip-code level Rural-Urban Commuting Area Codes (RUCA2) data from the University of Washington. These variables were calculated for 1,512 Wave One and Wave Two NTCS respondents for which the shortest-path travel time approximated respondents' self-reported commute time (see Section 6).

Table D-1 Commute Corridor Built Environment Variables

Variable Name	Variable Description
WorkDist	The straight line distance between the home and work locations in km
CommuteLenth_KM	The length of the shortest-path route from home to work locations in km
C_NEARESTBIZ	The North American Industry Classification System code of the retail location closest to the shortest-path commute route
C_KM2BIZ	Distance from the shortest-path commute route to the nearest retail location
C_NEARESTCITY	City center closest to the shortest-path commute route
C_KM2CITY	Distance from the shortest-path commute route to the nearest city center in kilometers
C_RUCA2_0	The lowest (most urban) RUCA v2.0 code of the zip code areas intersected by the shortest-path commute route
C_RUCA2INT	The integer value of the lowest (most urban) RUCA v2.0 code of the zip code areas intersected by the shortest-path commute route
C_RESID_BLKG_MAX_KM	The highest residential density of the census block groups intersected by the shortest-path commute route in households per km^2
C_RESID_BLKG_AVE_KM	The average residential density of the census block groups intersected by the shortest-path commute route in households per km^2
C_RESID_TRAC_MAX_KM	The highest residential density of the census tracts intersected by the shortest-path commute route in households per km^2
C_RESID_TRAC_AVE_KM	The average residential density of the census tracts intersected by the shortest-path commute route in households per km^2
C_BIZ_5KM	Count of retail locations within a 5 km buffer around the shortest-path commute route
C_BIZ_10KM	Count of retail locations within a 10 km buffer around the shortest-path commute route
C_INVDSQx1M	Sum of 1,000,000,000/$distance^2$ to each retail establishment within 30km of the shortest-path commute route
C_RDKM_5KM	Total length of roadway, in km, within 5 km of the shortest-path commute route

Appendix E – NTCS Vehicle Choice by Neighborhood Type

As shown in Sections 3 and 4, intra-household vehicle allocation is an important determinant of household fuel consumption. Consequently, it is important to understand the factors that drive vehicle allocation decisions. The NTCS asked a series of questions about how important different factor are in vehicle allocation decisions. These results are summarized by self-reported, home neighborhood type in the figures that follow. Table E-1 shows the total number of respondents in each neighborhood type.

Table E-1 NTCS Participants' Self-Identified Neighborhood Type

Home Type	N
City	203
Suburban	464
Village (Small town or rural village)	311
Rural (Outside of a town or village)	408

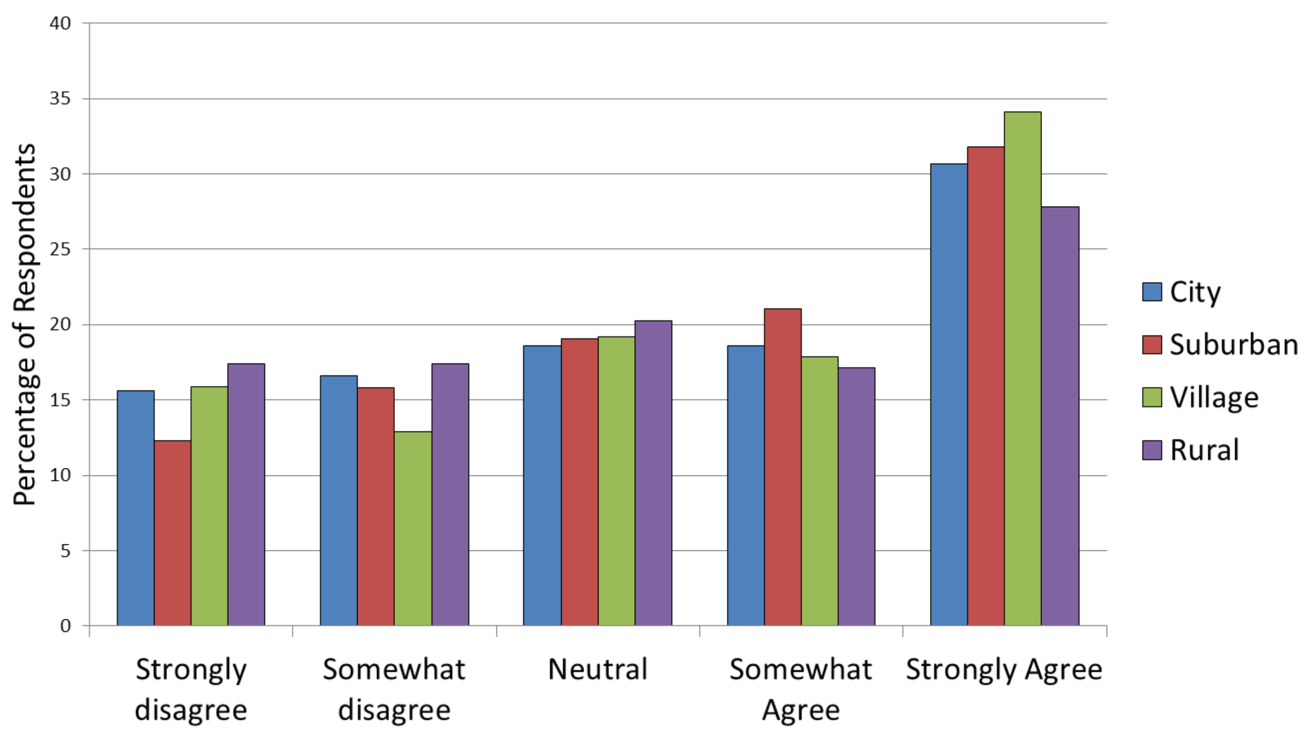

Figure E-1. Degree of agreement with the statement "When I take longer trips, I prefer the bigger vehicle"

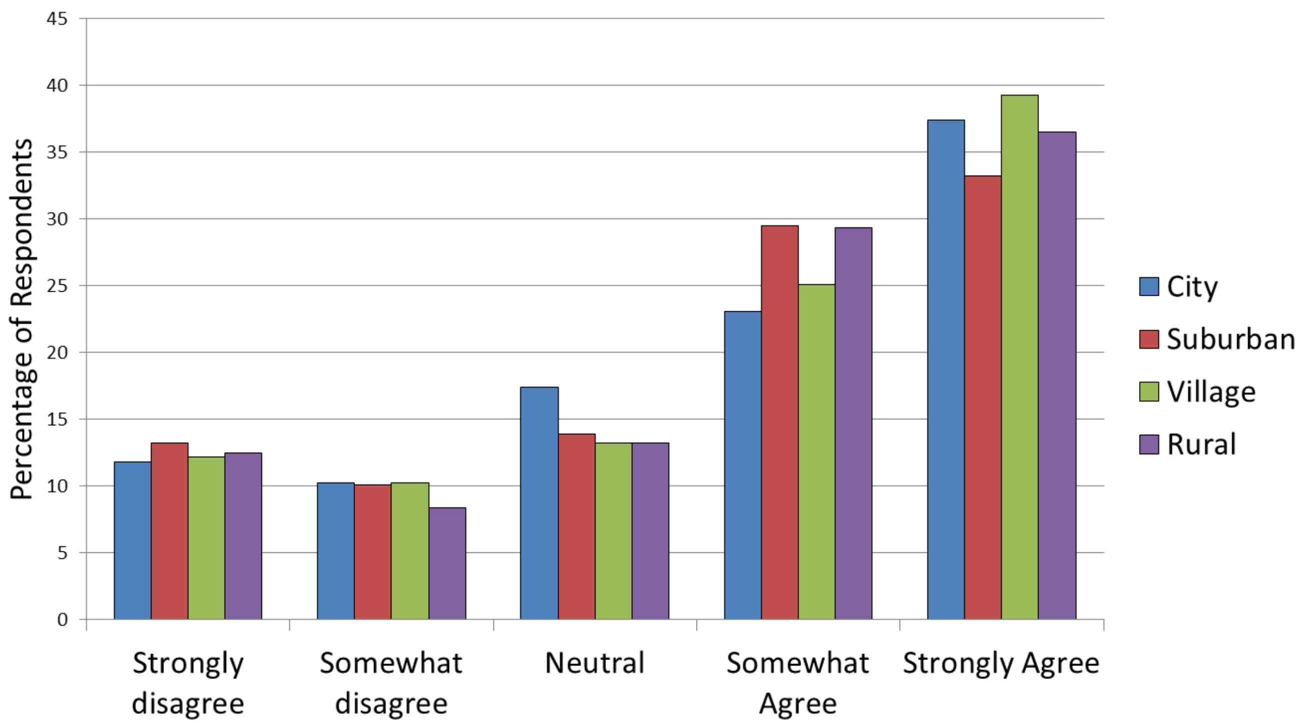

Figure E-2 Degree of agreement with the statement "The number of people traveling is a big factor in selecting which vehicle to use"

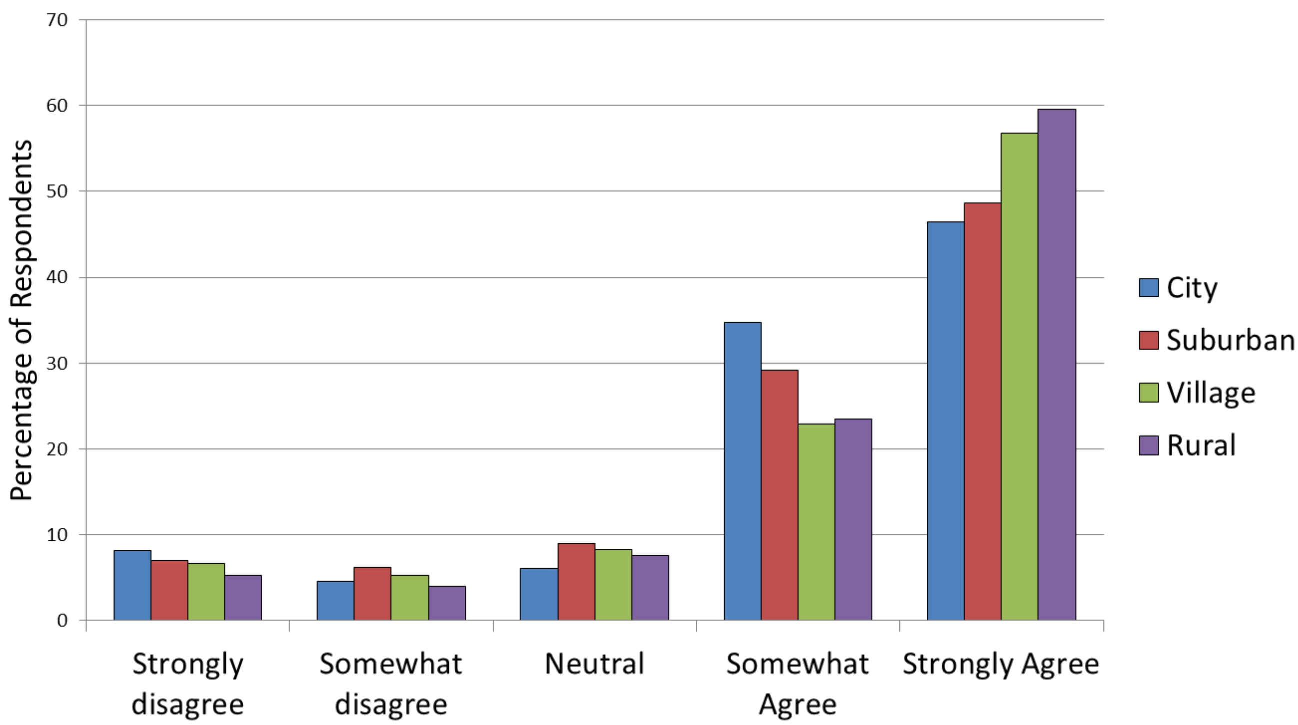

Figure E-3 Degree of agreement with the statement "If I have cargo it affect my choice of vehicle"

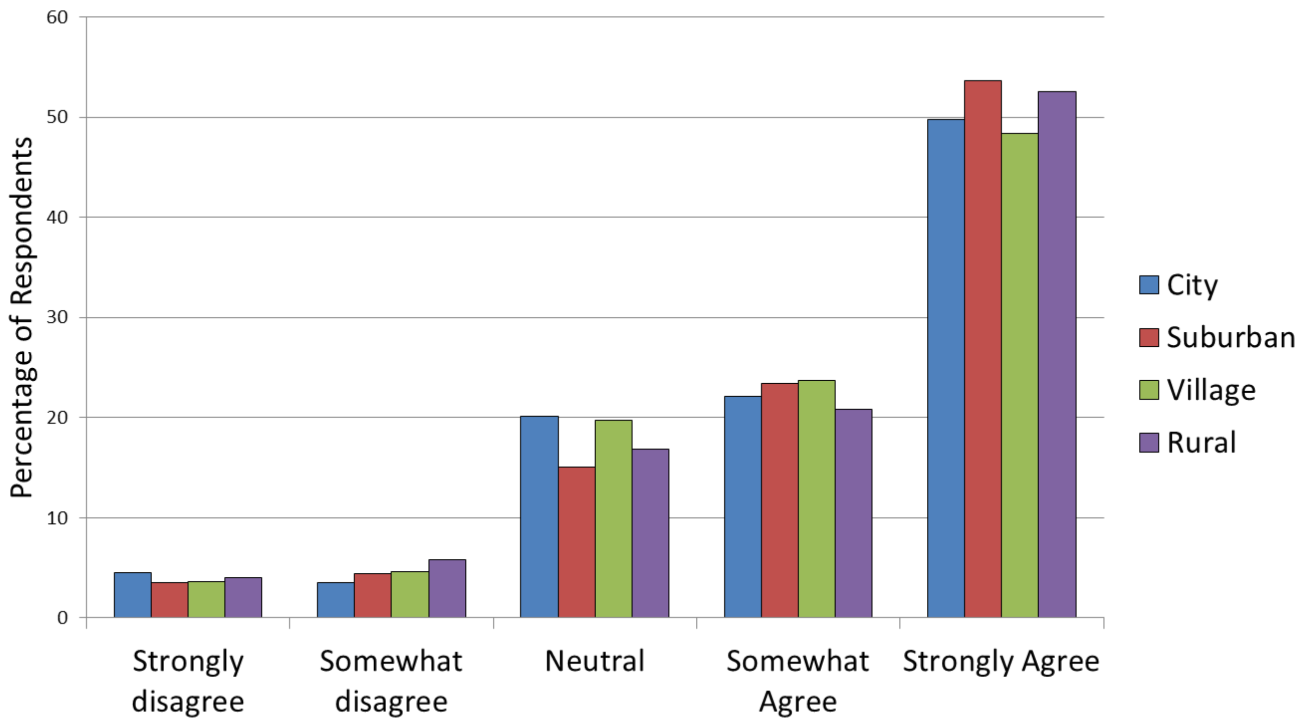

Figure E-4 Degree of agreement with the statement "I prefer to use 'my car'"

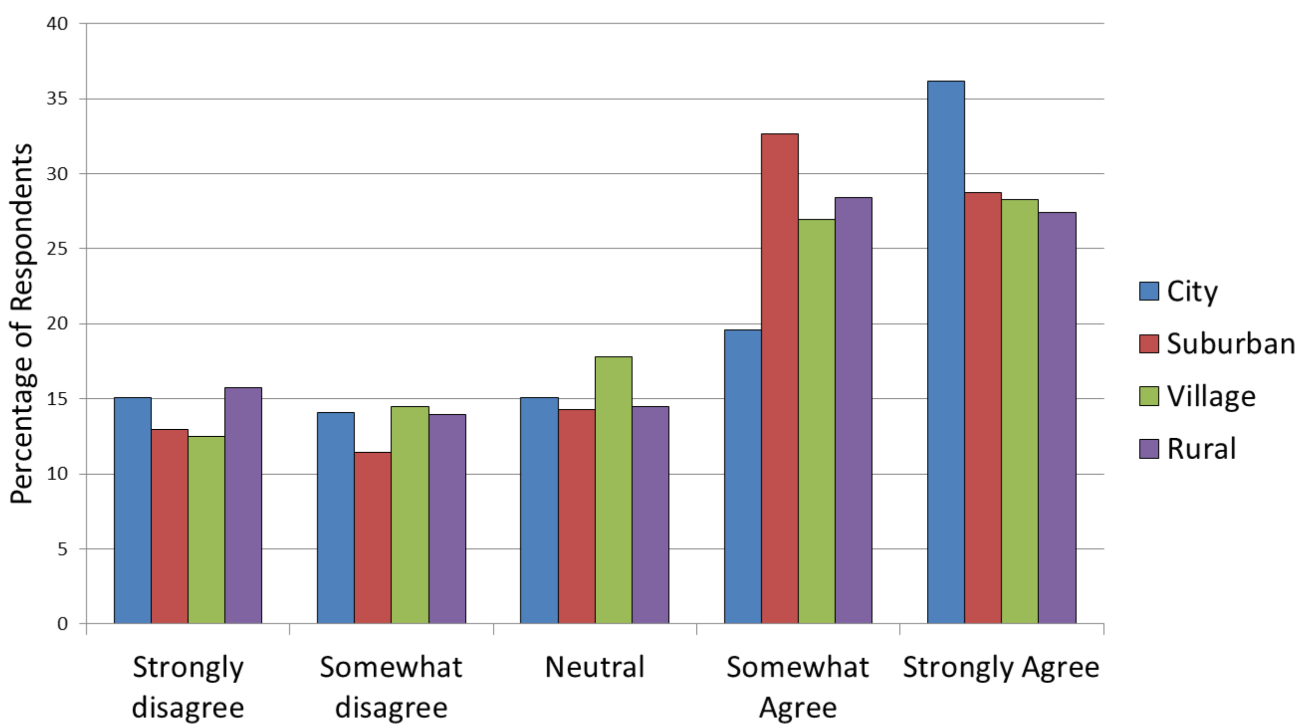

Figure E-5 Degree of agreement with the statement "The choice of vehicle is based on who is going to drive"

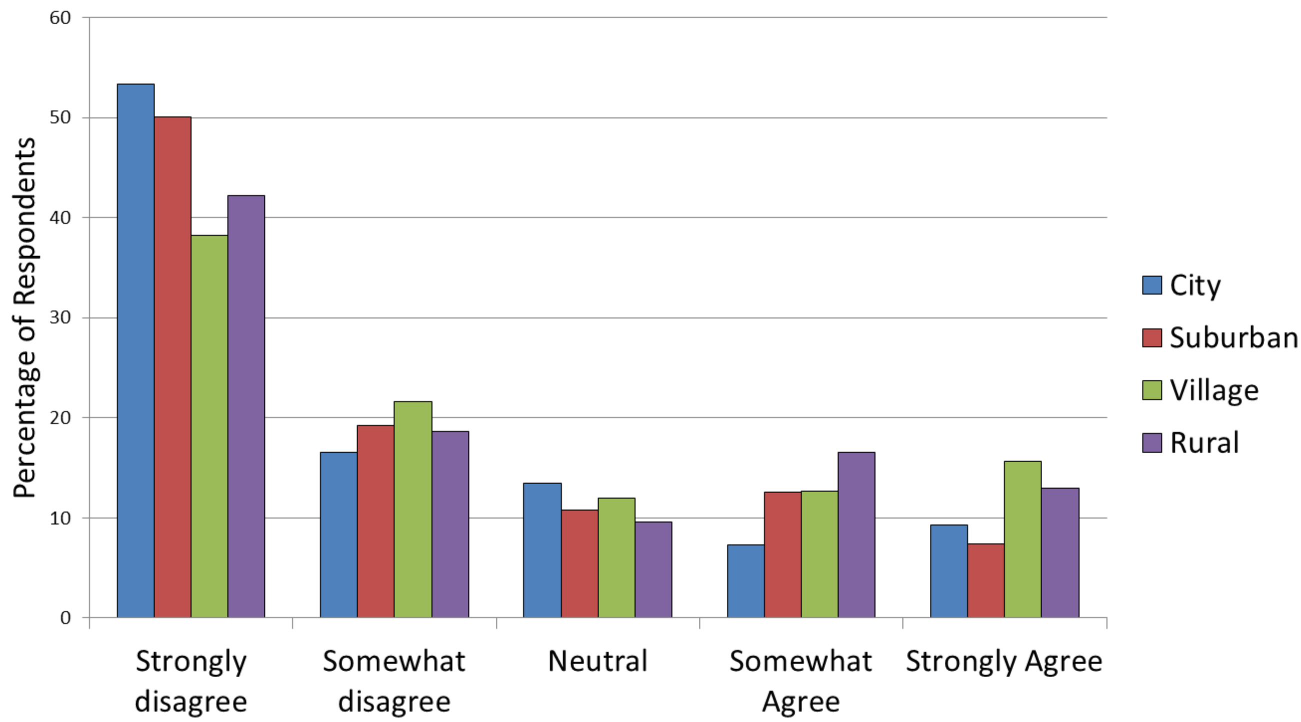

Figure E-6 Degree of agreement with the statement "I typically use a different vehicle for work and non-work trips"

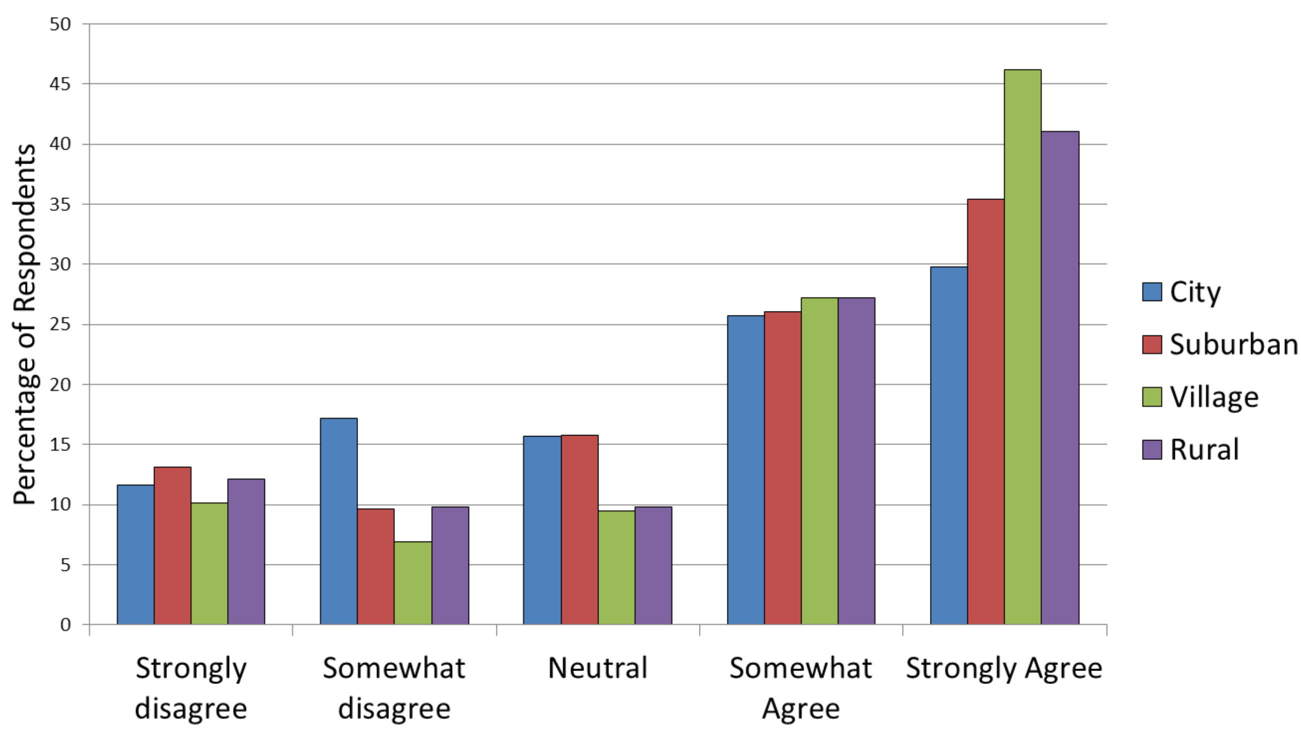

Figure E-7 Degree of agreement with the statement "The weather and road conditions affect my choice of vehicle"

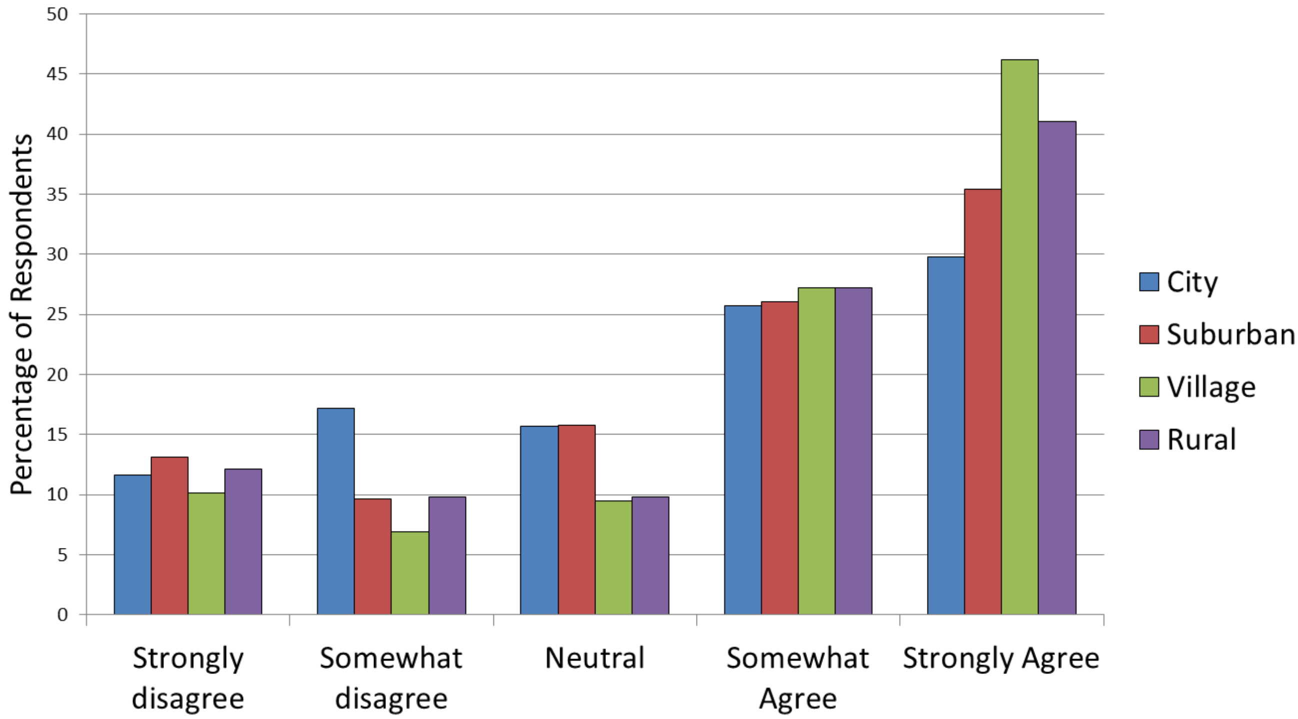

Figure E-8 Degree of agreement with the statement "We often discuss who will use which vehicle in our household"

Appendix F – NTCS Data from Employees of Green Mountain Coffee Roasters

The Northeast Travel Choices Survey was administered to Vermont-based employees of Green Mountain Coffee Roasters (GMCR). This included employees at the four primary locations within Vermont: South Burlington, Waterbury, Essex, and Williston. A vice president at GMCR was responsible for emailing survey invitations to employees. This invitation email contained a hyperlink to participate in the online survey. The online survey began August 14, 2012, and concluded August 30, 2012. Of the 4,500 GMCR employees invited by email, a total of 459 completed the survey, representing a response rate of 10.2%

In order to gain additional insight into the travel attitudes and behaviors of GMCR employees, the survey responses were further divided by geographic groups depending on workplace. This allowed further comparison to see if there were commonalities in travel behaviors or attitudes based on the different work locations.

The 18 employment locations were grouped into 3 major categories based on zip codes and geographic proximity. The first group consisted of all locations in Essex (n=77), the second those in Williston and South Burlington (n=155), and the final, largest group, all locations in Waterbury (n=226). The original locations listed in the survey and their reclassification information are listed in Table F-1.

TABLE F-1 Workplace Reclassification Groups and Respondent Location Distribution, Percentages by Workplace Location [question 5]

Work location as stated on survey	Street Address	Reclassified Location Group	Number of Respondents	Percentage of Overall Respondents
"Essex: Call Center"	30 Gauthier Drive Essex Junction, VT 05452	1	29	6.3
"Essex: Plant"	5 New England Drive Essex Junction, VT 05452	1	48	10.5
"South Burlington: 124 Technology Park"	124 Technology Park South Burlington, VT 05403	2	47	10.3
"Waterbury: 152 Main St"	152 Main Street Waterbury, VT 05676	3	9	2.0
"Waterbury: 33 Coffee Lane"	33 Coffee Lane Waterbury, VT 05676	3	28	6.1
"Waterbury: Demerrit 1"	81 Demerrit Place Waterbury, VT 05676	3	11	2.4
"Waterbury: Demerrit 2"	109 Demerrit Place Waterbury, VT 05676	3	13	2.8
"Waterbury: Distribution"		3	9	2.0
"Waterbury: Facilities Shop"		3	4	0.9
"Waterbury: Factory Outlet"	40 Foundry Street Waterbury, VT 05676	3	1	0.2
"Waterbury: Pilgrim 2"	93 Pilgrim Park Road Waterbury, VT 05676	3	39	8.5
"Waterbury: Pilgrim 5"		3	14	3.1
"Waterbury: Visitor's Center/Café"	1 Rotarian Place Waterbury, VT 05676	3	0	0.0
"Waterbury: Plant"		3	98	21.4
"Waterbury Center"		3	0	0.0
"Williston: Holly Court"	327 Holly Court Williston, VT 05495	2	6	1.3
"Williston: Maple Tree Place"	Boxwood Street Williston, VT 05495	2	3	0.7
"Williston: Marshall Ave"	687 Marshall Avenue Williston, VT 05495	2	99	21.6
Total			459	100.1

TABLE F-2 Distribution of Days Commuting, Percentages by Workplace Location [question 4]

	Essex	Williston and South Burlington	Waterbury
3 days per week	6.5	7.1	6.2
4 days per week	29.9	25.2	10.6
5 days per week	57.1	63.2	77.4
More than 5 days per week	6.5	4.5	5.8
Sum	100.0	100.0	100.0
Mean*	2.4 (5 days a week/ 4 days a week)	2.3 (5 days a week/ 4 days a week)	2.2 (5 days a week/ 4 days a week)
Standard Deviation*	0.7	0.7	0.6

TABLE F-3 Work Flexibility, Percentages by Workplace Location [question 28]

	Essex	Williston and South Burlington	Waterbury
I have no flexibility in my schedule	71.4	36.8	22.1
I have some flexibility to adjust my schedule, within about 30 minutes	23.4	49.0	58.4
I am pretty much free to adjust my schedule as I like	5.2	14.2	19.5
Sum	100.0	100.0	100.0
Mean*	1.3 (No flexibility/Some flexibility)	1.8 (No flexibility/Some flexibility)	2 (Some flexibility)
Standard Deviation*	0.6	0.7	0.6

TABLE F-4 Work Inflexibility Reasons, Number of People by Workplace Location [question 29]

	Essex	Williston and South Burlington	Waterbury
My work schedule requires me to be present for specific hours each day	54	55	49
My personal situation requires me to arrive and leave at specific times each day	2	1	2
Other	1	2	0
Sum	57	58	51

TABLE F-5 Telecommuting Frequency, Percentages by Workplace Location [question 27]

	Essex	Williston and South Burlington	Waterbury
More than 3 days/week	0	0	0
3 days/week	0	0	0.4
2 days/week	0	0	0
1 day/week	2.6	10.3	3.1
1-3 times/month	1.3	19.4	11.9
Less than once/month	10.4	21.3	35.4
Never	85.7	49.0	49.1
Sum	100.0	100.0	99.9
Mean*	6.8 (Less than once a month/Never)	6.1 (Less than once a month/Never)	6.3 (Less than once a month/Never)
Standard Deviation*	0.6	1.0	0.9

TABLE F-6 Midday Trip Requirement, Percentages by Workplace Location [question 25]

	Essex	Williston and South Burlington	Waterbury
Yes	13.0	27.1	27.4
No	87.0	72.9	72.8
Sum	100.0	100.0	100.2

TABLE F-7 Internet Access Modes, Number of People by Workplace Location [question 48]

	Essex	Williston and South Burlington	Waterbury
Able to access internet at work	67	150	221
Able to access internet at home	75	147	217
Able to access internet on mobile phone	45	116	185
Not able to access internet at listed options	0	1	0
Sum	187	414	623

TABLE F-8 Frequency of Electronic Information Use, Percentages by Workplace Location [question 44]

	Essex	Williston and South Burlington	Waterbury
Daily	3.9	6.5	3.1
Weekly	9.1	11.0	11.5
Monthly	5.2	16.8	18.6
Rarely	50.7	40.0	43.8
Never	31.2	25.8	23.0
Sum	100.0	100.0	100.0
Mean*	4.0 (Rarely)	3.7 (Monthly/Rarely)	3.7 (Monthly/Rarely)
Standard Deviation*	1.0	1.2	1.0

TABLE F-9 Residence Environment Types, Percentages by Workplace Location [question 8]

	Essex	Williston and South Burlington	Waterbury
City, downtown with a mix of offices, apartments, & shops	7.8	2.6	2.7
City, residential neighborhood	16.9	19.4	11.1
Suburban neighborhood, with a mix of houses, shops, & businesses	13.0	7.1	11.1
Suburban neighborhood, with houses only	11.7	19.4	10.2
Small town or rural village	19.5	20.6	23.0
Rural area, outside of a town or village	31.2	31.0	42.0
Sum	100.1	100.1	100.1

TABLE F-10 Residence Types, Percentages by Workplace Location [question 6]

	Essex	Williston and South Burlington	Waterbury
Single-family house (detached house)	68.8	67.7	68.1
Townhouse (attached house)	7.8	5.2	7.1
Building with 3 or fewer apartments or condos	2.6	9.7	8.4
Building with 4 or more apartments or condos	14.3	7.7	10.6
Mobile home or trailer	6.5	9.7	5.3
Dormitory or other institutional housing	0.0	0.0	0.4
Sum	100.0	100.0	99.9

TABLE F-11 Likelihood of a Residential Move within Five Years, Percentages by Workplace Location [question 13]

	Essex	Williston and South Burlington	Waterbury
Extremely unlikely	27.3	28.4	35.0
Somewhat unlikely	14.3	25.2	18.1
Neutral	11.7	15.5	12.8
Somewhat likely	24.7	8.4	10.6
Extremely likely	22.1	22.6	23.5
Sum	100.1	100.1	100.0
Mean*	3.0 (Neutral)	2.7 (Somewhat unlikely-Neutral)	2.7 (Somewhat unlikely-Neutral)
Standard Deviation*	1.5	1.5	1.6

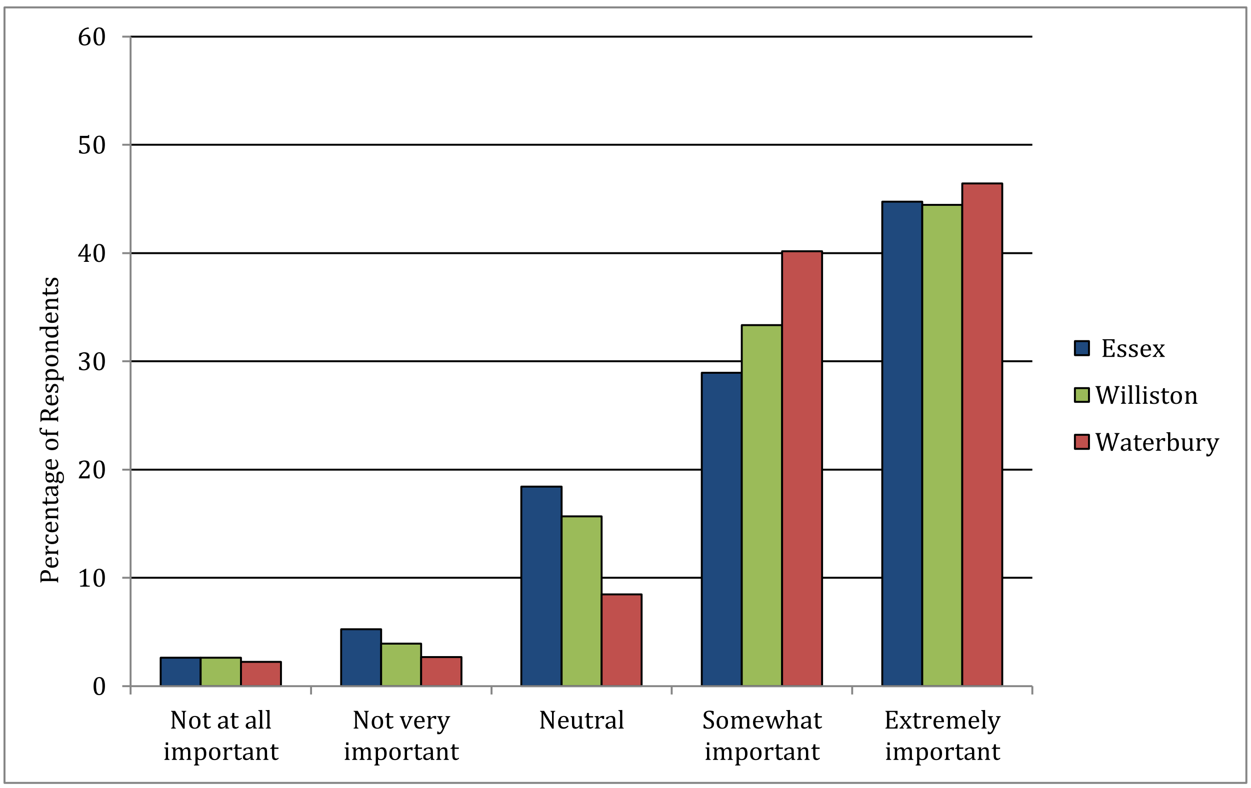

FIGURE F-1 Importance of Living Close to Work, School and Friends, Percentages by Workplace Location [question 14]

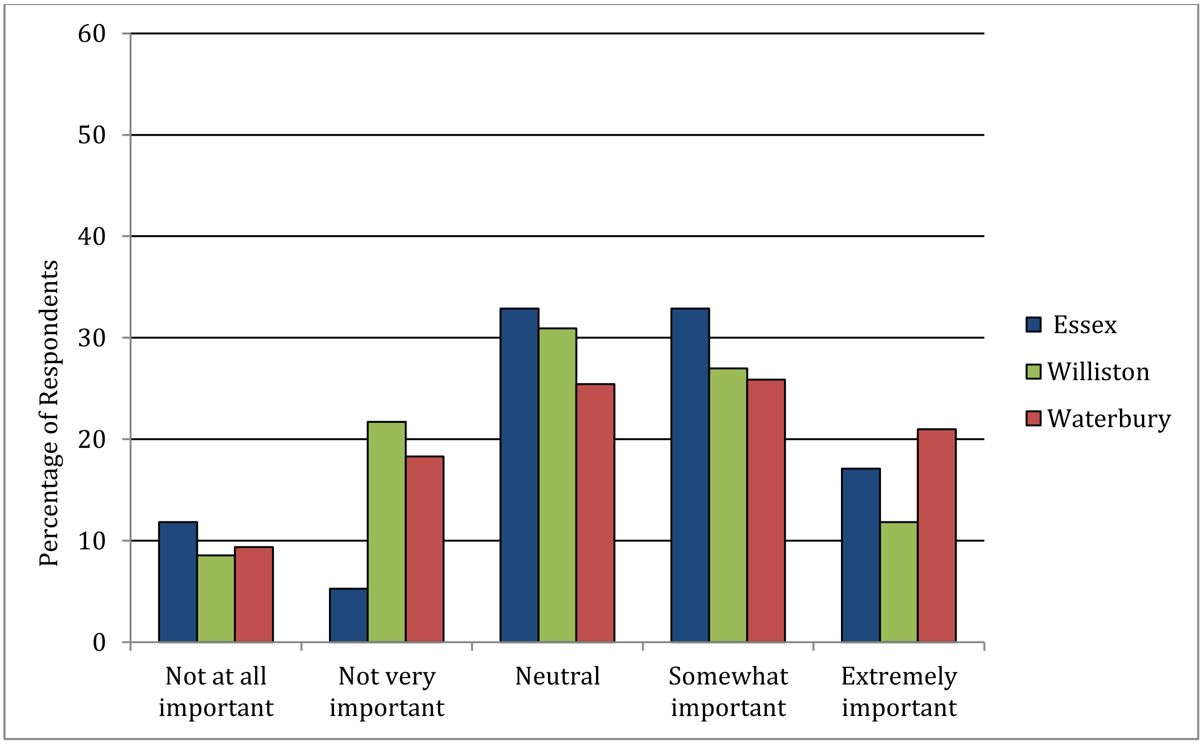

FIGURE F-2 Importance of Living Close to a Village or Commercial Center, Percentages by Workplace Location [question 14]

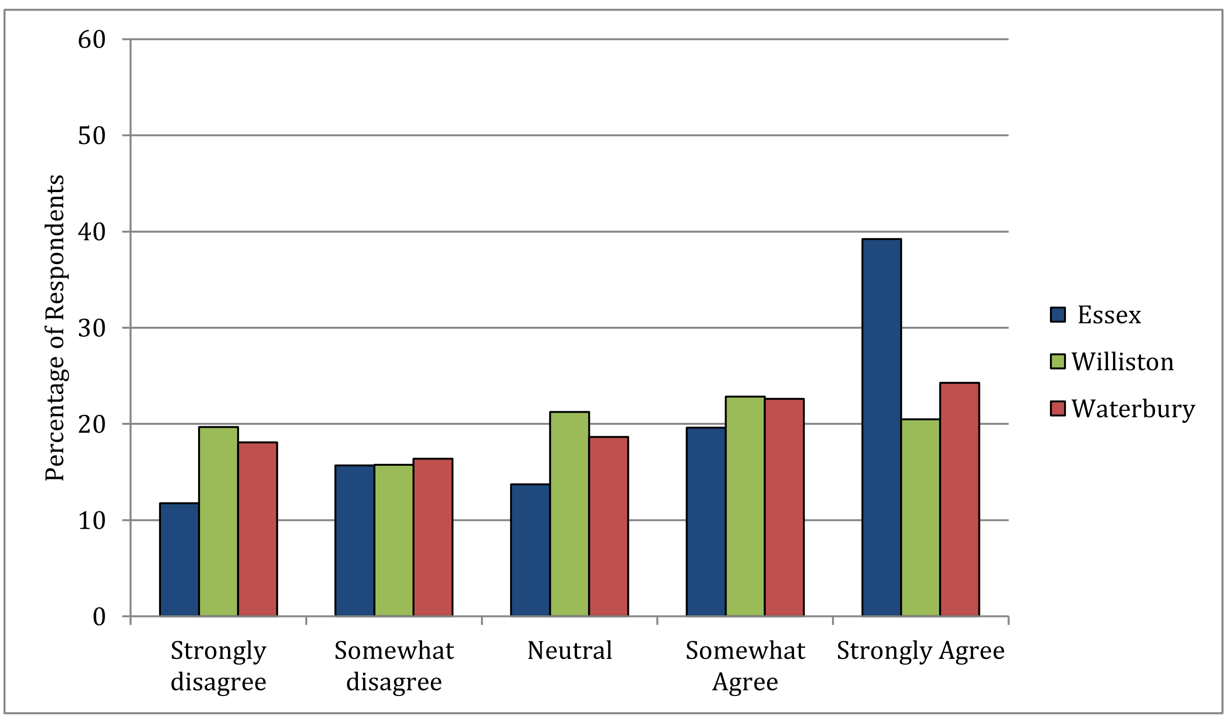

FIGURE F-3 Vehicle Attitude: Prefer Larger Vehicles for Longer Trips, Percentages by Workplace Location [question 21]

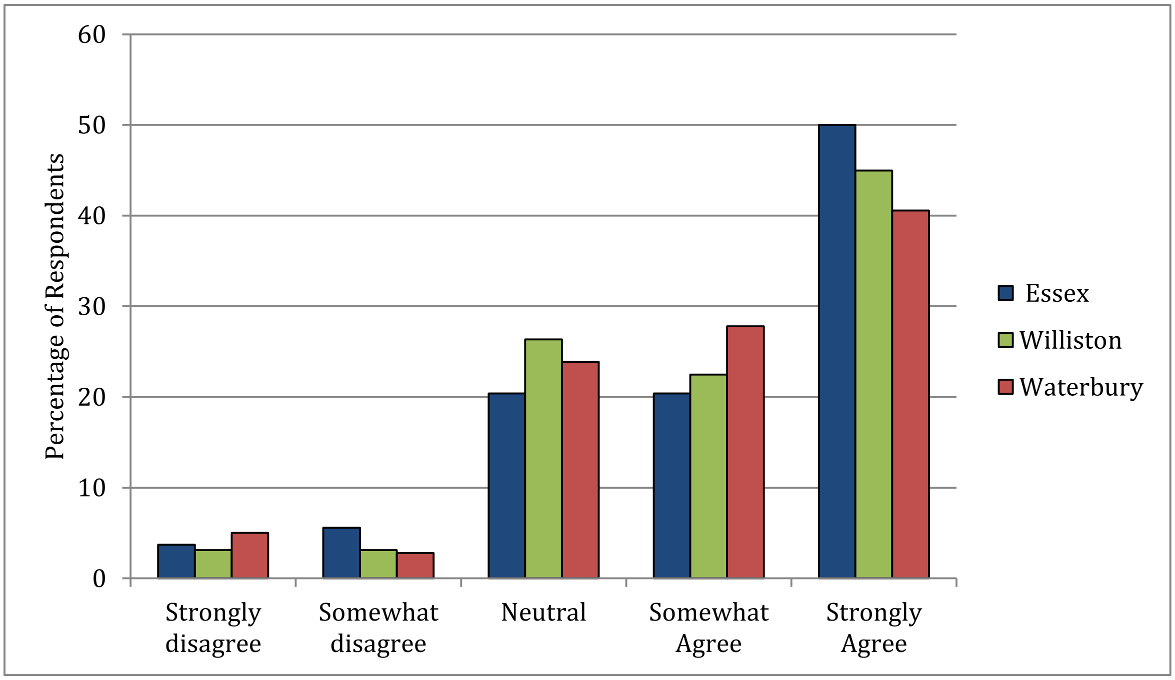

FIGURE F-4 Vehicle Attitude: Prefer to Use Own Vehicle, Percentages by Workplace Location [question 21]

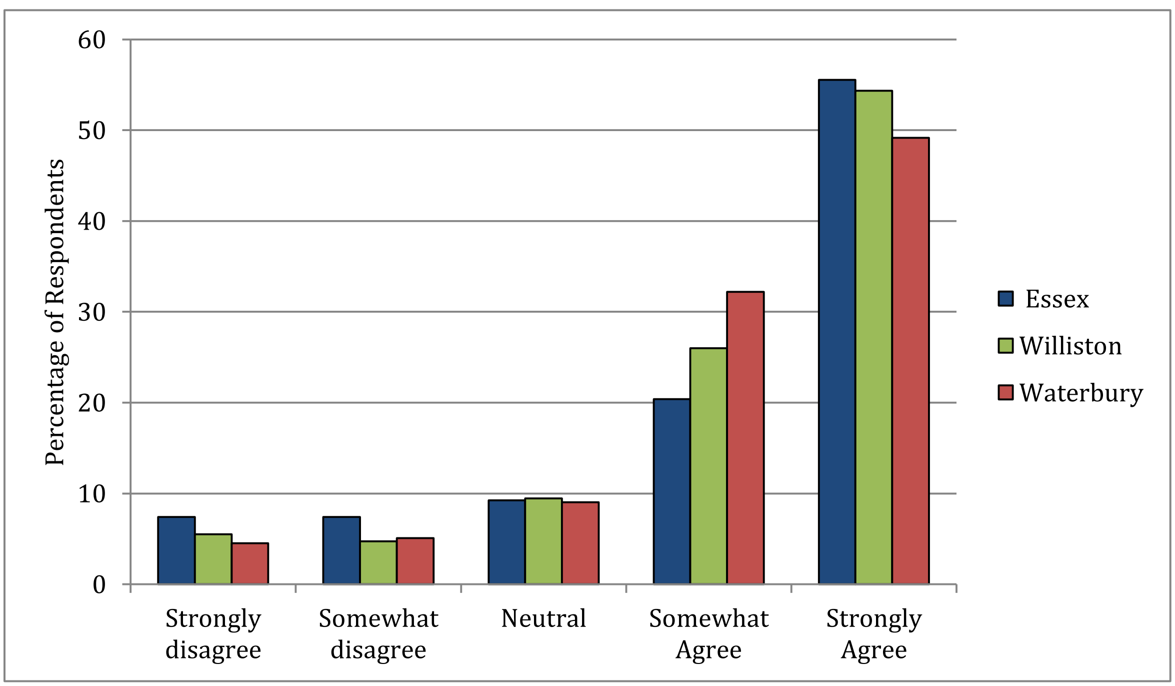

FIGURE F-5 Vehicle Attitude: Carrying Cargo Affects Vehicle Choice, Percentages by Workplace Location [question 21]

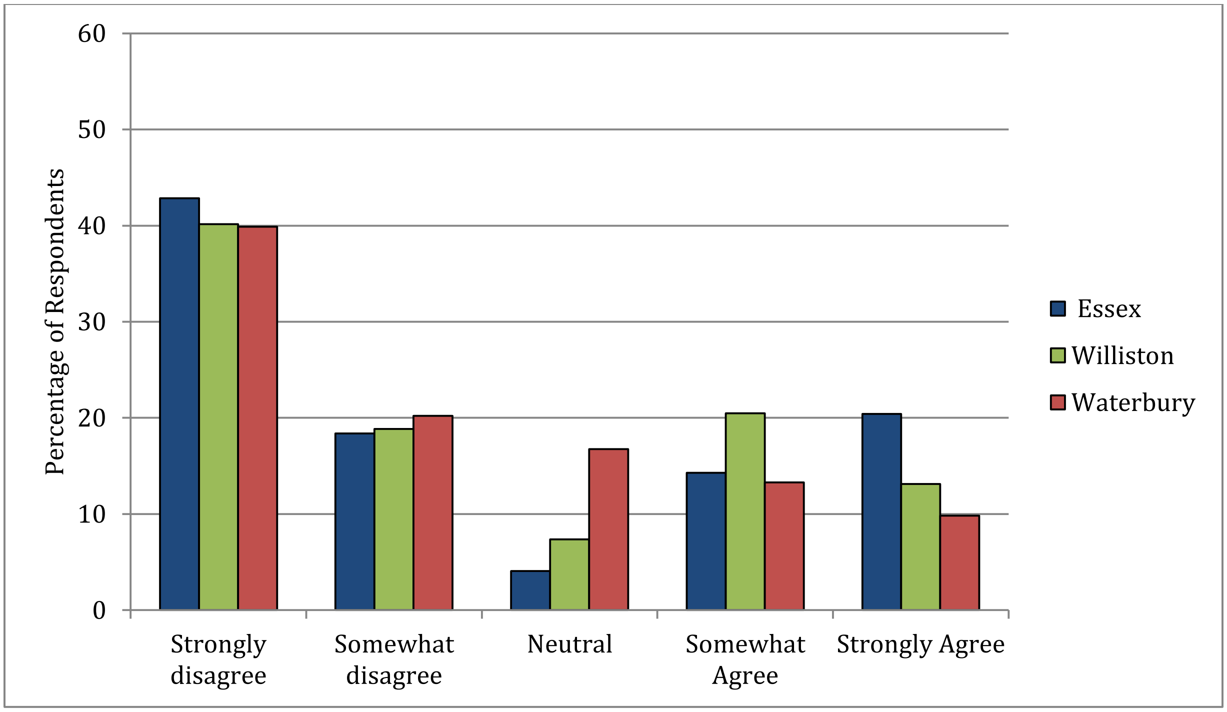

FIGURE F-6 Vehicle Attitude on Using a Different Vehicle for Work and Non-Work Trips, Percentages by Workplace Location [question 21]

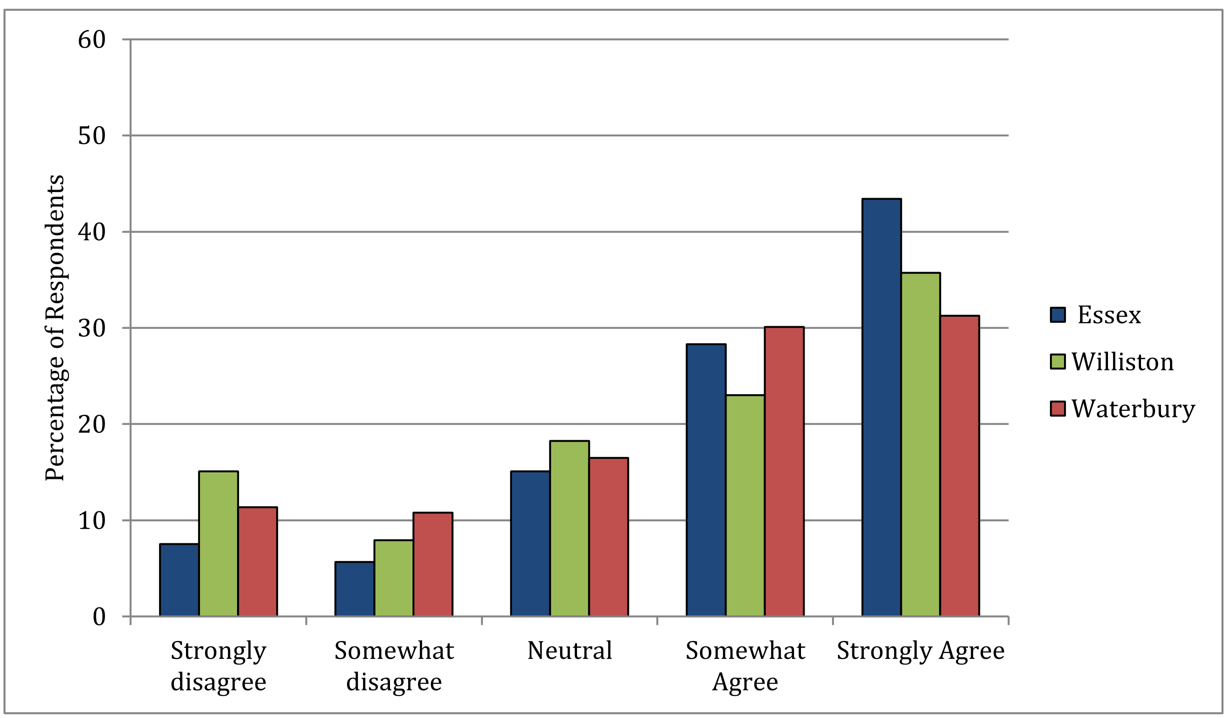

FIGURE F-7 Vehicle Attitude on the Number of Travelers Affecting Vehicle Choice, Percentages by Workplace Location [question 21]

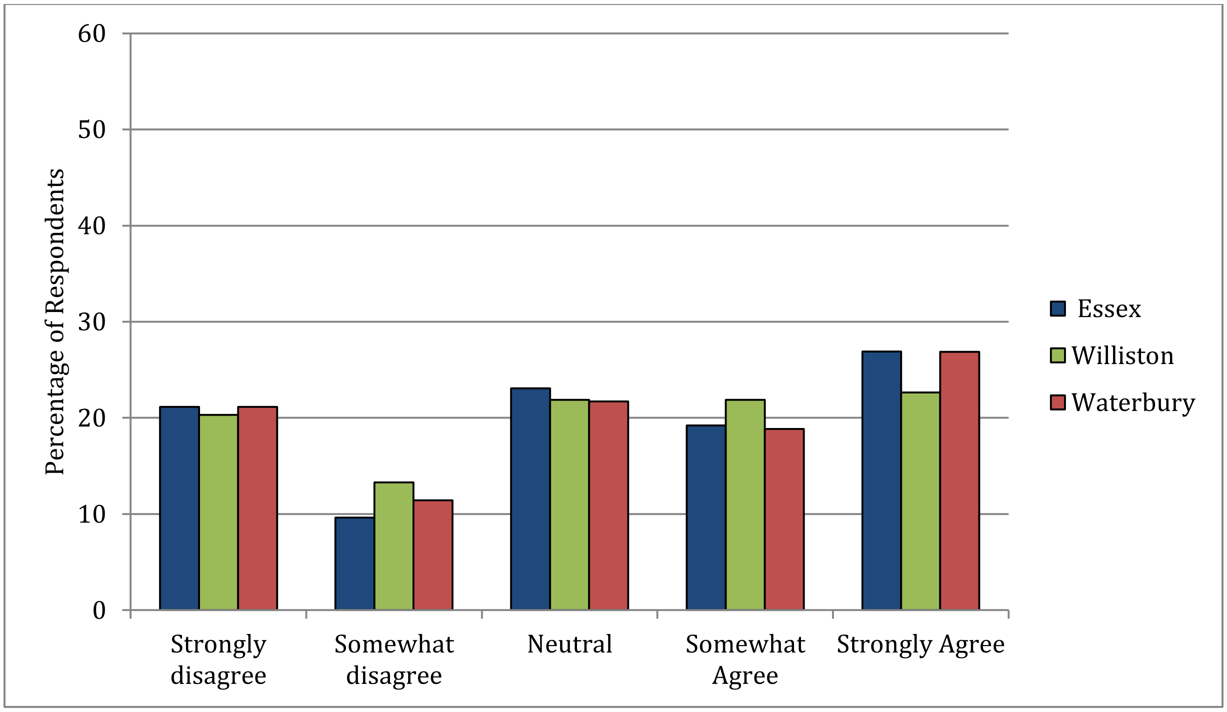

FIGURE F-8 Vehicle Attitude on Who Drives Affecting Vehicle Choice, Percentages by Workplace Location [question 21]

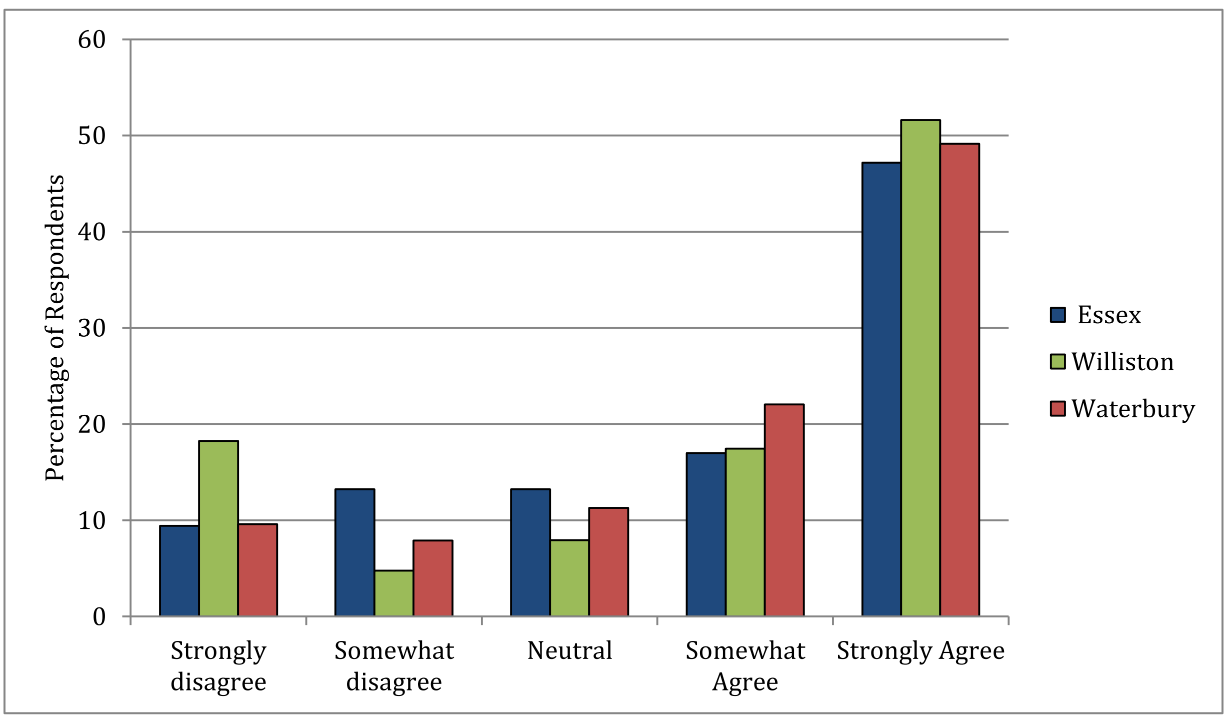

FIGURE F-9 Vehicle Attitude on Weather and Road Condition Affecting Vehicle Choice, Percentages by Workplace Location [question 21]

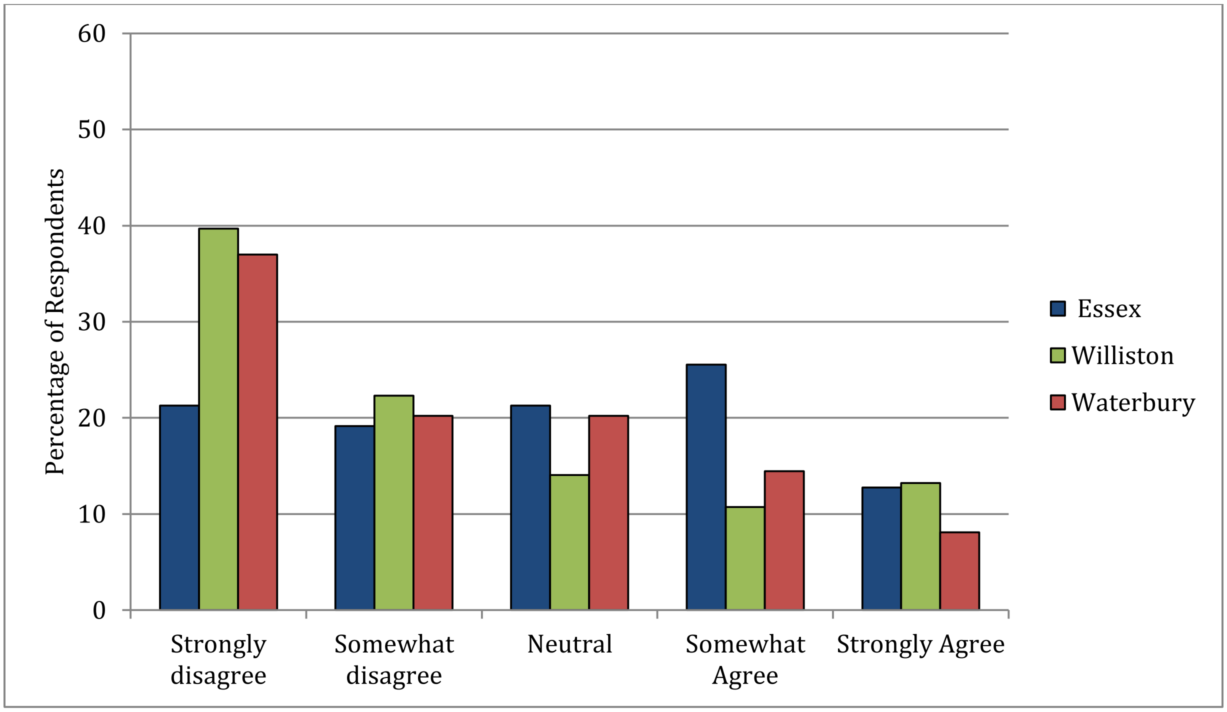

FIGURE F-10 Vehicle Attitude on the Household Often Discussing Who Will Use Which Vehicle, Percentages by Workplace Location [question 21]

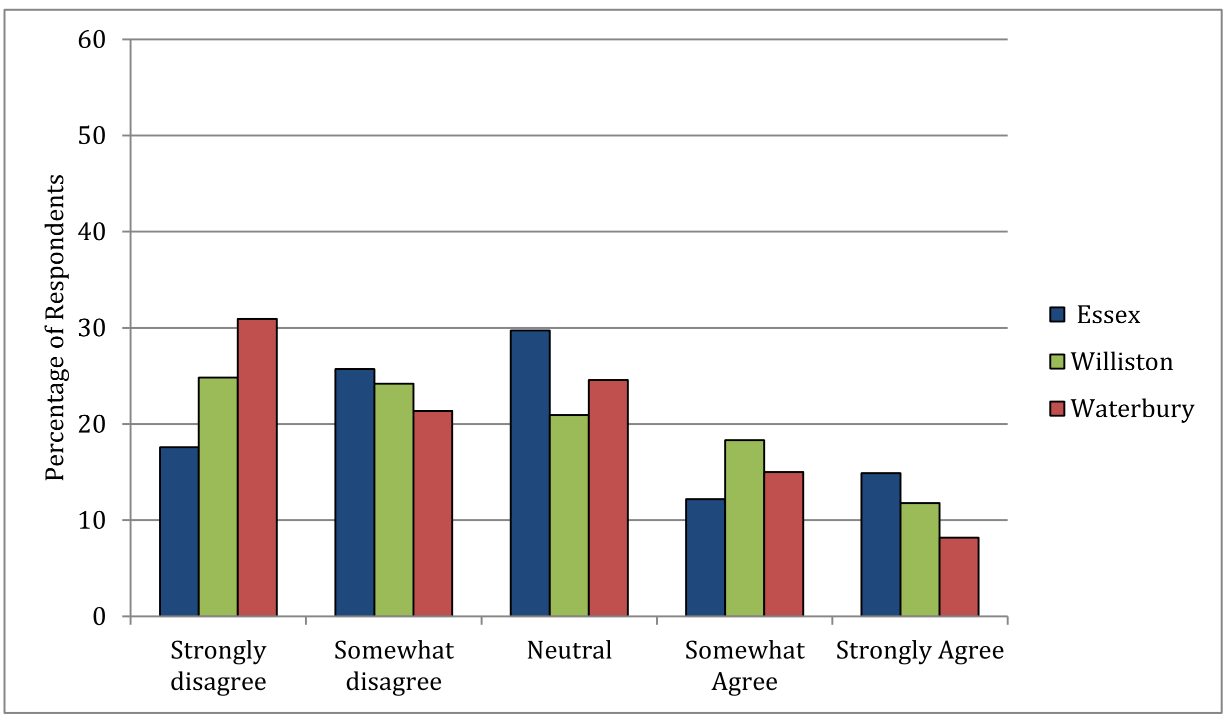

FIGURE F-11 Attitude on Shuttle Use and Concern about Traveling with Strangers, Percentages by Workplace Location [question 44]

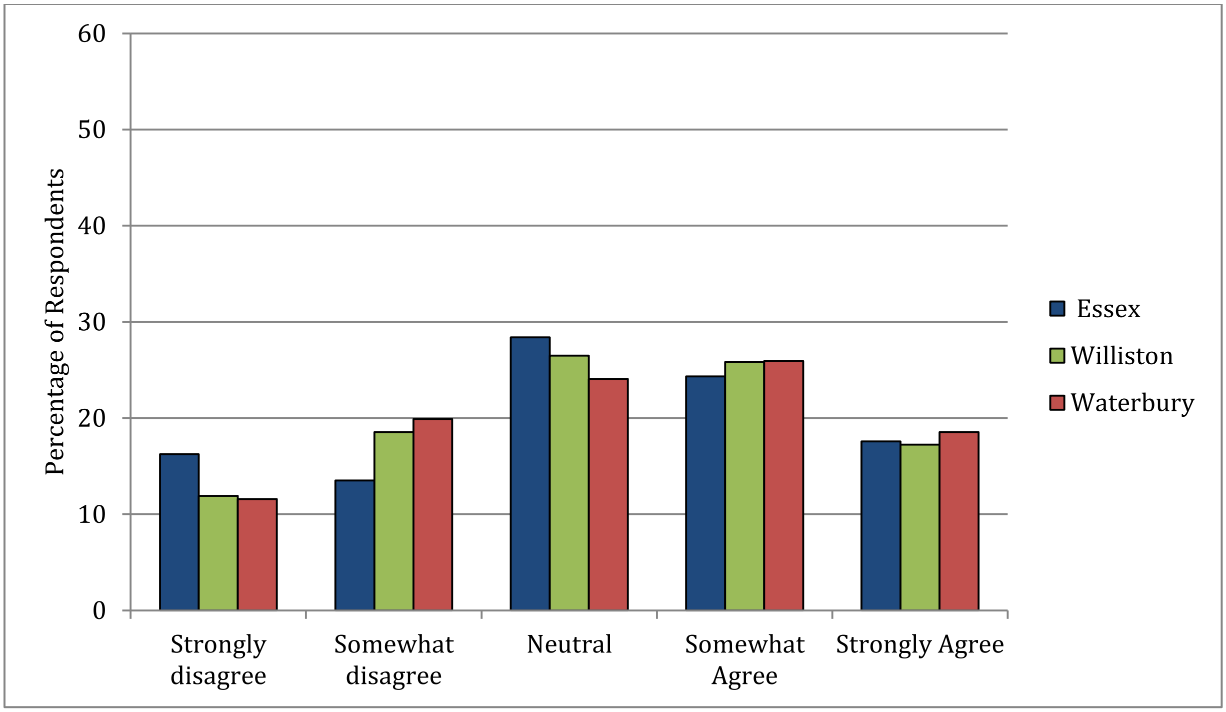

FIGURE F-12 Attitudes on Shuttle Use and Concern about Getting to Work Faster, Percentages by Workplace Location [question 44]

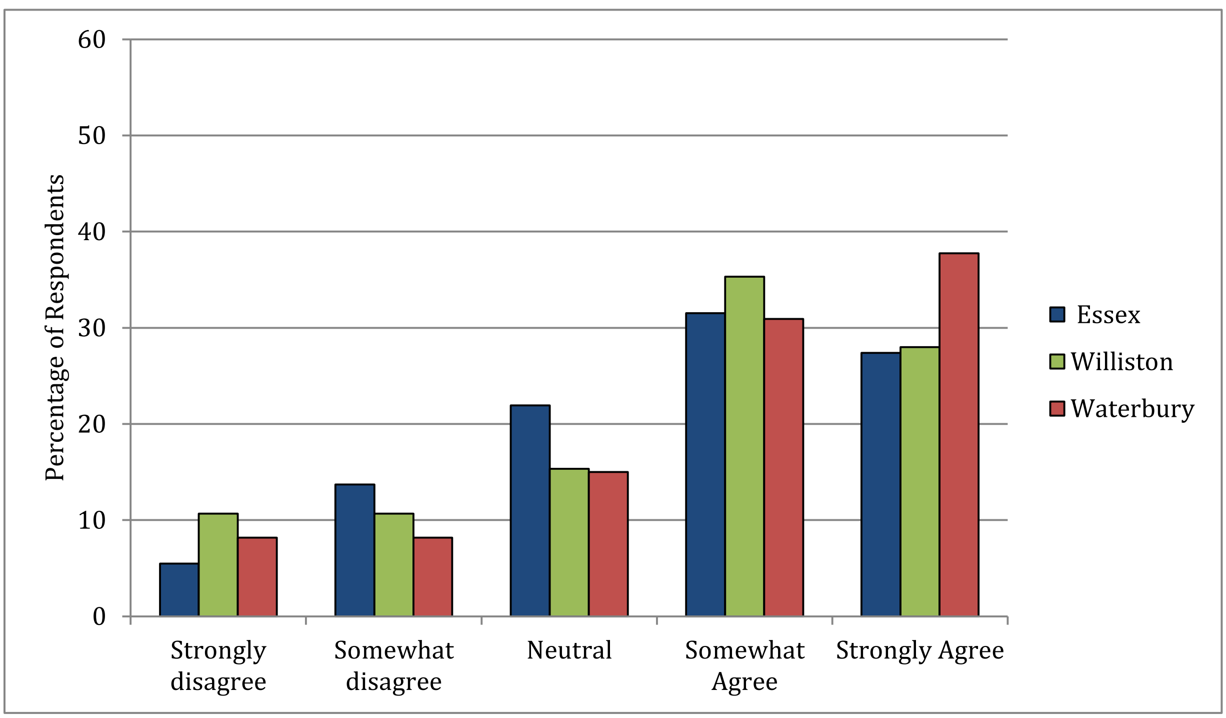

FIGURE F-13 Attitudes on Shuttle Use and Need to Come and Go Easily, Percentages by Workplace Location [question 44]

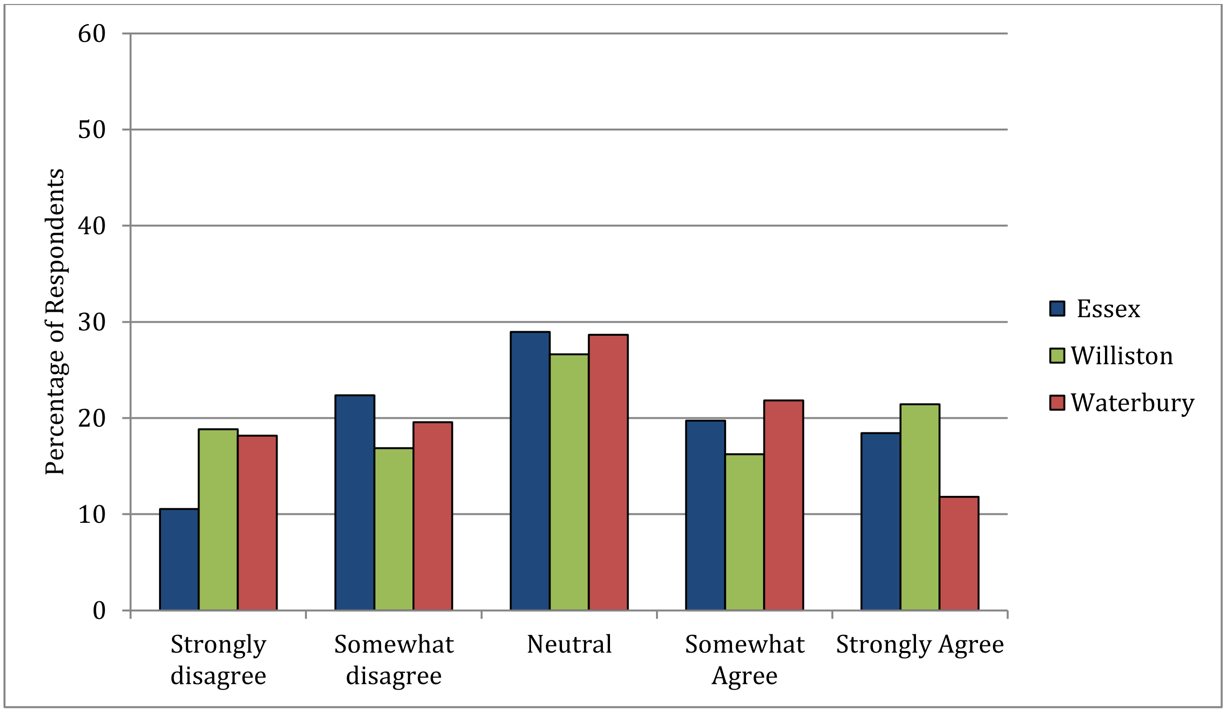

FIGURE F-14 Attitudes on Shuttle Use and Preferring to be the Driver, Percentages by Workplace Location [question 44]

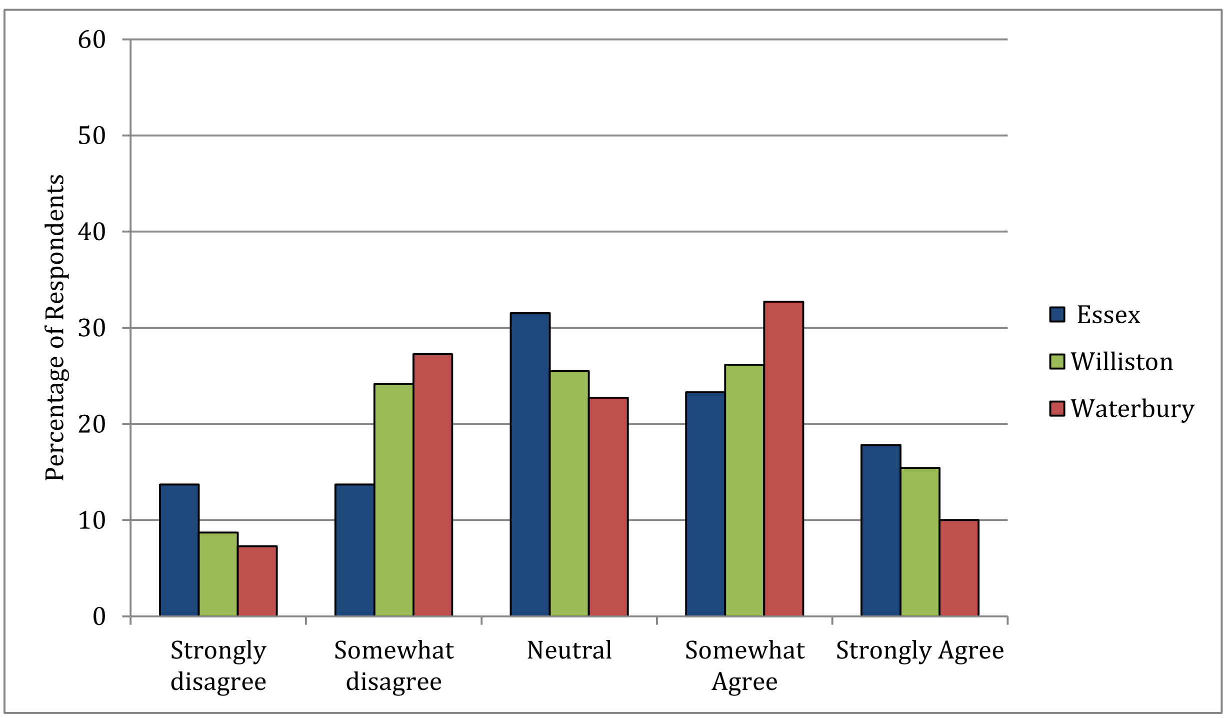

FIGURE F-15 Attitude on Using Most Convenient Mode of Transportation Regardless of Cost, Percentages by Workplace Location [question 44]

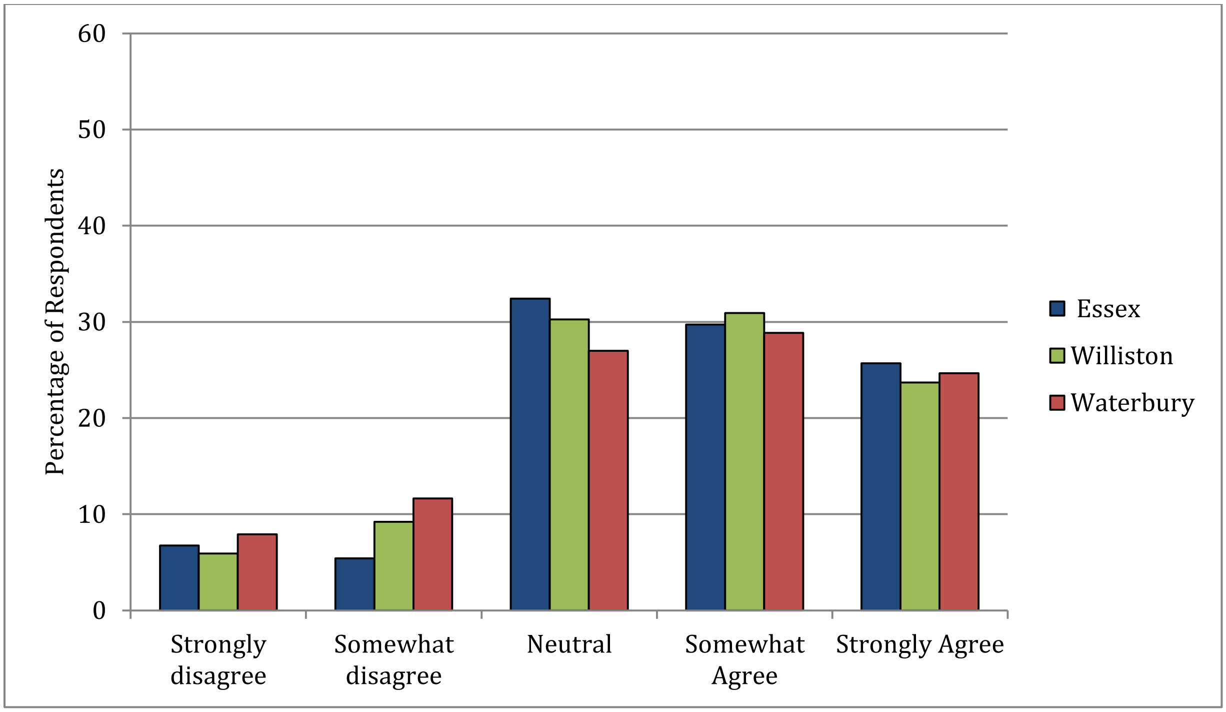

FIGURE F-16 Attitude on Willingness to Use Shuttle, Percentages by Workplace Location [question 44]

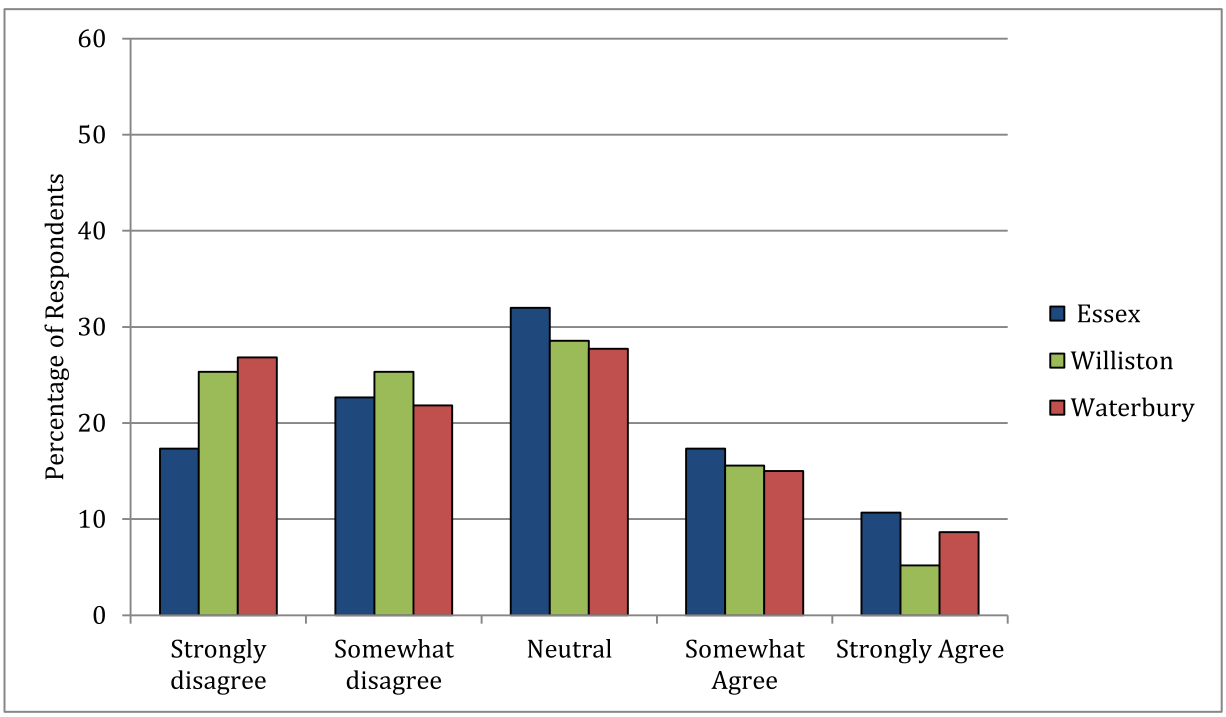

FIGURE F-17 Attitude on Shuttle Use and Importance of Controlling Vehicle Radio and Air Conditioning, Percentages by Workplace Location [question 44]

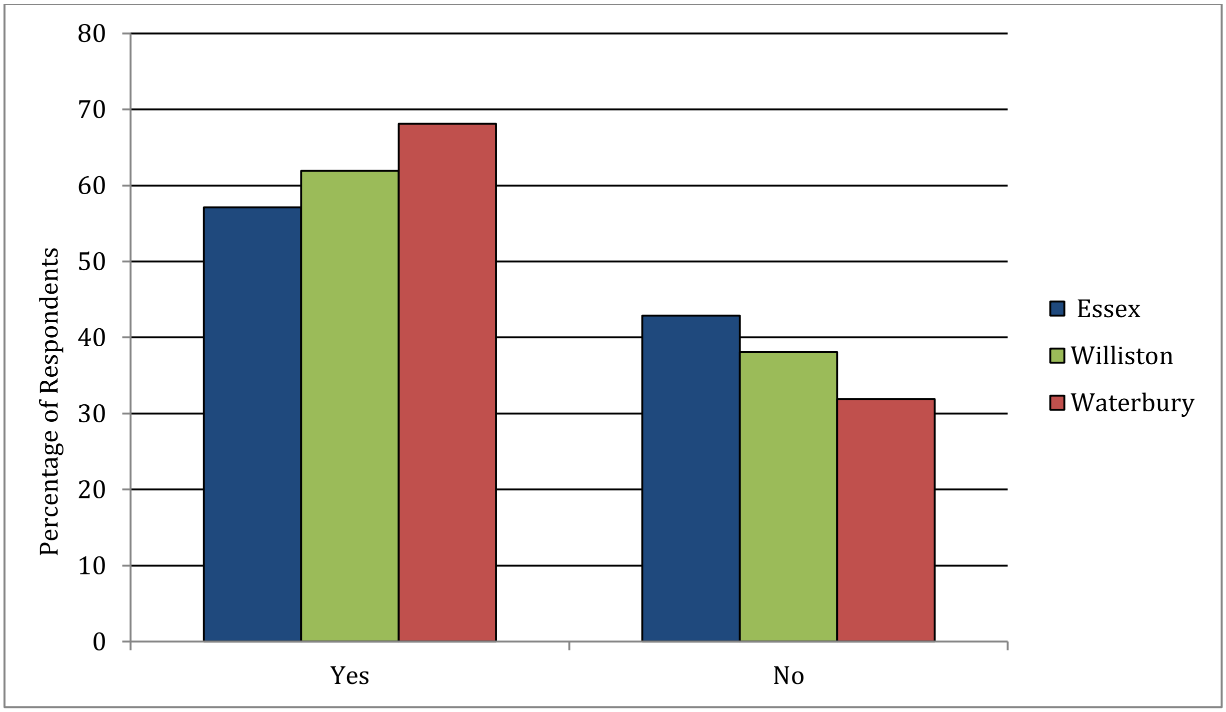

FIGURE F-18Willingness to rideshare with someone not known personally but registered for a Rideshare Program, Percentage of Respondents by Workplace Location [question 51]

TABLE F-12 Number of Bikes per Household, Percentages by Workplace Location [question 18]

	Essex	Williston and South Burlington	Waterbury
No bicycles	33.8	20.0	16.4
1 bicycle	18.2	15.5	17.7
2 bicycles	23.4	25.8	24.8
3 bicycles	14.3	13.6	16.4
4 bicycles	3.9	14.8	12.4
5 bicycles	3.9	3.2	3.5
6 or more bicycles	2.6	7.1	8.9
Sum	100.1	100.0	100.1
Average* (true #)	1.6	2.3	2.4
Standard Deviation*	1.6	1.8	1.8

TABLE F-13 Transit Availability, Number of People by Workplace Location [question 26]

	Essex	Williston and South Burlington	Waterbury
Large bus	29	60	59
Small bus	7	17	48
Special bus	10	32	23
Taxi	32	66	64
Other	1	1	4
None	28	50	95
I don’t know	11	17	22
Sum	118	243	315

TABLE F-14 Commuting Modes, Number of People by Workplace Location [question 30]

	Essex	Williston and South Burlington	Waterbury
Alone	60	127	194
Dropoff (R)	1	4	2
Carpool (R)	16	24	25
Vanpool (R)	0	0	0
Bus	0	1	0
Bike	2	2	5
Walk	1	0	6
Taxi	0	0	0
Other	2	2	3
Sum	82	160	235

TABLE F-15 Average Travel Time by Workplace Location [question 36]

	Essex	Williston and South Burlington	Waterbury
Average travel time [min]	32.1	29.2	28.0
Standard deviation	18.4	15.4	15.1

TABLE F-16 Average Longest Commute Distance by Workplace Location [question 43]

	Essex	Williston and South Burlington	Waterbury
Average	30.0	25.7	27.1
Standard deviation	25.9	22.0	14.5

TABLE F-17 To Work Stops, Percentages by Workplace Location [question 38]

	Essex	Williston and South Burlington	Waterbury
No stops	62.3	72.3	78.3
1 stop	28.6	22.6	18.6
2 stops	7.8	3.2	2.2
3 or more stops	1.3	1.9	0.9
Sum	100	100	100
Average to work stops	1.5 (No stop/1 stop)	1.4(No stop/1 stop)	1.3(No stop/1 stop)
Standard deviation	.7	.6	.5
Average stops per person	.5	.3	.3

TABLE F-18 To Work Stop Reasons, Number of People by Workplace Location [question 39]

	Essex	Williston and South Burlington	Waterbury
Food or coffee	10	8	15
Child care or school drop-off/pick-up	3	11	13
To drop someone else off	0	2	2
To pick someone up	8	9	8
Personal errand including shopping	3	6	4
Meeting or other work-related task	0	0	0
Visit or assist a friend or family member	0	0	0
Other	8	9	12
Sum	32	45	54

TABLE F-19 From Work Stops, Percentages by Workplace Location [question 40]

	Essex	Williston and South Burlington	Waterbury
No stops	62.3	50.3	56.6
1 stop	27.3	36.8	31.4
2 stops	9.1	9.0	8.4
3 or more stops	1.3	3.9	3.5
Sum	100	100	99.9
Average to work stops*	1.5(No stop to 1 stop)	1.7(No stop to 1 stop)	1.6(No stop to 1 stop)
Standard deviation *	0.7	0.8	0.8
Average stops per person	.5	.7	.6

TABLE F-20 From Work Stop Reasons, Number of People by Workplace Location [question 41]

	Essex	Williston and South Burlington	Waterbury
Food or coffee	4	21	19
Child care or school drop-off/pick-up	3	14	17
To drop someone else off	5	7	7
To pick someone up	1	4	8
Personal errand including shopping	11	28	48
Meeting or other work-related task	0	2	5
Visit or assist a friend or family member	2	1	1
Other	7	17	14
Sum	33	94	119

TABLE F-21 Alternate Modes of Transportation Considered, Number of People by Workplace Location [47]

	Essex	Williston and South Burlington	Waterbury
Drop off	10	32	33
Carpool	36	56	93
Vanpool	2	2	1
Bus	1	10	10
Taxi	2	2	0
Bike	2	17	26
Walk	3	1	15
Telecommute	3	26	33
Other	2	5	0
I don't know	9	25	41
Sum	70	176	252