University Transportation Research Center - Region 2

Final Report

Analyzing Willingness to Improve the Resiliency of New York City's Transportation System

Performing Organization: Cornell University

December 2015

Sponsor:
University Transportation Research Center - Region 2

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: "Planning and Managing Regional Transportation Systems in a Changing World." The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation's largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region's intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center's theme.

Education and Workforce Development

The modern professional must combine the technical skills of engineering and planning with knowledge of economics, environmental science, management, finance, and law as well as negotiation skills, psychology and sociology. And, she/he must be computer literate, wired to the web, and knowledgeable about advances in information technology. UTRC's education and training efforts provide a multidisciplinary program of course work and experiential learning to train students and provide advanced training or retraining of practitioners to plan and manage regional transportation systems. UTRC must meet the need to educate the undergraduate and graduate student with a foundation of transportation fundamentals that allows for solving complex problems in a world much more dynamic than even a decade ago. Simultaneously, the demand for continuing education is growing – either because of professional license requirements or because the workplace demands it – and provides the opportunity to combine State of Practice education with tailored ways of delivering content.

Technology Transfer

UTRC's Technology Transfer Program goes beyond what might be considered "traditional" technology transfer activities. Its main objectives are (1) to increase the awareness and level of information concerning transportation issues facing Region 2; (2) to improve the knowledge base and approach to problem solving of the region's transportation workforce, from those operating the systems to those at the most senior level of managing the system; and by doing so, to improve the overall professional capability of the transportation workforce; (3) to stimulate discussion and debate concerning the integration of new technologies into our culture, our work and our transportation systems; (4) to provide the more traditional but extremely important job of disseminating research and project reports, studies, analysis and use of tools to the education, research and practicing community both nationally and internationally; and (5) to provide unbiased information and testimony to decision-makers concerning regional transportation issues consistent with the UTRC theme.

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16. Abstract

The goal of this project is to provide statistical inference for the **community's willingness to pay for improvements in the resiliency to extreme events of the transportation system** in New York City.This objective seeks to provide better tools for better informing planning investments to improve both resilience and security of transportation infrastructure and services. A fundamental, specific goal is to collect microdata using a choice-experiment based specifically designed for this project. The population of interest for this study is those coastal communities in the NYC area facing increased risks of flood damage.

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Introduction

New York City has one of the largest and busiest transportation systems, both in the nation and in the world. This system is vital to the everyday success of the area's economy, environment, and overall well-being (NYS 2100 Commission, 2013). Any disruption to this system has far-reaching and serious ramifications. One of the largest disruptions in the system's history came in October of 2012 in the form of Hurricane Sandy. According to the National Centers for Environmental Information, Sandy was the second costliest and second deadliest tropical cyclone between 1980 and 2014, with Hurricane Katrina being first in both categories (NCEI). FEMA stated in their after-action report that "The storm's impact was intensified because it made landfall in the most populated region of the country—a region that includes critical infrastructure vital to the Nation's economy" (2013). The region they are referring to is the New York Metropolitan Area.

Sandy revealed some critical deficiencies in the area's transportation system, and, unfortunately, experts predict that future sea level rise and storms will exacerbate the problems caused by these deficiencies. Luckily, there are many solutions to the problem of transportation resiliency that are currently being explored, as well as many sources of funding for these solutions. By examining the effects of Hurricane Sandy on NYC and the surrounding areas, we can see what areas need to be addressed with specific solutions and can begin to discuss how these solutions might be financed.

Several measures were taken before the storm to try and prevent damage to transportation infrastructure, including moving mobile units like trains and buses out of low-lying areas, placing sandbags and tarps at the entrances of subways and over vent to prevent flooding, and preemptively clearing debris from drains and pumps (Kaufman et al., 2012). Bus services, subway services, and commuter and regional rail train services were shut down the night before Sandy made landfall in order to allow the city time to prepare. This left many people no other option but to either walk or use a car or taxi. At the same time, many of these precautions proved successful: almost all subway and bus services were restored just a few days after the storm, and all three major airports in the area (LaGuardia, Newark, and JFK) opened within two days after the storm (Kaufman et al., 2012).

However, much damage was still done; for example, some PATH train stations were still closed weeks after the storm. Infrastructure especially in Lower Manhattan and parts of Brooklyn and Queens near the shore line was greatly affected, with tunnels and subways inundated with storm and sea water, and surface and overground transport severely damaged by high winds and torrential rain. Some sections of subway lines were closed for up to 14 months. At one time, the MTA alone estimated about five billion dollars in damage was done after Sandy passed over. (MTA).

Plans, such as MTA's "Fix&Fortify", have been made to improve the resiliency of the transport infrastructure in the metro area. However, projects like these are costly. Some of the funding comes from the state and federal government, some from the Department of Transportation. Some also comes from revenue. Shutting down the entire system not only loses revenue, but also causes a loss of money the system already has. One way the MTA, for example, makes up for a deficit is to introduce a fare hike. On March 22, 2015, commuters saw the fourth fare hike for New York City Transit up to $2.75 per ride since 2009. Citizens complained saying that the paycheck they receive stays the same even when the fares increase. However, the fare hike is intended to help solve the financial obstacles MTA faces, and to support projects such as "Fix&Fortify" to make the system more resilient to inclement weather.

The damages from Sandy come at great cost for all of the areas affected. In New Jersey alone, over $3 billion in transportation-related recovery expenditures are predicted between 2012 and 2015 (Mantell et al., 2013).

There were also additional, non-monetary costs. In a survey of eight different "residence locations" including the five boroughs, New Jersey, the Northern suburbs, and Long Island, six of the eight locations reported an increase in travel time immediately after Hurricane Sandy, sometimes by as much as two and a half hours (Kaufman et al., 2012). These increased travel times correlated to an increase in the frustration levels of commuters. All of the locations surveyed reported some level of frustration due to transportation issues, with the most extreme frustration levels being experienced by those from Staten Island.

All of these factors – monetary costs due to damages from the storm, time lost due to an impaired transportation system, and increased levels of frustration – demonstrate why it is important and necessary to make the transportation system of New York City and the surrounding areas more resilient.

According to a study by Princeton and MIT researchers, there are two main contributors to increased flooding in NYC: hurricanes and other storms, and rising sea levels (Parry). Although it is difficult to predict how climate change will affect future storms, the change in sea levels can be predicted, and they are expected to rise in coming years. One estimate puts the mean annual sea level rise between 12 and 23 inches by the decade 2080 (*Climate Risk Information, 2009*). According to the NYS 2100 Commission, the maximum rise could be as high as six feet in NYC and Long Island (NYS 2100 Commission, 2013). Not only are sea levels themselves increasing, but so are their rates of change. As of now, sea level rise increases at a rate of 0.86-1.5 inches per decade; 150 years ago, these rates were as low as 0.34-0.43 inches per decade (*Climate Risk Information, 2009*). Because of these sea level increases, one can expect to see an increase in the number of 1-in-100 year flood occurrences. The NYC Panel on Climate Change estimates that these events could become four times as likely by 2100 (*Climate Risk Information, 2009*). This is an issue in terms of transportation because the mean storm surge that can be produced by one of these floods (8.6 feet) is about at or above the mean elevation above sea level of NYC (10 feet of less) (*Climate Risk Information, 2009*). This means that every flood poses a severe hazard to the transportation system. The possible effects of severe flooding on a transportation system can be seen by looking at the effects of Hurricane Sandy on the NYC transportation system and on that of the surrounding area.

2. Project Research Goals

The goal of this project is to provide statistical inference for the **community's willingness to pay for improvements in the resiliency to extreme events of the transportation system** in New York City.This objective seeks to provide better tools for better informing planning investments to improve both resilience and security of transportation infrastructure and services.

A fundamental, specific goal is to collect microdata using a choice-experiment based specifically designed for this project. The population of interest for this study is those coastal communities in the NYC area facing increased risks of flood damage.

2.1. Research Plan and Methods

Traditional sources of funding for both recovering from disasters and preventing future damages are not only limited, but also do not account for benefit transfers of the externalities induced by the provision of resilient infrastructure. For instance, the construction of massive structures such as surge barriers to protect coastal urban areas provokes a positive externality on the residential value of the properties in the area. This positive externality results from lower expected damage coming from lower flood risks. In principle, property owners should be willing to pay an amount equal to the perceived benefit if this positive externality is internalized by them following some **pricing mechanism**. Monetizing these benefit transfers can be used as a tool not only to leverage scarce public resources, but also to achieve a socially optimal resource allocation. An essential element is then the estimation of the **willingness to pay**, because this measure can be exploited to determine the cost share the community is willing to cover to secure infrastructure systems as well as to receive the benefits from minimizing potential damage. To make inference on the willingness to pay for flood risk reductions, this project adopts an approach based on **discrete choice experiments** (Hensher et al., 2005).

2.2. Literature Review

Although not directly related to the goals of this project, there is a well-established literature that looks at the challenges in the catastrophe risk insurance market (e.g., Jaffee and Russell, 1997; Grace et al., 1998; Froot 2001; Kunreuther et al., 2002; Grace et al., 2003; Kleindorfer and Klein, 2003; Kunreuther, 2006; Kunreuther and Michel-Kerjan, 2009; Kousky 2011; Paudel 2012).

Regarding demand-side dynamics of catastrophe risk insurance, there is strong evidence that property owners often do not fully insure their property nor do they invest in pre-event mitigation activities that can reduce losses (Kunreuther 1996; Kreisel and Landary 2004; Kunreuther and Pauly 2004; Dixon et al. 2006). Property owners frequently do not have adequate financial resources to recover losses they do experience, and may demand relief from the government (Kunreuther and Pauly 2004). In fact, evidence shows that major disasters are often followed by large, unplanned government expenditures that create major difficulties for local and state government budgets (Kunreuther and Pauly 2006). Over-reliance on post-disaster relief from the government may create serious stress on the private insurance market (Kunreuther and Pauly 2004).

Using discrete choice theory for modeling insurance decisions by property owners has appeared as a novel avenue of research. In particular, recent studies have looked at the determination of willingness to pay for flood insurance, usually in the Netherlands (Brower and Akter, 2010; Botzen and van den Bergh, 2012; Brouwer and Schaafsma, 2013). These studies analyze behavioral response in terms of willingness to pay (premium) for a given insurance cover, which may have an associated deductible.

In addition to the analysis of the dynamics of the catastrophe risk insurance market, there is a developing literature that looks at the role of other funding mechanism for improving resilience to floods. In particular, the following two examples analyze willingness to pay **higher taxes**.

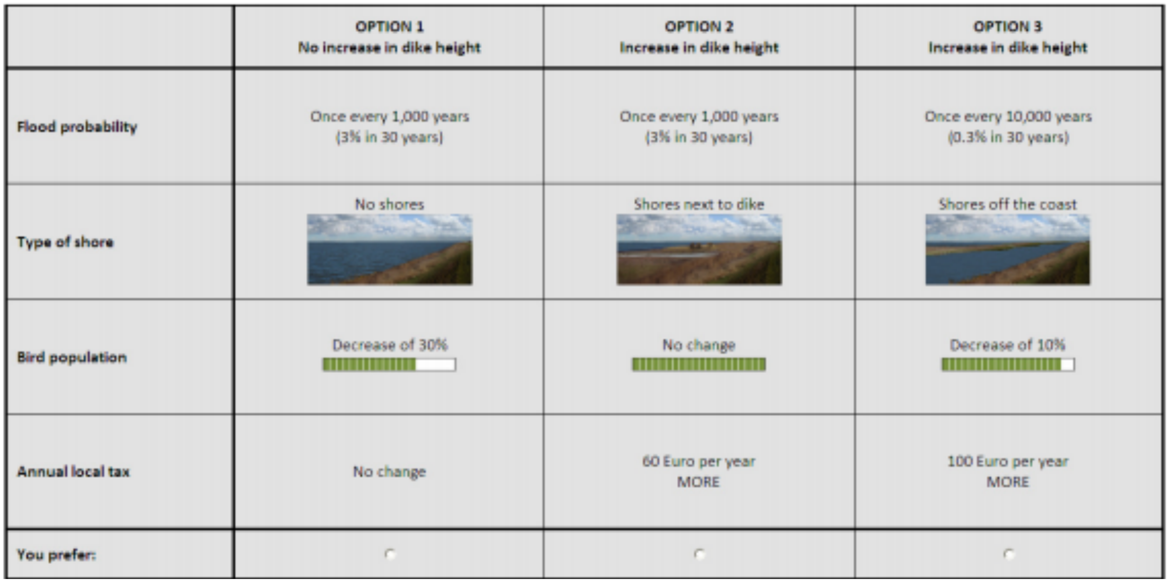
Reference Dependency and the WTP-WTA gap: Evidence from choice experiments in a low probability-high impact flood context. (Koetse and Brouwer, 2013). This study was conducted in the Ijsselmeer region of the Netherlands. The purpose was to utilize choice experiments to compare different economic measures of the same change in welfare and to examine the effect of reference point on preferences. To this end, four experiments were designed: two measuring willingness-to-pay (WTP) and two measuring willingness-to-accept (WTA). Each category had one experiment using a lower reference level flood probability (experiment 1) and one experiment using a higher reference level flood probability (experiment 2). The sample was made up of 1,208 households.

Table 1: Attributes and Levels for the discrete choice experiment of Koetse and Brouwer (2013)

Table 1. Attributes and their levels in the four choice experiments

Attributes	Attribute levels
Raising the dikes	▪ No (baseline scenario in WTP version) ▪ Yes (baseline scenario in WTA version)
Flood probability WTP1 & WTA1	▪ Once every 10,000 years (baseline scenario WTA1) ▪ Once every 2,000 years ▪ Once every 1,000 years (baseline scenario WTP1)
Flood probability WTP2 & WTA2	▪ Once every 5,000 years (baseline scenario WTA2) ▪ Once every 1,000 years ▪ Once every 500 years (baseline scenario WTP2)
Bird population	▪ 0 % (baseline scenario WTA) ▪ –10 % ▪ –30 % (baseline scenario WTP)
Type of shore	▪ No additional shores (baseline scenario WTP) ▪ Additional shores not connected to the dike ▪ Additional shores connected to the dike (baseline scenario WTA)
Change in annual local tax (increases in WTP, decreases in WTA)	▪ €0 (baseline scenario) ▪ €60 ▪ €100 ▪ €180

The survey used stated preferences and was administered as a web-based survey. The sample included almost equal numbers of male and female respondents. About one-fifth of the sample was under the age of 35, about two-fifths were between the ages of 35 and 55, and the remaining two-fifths were older than 55. 8% of respondents lived in the three main municipalities of Amsterdam, Rotterdam, and Den Haag; 5% lived in border municipalities, and the remainder lived in nearby provinces. The sample was relatively high class in terms of education and profession, with over half (55.5%) ranking at a 1 or 2 on a scale of 5, where 1 was the highest and 5 the lowest. 35% of households had 2 members, 20% had 4, 17% had 1, 17% had 3, and 9% had over 4.



	OPTION 1 No increase in dike height	OPTION 2 Increase in dike height	OPTION 3 Increase in dike height
Flood probability	Once every 1,000 years (3% in 30 years)	Once every 1,000 years (3% in 30 years)	Once every 10,000 years (0.3% in 30 years)
Type of shore	No shores	Shores next to dike	Shores off the coast
Bird population	Decrease of 30%	No change	Decrease of 10%
Annual local tax	No change	60 Euro per year MORE	100 Euro per year MORE
You prefer:			

Figure 1 Example choice card for the experiment of Koetse and Brouwer (2013)

In addition to presenting risk to respondents as the probability of one occurrence every number of thousands of years, it was also presented as the likelihood of having one flood every 30 years. This second, higher probability increases respondents' understandings of risk by providing a more accessible timescale (30 years is the length of an average mortgage).

The objective of the study was to test three hypotheses: that a WTP-WTA gap exists, that WTP and WTA values are dependent on the reference point, and that the WTP-WTA gap grows as the reference level flood probability increases. There is indeed a difference between WTP and WTA values, as can be seen by comparing the values from WTP experiment 1 to the values from WTA experiment 1, and from WTP experiment 2 to WTA experiment 2. For all attributes, the WTA values are much higher than the WTP values. From the comparison of WTP1 (WTA1) values to WTP2 (WTA2) values, it is shown that the reference point does have a significant effect on welfare. A higher reference level flood probability leads to lower WTP values and higher WTA values. Finally, by comparing the WTP-WTA difference in experiment 1 to the difference in experiment 2, it can be seen that the WTP-WTA difference for experiment 1 is smaller than it is for experiment 2, so a change in the reference level flood probability does affect the WTP-WTA gap.

<u>Implicitly or Explicitly Uncertain?</u> (Dekker et al., 2012). The purpose of this study was to estimate a model for WTP for flood risk reductions that included the effects of preference (un)certainty. It was conducted in the Netherlands, in the provinces of North- and South-Holland (which include Amsterdam, Rotterdam, and Den Haag). Respondents were presented with a sequence of 10 choice cards. The first and tenth cards were identical in each sample, and cards two through eight differed in sequence.

The survey was administered through the web and used stated preferences. Five groups of approximately 250 respondents each were surveyed; this paper focuses on one of these groups, which answered a follow-up question asking how certain they were of their choice. Of these 250, 144 respondents provided information regarding changes in their choice certainty throughout the survey; only these 144 were finally studied. Information of the composition of the sample was not included in the paper.

Table 2: Attributes and Levels for the discrete choice experiment of Dekker et al. (2012)

Table 1: Attributes and attribute levels

Attribute	Possible attribute levels			
Probability	1 in 4,000 years	1 in 6,000 years (1.5x smaller)	1 in 8,000 years (2x smaller)	1 in 10,000 years (2.5x smaller)
Compensation	0%	50%	75%	100%
Available evacuation time	6 hours	9 hours	12 hours	18 hours
Increase in annual tax	€40	€80	€120	€160
	Probability	**Compensation**	**Evacuation**	**Tax**
Status Quo Alternative	1 in 4,000 years	0%	6 hours	€0

As can be seen from the table above, the probability of a flood was presented as one occurrence per four, six, eight, or ten thousand years. This timescale is less relevant to respondents, as opposed to the study by Koetse and Brouwer (2012) that presented flood risk as the risk of an occurrence once every 30 years. A sample of an actual choice set was not included in this paper.

The authors used a multinomial logit model to describe choice and an ordered probit model to describe choice certainty. They linked these two models into an integrated model using a latent variable, preference certainty, which is a function of respondent and choice characteristics. This linkage is done to account for a bi-directional relationship between choice and self-reported certainty. The relevant hypothesis being tested by this study was that preference uncertainty affects the randomness of decision making and/or the tendency to choose the status quo choice (the adoption of a simplifying heuristic). Both of these were found to be true, with somewhat greater effects for the former. However, it was also found that certainty has a limited effect on the choice model, and most significantly it was found that certainty has no effect on the marginal WTP.

Review of previous discrete choice experiments about flood risks. A table summarizing these studies is presented below:

Table 3 Modeling willingness to pay for reducing flood risks

Reference	Koetse and Brouwer (2012)	Sheremet and Brouwer (2010)
Data	2012 survey of households 1,208 respondents Web-based survey Stated preference	2010 survey of households 1,253 respondents Web-based survey Stated preference
Attributes	Flood Probability 1 Flood Probability 2 Bird Population Type of Shore Change in annual local tax Raising the dikes (label)	Insurance Coverage Own risk Insurance Premium Loss Probability Increased risk of natural disaster
Model	Mixed Logit Multinomial	Equality Constrained Latent Class
Main Results	There exists a WTP-WTA gap. Reference point affects absolute WTP and WTA values as well as the size of the WTP-WTA gap.	Probability of Loss was the second most important attribute for choosing policies. Attribute non-attendance increased the marginal WTP for some attributes. More attributes caused more ANA.
Policy recommendations	N/A	N/A

Reference	Brouwer et at. (2010)	Reynaud and Nguyen (2012)
Data	2010 survey of households 224 respondents Web-based study Stated preference	2012 survey of households 448 respondents Face to face study Stated preference
Attributes	Flood Probability Compensation Available evacuation time Increase in annual tax Monthly Payment	Insurance Type Insurance Provider Coverage Premium
Model	Multinomial Logit Ordered Probit	Conditional Logit Random Parameter Logit
Empirical Results	Preference certainty affects both the Likelihood of choosing the status quo option and how random decisions made are. It does not affect marginal WTP.	Most respondents preferred the status quo. WTP for insurance that covered health effects was significant. There was much heterogeneity.
Policy recommendations	N/A	A carefully designed insurance program could be successful.

3. Survey Instrument

Given the costs of recovery and infrastructure improvements, a survey was designed to explore if New Yorkers are willing to financially support investment to make the transportation system more resilient to extreme weather. After a first draft of the survey was created, a round of two focus groups was set to pretest the instrument. After thee two focus groups, the final design of the survey was completed.

The survey comprised the following parts:

1. **Screening**: to make sure the respondent was an adult living in the New York Metropolitan area
2. **Daily transportation patterns**: this section asked the respondent to describe his or her daily trips in the city, including frequency of transportation modes, average commuting time, and parking preferences.
3. **Past flood/evacuation experience**: this section collected data about past flood and extreme weather events, including hurricanes, hurricane evacuation, and property damage
4. **Initial Sandy disruptions**: this section included a filter to know whether the respondent as in New York City or other affected area when superstorm Sandy made landfall. If that was the case, then it was asked whether the respondent missed work and for how long, whether he or she was paid for the missed work-days.
5. **Evacuation**: if the respondent evacuated, it was registered when he or she did so. Additional questions included whether the respondent suffered any personal loss or knew someone who did.
6. **Post Sandy Commute**: data about patterns of disruption for the post Sandy commute was registered in this section, including days before the commute returned to normal
7. **Commute disruptions**: this section collected more details about the disruptions experienced in the daily commute.
8. **Other Sandy disruptions**: in this section, the respondent had the opportunity to provide information about other transportation disruptions (such as plans to leave the city; subway line closures; abnormal traffic congestion) as well as other overall impacts and inconveniences (such as difficulty getting food, loss of cellphone signal, blackouts, lack of heating).
9. **General statement agreements**: that included data that can be used to create clusters of respondents
10. **Risks associated with extreme weather events**: this section asked for an evaluation of how likely a list of extreme weather events (heat wave, heavy precipitation, storm surge, nor'easter, among others) would harm vital transportation infrastructure
11. **Responsibility**: assessment of the degree of responsibility for being prepared for hurricanes
12. **Contingent valuation**: this section first introduced text about the mechanisms (infrastructure improvements) that can be implemented to prevent or reduce damage to the transportation system when floods and hurricanes occur and improve system resiliency. Then there was a series of contingent valuation question to determine how much the respondents were willing to pay for project that would reduce the transportation recovery time.

13. **Funding mechanisms**: this section collected data about the likelihood of supporting different funding schemes (such as increased tax on vehicle sales, increase tax on gas, increased subway fares and increased parking fees)
14. **Discrete choice experiment**: the discrete choice experiment contained 16 hypothetical choice situations, where the respondent was presented with tables, each containing 3 different hypothetical recovery scenarios. The scenarios varied in the percentage of the transportation system being operational 1-2 days, 3-5 days, 1 week, and 2 weeks after a highly disruptive extreme weather event (such as a superstorm at least as strong as Sandy). The first scenario represented current funding conditions. Scenarios A and B represented improvements to the first scenario, based on a hypothetical annual payment from you to support the required investments. The respondent was asked to select his or her preferred option for a random subset of 8 choice situations. More details about the discrete choice experiment are provided in section 5.2.
15. **Sociodemographic data:** the last section of the survey contained a set of question to gather sociodemographic characteristics of the respondents.

4. Data Collection and Descriptive Statistics

The data was collected in January 2015 using an online panel of 1,552 adult respondents living in the NYC metropolitan area. Tables 4.1 and 4.2 summarize the sociodemographic characteristics of the sample.

Table 4.1: Personal and household income distribution of the sample

Income level	Personal	Household
Income $\leq$ \$10,000	10.63%	4.77%
Income $>$ \$10,000 and $\leq$ \$19,999	6.89%	4.57%
Income $>$ \$20,000 and $\leq$ \$29,999	7.93%	5.67%
Income $>$ \$30,000 and $\leq$ \$39,999	8.96%	5.80%
Income $>$ \$40,000 and $\leq$ \$49,999	8.31%	7.09%
Income $>$ \$50,000 and $\leq$ \$59,999	9.73%	7.47%
Income $>$ \$60,000 and $\leq$ \$69,999	7.41%	7.93%
Income $>$ \$70,000 and $\leq$ \$79,999	8.96%	9.09%
Income $>$ \$80,000 and $\leq$ \$89,999	6.38%	6.38%
Income $>$ \$90,000 and $\leq$ \$99,999	6.05%	7.41%
Income $>$ \$100,000 and $\leq$ \$149,999	12.50%	19.14%
Income $>$ \$150,000	6.25%	14.69%

Table 4.2: Sociodemographics characteristics of the sample

Respondent characteristics	Percentage
Male	44.01
Age from 18-24	8.25
Age from 25-34	19.78
Age from 35-44	17.91
Age from 45-54	17.78
Age from 55-64	19.78
Age from 65-74	13.14
75 years or older	3.35
Living in evacuation zones	22.81
Single	26.61
In a relationship	6.38
Married	49.42
Living with partner	4.83
Divorced or separated	8.05
Widowed	3.54
Own pets	48.00
Full-time ($\geq$ 30 hours per week) job	52.45
Part-time/casual job	14.56
Homemaker	3.67
Full-time student	3.80
Retired	1.22
Less than High School	0.32
Some High School	1.55
High School Graduate	11.79
Some College	20.30
Trade/technical/vocational training	3.93
College Graduate	34.60
Some post-graduate work	5.03
Post-graduate degree	22.49
White/Caucasian	77.00
Black or African American	10.31
Asian	7.28
American Indian or Alaska Native	0.45
Native Hawaiian or other Pacific Islander	0.13
Hispanic	11.60
Household income $\leq \$30,000$	22.43
Household income $> \$30,000$ and $\leq \$60,000$	34.01
Household income $> \$60,000$ and $\leq \$90,000$	23.82
Household income $> \$90,000$	19.74

Notes: The white, black, Hispanic and Asian percentages sum to more than 100 percent because some of the respondents have multicultural backgrounds.

Highlights from the survey data

See Appendix for the results of each individual question in the survey. Below we highlight some of the main findings from the data, especially those related to the disruptions experienced.

People experienced a varied number of disruptions, including difficulties getting food, water, fuel, loss of cellphone signal, and electric power. 72.99% and 70.88% of all the affected respondents experienced difficulty getting fuel and malfunction of traffic signals, respectively. In fact, 74.13% and 59.01% respectively, indicated that these two problems lasted for more than 3 days, revealing the time that it may take the system to recover. Mora than 10% experienced malfunction of traffic signals for more than one week. Getting fuel was a main issue as well, with 18.61% of respondents reporting experiencing that disruption for more than one week. Loss of electricity and lack of heating are two the problems that affected an important share for a longer period of time.

Table 5: Question 27 -- Did you experience any of the following as a result of Hurricane Sandy?

	Not at all	Only for a few hours	For 1-2 days	For 3-5 days	For a week	For 1 - 2 weeks	For more than 2 weeks
Difficulty getting food	46.01%	9.21%	20.26%	10.63%	6.91%	4.31%	2.66%
Difficulty getting water	56.53%	8.45%	14.83%	8.51%	5.73%	4.02%	1.95%
Poor water quality	61.78%	6.91%	10.57%	7.27%	6.14%	4.31%	3.01%
Difficulty getting fuel	26.99%	5.79%	13.11%	17.48%	18.02%	11.64%	6.97%
Malfunction of traffic signals	29.12%	8.68%	20.38%	17.84%	13.05%	7.68%	3.25%
Loss of cellphone signal	38.81%	17.90%	15.95%	12.64%	8.09%	4.67%	1.95%
Loss of electric power	28.59%	11.52%	12.17%	17.07%	12.99%	12.52%	5.14%
Elevators not working	61.84%	5.02%	9.51%	8.51%	7.32%	5.20%	2.60%
Lack of heating	43.89%	6.67%	8.86%	13.23%	11.75%	11.05%	4.55%
Staying at home	21.03%	6.67%	26.46%	19.02%	14.59%	7.97%	4.25%
Staying at a friend's/family member's home	63.32%	4.73%	9.21%	7.80%	6.26%	5.02%	3.66%

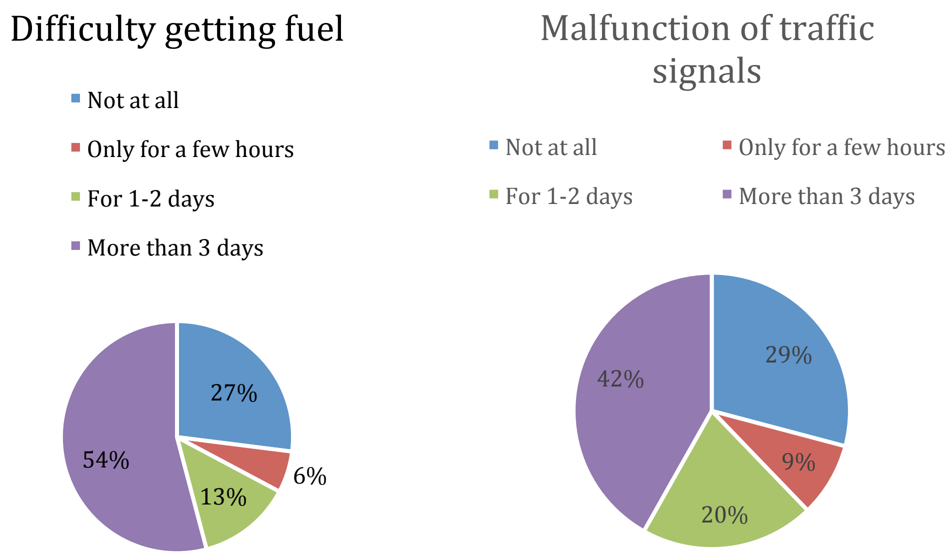
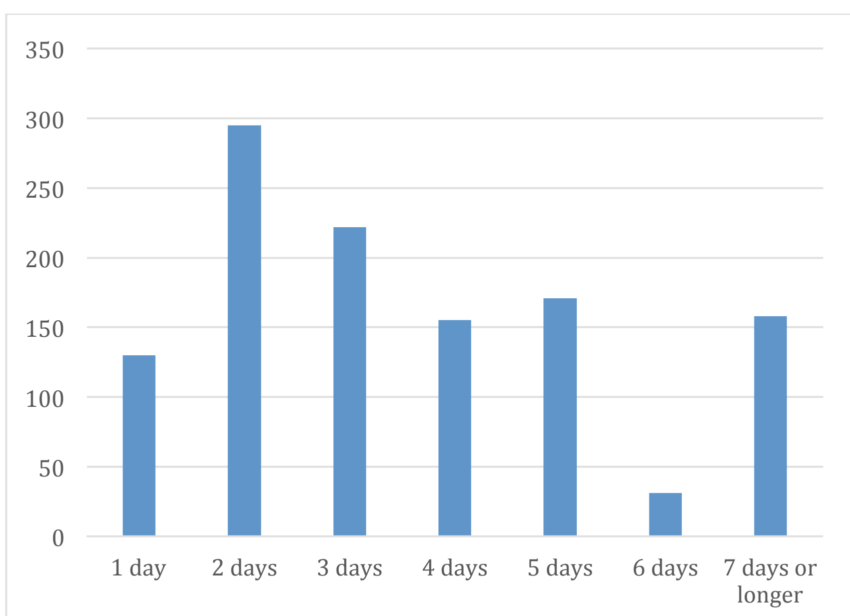


Figure 2: transportation disruptions

About 69% of the affected sample missed work, with a majority missing work for 2 - 3 days but still getting paid for the lost days.

Figure 3 -- Question 11 For how long did you miss work?



With respect to transportation, besides the traffic signals problem mentioned above, 65% of the respondents stated that their normal commute was disrupted during or immediately following superstorm Sandy. Most of the respondents described the duration of the overall impact on their daily routine in a *days* level. According to the distribution of disruption time, the average commute disruption time was 5.38 days, where about 24% of the respondents stated that the disruption lasted more than 7 days. Compared with the normal time to go work or school, average commute time increased by 14.30%, from 49.78 min to 56.89 min; the longest reported commute time was 67.35 min, being 35.30% higher than its normal value.

Figure 4 -- Question 16 How long was it before your commute returned to normal, in terms of both the mode(s) of transportation you used and your average commute time?

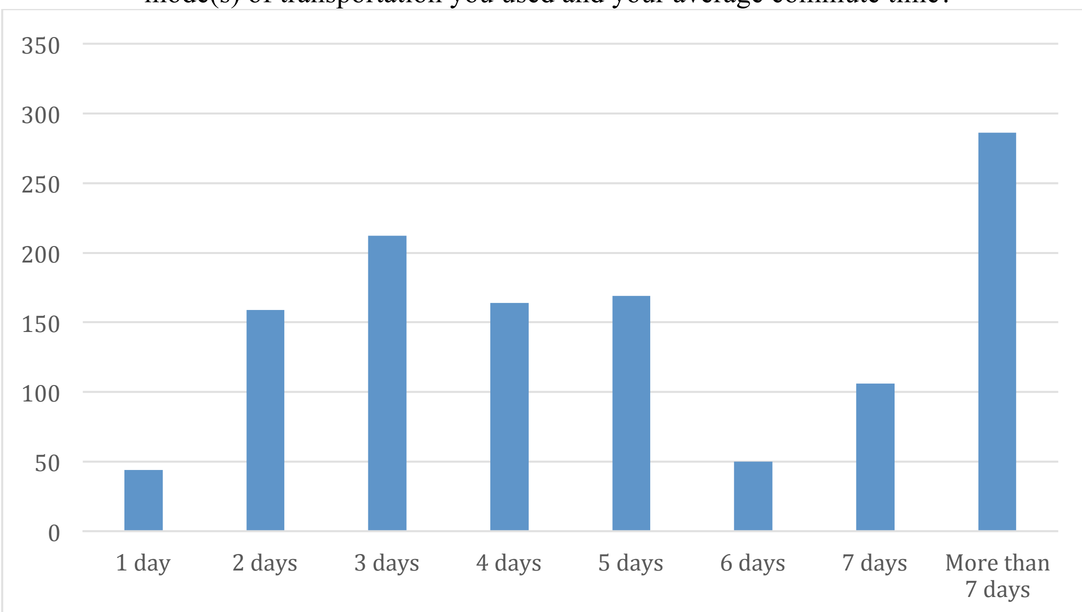


Figure 5 -- Question 17 How long was your commute on average the week immediately following Hurricane Sandy?

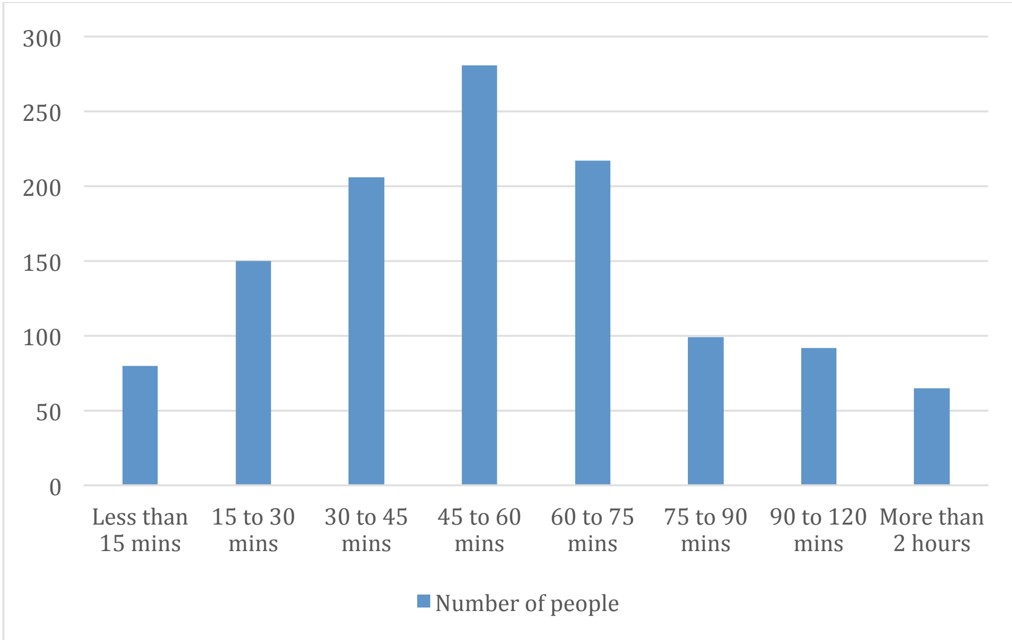
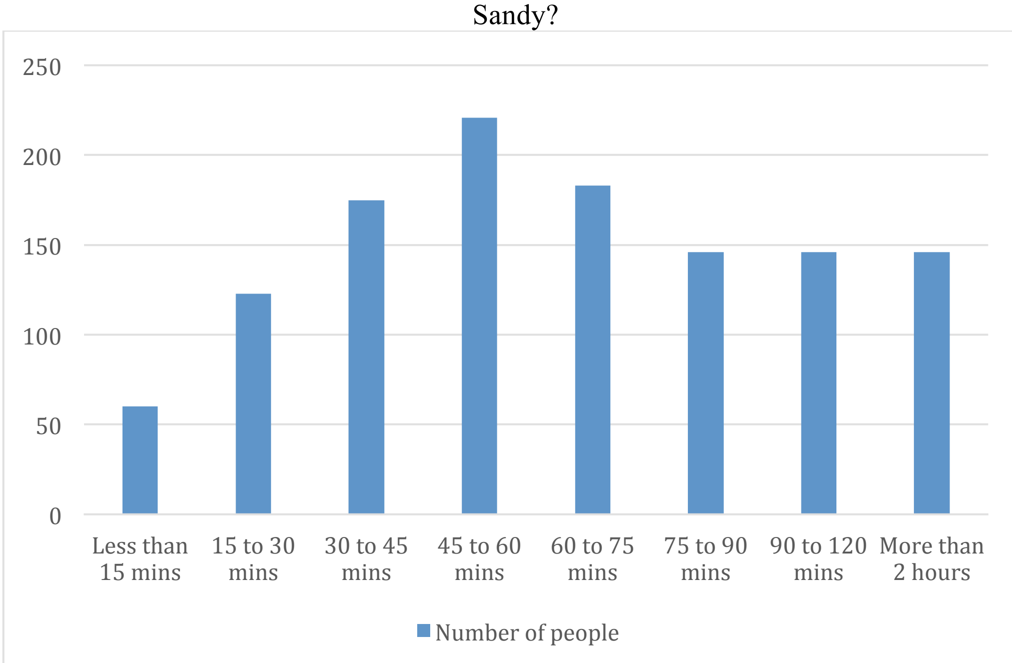


Figure 6 -- Question 18 How long was the longest commute that you experienced following Hurricane Sandy?



Superstorm Sandy also impacted modal share. The share of car as a driver or passenger to work during Hurricane Sandy increased by 20% compared with the normal distribution. Subway also exhibit a significant increase in it share compared to other public transportation modes, such as bus, ferry, commuter rail during Hurricane Sandy.

Overall, 67% of the respondents evaluated superstorm Sandy at least as a *moderate* inconvenience. Practically the same number of respondents (68%) described the severity on the transportation level as at least moderate.

Figure 7 -- Question 24 How would you describe the severity of the overall impact of Hurricane Sandy?

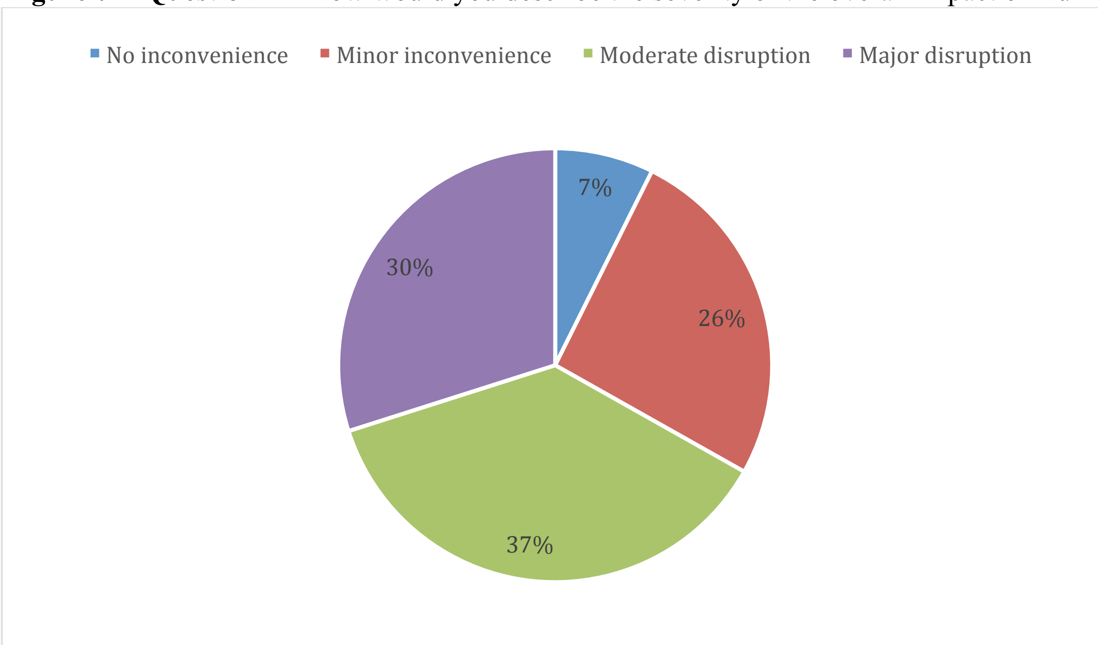
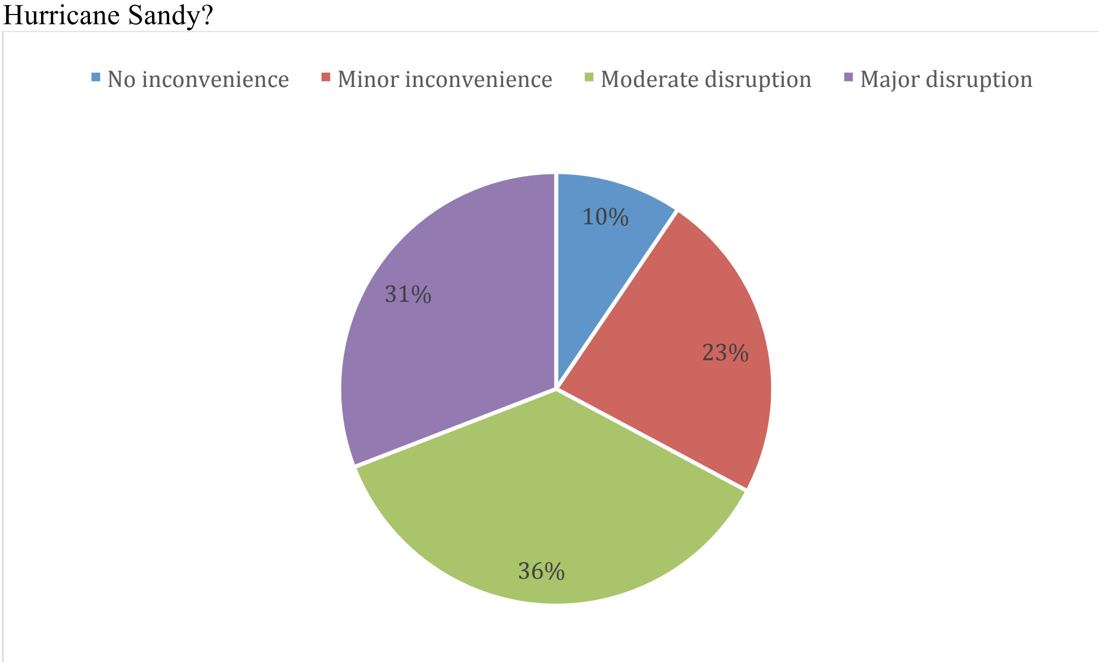


Figure 8 -- Question 25 How would you describe the severity of the impact on transportation of Hurricane Sandy?



In terms of other specific disruptions that lasted for at least one week, 20.31% of the sample experienced subway line closures, 22.21% subway station closures, and 20.56% limited bus service.

Table 6 -- Question 26

A) Did you experience any of the following disruptions as a result of Hurricane Sandy?

	Not at all	Only for a few hours	For 1-2 days	For 3-5 days	For a week	For 1 - 2 weeks	For more than 2 weeks
Subway line closures	42.00%	6.97%	17.90%	12.82%	7.97%	6.26%	6.08%
Subway station closures	42.65%	6.67%	16.77%	11.70%	8.74%	7.03%	6.44%
Closed bridges	49.20%	7.38%	18.25%	11.16%	6.91%	4.19%	2.89%
Closed tunnels	50.27%	5.55%	16.72%	11.05%	7.56%	4.49%	4.37%
Abnormal traffic congestion	31.42%	7.32%	18.37%	15.06%	13.17%	9.04%	5.61%
Limited bus service	41.29%	6.62%	17.66%	13.88%	10.40%	7.03%	3.13%
Commuting times more than twice as normal	37.27%	7.21%	16.60%	15.53%	11.16%	7.56%	4.67%
Having to use alternate routes	31.19%	6.85%	16.48%	16.60%	12.40%	9.74%	6.73%
Working at alternate sites	59.60%	4.13%	10.22%	9.75%	7.62%	4.96%	3.72%
Severe crowding in mass transit	45.36%	5.43%	13.29%	11.40%	10.63%	7.97%	5.91%

B) How would you rate the level of inconvenience of the following problems (due to the arrival of a hypothetical hurricane)?

	Wouldn't affect me	Minor inconvenience	Somewhat inconvenient	Extremely inconvenient
Subway line closures	43.66%	15.98%	19.35%	21.00%
Subway station closures	43.84%	15.75%	20.72%	19.69%
Closed bridges	41.72%	17.41%	24.66%	16.21%
Closed tunnels	45.55%	16.84%	21.75%	15.87%
Abnormal traffic congestion	27.11%	21.58%	29.28%	22.03%
Limited bus service	44.58%	17.75%	21.58%	16.10%
Commuting times more than twice as normal	29.57%	17.35%	26.48%	26.60%

Having to use alternate routes	25.23%	24.54%	32.13%	18.09%
Working at alternate sites	49.14%	17.41%	20.66%	12.79%
Severe crowding in mass transit	40.92%	15.58%	23.57%	19.92%

Based on question 26 (A) and (B), an Inconvenience Expectation (IE) index was defined for every disruption in the survey. According to the IE order it is possible to rank the disruptions.

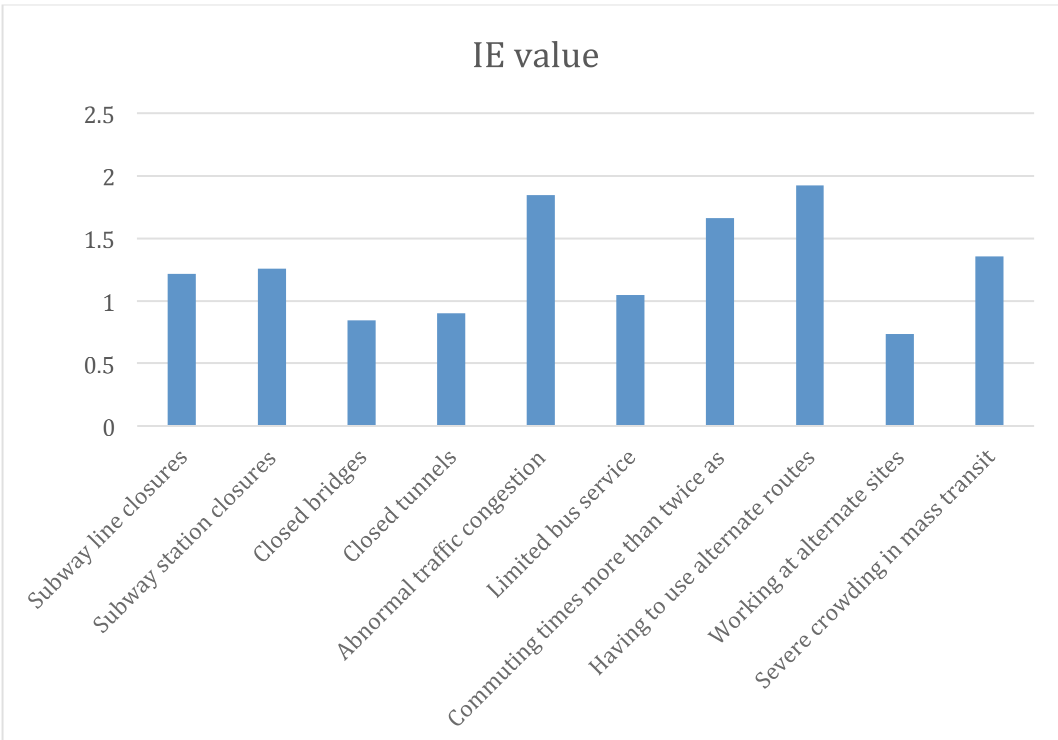


Figure 9 – Inconvenience Expectation Index

The top three transportation disruptions were: *having to use alternate routes*, *abnormal traffic congestion* and *commuting times more than twice as normal*, which affect both public and private transportation modes.

5. Models and Results

5.1. Contingent Valuation

Before the discrete choice experiment, the survey considered an open contingent valuation question, where respondents where asked to elicit their willingness to pay. Considering the question of a one-time annual payment to support investments in making subway infrastructure more resilient, 81.3% of the respondents indicate that they would pay less than $1,000 (as a one-time payment). Only 3.61% would pay more than $4,000. When asked for a monthly payment, 63.23% of the respondents declared that they would pay less than $10 per month, while only 0.19% would pay more than $200.

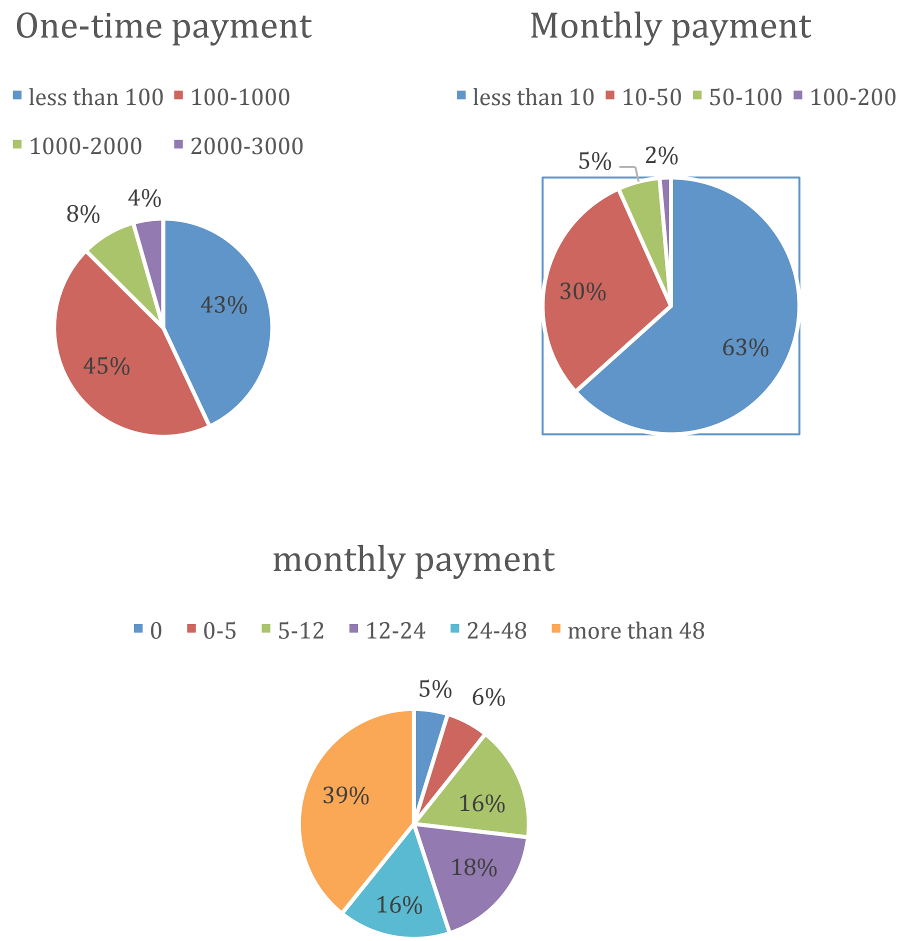


Figure 10 – Contingent valuation, elicitation of willingness to pay for supporting investments

With the answers to the one-time payment, we estimate a tobit model which is a regression for non-negative dependent variables. Taking into consideration that the model has a negative constant of -$220, males, young people (under 25 years), those living in evacuation zones, those with 3 or more children, non-whites, and those with a higher experience in previous evacuation are all willing to pay a significant, positive amount of money. Also note that these willingness-to-pay measure are additive for each independent variable. Frequent users of subway, and then even more frequent users of rail, appear as willing to support financially a more resilient subway system for the city. Interestingly, both suffering personal loss and surge at home have a positive amounts, but knowing someone who experienced loss or surge have negative parameters.

Table 7 – Estimates of a tobit model

Variables	Estimate	s.e.	t-stat
Male	253.28	69.60	3.64
Age under 25	201.79	129.40	1.56
Owner	63.11	78.96	0.80
Lives in Evac Zone	478.27	91.03	5.25
Lives in brownstone	476.84	107.13	4.45
Married	78.07	80.09	0.97
Children: 1-2	178.30	79.33	2.25
Children: over 3	639.61	132.70	4.82
Homemaker	-219.79	186.02	-1.18
Education college	-175.04	72.64	-2.41
Income over $150,000	86.79	139.03	0.62
African American	191.78	113.48	1.69
Asian	236.93	128.15	1.85
Hispanic	236.11	105.99	2.23
Liberal	240.66	71.02	3.39
Times experienced hurricane	-28.49	10.57	-2.70
Times evacuated	151.94	47.13	3.22
Times experienced damage	54.37	43.82	1.24
Was paid for lost workdays	176.99	70.58	2.51
Experienced personal loss	135.50	88.16	1.54
Know people who experienced loss	-164.81	76.53	-2.15
Experienced surge at home	219.82	99.13	2.22
Experienced surge in neighborhood	-272.06	84.51	-3.22
Evacuated for Sandy	213.05	118.02	1.81
Used social media	334.70	80.25	4.17
Freq user: subway	207.14	82.39	2.51
Freq user: rail	478.82	125.35	3.82
Freq user: car as pass	188.16	104.83	1.79
Constant	-220.66	106.54	-2.07

5.2. Discrete Choice Experiment

A fundamental research problem in environmental economics and engineering is to determine the consumer valuation of environmental goods and services for which there is no market price. To address this problem in this project the **choice modeling** approach (McFadden, 2001) for decisions under risk was adopted. Building on the theory of random utility maximization, choice modeling is more flexible than other stated-preference techniques, such as the contingent valuation method used above, because implicit prices are determined within a controlled experiment that offers better framing and scope, while easing the process of benefit transfer. In transportation, choice modeling has become the standard technique for estimating the willingness to pay for travel-time savings (used for establishing fares and tolls) and for deriving demand functions, especially in the case of new alternatives.

The stated-preference experiment was designed using a Bayesian efficient design, using the software Ngene (Rose and Bliemer, 2009). Efficient designs go beyond traditional ways of determining fractional factorial designs. An efficient design maximizes the information extracted from each choice situation by minimizing asymptotic standard errors. In the case of a Bayesian design, there is the possibility of assuming prior parameters.

5.2.1. Experimental Design

In addition to several questions about the disruptions to daily routine experienced right after the landfall of hurricane Sandy, the online survey also contained a series of discrete choice questions about the respondents' willingness to pay to improve the recovery time of the transportation system. In the choice experiment, two hypothetical scenarios of infrastructure improvement as well as a status-quo scenario were described in terms of the percentage of the transportation system being operative 1-2 days, 3-5 days, 1 week, and 2 weeks after a highly disruptive extreme weather event. The extreme weather event was described as being at least as strong as hurricane Sandy. We will refer to these percentages as operative levels in the remainder of the report. The two scenarios of infrastructure improvement required financial support in the form of a hypothetical annual payment. The attribute levels are shown in Table 8.

Table 8: Experimental attribute levels

Attribute	Levels
Operative levels 1-2 days after, status-quo	0%
Operative levels 1-2 days after, improvement	0%, 25%
Operative levels 3-5 days after, status-quo	5%, 15%
Operative levels 3-5 days after, improvement	35%, 50%
Operative levels 1 week after, status-quo	25%, 40%
Operative levels 1 week after, improvement	60%, 85%
Operative levels 2 weeks after, status-quo	70%, 85%
Operative levels 2 weeks after, improvement	90%, 100%
Annual payment, status-quo	$0
Annual payment, improvement A	$120, $250, $500
Annual payment, improvement B	$100, $300, $400

5.2.2. Model estimates and inference on willingness to pay

In all models, we considered the operative levels incrementally. For example, if the operative level 1-2 days after the storm was 25%, and then increased to 35% for days 3-5, then we considered 25% for the first 1-2 days, and 10% for days 3-5. All estimation was performed using the gmnl package in R (Sarrias and Daziano, 2016).

Base Models

MNL

The first base model that was estimated was a multinomial logit (MNL) model, which is a choice model with fixed parameters. Models with fixed parameters assume that all the individuals in the sample have the same preferences. Results of the fixed parameter estimates are shown in Table 9.

Table 9 – Multinomial Logit Model (MNL) estimates

Variables	Estimate	s.e.	t-stat
Annual payment	-0.00465	0.00011	-41.38
Operative level: 1-2 days	0.01944	0.00153	12.70
Inc. operative level: 3-5 days	0.01862	0.00114	16.38
Inc. operative level: 1 week	0.01525	0.00139	10.97
Inc. operative level: 2 weeks	0.01249	0.00133	9.42

All the parameters have the expected signs. The annual payment parameter represents the marginal utility of income and is negative, meaning that individuals value saving money. All the operative levels are positively valued. The order of the valuation is decreasing, meaning that a 1% increase in the operative level is valued higher, the faster the recovery is.

MIXL

The second base model that was tried was a mixed multinomial logit model (MIXL), which is a random parameter choice model. Random parameter models allow for unobserved heterogeneity in preferences. For random parameter models with continuous heterogeneity distributions, model estimates include the population mean and the standard deviation. The standard deviation measures how preferences vary with respect to the population mean. Results of an MIXL with normally distributed parameters are presented in the table below.

Table 10 – Mixed Logit Model estimates

Variables	Estimate	s.e.	t-stat
Annual payment (mean)	-0.0272	0.0009	-30.80
Operative level: 1-2 days (mean)	0.1248	0.0031	40.26
Inc. operative level: 3-5 days (mean)	0.1003	0.0025	40.14
Inc. operative level: 1 week (mean)	0.0686	0.0023	30.00
Inc. operative level: 2 weeks (mean)	0.0501	0.0021	23.72
Annual payment (SD)	0.0254	0.0008	30.02
Operative level: 1-2 days (SD)	0.0241	0.0037	6.45
Inc. operative level: 3-5 days (SD)	0.0277	0.0023	11.98
Inc. operative level: 1 week (SD)	0.0008	0.0029	0.26
Inc. operative level: 2 weeks (SD)	0.0150	0.0019	7.83

As with the MNL, all parameters have the expected signs and magnitudes. The only parameter being negative is that of the mean valuation of the annual payment. The operative levels are all positive and increasing with a shorter recovery, indicating that individuals value a quicker recovery of the transportation system. All the parameters are statistically significant, with the exception of the standard deviation of the incremental operative level at 1 week. In general, this model supports the presence of important heterogeneity in preferences.

To disentangle some of the heterogeneity, a hierarchical Mixed Logit model was estimated, where some interactions with sociodemographic variables were introduced. These interactions represent determinist preference variations. Model estimates are shown below:

Table 11 – Hierarchical Mixed Logit model estimates

Variables	Estimate	s.e.	t-stat
Annual payment (mean)	-0.0255	0.0013	-20.39
Operative level: 1-2 days (mean)	0.1104	0.0048	23.04
Inc. operative level: 3-5 days (mean)	0.0848	0.0038	22.42
Inc. operative level: 1 week (mean)	0.0613	0.0038	16.26
Inc. operative level: 2 weeks (mean)	0.0457	0.0036	12.88
payment × income below $70,000	-0.0049	0.0013	-3.74
payment × male	0.0037	0.0013	2.81
oper:1-2 days × missed work	0.0205	0.0055	3.73
incoper:3-5 days × missed work	0.0221	0.0043	5.12
incoper:1week × missed work	0.0105	0.0045	2.35
incoper:2weeks × missed work	0.0059	0.0043	1.39
Annual payment (SD)	0.0250	0.0008	30.60
Operative level: 1-2 days (SD)	0.0231	0.0036	6.33
Inc. operative level: 3-5 days (SD)	0.0276	0.0022	12.55
Inc. operative level: 1 week (SD)	0.0001	0.0029	0.05
Inc. operative level: 2 weeks (SD)	0.0145	0.0019	7.54

In general, the estimates are similar to those of the standard MIXL. Note that individuals with income lower than $70,000 per year are more sensitive to price, which is an expected result according to microeconomic theory. Males appear less sensitive to the annual payment, indicating that they are willing to pay more for supporting investments in resilience. People who missed work are also willing to pay more.

Double Mixture Models

Because MIXL imposes a very specific shape for the distribution of preferences, we also specified a double mixture model. In a discrete-continuous mixture model, there is a discrete number of clusters of individuals, and within each cluster preferences are modeled according to an MIXL. From a statistical point of view, this discrete-continuous representation of preference heterogeneity is interpreted as a Gaussian mixture. Gaussian mixtures – i.e. a combination of normal distributions – can approximate any distribution, including multimodal cases. A logit-type model with a Gaussian mixture is known in the recent choice modeling literature as Mixed-Mixed Logit (MM-MNL) model (Keane and Wasi, 2013; see also Greene and Hensher, 2013).

After preliminary tests, an MM-MNL with two discrete classes was specified. The estimates of relevant parameters are presented in Table 12.

Table 12 – Mixed-Mixed Logit model estimates, with two classes

Variable	Estimate	SD	t-stat
Fixed coefficients			
Inc. operative level: 3-5 days	0.1054	0.0377	2.796
Inc. operative level: 1 week	0.0823	0.0301	2.734
Random coefficients			
Class 1			
Annual payment (mean)	-0.0855	0.0241	-3.548
Operative level: 1-2 days (mean)	0.0556	0.0350	1.589
Inc. operative level: 2 weeks (mean)	0.0824	0.0216	3.815
Annual payment (SD)	0.0434	0.0124	3.500
Operative level: 1-2 days (SD)	0.0975	0.0704	1.385
Inc. perative level: 2 weeks (SD)	0.0349	0.0181	1.928
Class 2			
Annual payment (mean)	-0.0111	0.0031	-3.581
Operative level: 1-2 days (mean)	0.1240	0.0394	3.147
Inc. operative level: 2 weeks (mean)	0.0590	0.0240	2.458
Annual payment (SD)	0.0078	0.0069	1.130
Operative level: 1-2 days (SD)	0.0284	0.0085	3.341
Inc. perative level: 2 weeks (SD)	0.0197	0.0064	3.078
Assigntment to class 2			
Male	0.0951	0.0658	1.445
Income below $70,000	-0.4821	0.3145	-1.533
Missed work after Sandy	0.4640	0.2088	2.222
Liberal	0.4280	0.1918	2.231
Conservative	-0.1262	0.0734	-1.719
African American	0.0956	0.4534	0.211
Asian	0.4199	0.3282	1.279
Hispanic	0.5579	0.3030	1.841

As expected, the population coefficient of the annual payment is negative while the other population coefficients -- associated with the improvements in the transportation system – are positive. Note how whereas class 1 exhibits more heterogeneity in the payment attribute, class 2 shows more heterogeneity in the incremental improvements in the operative levels. Regarding the assignment to classes, those respondents that are liberal and missed work after Sandy, are statistically significantly more likely to belong to class 2. As we discuss below, individuals in class 2 are willing to pay more for improving recovery of the transportation system. Hispanic and Asian males with a household income greater than $70,000 are also more likely to belong to class 2, although the effect is not significant at the 95% level.

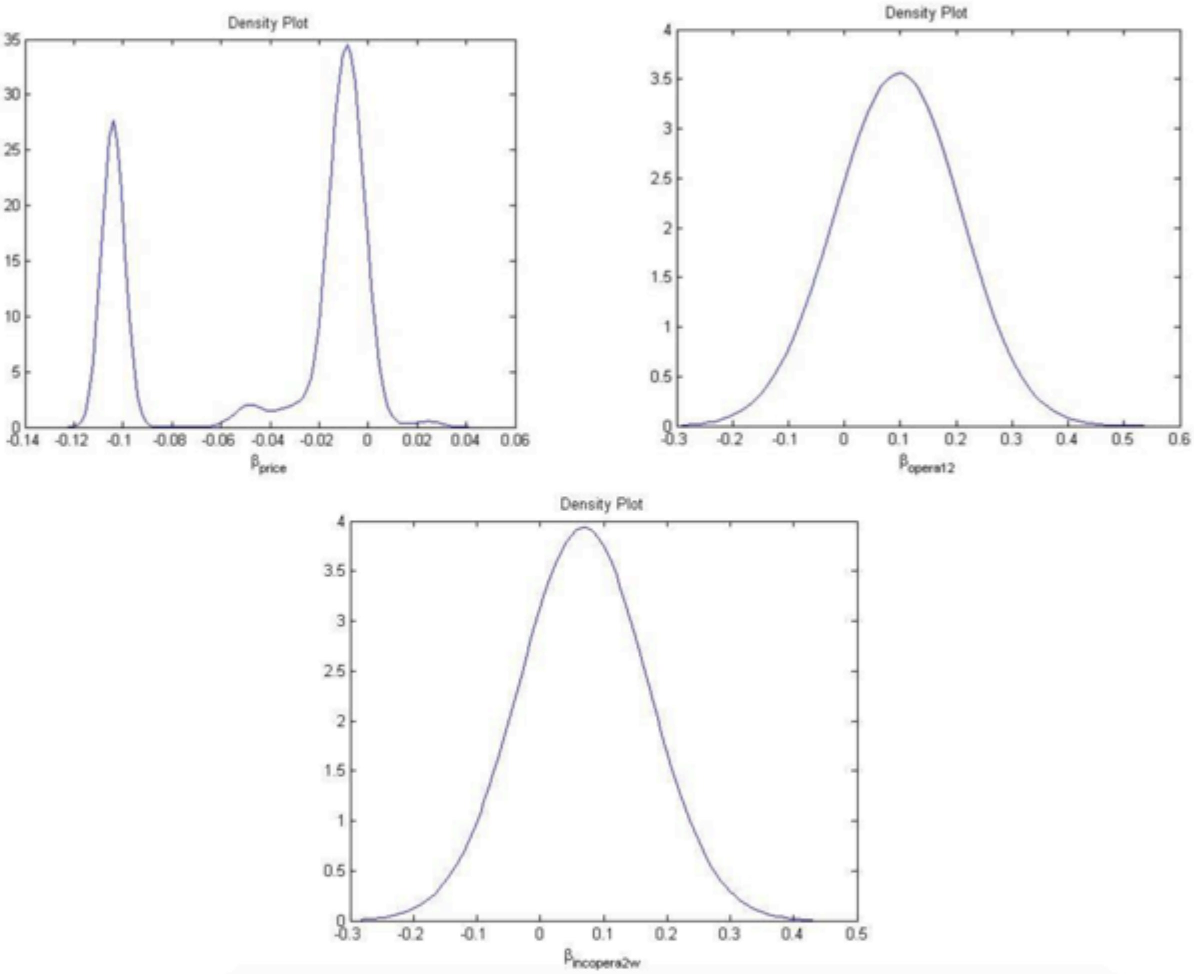


Figure 11: mixing distributions for the random parameters

The estimated mixing distributions for the random parameters are shown in Figure 11. These are based on a normal kernel function of the point estimates. The estimated mixing distributions of the marginal utility for both the recovery 1-2 days after the event and 2 weeks after are Gaussian-shaped. This result indicates that, instead of a mixture, using a normal distribution to approximate the taste variations of these two attributes would be appropriate. However, the estimated mixing distribution of the marginal disutility of the payment (the parameter of the annual payment), shows two separated peaks in correspondence with the values of the means of each component. Hence, the heterogeneity distribution of the marginal disutility for the annual payment clearly is bimodal, which would have not been revealed by using a simple normal density as mixing distribution.

To actually monetize the estimates, we also calculated the willingness-to-pay (WTP) for each attribute. Residents are willing to pay more for a faster recovery of the transportation system after an extreme weather event. Note that the willingness to pay is considerably higher for class 2, which is more likely to include individuals who missed work during superstorm Sandy. Those individuals who missed work suffered directly the impacts of Sandy and it is possible that one of the reasons to miss work was the problems in the transportation system.

Table 13 – Marginal willingness to pay estimates

WTP [$/percent-point]	Mixture Est.	Mixture SD	Class 1 Est.	Class 1 SD	Class 2 Est.	Class 2 SD
Operative level: 1-2 days after event	8.6377	604.44	1.1813	2.4203	14.2089	3.0806
Incremental operative level: 3-5 days	7.7826	512.22	1.5671	1.9079	12.0162	2.8634
Incremental operative level: 1 week	6.0721	457.40	1.1904	1.2859	9.6324	3.4012
Incremental operative level:	4.5678	404.62	1.0938	0.6868	6.7232	2.5661

To have a better idea of the derived estimates, Table 14 shows the total annual willingness to pay for investments in the transportation system under differing hypothetical scenarios. Each scenario describes different recovery times for the transportation system with respect to a hypothetical base level. The base scenario considers that the transportation system is shut down 1-2 days after a highly disruptive event; only 5% is operative 3-5 days after; one week after the system is 25% operative; and 2 weeks after the event, 70% of the system is in operation. The scenarios are ordered in increasing recovery speed. The willingness to pay for each scenario is incremental with respect to the base condition.

The willingness to pay for class 1 ranges from about $15 to $50, whereas that of class 2 ranges from $120 to $775. For the mixture, the range of variation is $75-$450. In a contingent-valuation question, where respondents were asked how much they would pay to ``support investments that would reduce the recovery time from 3 weeks to only 3 days", the average annual willingness to pay was $192, with a standard deviation of $305.

Table 14 – Scenario willingness to pay estimates

Situation	Annual WTP ($) Mixture	Annual WTP ($) Class 1	Annual WTP ($) Class 2	Operative levels certain period after(%) 1-2 days	3-5 days	1 week	2 weeks
Base Scenario	NA	NA	NA	0	5	25	70
Situation 1	76.80	14.27	122.79	0	10	40	80
Situation 2	169.66	30.91	272.04	0	20	60	90
Situation 3	149.64	19.88	250.58	10	30	60	80
Situation 4	305.29	51.22	490.90	10	50	80	100
Situation 5	261.68	31.60	438.43	30	50	70	90
Situation 6	322.40	43.50	534.75	30	50	80	100
Situation 7	295.88	27.65	506.12	50	60	70	90
Situation 8	388.75	44.29	655.38	50	70	90	100
Situation 9	377.28	29.40	655.84	70	80	90	90
Situation 10	455.11	45.07	776.00	70	90	100	100

Finally, density plots for the WTP measures are shown in Figure 12. All 4 post-processed WTP measures are bimodal, which explains the overall large standard deviations for the mixture WTP of Table 13.

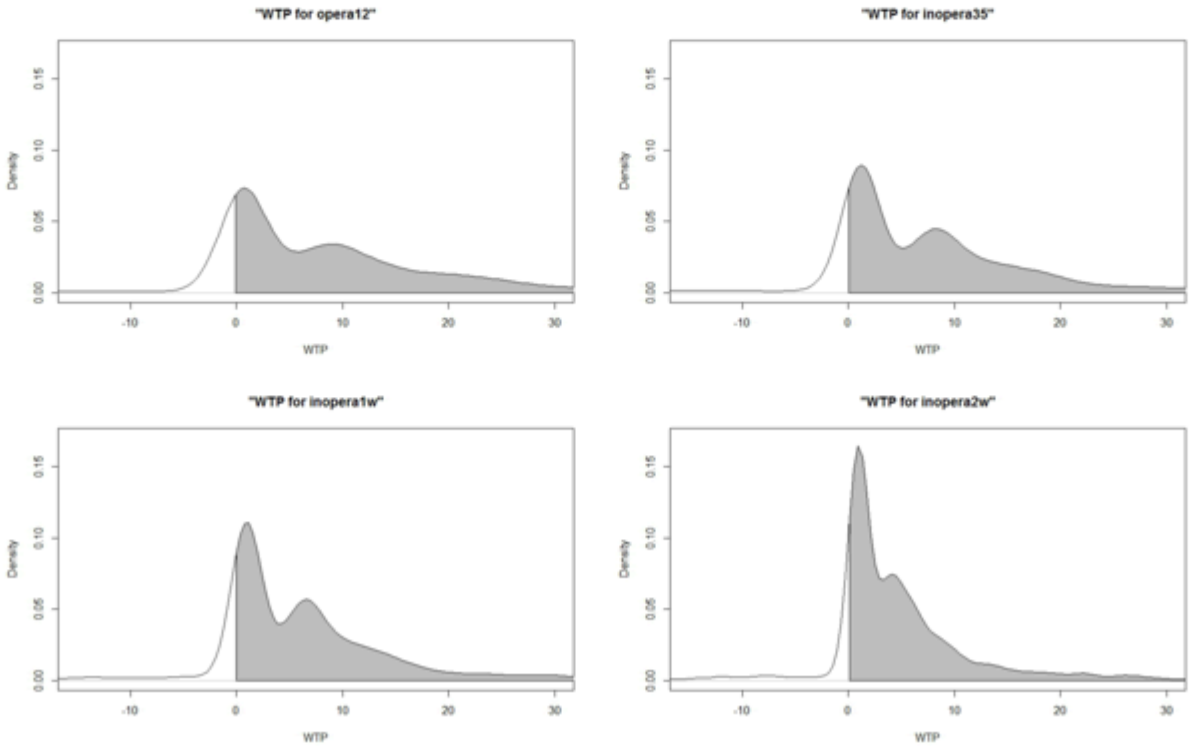


Figure 12: Nonparametric density plot of willingness to pay

Conclusions

New York City is known to many as the "city that never sleeps". With over eight million citizens, it is the most populated city in the United States. The area surrounding the city itself is known as the New York Metropolitan Area, which includes some New York State counties north of the city, parts of New Jersey, Pennsylvania, and Connecticut as a combined statistical area, or CSA. This CSA is also the most populated in the US at over 23 million people. An area with this large number of residents needs a well-built and well-maintained public transportation system. Most people living outside New York City commute to the city for both business and leisure. Not many can afford a car, or afford the extremely high prices of parking in the city. Therefore, agencies like New Jersey Transit (NJT), Port Authority of New York and New Jersey (PANYNJ), and Metropolitan Transportation Authority (MTA) have worked together to provide vital bus and rail services in the area. If these services were to cease operations for any amount of time, the entire area would come to a halt as well.

In this project, a survey was designed to collect data on the disruptions that individuals experienced during and after superstorm Sandy. 1,552 adults living in the metropolitan area of New York City participated in the online survey. For those who were in an area affected by Sandy, more then 20% experienced subway line and station closures, and limited bus service for at least one week. 30% of those affected stated that they considered superstorm Sandy a major disruption.

The empirical dataset was complemented with a unique choice experiment. In the experiment, respondents faced differing scenarios of the expected transportation system recovery after an extreme weather event (as strong as superstorm Sandy) under a hypothetical annual payment. Recovery was expressed in terms of the percentage of the system being operative in discrete times after the disruptive shock. With a nonlinear specification, the preferences with respect to both recovery and payment turned out to be heterogeneous in the sample.

Whereas some components of recovery seem to be normally distributed, payment heterogeneity is better represented by a bimodal distribution that can be reasonably approximated by a mixture of two normal distributions. The estimate of the weights of the mixture – modeled as a logit-type function of subject covariates – revealed that individuals who missed work after Sandy hit the area – which acts as a proxy for those individuals who experienced major disruptions in their routines, reducing their earnings in some cases – are more likely to pay more for improving recovery of the transportation system. A similar effect is observed for individuals who identified themselves as politically liberal.

These variables defined a specific class of residents, which we labeled as class 2. Using hypothetical scenarios of recovery, the willingness to pay as an annual for class 1 ranges from about \$15 to \$50, whereas that of class 2 ranges from \$120 to \$775. For the mixture, the range of variation is \$75-\$450. In a contingent-valuation question, where respondents were asked how much they would pay to "support investments that would reduce the recovery time from 3 weeks to only 3 days", the average willingness to pay was \$192, with a standard deviation of \$305.

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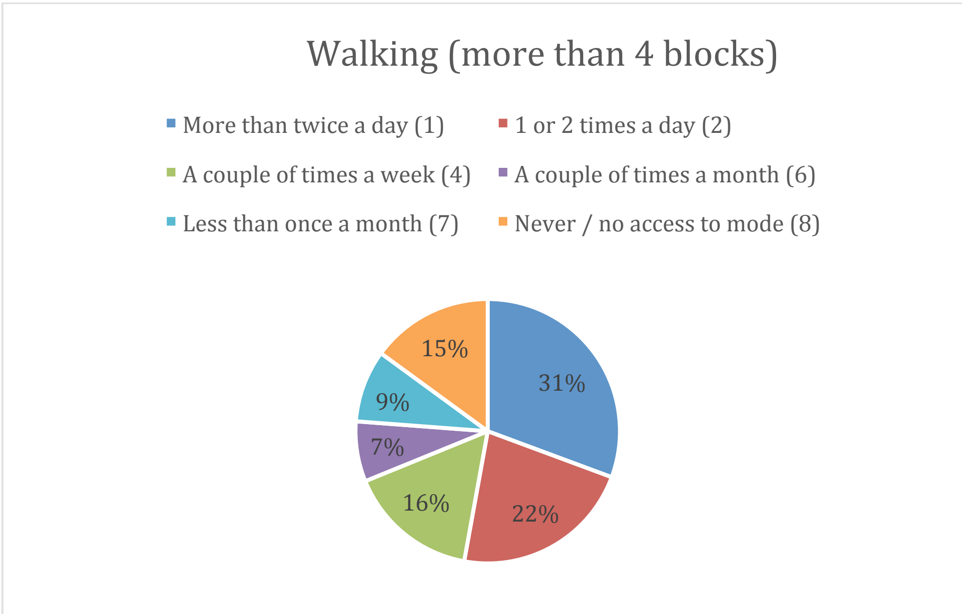
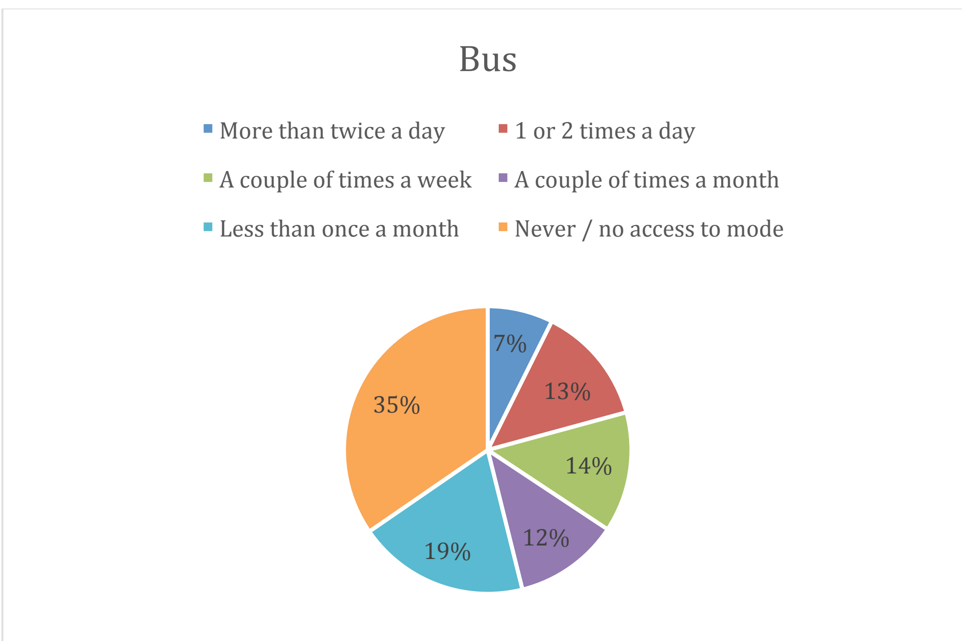
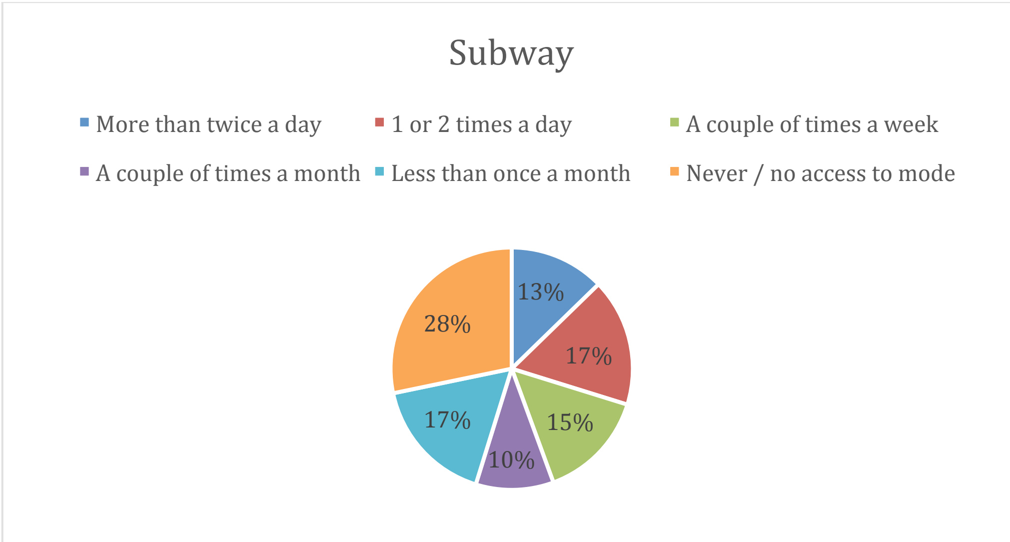
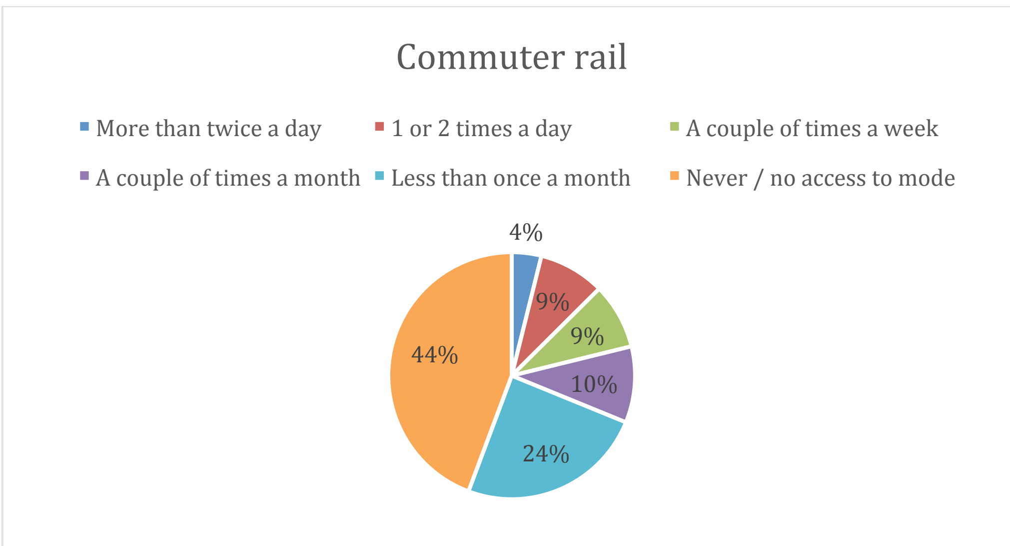
APPENDIX

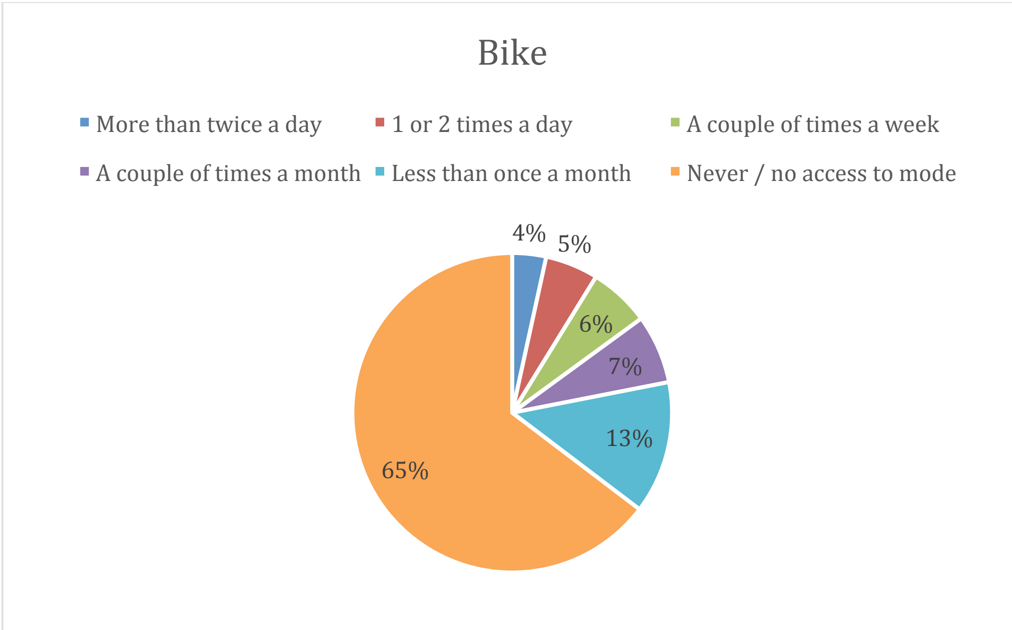
Question 1.
During typical business days, how frequently do you use the following transportation modes?

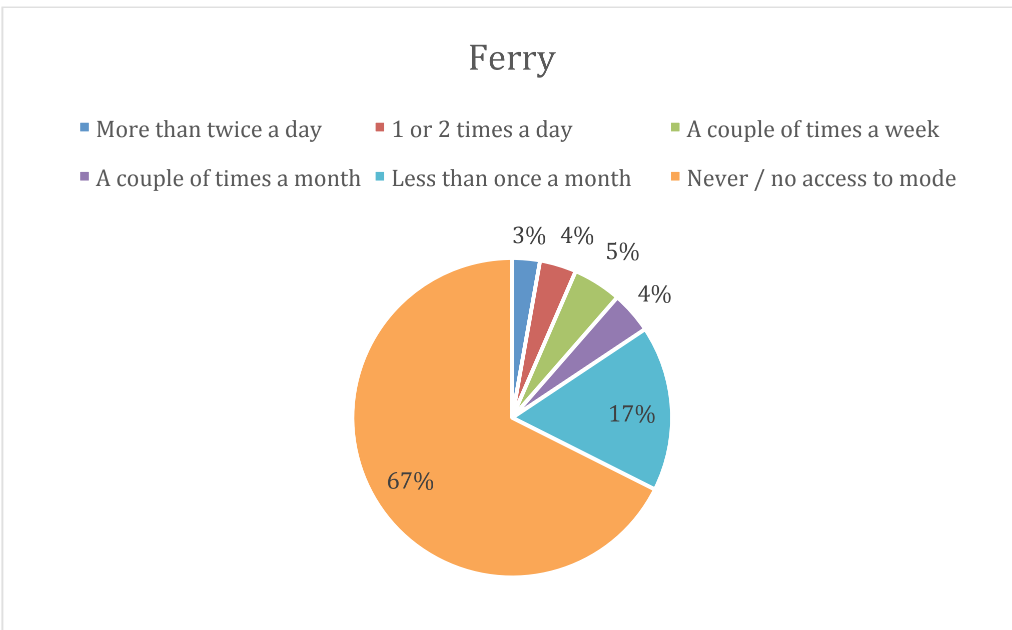


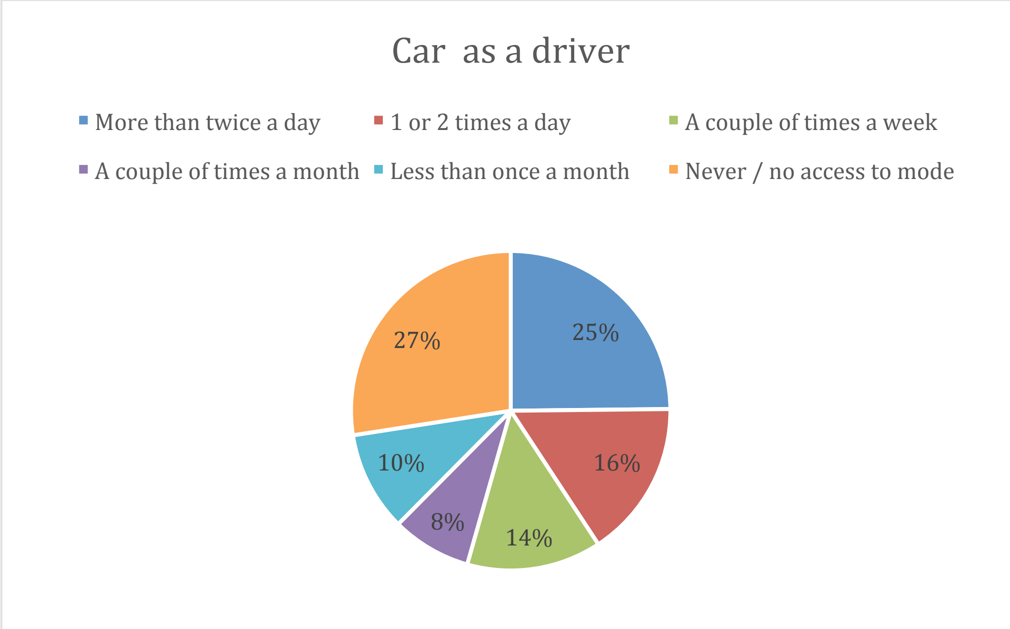


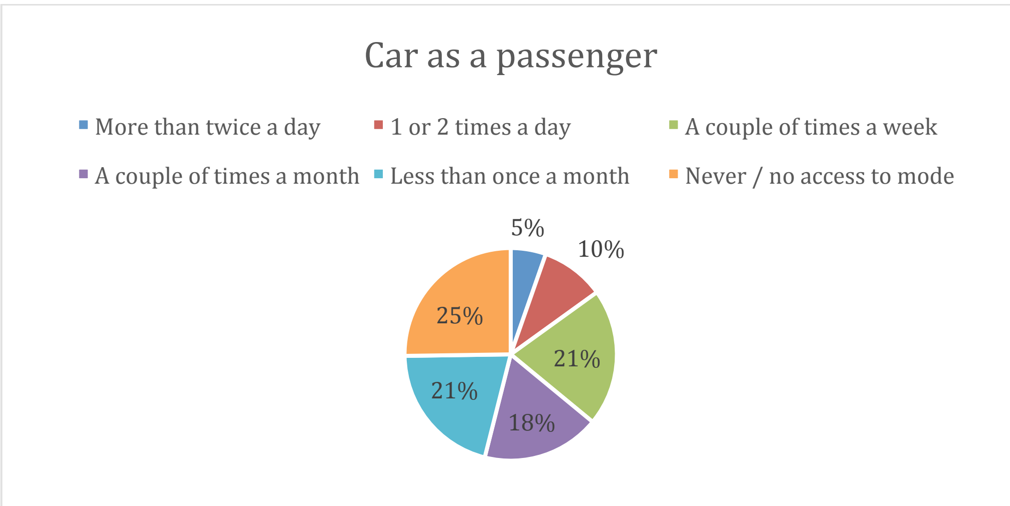

Subway
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
13%
17%
15%
10%
17%
28%

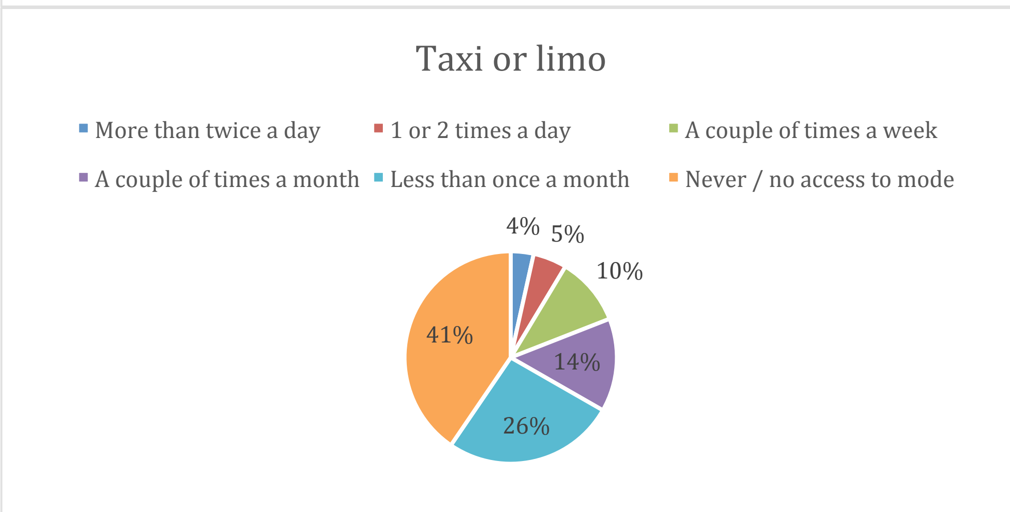

Commuter rail
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
4%
9%
9%
10%
24%
44%

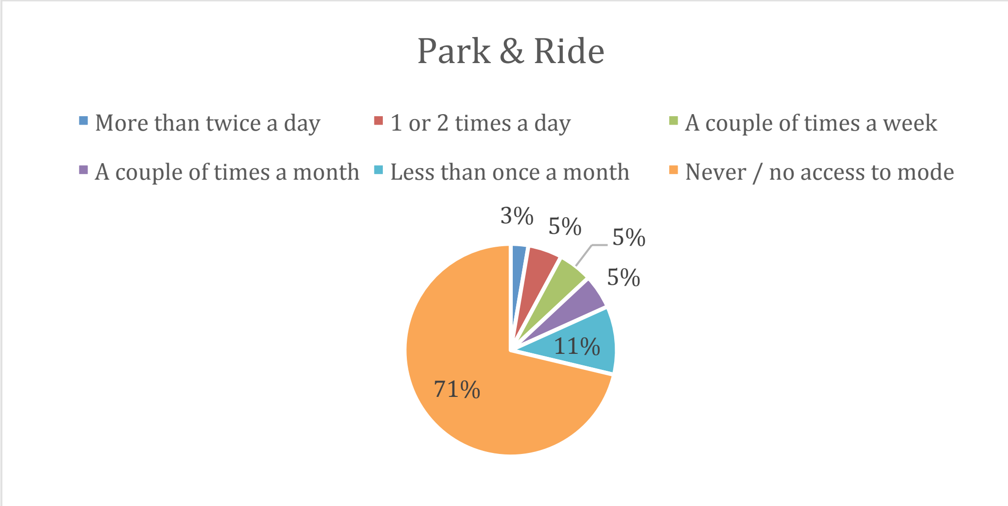

Bike
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
4%
5%
6%
7%
13%
65%

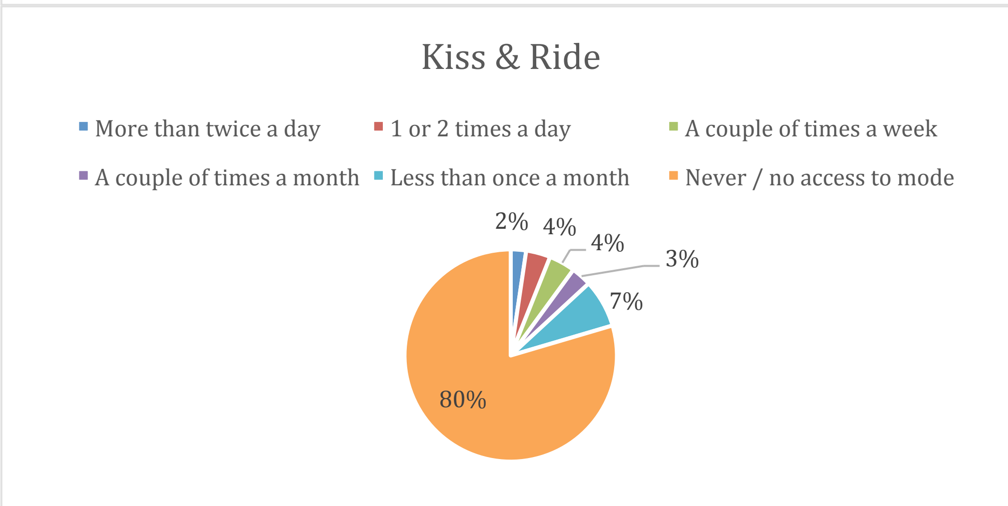

Ferry
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
3%
4%
5%
4%
17%
67%

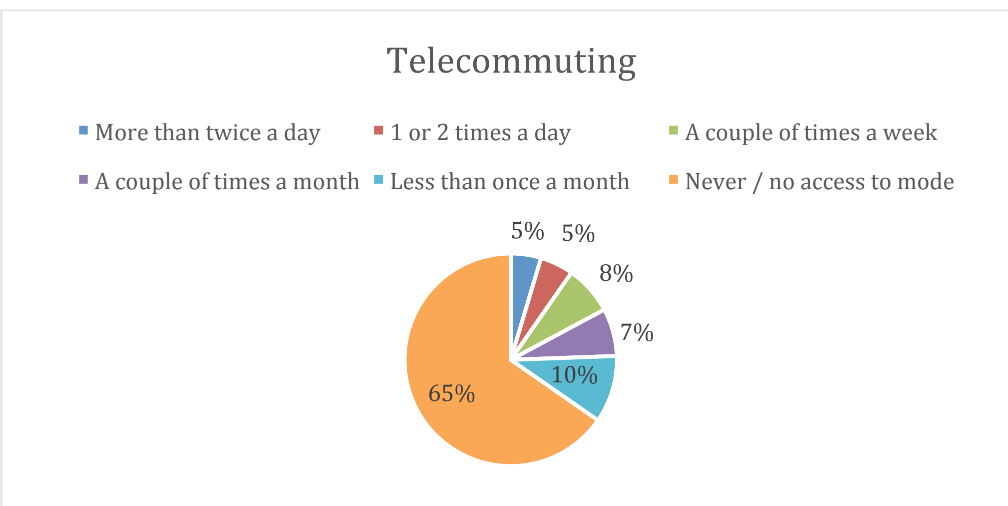

Car as a driver
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
25%
16%
14%
8%
10%
27%


Car as a passenger
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
5%
10%
21%
18%
21%
25%

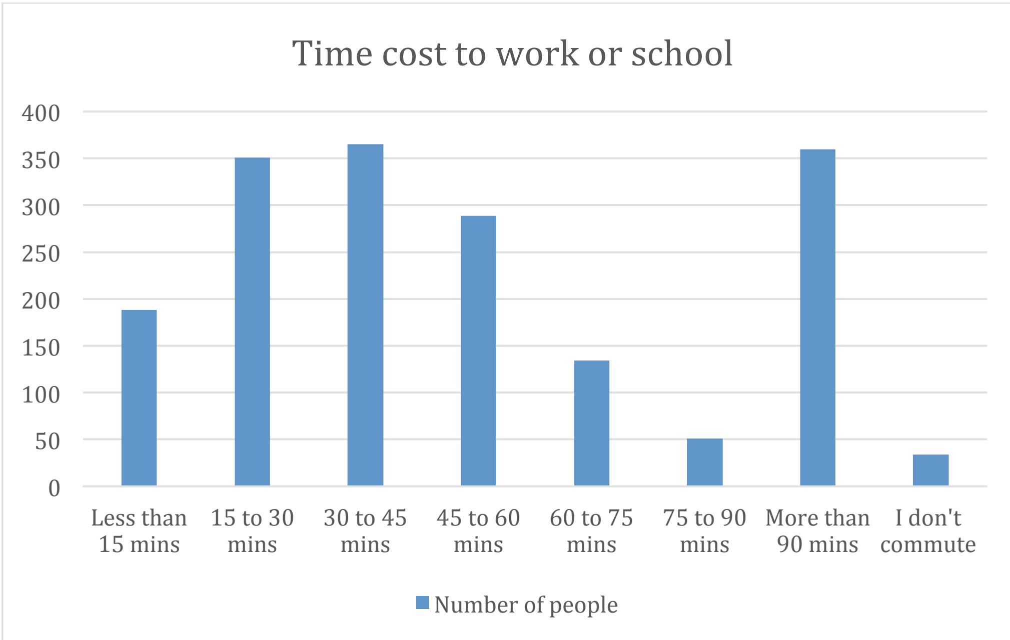

Taxi or limo
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
4%
5%
10%
14%
26%
41%


Park & Ride
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
3%
5%
5%
5%
11%
71%

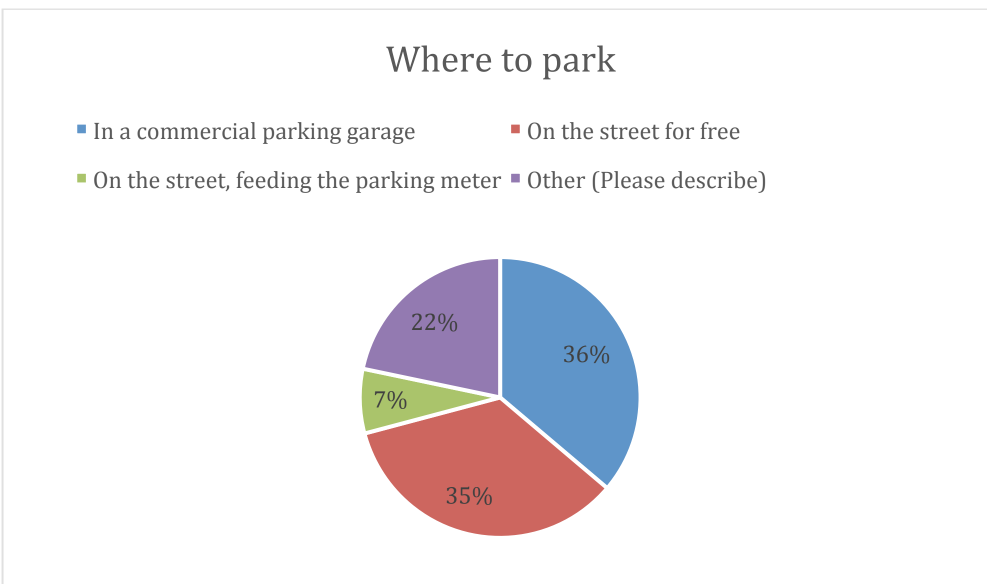

Kiss & Ride
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
2%
4%
4%
3%
7%
80%


Telecommuting
More than twice a day
1 or 2 times a day
A couple of times a week
A couple of times a month
Less than once a month
Never / no access to mode
5%
5%
8%
7%
10%
65%

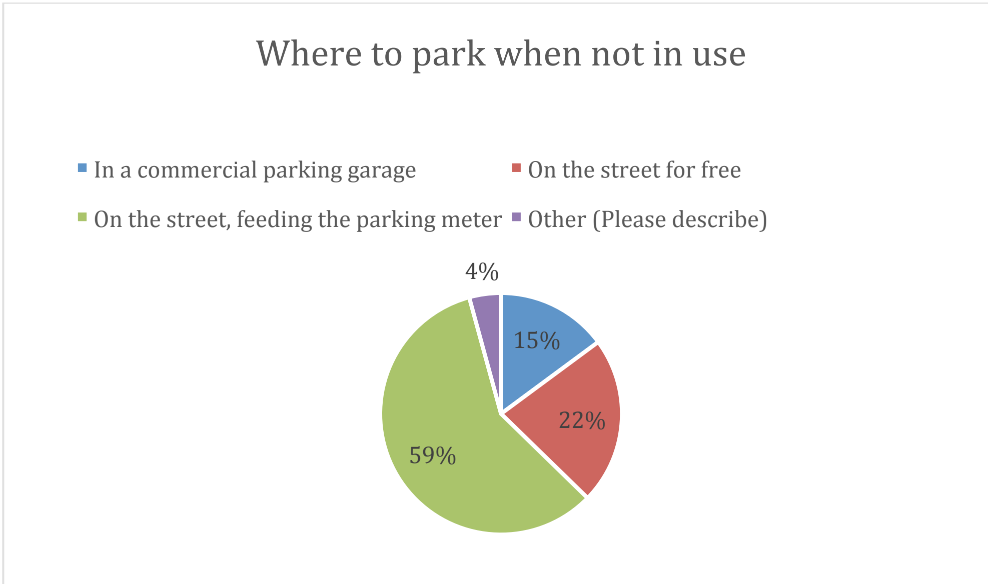
Question 2
How long does it take you on average to commute to work or school (one way trip)?



Question 3
Where do you park the car when you use it to go to work or school?



Question 4
Where do you park the car when it is not in use?



Question 5
How many hurricanes have you been in?

	Number of people, Percentage
0	127, 7.25%
1-2	712, 40.64%
3-4	476, 27.17%
5-6	181, 10.33%
7 or more	256, 14.61%

Question 6
How many times have you evacuated from a hurricane?

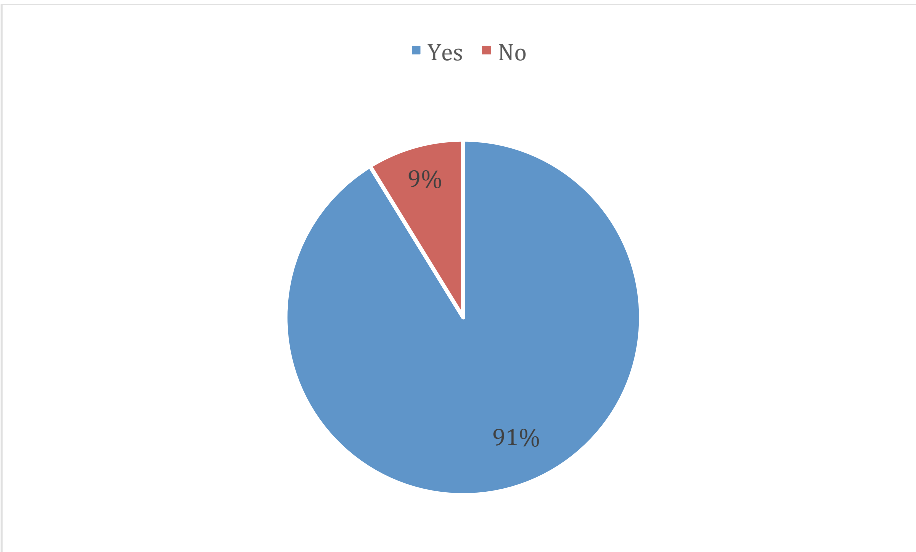
	Number of people, Percentage
0	1217, 69.50%
1-2	426, 24.33%
3-4	75, 4.28%
5-6	25, 1.43%
7 or more	8, 0.46%

Question 7
How many times have you had property damage from a hurricane?

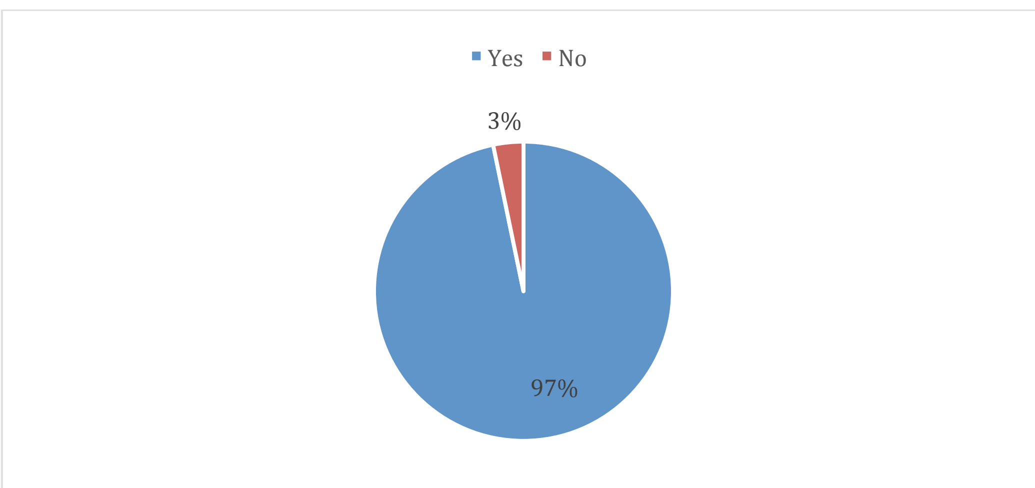
	Number of people, Percentage
0	798, 45.55%
1-2	801, 45.72%
3-4	123, 7.02%

5-6	19, 1.08%
7 or more	11, 0.63%

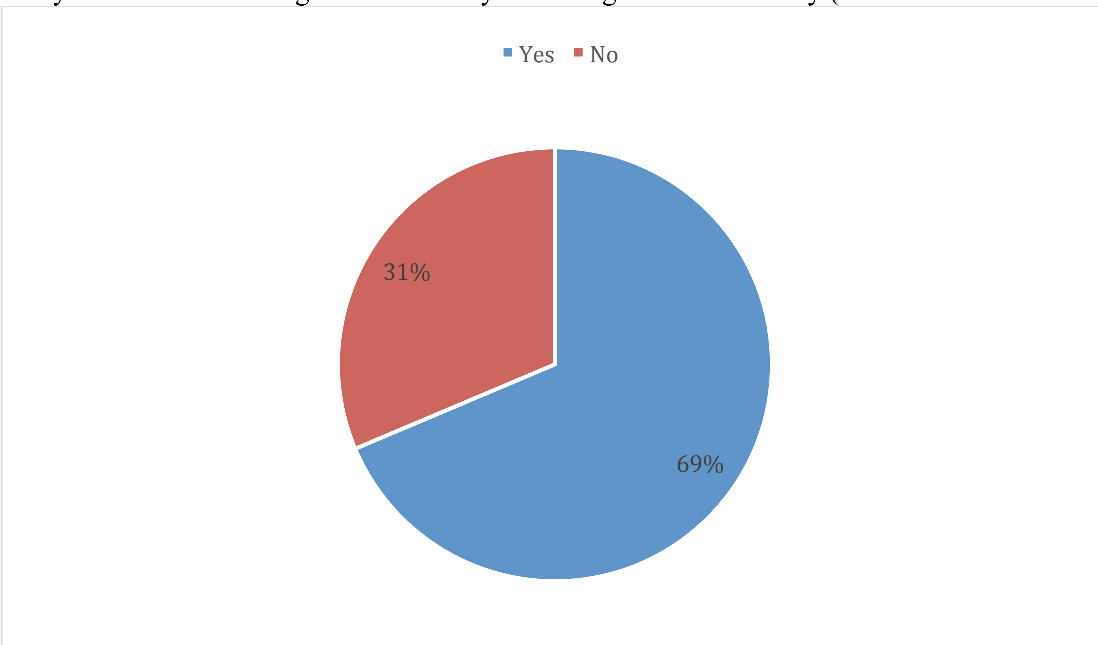
Question 8
Were you in the New York City metropolitan area before, during, or after Hurricane Sandy made landfall around New York City (October 29th, 2012)?



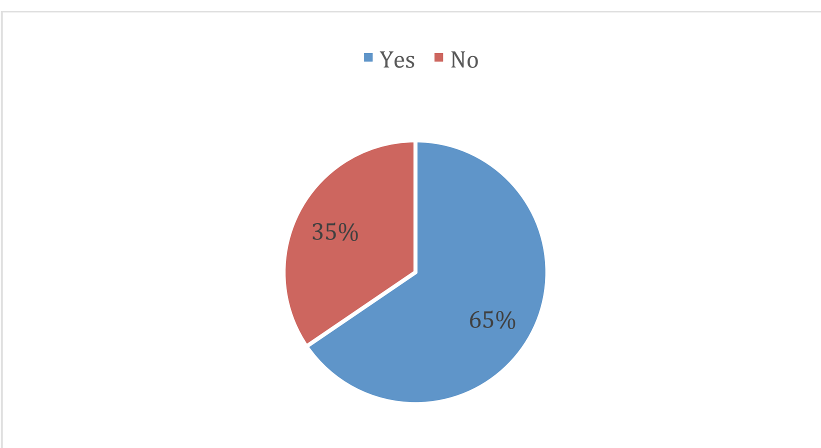
Question 9
Were you in another area that was affected when Hurricane Sandy made landfall on October 29th, 2012?



Question 10
Did you miss work during or immediately following Hurricane Sandy (October 29th-November 2nd)?



Question 12
When you missed work, were you paid for the days that you missed?



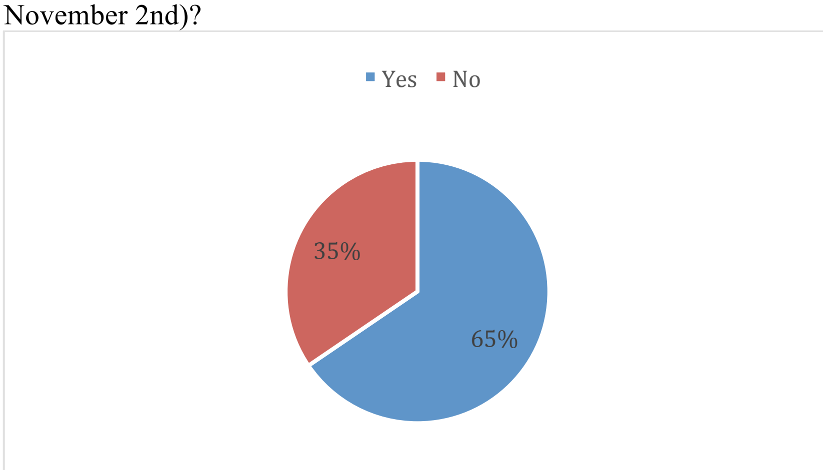
Question 13

The following questions are about your experience with Hurricane Sandy:

	Yes	No	Don't know/can't remember
Did you experience any personal loss from Hurricane Sandy?	33.90%	64.32%	1.78%
Did someone you know experience any personal loss from Hurricane Sandy?	67.99%	28.23%	3.78%
Did your home experience any storm surge from Hurricane Sandy?	27.64%	69.70%	2.66%
Did your neighborhood experience any storm surge from Hurricane Sandy?	40.99%	55.05%	3.96%
Did your community experience any storm surge from Hurricane Sandy?	49.88%	45.15%	4.96%
Was there an evacuation order for your area during Hurricane Sandy?	23.33%	72.18%	4.49%
Did you actually evacuate?	16.48%	81.22%	2.19%

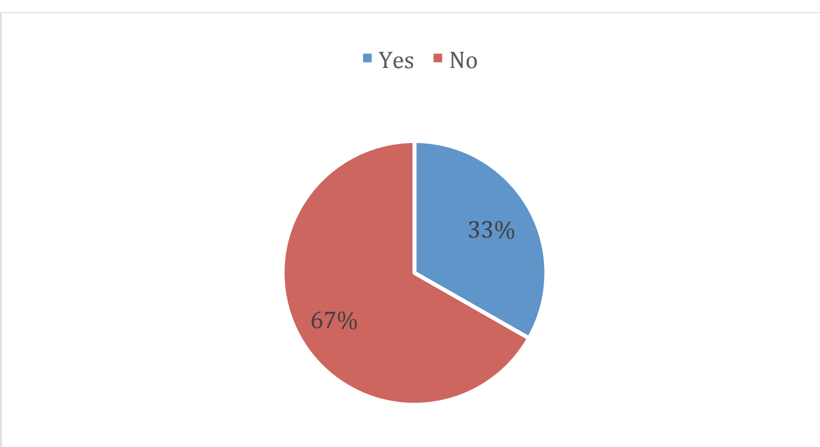
Question14

Was your normal commute disrupted during or immediately following Hurricane Sandy (October 29th-November 2nd)?

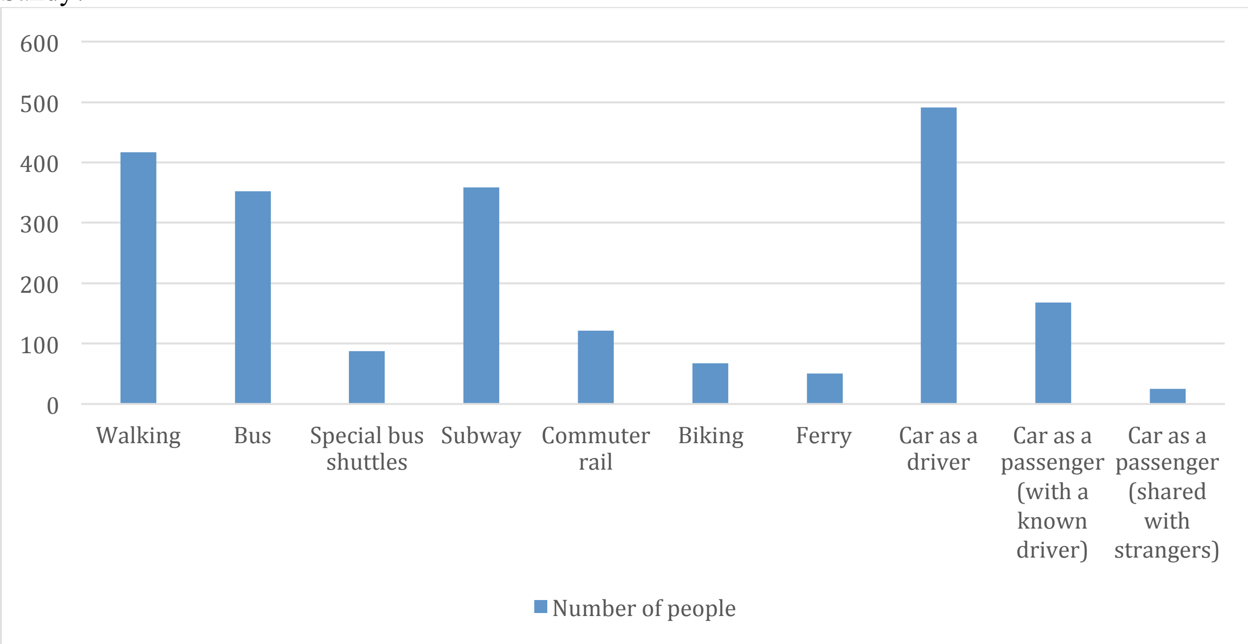


Question 15

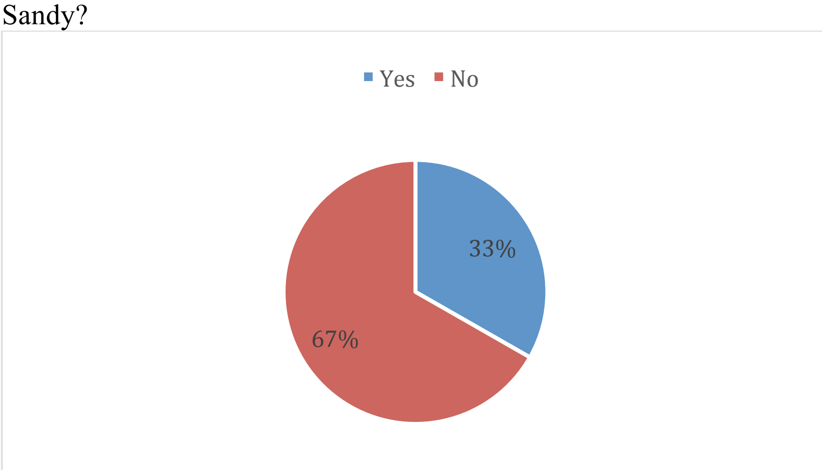
Did you use social media to find open gas stations?



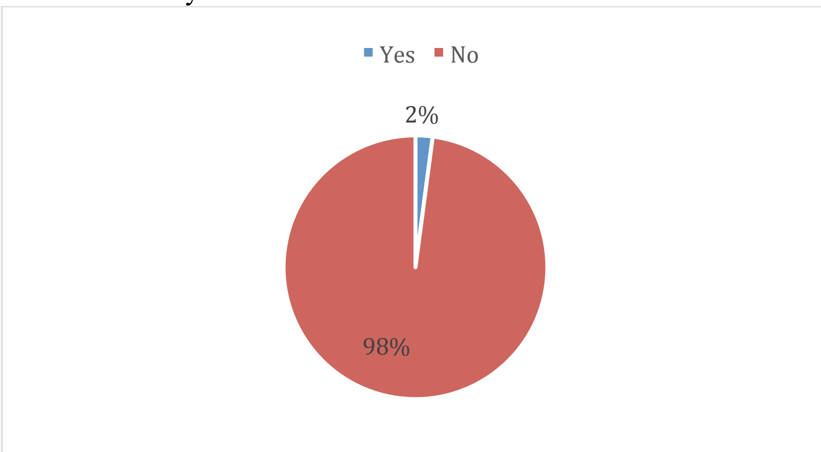
Question 19
What mode(s) of transportation did you use to commute the week immediately following Hurricane Sandy?



Question 20.
A) Did you have plans to leave the New York City metropolitan area that were disrupted by Hurricane Sandy?

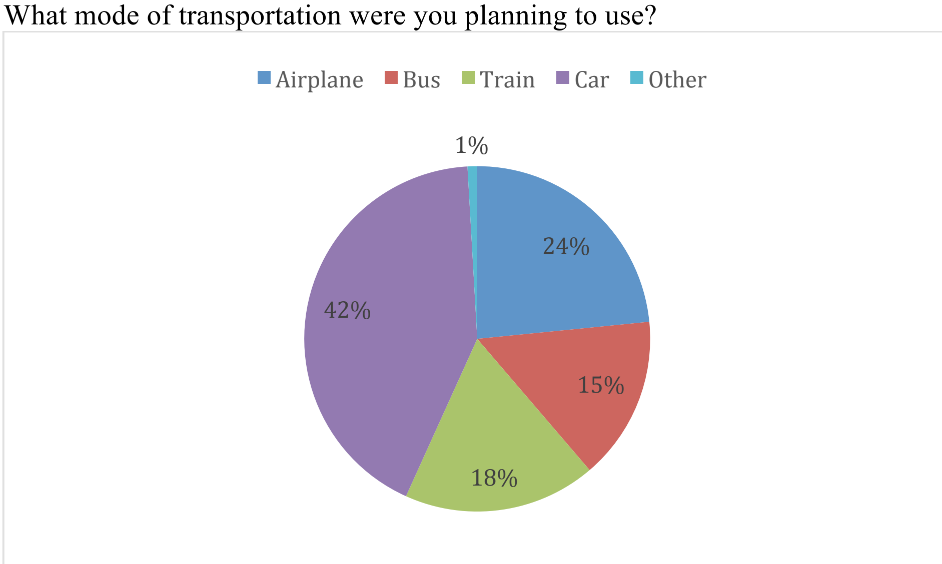


B) Did you have any plans to move around New York, Connecticut or New Jersey that were disrupted by Hurricane Sandy?

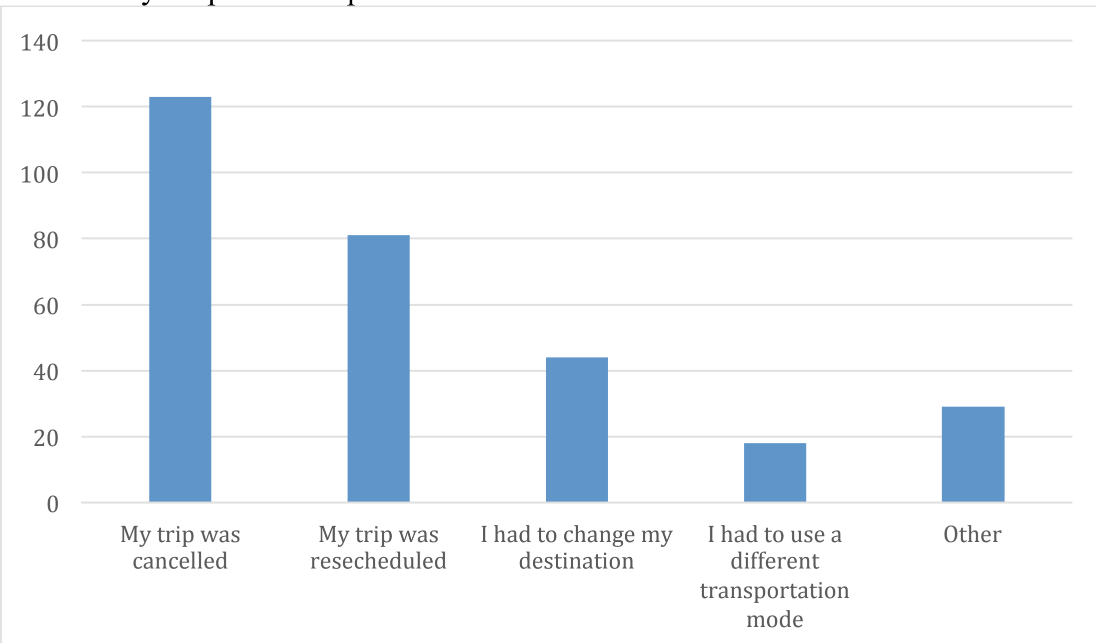


Question 21

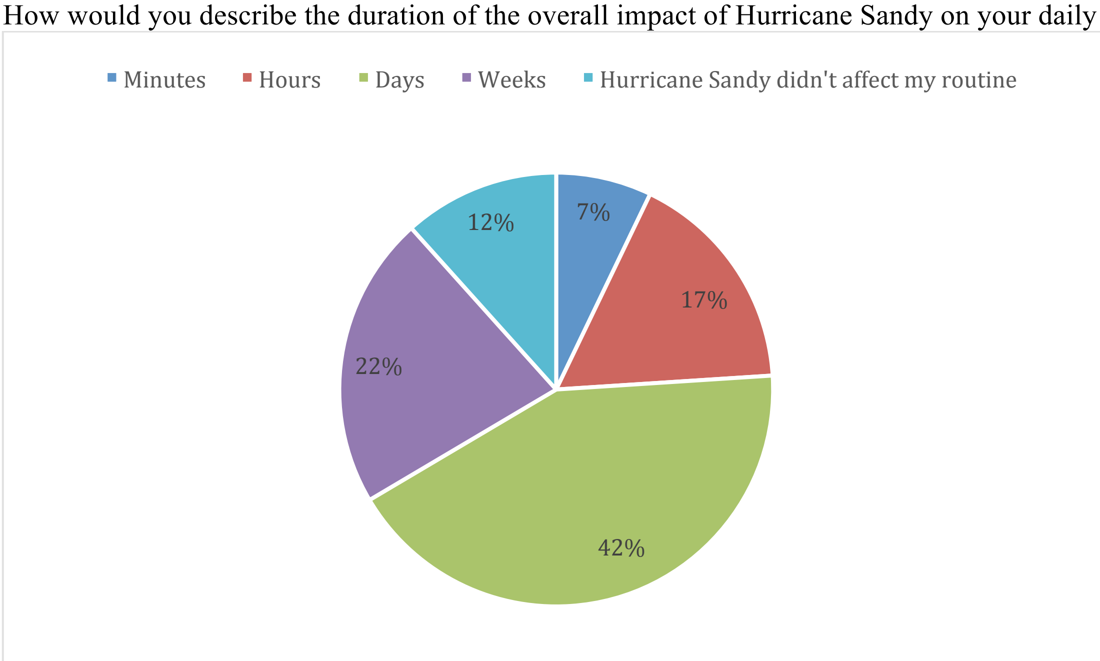
What mode of transportation were you planning to use?



Question 22
How were your plans disrupted?



Question 23
How would you describe the duration of the overall impact of Hurricane Sandy on your daily routine?



Question 26

A) Did you experience any of the following disruptions as a result of Hurricane Sandy?

	Not at all	Only for a few hours	For 1-2 days	For 3-5 days	For a week	For 1 - 2 weeks	For more than 2 weeks
Subway line closures	42.00%	6.97%	17.90%	12.82%	7.97%	6.26%	6.08%
Subway station closures	42.65%	6.67%	16.77%	11.70%	8.74%	7.03%	6.44%
Closed bridges	49.20%	7.38%	18.25%	11.16%	6.91%	4.19%	2.89%
Closed tunnels	50.27%	5.55%	16.72%	11.05%	7.56%	4.49%	4.37%
Abnormal traffic congestion	31.42%	7.32%	18.37%	15.06%	13.17%	9.04%	5.61%
Limited bus service	41.29%	6.62%	17.66%	13.88%	10.40%	7.03%	3.13%
Commuting times more than twice as normal	37.27%	7.21%	16.60%	15.53%	11.16%	7.56%	4.67%
Having to use alternate routes	31.19%	6.85%	16.48%	16.60%	12.40%	9.74%	6.73%
Working at alternate sites	59.60%	4.13%	10.22%	9.75%	7.62%	4.96%	3.72%
Severe crowding in mass transit	45.36%	5.43%	13.29%	11.40%	10.63%	7.97%	5.91%

B) How would you rate the level of inconvenience of the following problems (due to the arrival of a hypothetical hurricane)?

	Wouldn't affect me	Minor inconvenience	Somewhat inconvenient	Extremely inconvenient
Subway line closures	43.66%	15.98%	19.35%	21.00%
Subway station closures	43.84%	15.75%	20.72%	19.69%
Closed bridges	41.72%	17.41%	24.66%	16.21%

Closed tunnels	45.55%	16.84%	21.75%	15.87%
Abnormal traffic congestion	27.11%	21.58%	29.28%	22.03%
Limited bus service	44.58%	17.75%	21.58%	16.10%
Commuting times more than twice as normal	29.57%	17.35%	26.48%	26.60%
Having to use alternate routes	25.23%	24.54%	32.13%	18.09%
Working at alternate sites	49.14%	17.41%	20.66%	12.79%
Severe crowding in mass transit	40.92%	15.58%	23.57%	19.92%

Question 27
Did you experience any of the following as a result of Hurricane Sandy?

	Not at all	Only for a few hours	For 1-2 days	For 3-5 days	For a week	For 1 - 2 weeks	For more than 2 weeks
Difficulty getting food	46.01%	9.21%	20.26%	10.63%	6.91%	4.31%	2.66%
Difficulty getting water	56.53%	8.45%	14.83%	8.51%	5.73%	4.02%	1.95%
Poor water quality	61.78%	6.91%	10.57%	7.27%	6.14%	4.31%	3.01%
Difficulty getting fuel	26.99%	5.79%	13.11%	17.48%	18.02%	11.64%	6.97%
Malfunction of traffic signals	29.12%	8.68%	20.38%	17.84%	13.05%	7.68%	3.25%
Loss of cellphone signal	38.81%	17.90%	15.95%	12.64%	8.09%	4.67%	1.95%
Loss of electric power	28.59%	11.52%	12.17%	17.07%	12.99%	12.52%	5.14%
Elevators not working	61.84%	5.02%	9.51%	8.51%	7.32%	5.20%	2.60%
Lack of heating	43.89%	6.67%	8.86%	13.23%	11.75%	11.05%	4.55%
Staying at home	21.03%	6.67%	26.46%	19.02%	14.59%	7.97%	4.25%
Staying at a friend's/family member's home	63.32%	4.73%	9.21%	7.80%	6.26%	5.02%	3.66%

Question 28.
Please indicate to what extent you agree or disagree with the following statements:

	Completely Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Completely Agree
I live near the coastline	22.89%	14.61%	15.87%	26.60%	20.03%
If I had to	5.94%	8.85%	17.87%	39.27%	28.08%

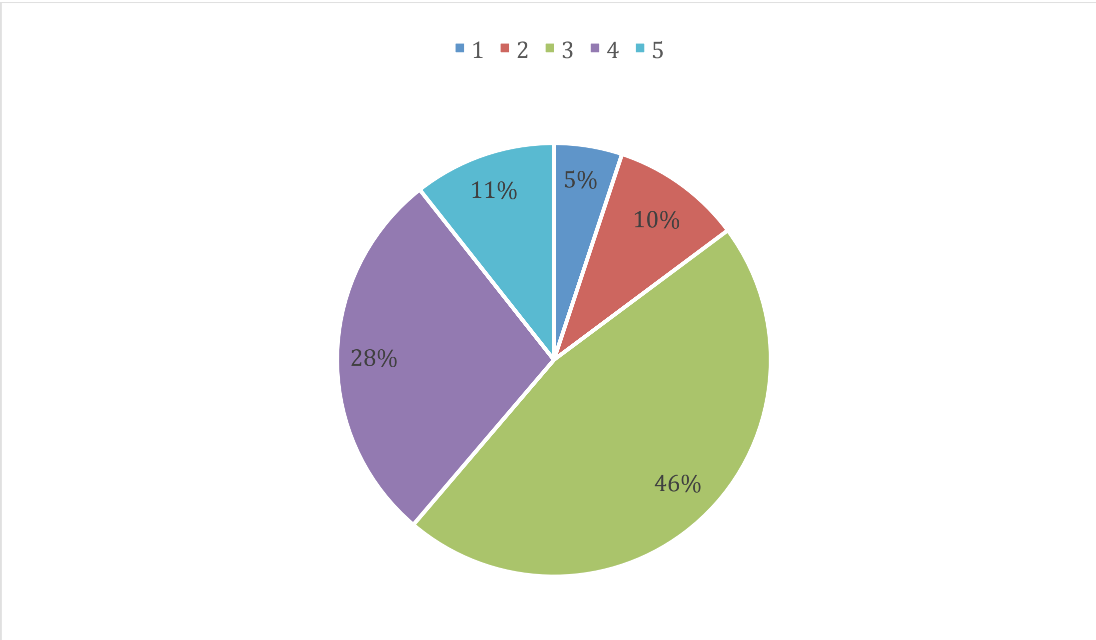
evacuate my home, I could easily access a highway or other exit route					
If I had to evacuate my home, I could easily access mass transit	15.81%	15.47%	18.32%	31.62%	18.78%
The frequency of floods has been increasing in recent years	4.74%	7.02%	23.46%	40.01%	24.77%
I live inland	14.16%	13.58%	18.66%	29.85%	23.74%
The severity of floods has been increasing in recent years	4.05%	7.02%	22.72%	39.84%	26.37%
The government is solely responsible for financing projects that improve transportation infrastructure	4.39%	10.39%	26.66%	35.39%	23.17%
The frequency of natural disasters has been increasing in recent years	4.00%	6.74%	18.32%	39.33%	31.62%
Communities should contribute to financing projects that improve resiliency	4.74%	6.74%	27.28%	41.44%	19.81%
The severity of natural disasters has been increasing in recent years	4.28%	5.37%	18.38%	40.30%	31.68%

Global climate change is a real and urgent issue	6.45%	5.65%	17.81%	29.34%	40.75%
Select 'Neutral'	1.54%	1.54%	88.64%	4.51%	3.77%

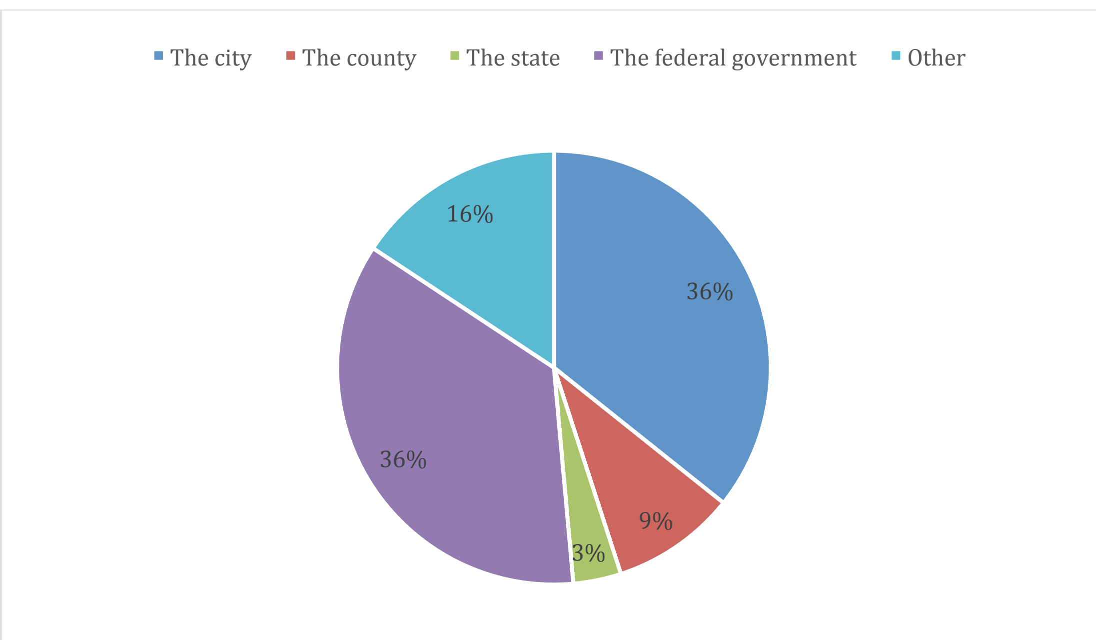
Question 30
How likely is it that these extreme weather events would harm vital transportation infrastructure in your area:

	Not At All Likely	Somewhat Likely	Moderately Likely	Very Likely	Extremely Likely
Heat wave	31.75%	25.43%	24.02%	12.11%	6.70%
Heavy precipitation	15.52%	24.02%	27.43%	20.93%	12.11%
Blizzard	3.93%	17.19%	22.86%	30.59%	25.43%
Storm surge	12.94%	21.31%	24.98%	23.25%	17.51%
Hurricane of category 1	15.39%	26.08%	26.53%	20.35%	11.65%
Hurricane of category 2	7.02%	18.80%	28.65%	28.78%	16.74%
Hurricane of category 3	3.73%	12.75%	22.22%	30.20%	31.10%
Nor'easter	5.92%	22.73%	25.50%	26.85%	19.00%
Damaging winds	6.44%	24.15%	27.11%	25.24%	17.06%

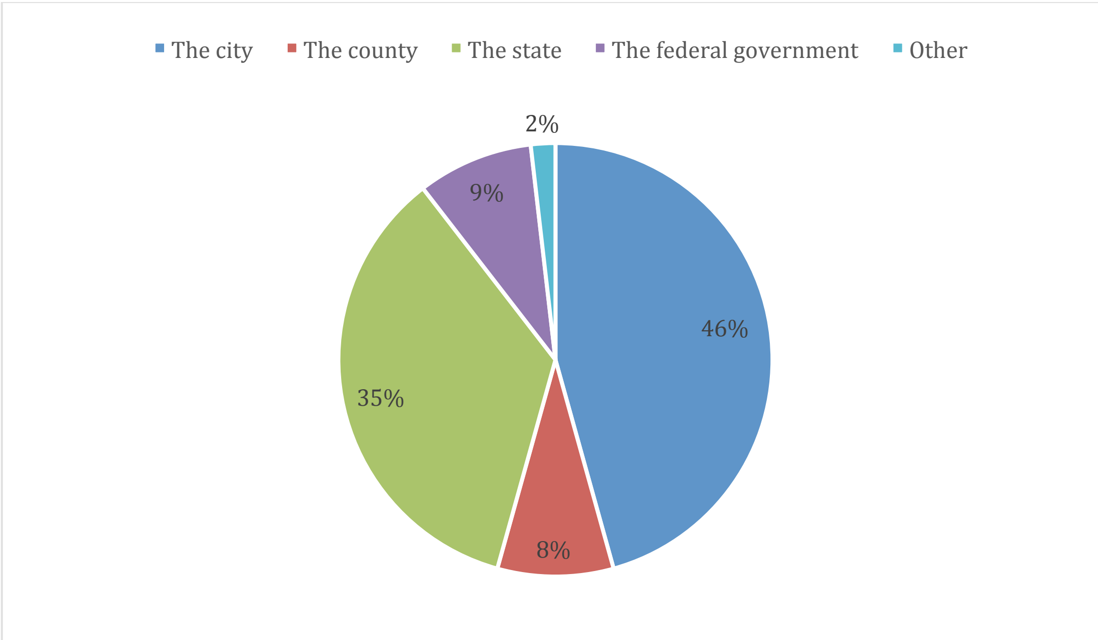
Question 31
Please tell us whether you think government policies have made the transportation system in your area more or less prepared for hurricanes.



Question 31.1
Who do you think should get the blame for the transportation system being less prepared for hurricanes?



Question 31.2 Who do you think should get the credit for the transportation system being more prepared for hurricanes?



Question31.3 To what extent do you disagree or agree with the following statements:

	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
Government has not been doing enough to prepare the transportation system for hurricanes	1.11%	8.32%	48.68%	37.03%	4.85%
Government policies simply do not matter when it comes to the issue of hurricanes	5.96%	27.88%	43.83%	19.83%	2.50%

Question 32
In your opinion, how trustworthy are the following:

	Not at all trustworthy	Somewhat trustworthy	Moderately trustworthy	Very trustworthy	Extremely trustworthy
City Government	15.07%	29.23%	39.28%	12.69%	3.73%
County	14.55%	30.78%	40.18%	11.78%	2.70%

Government					
State Government	17.00%	30.14%	36.25%	12.49%	4.12%
Federal Government	22.60%	30.07%	32.07%	11.59%	3.67%

Question 33
Please rate the extent to which you disagree or agree with each statement.

	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
No level of government should be held accountable for what happened to the people affected by Hurricane Sandy in your state.	21.51%	23.44%	23.44%	18.48%	9.85%	3.28%
Subway operations recovered rather quickly	4.31%	12.88%	23.31%	41.98%	14.17%	3.35%
First responders (Fire, police and EMT personnel) did all they could to save people from rising flood waters during Hurricane Sandy	1.09%	1.09%	5.86%	25.11%	34.77%	32.07%
My local and state government did not convey to me the severity of the risks posed by Hurricane Sandy	14.62%	22.34%	24.86%	21.18%	12.30%	4.70%
TV media	2.06%	2.96%	7.98%	29.62%	34.51%	22.86%

conveyed to me the severity of the risks posed by Hurricane Sandy						

CV1.1 Suppose that the city is considering projects that would reduce the transportation recovery time from 1 week to 2 days. How likely would you be willing to pay the amounts below as a recurring annual payment to support these infrastructure investments.

	Very Unlikely	Somewhat Unlikely	Undecided	Somewhat Likely	Very Likely
$50	30.61%	7.99%	15.48%	21.94%	23.98%
$100	40.41%	9.85%	18.85%	17.49%	13.41%
$200	47.63%	14.75%	19.15%	11.53%	6.95%
$400	60.03%	12.93%	15.48%	7.48%	4.08%
$800	65.59%	11.86%	14.58%	5.59%	2.37%
More than $800	70.46%	9.17%	13.58%	4.41%	2.38%

CV1.2 Suppose that the city is considering projects that would reduce the transportation recovery time from 1 week to 4 days. How likely would you be willing to pay the amounts below as a recurring annual payment to support these infrastructure investments.

	Very Unlikely	Somewhat Unlikely	Undecided	Somewhat Likely	Very Likely
$50	33.76%	9.03%	13.98%	21.94%	21.29%
$100	44.52%	9.68%	18.28%	15.05%	12.47%
$200	54.62%	11.18%	18.49%	11.18%	4.52%
$400	64.52%	11.18%	15.05%	6.45%	2.80%
$800	70.32%	9.68%	13.98%	3.87%	2.15%
More than $800	76.13%	6.24%	11.61%	3.87%	2.15%

CV1.3 Suppose that the city is considering projects that would reduce the transportation recovery time from 2 weeks to 2 days. How likely would you be willing to pay the amounts below as a recurring annual payment to support these infrastructure investments.

	Very Unlikely	Somewhat Unlikely	Undecided	Somewhat Likely	Very Likely
$50	31.72%	7.27%	15.76%	19.80%	25.45%
$100	46.87%	7.47%	16.97%	12.73%	15.96%
$200	54.55%	10.10%	17.17%	10.71%	7.47%
$400	61.62%	13.54%	14.95%	5.45%	4.44%
$800	68.08%	12.73%	12.73%	2.83%	3.64%
More than $800	73.74%	10.30%	11.31%	3.23%	1.41%

CV2 Suppose that the city is considering projects that would reduce the recovery time of transportation from 1 week to 2 days. How likely would you be willing to pay the amounts below as a recurring monthly payment to support these infrastructure investments.

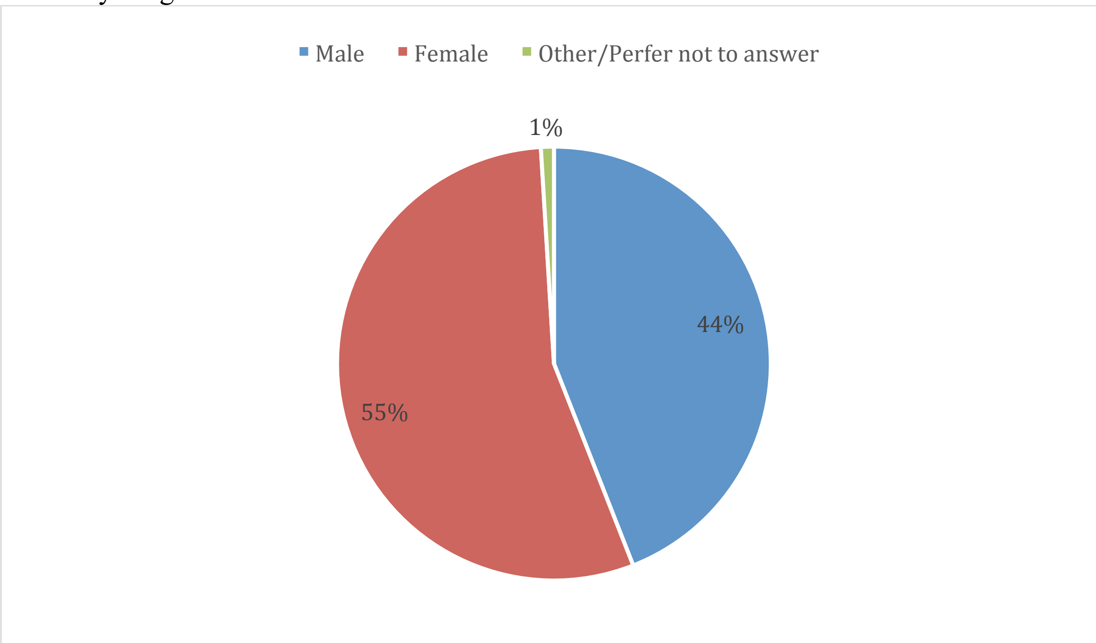
	Very	Somewhat	Undecided	Somewhat	Very Likely

	Unlikely	Unlikely		Likely	
$50	28.40%	5.50%	11.77%	20.18%	34.15%
$100	34.41%	6.14%	14.29%	18.76%	26.39%
$200	40.75%	9.31%	16.88%	15.52%	17.53%
$400	49.58%	11.97%	17.48%	10.29%	10.68%
$800	58.31%	13.70%	14.41%	7.82%	5.75%
More than $800	65.63%	11.13%	13.46%	5.95%	3.82%

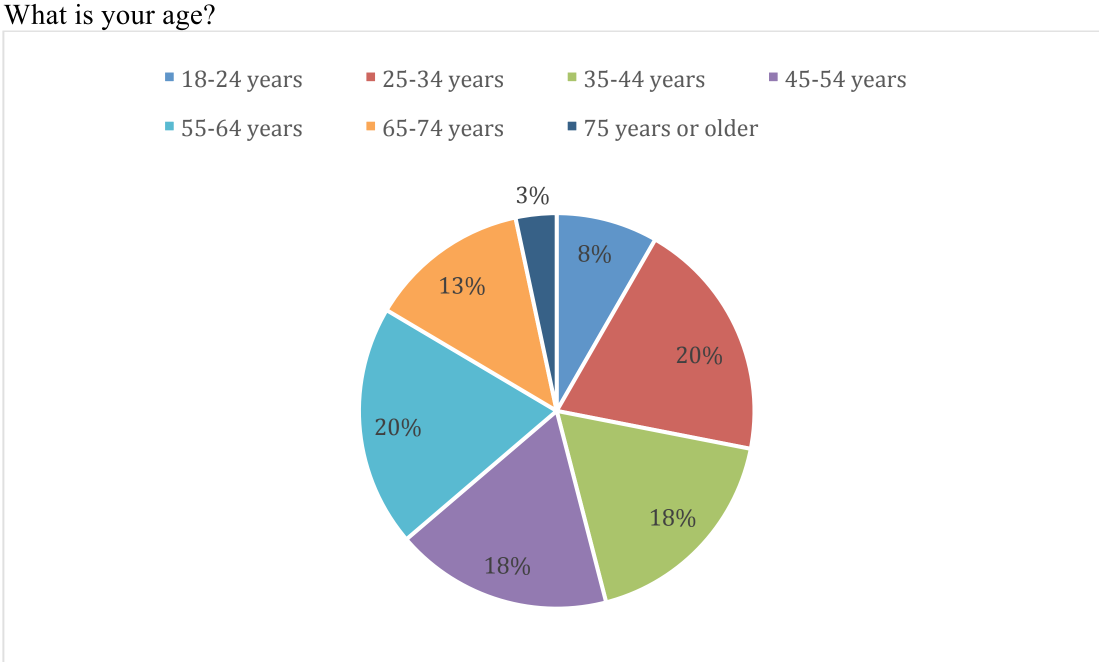
Q36 How likely would you be willing to pay any of the following in order to support funding of projects like those described previously that improve transportation infrastructure resiliency?

	Very Unlikely	Somewhat Unlikely	Undecided	Somewhat Likely	Very Likely
Increased tax on vehicle sales	36.70%	11.14%	20.80%	22.09%	9.27%
Increased tax on vehicle registration	36.96%	13.01%	19.96%	22.54%	7.53%
Increased tax on gas	42.69%	17.06%	17.39%	15.65%	7.21%
increased property tax	49.71%	16.48%	17.77%	12.11%	3.93%
One-time increase in income tax	43.72%	13.46%	21.51%	15.58%	5.73%
Insurance premium	44.95%	15.71%	21.12%	13.72%	4.51%
Increased bus fares	39.41%	13.26%	20.93%	19.45%	6.95%
Increased subway fares	39.79%	13.33%	19.32%	19.96%	6.76%
Increased bridge tolls	41.60%	14.75%	20.09%	16.81%	6.76%
Increased parking fees	41.02%	15.84%	19.25%	17.32%	6.57%

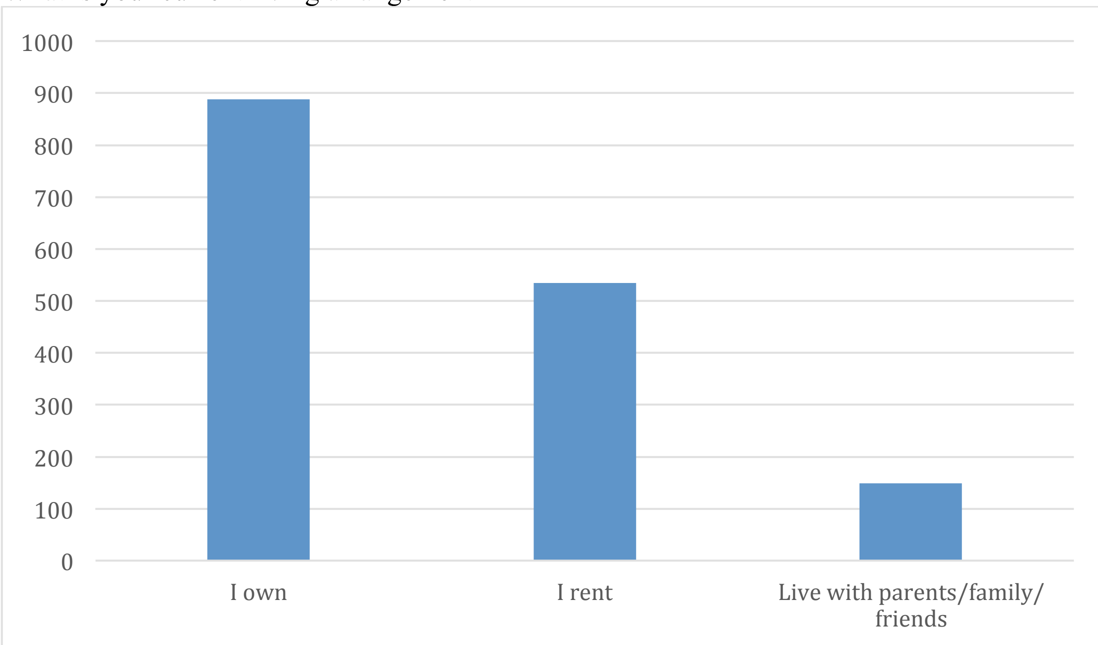
Question 37
What is your gender?



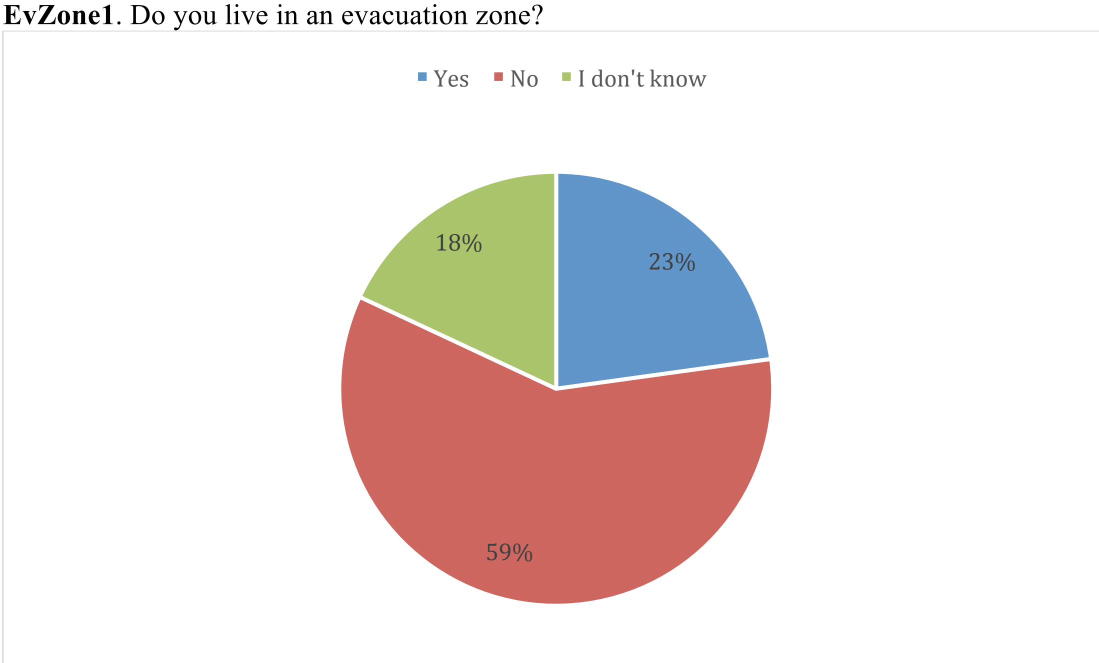
Question 38
What is your age?



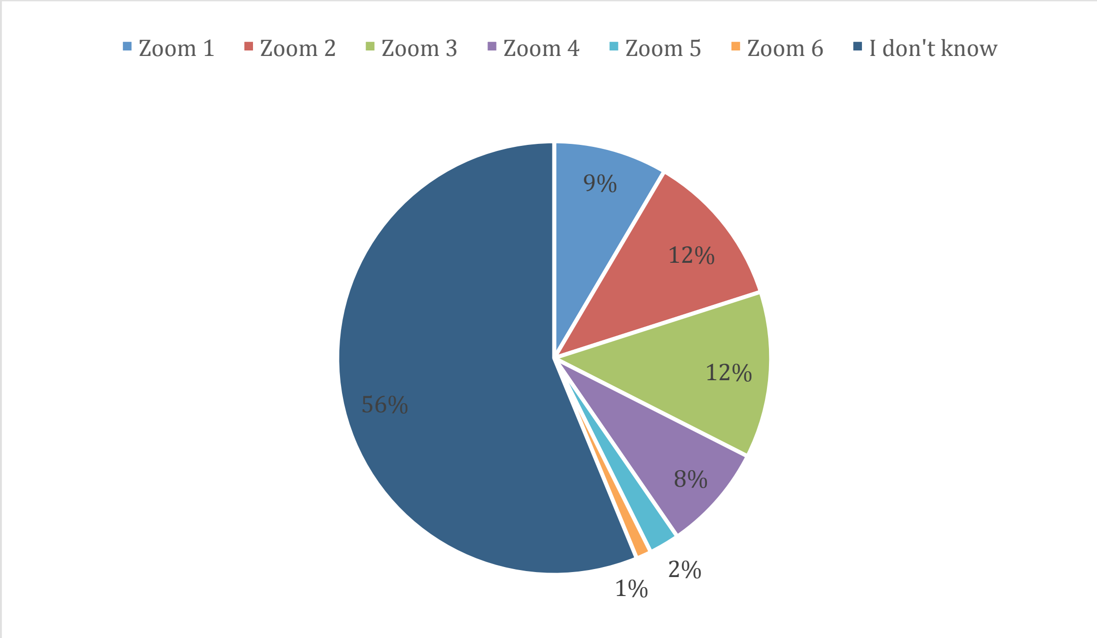
Question 39
What is your current living arrangement



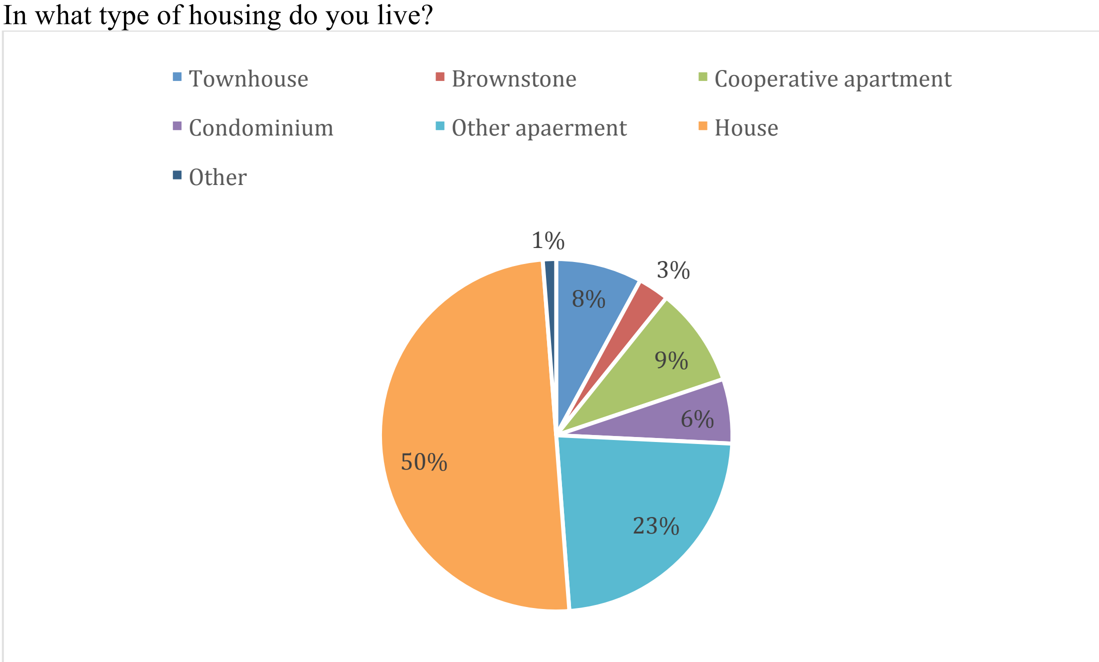
EvZone1. Do you live in an evacuation zone?



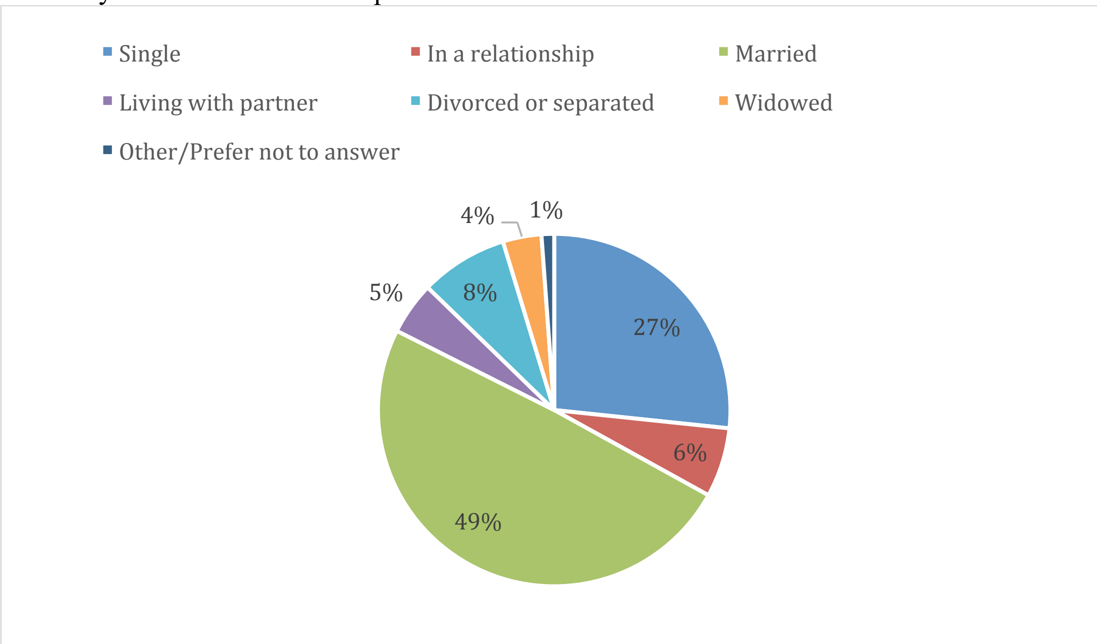
EvZone2. Do you know which is your evacuation zone?



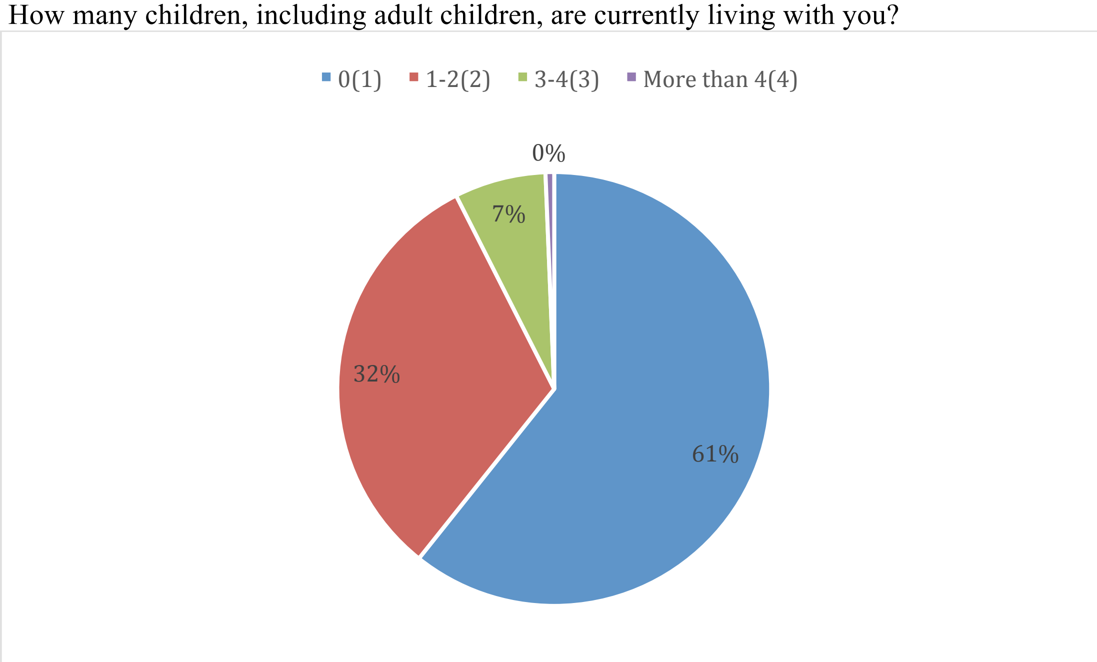
Question 42
In what type of housing do you live?



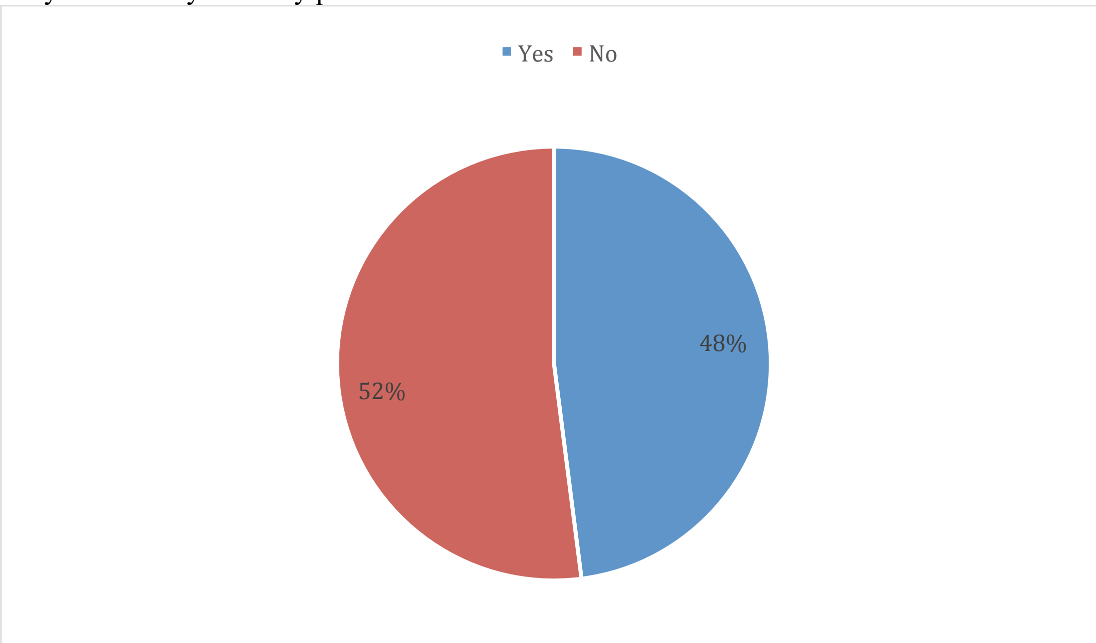
Question 43
What is your current relationship status?



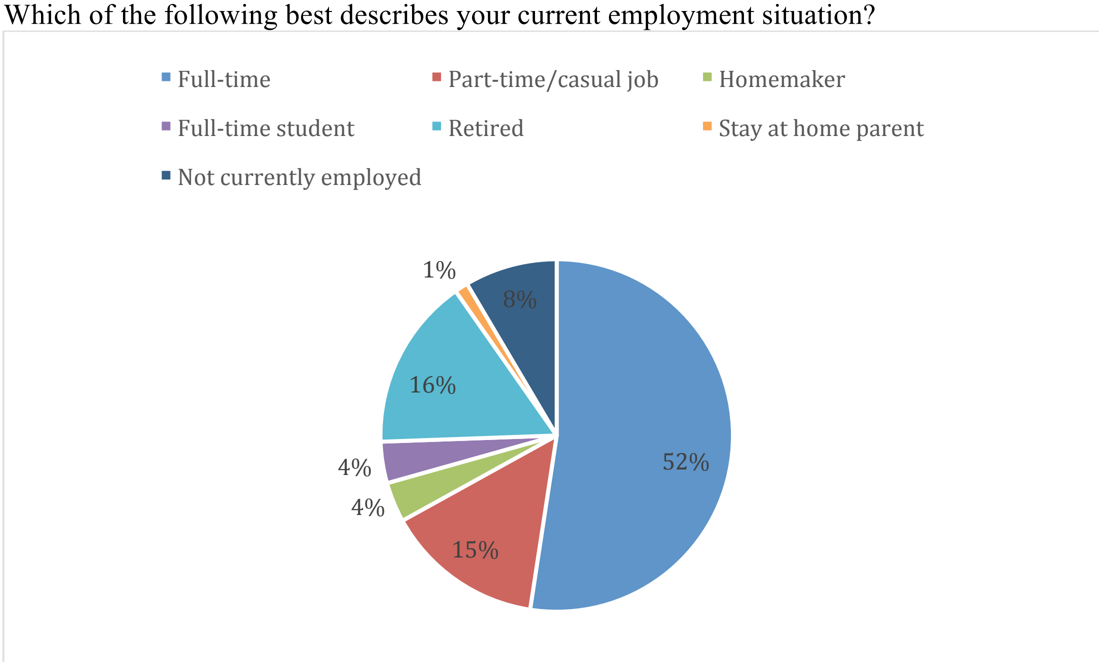
Question 44
How many children, including adult children, are currently living with you?



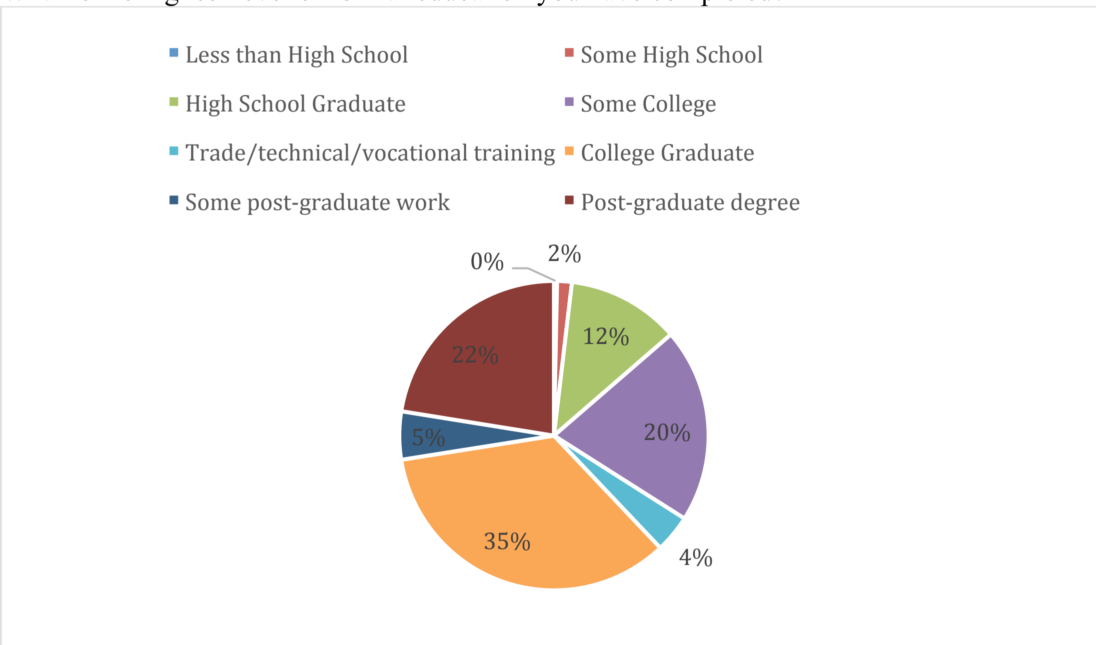
Question 45
Do you currently own any pets?



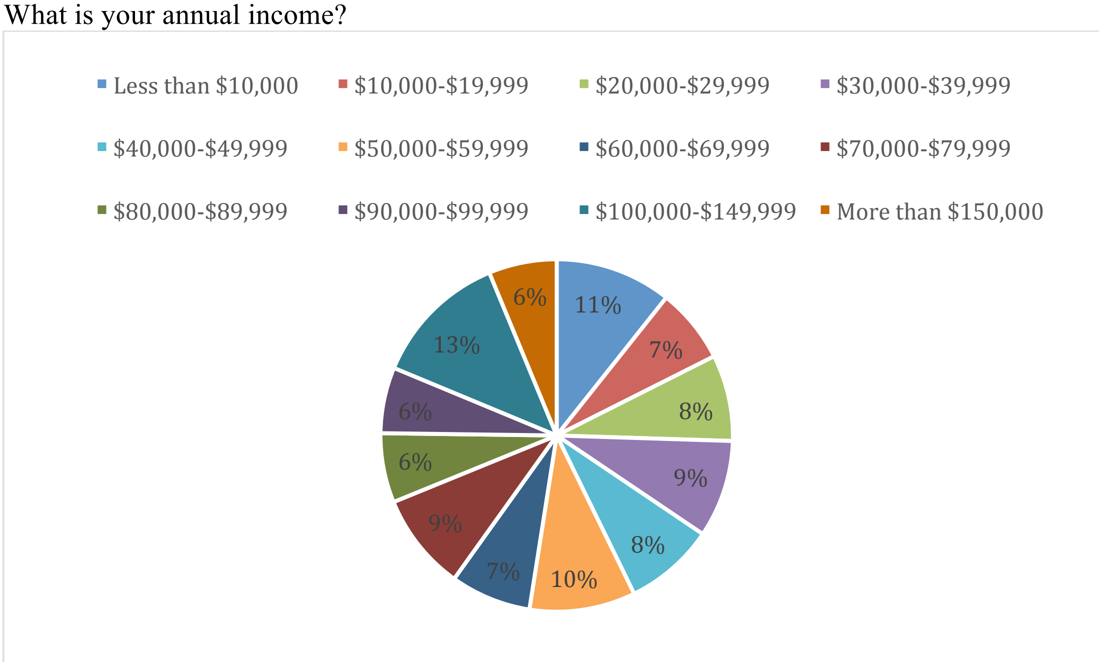
Question 46
Which of the following best describes your current employment situation?



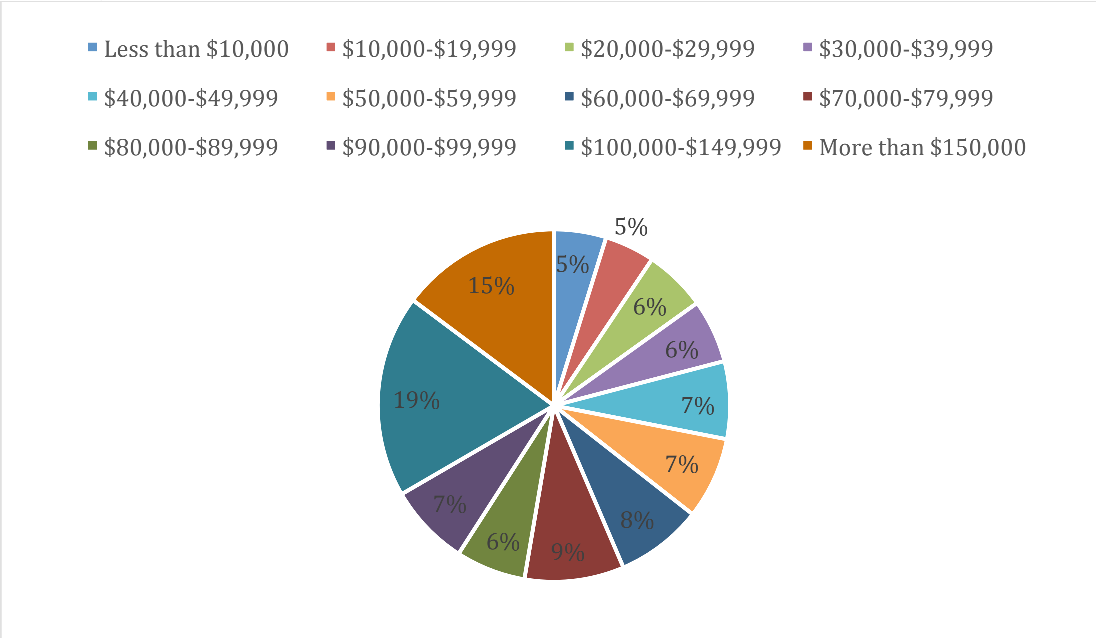
Question 47
What is the highest level of formal education you have completed?



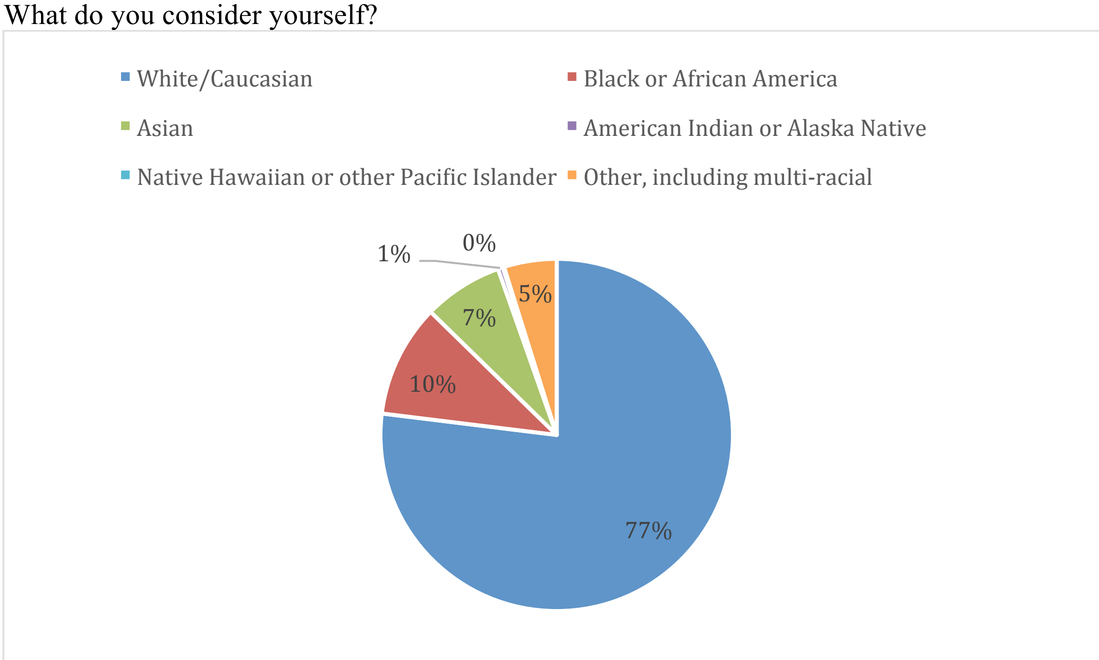
Question 48
What is your annual income?



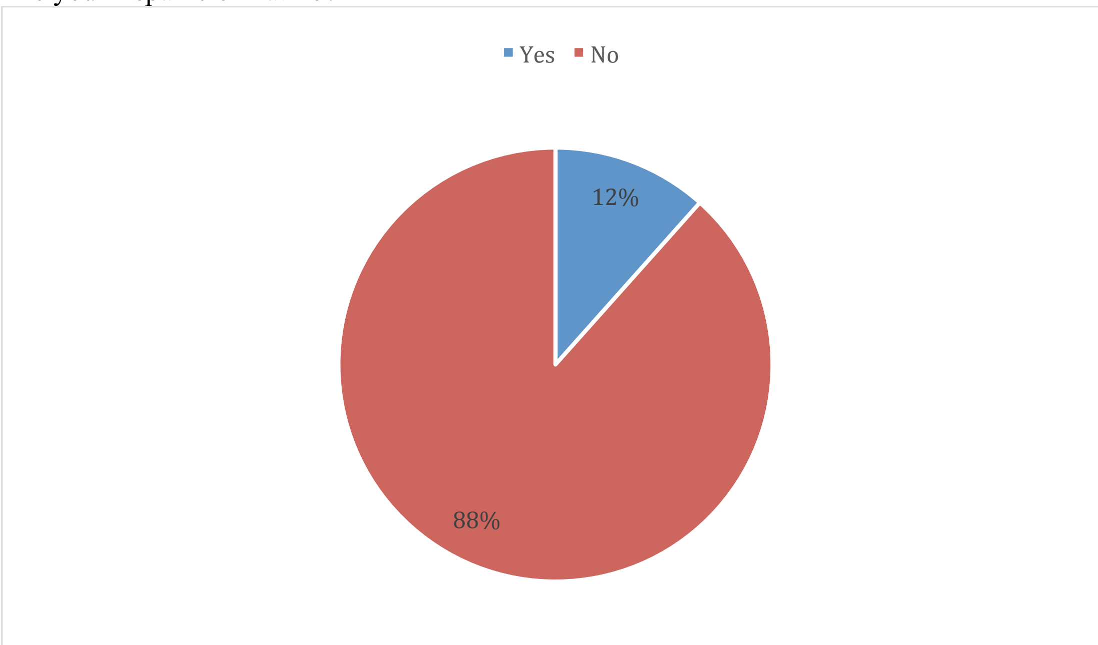
Question 49
What is your estimated annual household income?



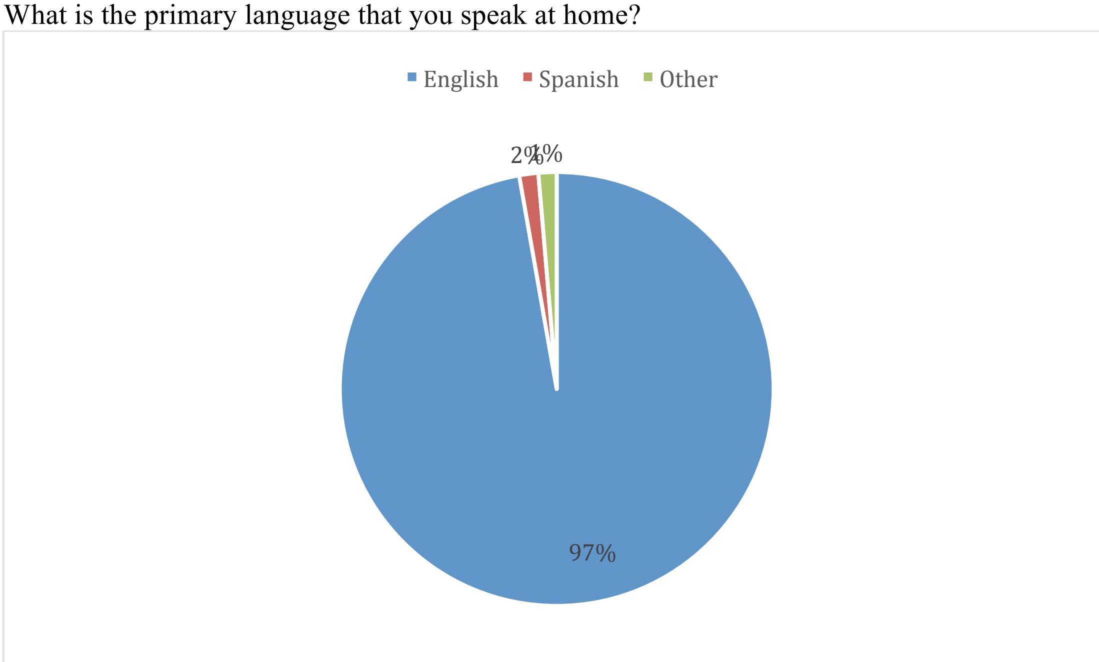
Question 50
What do you consider yourself?



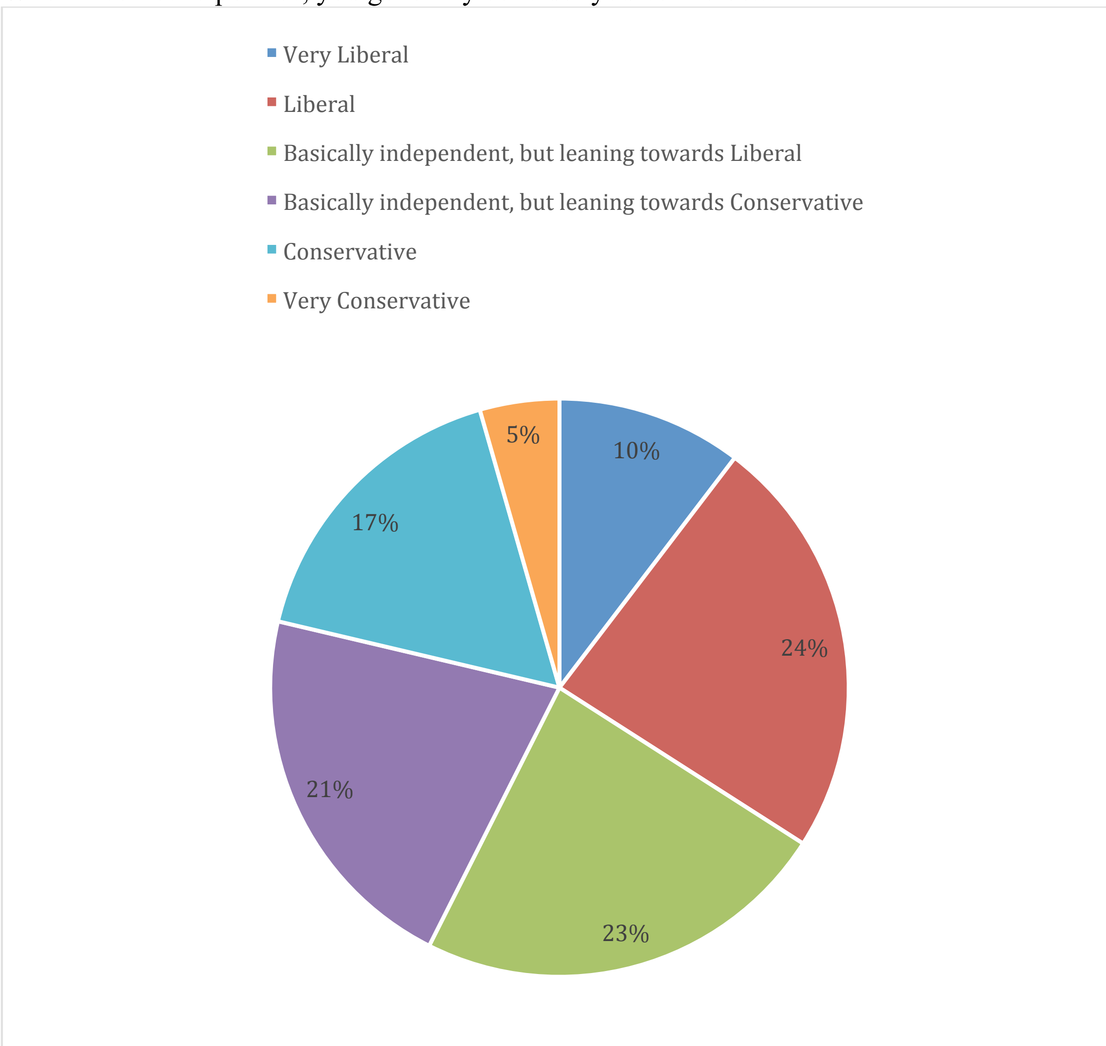
Question 51
Are you Hispanic or Latino?



Question 52
What is the primary language that you speak at home?



Question 53
When it comes to politics, you generally consider yourself to be...



University Transportation Research Center - Region 2

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