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MODELING THE IMPACT OF SUSTAINABLE TRANSPORTATION OPTIONS ON AUTO OWNERSHIP AND USE IN CAR-DOMINANT DEVELOPING COUNTRY CONTEXTS: THE CASE OF LEBANON

by
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AN ABSTRACT OF THE THESIS OF

Lara Said Otary for Master of Engineering
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Title: Modeling the Impact of Sustainable Transportation Options on Auto Ownership and Use in Car-Dominant Developing Country Contexts: The case of Lebanon

Car ownership and use is a main contributor to the deterioration of air quality in cities. This thesis studies car ownership and use decisions in car-dominant developing country contexts, and quantifies the effect of public transportation availability on these decisions. A discrete-continuous modeling framework that estimates car ownership and use simultaneously is presented. The correlation between the two decisions is captured through error components that represent the unobserved factors affecting the joint decision. People's latent attitudes towards public transportation and the private car are also assumed to influence these decisions.

The model was applied to the case of Lebanon, a developing country characterized by a high car ownership rate (estimated at 1 car per 3 persons), a high percentage of trips made by car (estimated at 80% in the Greater Beirut Area), and an unreliable public transportation system. This has resulted in an unsustainable situation leading to gridlock, pollutant concentrations in the air exceeding safe limits, excessive fuel consumption, and lower overall well-being of Lebanese citizens. The model estimation results were used to predict shifts in car ownership levels and changes in annual kilometers traveled with respect to the current situation. Five policy scenarios involving potential improvements to the public transportation system, land use densification, or increase in fuel taxes were tested. The findings show that the current public transportation accessibility level has a minor impact on car ownership, but none on car usage. Only if major improvements to the public transportation services (such as major reduction in travel time of the bus) are enacted would a decrease in car ownership and usage be achieved. Model outcomes value this improvement at around 5.88% and 15.21% reduction for car ownership and usage, respectively. As a result, emissions, fuel consumption and heat generation will be reduced by 15%. Densification of zones outside Municipal Beirut is also a promising strategy for reducing car usage.

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CHAPTER 1

INTRODUCTION

This thesis addresses the topic of car ownership and use in car-dominant developing country contexts. It particularly analyzes the determinants of household car holding decisions (number of cars owned) and usage (kilometers traveled) by developing an advanced econometric model which is able to link these decisions to the accessibility of public transportation services in Lebanon. This study also works towards investigating the associated environmental benefits as a result of future public transportation improvement and land development scenarios.

This chapter is organized as follows. The first section gives a motivation for the research. The second section presents the research objectives and contributions. The last section presents the structure of the thesis.

1.1. Motivation

Due to the absence of good public transportation services, the transportation sector in Lebanon is characterized by high dependency on the private car. As cited in El-Fadel (2001) and Irani and Chalak (2015), Lebanon has a high car ownership rate of 1 car for every 3 persons. This rate is approximately 50 percent less than that found in the U.S. (1 car for every 1.25 persons), quite comparable to that of Japan (1 car for every 2.5 persons), yet considerably more than the average rate in E.U. countries (1 car for every 5 persons). Although the car ownership rate in Lebanon seems to be very comparable to that in developed countries, its GDP falls far behind theirs. According to the World Bank, the national GDP in Lebanon for the year 2017 is less than 1% of that of the U.S., E.U. counties, and Japan ($53,576 million compared to $19.39 trillion, $17.28 trillion, and $4.87 trillion, respectively). An increase of 538% in the number of cars in Lebanon took place from 1974 to 1998 (Perry, 2000). The Lebanese vehicle fleet is mainly composed of private cars that constitute 85% of the total fleet (MoE et al., 2015, 2016). An estimated 665,000 passenger-car-units enter Beirut daily; 350,000 cars enter through the Northern corridor, 225,000 cars enter through the Southern corridor, and 90,000 cars enter from the Eastern corridor, causing high traffic congestion at the entrances to Beirut. It is expected that within the next 30 years, both the number of motorized person trips and the car fleet will double in response to a predicted demographic growth. The mobility of people and goods will be highly restricted mainly along the Northern Corridor of Greater Beirut Area (CDR and World Bank, 2017).

The continuous rise in auto ownership and use rates in Lebanon is mainly attributed to a number of factors including poor urban planning policies, inefficient public transit facilities which make owning an auto seem like a necessity, the general social belief that auto ownership reflects privilege and prestige, the introduction of relatively cheaper vehicle models from Asian markets, and the abundance of second-hand vehicles in the market as well as the bank facilities that facilitate credit purchasing (BankMed, 2014, 2016; Belgiawan et al., 2014; Chalak et al., 2016). Perhaps the main reason behind high car ownership and use levels is that the public transportation system is unreliable and unregulated.

In Lebanon, there are two main types of public transportation. First there are the buses, minibuses and the vans operated mostly by private operators and to a very limited extent by the government. A small number of buses / vans operate on fixed routes and at predefined schedules. Moreover, they are limited in geographical coverage as most of these buses operate in Greater Beirut only. Second there are the shared taxis, known as "services", which are privately owned and operate inside and outside Greater Beirut. "Services" do not follow fixed routes or predefined schedules, but they offer a better level of service than buses / vans (Kaysi et. al, 2010). The absence of government planning and the disregard of traffic regulations led to the oversupply of "services" compared to mass public transport systems.

Several studies have been conducted to plan an integrated mass transit system in Greater Beirut Area which would be capable of reducing congestion and increasing transit ridership. However, none of these studies have been implemented yet. As a result, public transportation is perceived to be of low quality in Lebanon and people who use it are mostly captive riders because they don't have other reliable alternatives.

Besides high car ownership rates, the car fleet in Lebanon is old and polluting. According to the data of the Traffic, Trucks, and Vehicles Management Authority (TTVMA), 54% of the total fleet of passenger cars in Lebanon are more than 15 years old (MoE et al., 2017). Moreover, the market share of hybrid and electric cars in Lebanon is low due to their high purchase prices and the absence of incentives (up until recently) to buy these types of environmentally friendly cars, such as tax waivers.

High levels of auto ownership and use are associated with a number of negative consequences at the household level, community level and the regional level. At the household level, the high reliance on the private auto leads to high expenditures resulting from transportation costs (purchase price, fuel, maintenance, etc.) (CES, 2004). At the community level, the dependence on the private auto could lead to inequity among population segments; i.e. higher income households have the ability to own more cars and bear the costs associated with using them unlike lower income households (Engwicht, 1993; Litman, 2002, 2005). At the regional level, the dependence on the private auto and the aging of the fleet lead to rising levels of congestion and emissions causing the deterioration of air quality, high fuel consumption and urban heat as well as the degradation of social welfare (Litman and Laube, 2002; Schrank and Lomax, 2005) (as cited in Bhat et al., 2009). Gridlock in Beirut has become unsustainable. The high concentrations of nitrogen dioxide and particulate matter, which are currently two times more than the allowable limits set by the World Health Organization (WHO), have considerably increased the probability of fatalities (Baalbaki et al., 2013) (as cited in Chalak, 2016). A study by the World Bank (Sarraf et al., 2004) found that the cost of air pollution in Lebanon is $170 million per year.

Moreover, the production of waste heat from motorized vehicular traffic as well as the high level of pollution in urban areas are major contributors to the development of the Urban Heat Island (UHI) (Sailor, 2011; Oke, 1982). “UHI is a climatic phenomenon in which urban areas have higher air temperature than their rural surroundings as a result of anthropogenic modifications of land surfaces, significant energy use, and its consequent generation of waste heat” (Shahmohamadi et al., 2011).

1.2. Research Objectives and Contributions

This thesis aims to quantify the extent to which car ownership and use can be reduced through the provision of improved public transportation services and the associated environmental benefits in a developing country context with informal public transportation. Within this context, the specific objectives of this research are:

1. Analyzing the determinants of car ownership and use.

2. Estimating the contribution of existing public transportation availability and quality to car ownership and use levels.
3. Estimating the reduction in car ownership and use levels and the associated environmental benefits (reduction in vehicular emissions, fuel consumption, and heat island effects) as a result of future public transportation improvement scenarios and other possible interventions.

To achieve these objectives, a discrete-continuous model of car ownership and use decisions is developed based on data of a travel behavior survey conducted with a sample of residents in Greater Beirut area.

This research aims at testing the following hypothesis:

The higher the quality and accessibility of public transportation, the less likely it is that households will own more cars and have high vehicle usage, while controlling for socio-economic and demographic characteristics and other built environment attributes.

According to previous studies, this relationship between public transportation and car ownership has been found in both developed and developing countries. However, this hypothesis hasn't been tested before in a context similar to the context of Lebanon where public transportation is unregulated and unorganized.

Previous work focusing on public transportation in Lebanon has applied models to investigate the effect of different public transportation investment scenarios (such as improved bus frequency, route coverage, speed, dedicated bus lane) on mode choice and congestion (Chalak et al., 2016; Danaf et al., 2014; El-Fadel and Bou-Zeid, 2000; IBI Group and TEAM International, 2009; etc.). To the best of our knowledge, there are no studies which have modeled auto ownership and use in Lebanon. To that end, this thesis will advance the state of the knowledge in this area in Lebanon by developing a discrete-continuous model of household vehicles holdings and usage. The innovation of this study draws from exploring whether enhancing public transportation services, in a country which lacks organized and regulated forms of transportation, can deter people from purchasing and using a car as a means of transportation. It can help answer questions such as whether simply reducing access distance to existing public transportation has any effect on car ownership and use or whether substantial changes in the public transport system are necessary to observe any major effect. Additionally, the model results can inform the design and evaluation of public policy to reduce car ownership and use through land use strategies (such as densification and jobs-housing balance), and fuel prices. The developed model and policy analysis can be adapted to other developing country contexts with similar public transport characteristics.

1.3. Thesis Organization

The remainder of this thesis is structured as follows:

- Chapter 2 reviews the literature of car ownership and use, and gives a brief literature review about hybrid and electric cars.
- Chapter 3 presents the modeling methodology and describes the data required to conduct the research.
- Chapter 4 is an application of the methods to Greater Beirut Area. It describes the survey design and other data collected. It also presents a descriptive analysis of the sample used for modeling. The last section of Chapter 4 presents the model formulation, and outlier analysis.

- Chapter 5 presents the model results and defines multiple policy scenarios that can serve as a decision tool for the reduction of car ownership levels and usage.
- Chapter 6 concludes the thesis and presents its contribution, limitations, and directions for future research.

CHAPTER 2

LITERATURE REVIEW

One of the key dimensions of individual and household travel behavior is auto ownership (Bhat and Pulugurta, 1998). Auto ownership affects various dimensions of travel such as the trip frequency (Meurs, 1990), non-work activity destination choice (Wrigley, 1990), mode choice of both work and non-work trips (Uncles, 1987; Bhat, 1996), and the tendency to chain trips in a tour (Hamed and Mannering, 1993, as cited in Bhat and Pulugurta, 1998). The causal relation between public transportation availability and auto ownership and use has received considerable attention in many studies. The first section of this chapter discusses the demographic, socio-economic and planning factors which affect auto ownership and use. The second section discusses the relation between public transportation and auto ownership / use. The third section reviews the models used to study car ownership and use. The fourth section of this chapter gives a brief literature review about hybrid and electric cars which can serve in developing the second phase of this research to estimate the willingness of people to buy environmentally friendly vehicles as a replacement of their current gasoline cars and the associated environmental benefits. The last section discusses the gaps in the literature and how this thesis intends to fill these gaps.

2.1. Demographic, Socio-economic and Planning Factors Affecting Car Ownership and Use

Previous studies have categorized the variables which influence car ownership and use into two broad categories: (a) socio-economic and demographic characteristics of the household, (b) planning factors represented by land use patterns, urban form, transportation infrastructure and services and proximity of public transportation at the place of residence, traffic management strategies, and prices of alternative modes of travel which impact car ownership and use patterns. The variables under the planning factors category may be considered by policy makers for reducing car ownership and use.

According to previous work, household income and household size have a significant effect on the number of cars owned by the household and the miles traveled, where higher incomes and more household members are associated with higher levels of auto ownership and use. Moreover, the number of family members with a driving license has a positive impact on car ownership and use. On the other hand, other variables such as the presence of children and the number of employees in a household may or may not affect car ownership and use decisions. The study of Kim and Kim (2004), conducted on a sample of households in the USA, resulted in a number of findings, primarily that: (1) the number of licensed drivers is the most important variable for determining the number of automobiles owned, (2) the presence of children does not impact the automobile ownership decision or vehicle miles traveled. Using household travel survey data collected in the Washington DC Metropolitan Area, Liu and Cirillo (2014) found that vehicle usage increases if the household owns the house, and that as the number of licensed drivers increases in a household, the number of cars owned and miles traveled will increase. Potoglou and Kanaroglou (2008) developed a model based on data collected in the Census Metropolitan Area of Hamilton. The results show that household life-cycle stage, socio-economic characteristics and distance to work are significant in determining the number of vehicles owned in the household.

Gomez-Gelvez and Obando (2013) have also investigated the effect of distance to work on data from mobility surveys undertaken in Bogota, Colombia. The distance to work variable is defined as the number of household members who work at a distance greater than 5 kilometers from the place of residence. The results showed that as the number of people who work far from residence increases, the probability of owning more cars increases.

Variables such as education and age of the household head did not always have a pronounced impact in explaining car ownership / use. Holder (2013) evaluated the effect of household education and the age of the household head on miles traveled using data from the Oregon Household Activity Survey. He found positive relationship between vehicle miles traveled and both age and education. Based on data collected in the State of Maryland, Liu (2010) found that car ownership increases as the educational level of the household head increase.

Variables related to the planning factors also have an effect on car ownership and use. By integrating geographic data and the characteristics of transit services into the household travel survey data, Liu and Cirillo (2014) concluded that households located in dense areas are less likely to own more cars and to have high vehicle usage. Potoglou and Kanaroglou (2008) further investigated the effect of urban form and the built environment on car ownership through incorporating two additional variables in the model namely: population and employment densities (MDI) and land-use in the vicinity of a household’s residence (EI). The conclusion is that higher densities and mixed land use negatively influence the number of cars owned. Using the data collected from the 2000 San Francisco Bay Area Survey, Bhat et al. (2009) found that high residential density and the presence of bike lanes have a negative impact on car ownership and use. It was also concluded that households located in urban areas are associated with lower levels of auto ownership compared to those located in areas which are less dense (Bhat et al, 2009; Brownstone and Golob, 2009). This result is consistent with that found in the study of Gomez-Gelvez and Obando (2013) who concluded that high population density is associated with low auto ownership levels. Holtzclaw et al. (2002) investigated the effect of neighborhood characteristics on car ownership and use based on data for Chicago, Los Angeles, and San Francisco. The results show that household members will drive less if the household is in a high density neighborhood: vehicle miles traveled per household decrease by 20-30% when the residential density in the household's neighborhood doubles. Li et al (2010) examined the effect of population density in China on car ownership. They found that population density is negatively associated with car ownership.

Previous work assessed the impact of fixed and variable car costs on car use and found that a higher level of these costs is associated with a lower probability of using the car (de Jong, 1990). Similarly, Liu and Cirillo (2014) and Kim and Kim (2004) found that households are less likely to have high vehicle usage when driving costs increase.

2.2. The Relation between Public Transportation Availability and Car Ownership and Use

The link between auto ownership and use and quality of public transportation has been investigated in a number of studies. For instance, based on the results of an attitudinal survey conducted with university students in Hong Kong, Cullinane (2002) concluded that good and cheap public transportation could reduce car ownership and use. Liu and Cirillo (2014) developed a discrete-continuous model to study the effect of improving public transportation on auto ownership and use decisions. The conclusion is that households are less likely to own and use cars if they have good accessibility to transit services. Huang et al. (2016) studied the effect of multiple public transportation accessibility measures on car ownership in Guangzhou, China. Two factor scores, local transit access (measuring access around respondents' households) and regional transit access (measuring access according to the location of the household with respect to the regional transit network and accessibility to the core of transit), were derived from these measures to be tested in the model. They found that greater accessibility to local transit access is associated with lower car ownership. They also concluded that local transit access is more important than regional transit access because one would not use public transportation if is not available in the vicinity of the individual's household. Kim and Kim (2004) developed econometric models to estimate the effect of public transportation accessibility on auto ownership and miles driven. They concluded that households have a lower propensity to own and use automobiles when transit services are accessible. In a London-based study, Fairhurst (1975) correlated the levels of auto ownership and use to availability and accessibility of public transportation facilities, concluding that the higher the frequency of public transportation services located within the vicinity of a household, the less likely it is that the household owns and/or uses a private vehicle. Holtzclaw et al. (2002) defined transit accessibility at the zonal level as the daily average number of buses or trains per hour multiplied by the fraction of the zone within a certain predefined distance from a bus or rail stop and summed for all transit routes near the zone. The aforementioned accessibility index was found to be a significant predictor of auto ownership in Chicago, Los Angeles, and San Francisco. Similar results have also been reported in Ho and Yamamoto (2011) who concluded that perceived bus coverage and the ease of bus use have a negative impact on car ownership. They also found that bus operators' attitude is negatively associated with the number of cars owned in a household. Zegras and Hannan (2012) found that public transportation proximity has a negative effect on owning more cars. In conclusion, recent studies show that good public transportation is associated with lower levels of auto ownership and use (Liu and Cirillo, 2014).

In Table 1 below, we summarize the main features of the models in the above mentioned studies.

Table 1: Car ownership and use: summary of the literature

Research Paper	Data Collection	Type of Model	Dependent Variable/s	Significant Factors	Direction of factor effect on dependent variable
Fairhurst (1975)	London Transportation Study in 1962	Linear regression	Probability of not owning a car	Public transport access indices / residential density	Positive Coefficient
				Household income / Household size	Negative Coefficient
de Jong (1990)	Dutch national budget survey of 1985	Indirect utility model	Car Ownership and vehicle miles traveled.	Income	Positive Coefficient
				Fixed costs variable costs	Negative Coefficients
Holtzclaw et al. (2002)	Data for Chicago, Los Angeles, and San Francisco	Power regression	Vehicles per household and vehicle miles traveled per household	Density / transit service	Negative coefficient
				Household size /household income	Positive coefficient

Table 1 (cont.): Car ownership and use: summary of the literature

Research Paper	Data Collection	Type of Model	Dependent Variable/s	Significant Factors	Direction of factor effect on dependent variable
Kim and Kim (2004)	1995 Nationwide Personal Transportation Survey (NPTS)	Ordered Logit Model	Number of cars owned	Number of licensed drivers / income (log) / household size (log) / number of working adults / couple households	Positive Coefficient
				Household location / transit accessibility	Negative Coefficients
		Multiple Regression Model	Vehicle miles traveled	Ln(income/size) / ln(driver/size) / ln(size/no. vehicles)	Positive Coefficient
				Operating cost / transit accessibility	Negative Coefficients
Potoglou and Kanaroglou (2007)	CIBER-CARS Internet survey in the census metropolitan area of Hamilton And TTS 2001 data: GIS layer of TAZ, number of households and work trips per TAZ in the study area.	Multinomial Logit model	Car ownership	Type of dwelling: single family house (dummy)/ working adults / number of individuals working at a distance > 6km/ licensed drivers/ household type / household income (dummy) number of working individuals	Positive Coefficient
				MDI and EI/ number of bus stops within 500m from dwelling/ part-time workers	Negative Coefficients

Table 1 (cont.): Car ownership and use: summary of the literature

Research Paper	Data Collection	Type of Model	Dependent Variable/s	Significant Factors	Direction of factor effect on dependent variable
Bhat et. al (2009)	2000 San Francisco Bay Area Travel Survey (BATS)	Multiple discrete-continuous extreme value model (MDCEV)	Vehicle usage	Household income/ presence of children	Positive coefficient
				High residential or commercial/industrial neighborhoods / high bike lane density / fuel costs / street block density / number of employed members	Negative coefficient
			Vehicle holdings	Household income	Positive coefficient
				high residential or commercial/industrial neighborhoods / high bike lane density / street block density / fuel costs	Negative coefficient
Brownstones and Golob (2009)	2001 National Household Travel Survey (NHTS)	Structural equations model	Household mileage	Household income / number of workers / number of drivers	Positive coefficient
				Residential density	Negative coefficient
			Household fuel usage	Household mileage / household income / number of children / number of workers / number of drivers	Positive coefficient
				Residential density	Negative coefficient

Table 1 (cont.): Car ownership and use: summary of the literature

Research Paper	Data Collection	Type of Model	Dependent Variable/s	Significant Factors	Direction of factor effect on dependent variable
Liu (2010)	National Household Travel Survey	Multinomial Logit Model	Car Ownership	Household income/ household size/ number of children/ number of employees/ drivers/ education of hh/ household location	Positive coefficient
				Housing density /Percent renter-occupied housing	Negative coefficient
Li et. al (2010)	Household survey data collected.	Multinomial Logit Model	Car ownership	Income/ own house/ children/ education/	Positive coefficient
				Population density/ distance to CBD/ own bike/ age/nearest bus stop	Negative coefficient
Zegras and Hannan (2012)	1991 and 2001 household origin and destination OD surveys in Chile	Multinomial Logit Model	Car ownership	Income/ number of children / distance to CBD/	Positive coefficient
				Residential density / <500m to metro station	Negative coefficient
Ho and Yamamoto (2011)	Household interview survey data collected in Ho Chi Minh metropolitan area, Vietnam	Generalised Nested Logit models	Auto ownership	Household income / number of adults / number of children / area of house owned	Positive coefficient
				Population density at residential zone / mixed land use index / bus coverage / ease of bus use	Negative coefficient
Holder D.R. (2013)	Oregon Household Activity survey	OLS Regression	Household mileage	Income/ education/ age/ children/ number of cars owned/ number of workers	Positive coefficient
				Fuel price/age squared	Negative coefficient

Table 1 (cont.): Car ownership and use: summary of the literature

Research Paper	Data Collection	Type of Model	Dependent Variable/s	Significant Factors	Direction of factor effect on dependent variable
Liu and Cirillo (2014)	2009 NHTS in Washington DC. Metropolitan Area (1420 observations) General transit feed specification data (GTFS)	Integrated discrete-continuous model	Number of cars owned	Household income / Number of drivers	Positive Coefficient
				Gender of household head (female) / urban size / residential density / bus accessibility / percentage coverage of metro routes	Negative Coefficient
			Miles (10k)	Household income / own home	Positive Coefficient
				Residential density / driving cost ($ per mile) / bus accessibility / percentage coverage of metro	Negative Coefficient
Gomez-Gelvez and Obando (2015)	Mobility Surveys undertaken in Bogota in 1995 and 2005	Multinomial Logit model and Ordered Logit model	Number of cars	Household income /number of working adult/ distance to work	Positive Coefficient
				Number of children / population density / number of company cars	Negative Coefficient
Huang, Cao and Cao (2016)	2011-2012 Survey of household in 21 communities in Guangzhou	Ordered Probit Model	Number of cars owned	Household income/ household size/ having driver's license density of road network /occupation	Positive Coefficient
				Local transit access	Negative Coefficient

2.3. Overview of Car Ownership and Use Models

This section focuses on the type of models that are used to study car ownership and use. Some previous studies have developed separate models of auto ownership and use; on the other hand, a large number of studies have investigated this topic using discrete-continuous models, the assumption being that a household simultaneously chooses the number of cars it wants to own (discrete choice) and the number of miles that each auto will be driven (continuous decision). As stated by Train (1986), the situation where individuals have to make a decision on how many cars to own and the number of kilometers to drive each car is called a joint discrete-continuous situation because these decisions are interrelated.

Mannering and Winston (1985), Train (1986), and de Jong (1989) developed models which are based on random utility maximization; i.e. households will choose a certain number of cars to own and the number of kilometers to drive each car that will maximize their utility. Roy’s identity is applied in these models to derive the equation of demand for car use from the indirect utility function. Aligned with microeconomic theories, and using observed explanatory variables, these models are able to capture the correlation between the decision on car ownership and usage (Liu and Cirillo, 2014).

Bhat (2005) proposed a multiple discrete-continuous extreme value (MDCEV) model to study the joint decision of car ownership and use. This model was then developed in Bhat and Sen (2006) and Bhat et al. (2009). The model’s framework is based on random utility maximization and is applied to estimate the decision of owning multiple vehicle types and the usage by each type. More specifically, this type of model handles situations where simultaneous demand for more than one alternative is possible because these alternatives might not be perfect substitutes for one another (Bhat, 2005).

The MDCEV approach assumes that each household's utility is maximized conditional on a total mileage budget. The probability function of the MDCEV model is of a closed form and can collapse to a multinomial logit (MNL) choice model in cases of one car households. Bhat and Sen (2006) applied an extension to the MDCEV model by accommodating unobserved heteroskedasticity and error correlation through using mixing distributions. The resulting model is the mixed MDCEV (MMDCEV).

The MDCEV model offers a practical method for modeling car ownership and use as it is able to capture the correlation between the choice of vehicle type and mileage. It is also able to accommodate a large number of discrete consumption alternatives. On the other hand, model implementation requires finer classification of vehicles so that households can only own one vehicle from each type. Moreover, this model restricts the prediction of changes in the number of miles driven by households in response to particular polices because total vehicle utilization (miles traveled) for each household is assumed to be fixed.

Fang (2008) developed the BMOPT (Bayesian Multivariate Ordered Probit and Tobit) model which consists of a multivariate ordered Probit model used to model the discrete decision (vehicle holding decision and type) and a multivariate Tobit model used to model the continuous decision (mileage). The model is estimated by assuming that all the equations in the model are linked by an unrestricted covariance matrix and therefore is able to correlate the discrete part and the continuous part of the model. However, the model has one major drawback. The number of equations to be estimated is directly proportional to the number of vehicle types; i.e. as the number of vehicle types increases, the number of equations to be estimated increases as well.

Liu and Cirillo (2014) formulate and estimate an integrated discrete-continuous model by allowing the unobserved factors of the discrete and the continuous parts to be correlated. The resulting model allows for the estimation of a full variance-covariance matrix that explains the correlation between the discrete part (car ownership) and continuous part (miles driven), and the correlation amongst the alternatives of the discrete part (the decision of owning a certain number of cars).

2.4. Car Type Choice

The transportation sector is considered to be the biggest contributor to air pollution and the emissions of greenhouse gases (GHG) which cause global warming. According to the International Energy Agency (IEA, 2012), the combustion of fossil fuels leads to 22 percent of total carbon emissions. One way to mitigate emissions and fuel consumption other than reducing the number of cars and revitalizing public transportation is shifting to environmentally friendly cars such as hybrid and electric cars.

To this end, previous studies have investigated consumer demand for such types of vehicles through stated preference studies of the purchase decision since the market share of hybrid and electric cars is still small and hence limited real market data is available. For instance, Irani and Chalak (2015) investigated the readiness of motorists in Beirut, Lebanon to purchase hybrid electric vehicles (HEVs) by applying a generalized multinomial logit model on the data of the choice experiment, and simulating four scenarios of financial incentives. The conclusion was that under the scenario of full exemption on custom and excise taxes, there was an 80% probability of choosing HEV over the conventional gasoline vehicle. Moreover, the results under this scenario showed that people who purchase a hybrid car would benefit from a 30.9

percent reduction in fuel consumption which translates to $572 savings in fuel cost per year. Lastly, among all four scenarios, this scenario has the highest contribution at the environmental level where CO2 emissions will be reduced by 20.5 percent per car. The results of this paper showed that providing tax incentives is a powerful tool for encouraging motorists to own environmentally friendly vehicles and therefore creating a high market share of hybrid and electric cars. Hoen and Koetse (2014) also found that implementing CO2 differentiated vehicle taxes in the Netherlands is a successful approach to stimulate the adoption of alternative fuel vehicles. This result applies to both company cars and private passenger cars.

Using the results of a choice experiment conducted with potential car buyers in Germany, Achtnicht (2011) applied a mixed logit model to study consumer perceptions of environmental issues and their willingness to pay to lessen the emissions of CO2. The choice experiment included scenarios where the respondent had to choose among several car types (including gasoline or a diesel car and alternative fuel cars) which are characterized by a number of attributes namely: fuel type, purchase price, engine power, fuel cost per 100 km, CO2 emissions per km, and fuel availability. The results suggest that CO2 emissions affect the choice decision and that Germans are aware of the environmental impacts caused by conventional gasoline cars. Therefore, they are willing to pay in order to reduce CO2 emissions by purchasing alternative fuel vehicles. Batley et al. (2004) and Potoglou and Kanaroglou (2007) also found large willingness-to-pay estimates when they incorporated the emissions attribute in the choice experiment.

Other studies have explored the main attributes that affect vehicle type choice. For example, Achnicht (2011) found that fuel cost per 100 km and car horsepower influence choice decisions. Moreover, the results of Batley et al. (2004) showed that

that operating costs (represented by British pound per mile) along with purchase price, range, maximum speed, and fuel availability, have an effect on the motorists' preferences for different types of vehicles. This result is consistent with that found in the studies of Ewing and Sarigollu (2000) and Qian and Soopramanien (2011) with respect to the purchase price, range and operating cost attributes, where they concluded that these attributes are important to consumers when choosing which type of vehicle to purchase. Potoglou and Kanaroglou (2007), also found that the price of the vehicle and the range affect vehicle type choice.

2.5. Conclusion

Based on the literature review, prior research has studied the effect of public transportation on car ownership and use in both, developed (e.g. Liu and Cirillo (2014), Kim and Kim (2014), Holtzclaw et al. (2002)) and developing (e.g. Zegras et al. (2012), Ho and Yamamoto (2011), Li et al. (2010)) countries. However, previous studies were limited to cases where public transportation is organized, leaving a gap in the literature with respect to modeling car ownership and use in contexts where public transportation is largely unregulated.

Most of prior research has provided evidence of a relationship between car ownership / use and public transportation suggesting that improvements in the accessibility to public transit can suppress the growth in car ownership and use. A critical open question is whether this relationship holds when public transportation is inefficient and unorganized. This research intends to answer this question by developing and estimating a model to measure how unregulated public transport can influence car ownership and use in a developing country context.

It is important to note that the modeling approach in this thesis is not very different from that adopted by previous research that studied the effect of public transportation on car ownership and use. However, capturing the level of accessibility to informal public transportation in our study context is challenging due to the following reasons:

1. The buses and vans do not have fixed stops. While typical methodologies measure the effect of the bus availability on car ownership and use by measuring the distance between each household and the nearest bus stop, we test this effect by taking the distance between each household and the nearest bus route.
2. Operating schedules of the buses and vans are not widely available. Thus measures in terms of the headway are approximate.
3. Shared taxis or the "services" don't have fixed routes. Therefore, it is not possible to obtain an effective measure for this kind of public transport. Testing their effect on car ownership and use shall rely on the awareness of people about their availability.

CHAPTER 3

RESEARCH METHODS

The modeling framework used to quantify the extent to which car ownership and use can be reduced through the provision of accessible public transportation services relies on data collected through a revealed preference survey and other data including demographics, land use, and public transportation characteristics. The first section of this chapter describes the data required to conduct this research. The second section presents the modeling framework of this thesis. The last section discusses the approach followed for conducting policy analysis using the estimated model.

3.1. Data Needs

The modeling framework utilizes two categories of data described below.

3.1.1. Data Collected from a Household Survey

Data from a household survey need to be collected to include the below listed items. According to Chapter 2, these items have been found to be significant in explaining car ownership and use.

1. Households' car ownership and use where the interviewed household member reports on the number of vehicles owned and the number of kilometers driven by each vehicle in the household. These are the dependent variables in the model.
2. Socioeconomic characteristics of all the members in the household such as: gender, income, educational level, age, occupation, distance to work, etc.

3. Public transportation characteristics where the interviewed household member reports on the availability of public transportation in the vicinity of his/her residence by answering a set of questions.
4. Attitudes and perceptions towards cars and public transportation in the study context. The respondent indicates his/her level of agreement with presented statements measuring these attitudes and perceptions. The response to those statements can help explain car ownership and use and vehicle type preference.

3.1.2. Other Data Collection

Based on the literature, it was clear that land use, population and employment densities, as well as the characteristics and the availability of public transportation influence car ownership and use. Therefore, such data needs to be collected to be used in the model.

3.2. Modeling Framework

A joint discrete-continuous model is developed in this thesis to investigate car ownership and use. We use a modeling approach similar to that of Liu and Cirillo (2014) whereby the error terms of the utility equations and the mileage equation are all correlated with each other. Liu and Cirillo (2014) adopt a multivariate probit model. We adopt a logit modeling framework and account for the correlations through the inclusion of error components which represent the unobserved factors that affect the joint decision. Our methodological framework is different from other discrete-continuous models in the literature as it incorporates latent variables in both sub-models: the discrete and the continuous sub-model. This approach is based on the assumption that individuals' attitudes toward public transportation and the private car influence their household's choice of how many cars to own and their usage. In this thesis, we assume that the number of cars owned and the kilometers driven result from a collective decision by all the individuals in the household; therefore, the decision maker corresponds to the household as a unit. Accordingly, the attitude of the respondent is considered to be representative of the household's attitude.The framework of the discrete-continuous model adopted in this thesis is illustrated in Figure 1. In this figure, the correlation between the discrete sub-model and the continuous sub-model is represented by the double curved arrow. Solid arrows represent structural relationships, and dashed arrows represent measurement relationships. Observed variables are shown in rectangles, and latent variables are shown in ovals. Each of the discrete and continuous sub-models is presented below.

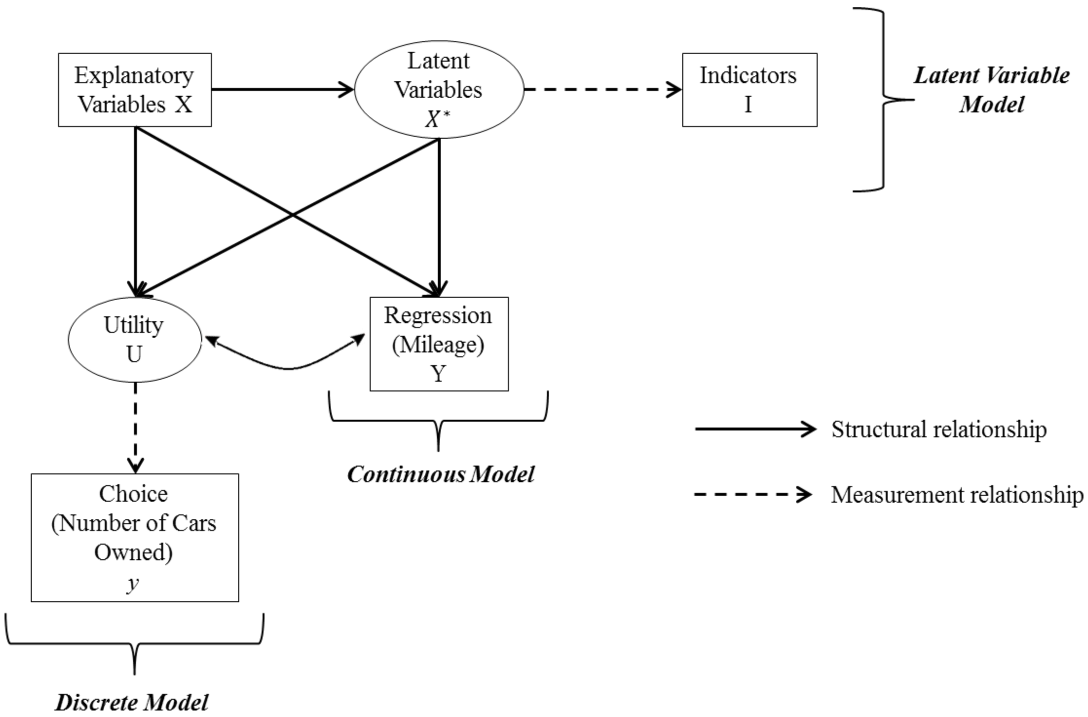

Figure 1: Framework of the discrete-continuous model

3.2.1. The Discrete Sub-Model

The car ownership model is a discrete model that is based on random utility maximization: individuals or households choose to own a certain number of cars that maximizes their utility (Ben Akiva and Lerman, 1985). The utility function associated with an alternative is a function of observed variables related to the alternative and the decision maker (the household in this case), and a non-observable part (disturbance term). Latent factors are also introduced as explanatory variables as decision makers' attitudes towards public transportation may influence their choice on how many cars to own. When incorporating latent variables in a discrete choice model, the resulting model is called hybrid choice model (HCM) (Ben-Akiva et al., 2002; Walker and Ben-Akiva, 2002). This type of model has been widely used recently since it represents behaviorally the unobserved heterogeneity between individuals arising from individual attitudes or perceptions. It is thus believed to lead to more realistic behavioral representation and better predictions than conventional models (Abou-Zeid and Ben-Akiva, 2014).

As shown in Figure 1, the HCM model is composed of two sub-parts: latent variable model and a choice model.

3.2.1.1.The Latent Variable Model

The latent variable model, also known as a structural equation model, is made up of two sub-models. The first one is a structural model which describes the relationship between the endogenous latent variables X_n^* and the observed explanatory variables X.

$$\mathrm{X}_n^* = \mathrm{X}^*(\mathrm{X}_n; \alpha) + \eta_n \qquad (1)$$

Where $X^*(.)$ is a function, X_n^* is a vector of latent variables for household n (of dimensions $L \times 1$ where L is the number of latent variables), X_n is a vector of explanatory variables related to household n, α is a vector of coefficients, and η_n is a vector of random disturbance terms normally distributed with a mean equal to zero and a variance-covariance matrix denoted as $\sum_\eta$.

$$\eta_n \sim \mathrm{N}\ (0, \textstyle\sum_\eta) \tag{2}$$

The second sub-model is a measurement model which relates the latent variables X_n^* to their corresponding indicators I_n (assumed to be continuous) and can be expressed as follows:

$$I_{r,l,n} = \mathrm{q}\ (X_{n,l}^*; \lambda_{r,l}) + \upsilon_{r,l,n} \qquad \begin{array}{l}\forall r = 1,\ldots, R_l \\ \forall l = 1,\ldots, \mathrm{L}\end{array} \tag{3}$$

Where $I_{r,l,n}$ is the r^{th} indicator of the l^{th} latent variable (and I_n is a vector of all indicators for household n), r=1,…,R_l for latent variable l, and R_l is the total number of indicators of latent variable l, q(.) is a function, $\lambda_{r,l}$ is a parameter (factor loading) to be estimated for each indicator of the l^{th} latent variable, and $\upsilon_{r,l,n}$ is a measurement error term normally distributed with zero mean and variance $\sigma^2_{\upsilon_{r,l}}$ expressed as in equation (4). It is assumed that the measurement errors are uncorrelated across indicators and the indicators of a given latent variable measure that latent variable only.

$$\upsilon_{r,l,n} \sim \mathrm{N}\ (0, \sigma^2_{\upsilon_{r,l}}) \tag{4}$$

3.2.1.2.The Choice Model

The choice model specifies the utilities of the car ownership alternatives (e.g. 0, 1, 2+) as a function of the observed exogenous variables related to the alternatives and the decision maker, the latent variables, and a disturbance term. The utility of alternative i for household n can be expressed as follows:

$$U_{in} = V(X_{in}, X_n^*; \beta) + \Omega_{in} + \varepsilon_{in} \qquad \forall i = 0,\ldots, J \qquad (5)$$

$$U_{in} = V_{in} + \Omega_{in} + \varepsilon_{in}$$

Where V (.) is the systematic utility function and V_{in} is the systematic utility of all *i* for household *n*, *J*+1 is the total number of alternatives, X_{in} is a vector of observed explanatory variables related to alternative *i* and household *n*, β are the parameters to be estimated for the observed variables and the latent variables, and ε_{in} is a random disturbance term assumed to be distributed as Extreme Value Type I with zero mean and variance normalized to $\pi^2/6$ to set the scale of the utility. The disturbance terms are assumed to be independently and identically distributed across alternatives and individuals. The term Ω_{in} is an error component normally distributed with mean 0 and variance equal to 1, i.e. $\Omega_{in} \sim N(0, 1)$. The error components are introduced in the utilities of all the alternatives except for the utility where *i* = zero, i.e. no cars owned, and they are assumed to be independent across alternatives.

3.2.2. The Continuous Sub-Model

Ordinary Least Square (OLS) Regression is adopted to model the continuous part of the model or the household total annual kilometers. In regression, the dependent variable is a function of observed variables (predictors) plus an error term assumed to be normally distributed with mean zero. In order to improve the prediction capabilities of the continuous-sub model, latent variables that are captured via attitudinal indicators are incorporated in the regression equation. A logarithmic specification of the dependent variable is adopted to ensure that the predicted value of the household total annual kilometers is always positive.

$$\log(\mathrm{Y}_{n,reg}) =$$

$$\mathrm{f}(\mathrm{X}_{n,reg}, \mathrm{X}_n^*; \beta_{reg}) + \sigma_{\Omega_1} {}^* \, \Omega_{1n} + \cdots + \sigma_{\Omega_J} {}^* \, \Omega_{Jn} + \epsilon_{reg} \qquad \epsilon_{reg} \sim \mathrm{N}\,(0, \sigma^2_{\epsilon,reg}) \qquad (6)$$

Where $\mathrm{Y}_{n,reg}$ is the dependent variable (total annual household kilometers), $\mathrm{X}_{n,reg}$ is a vector of observed exogenous variables, X_n^* is a vector of the latent variables, β_{reg} are the coefficients to be estimated for the observed variables and the latent variables, ϵ_{reg} is an error term, Ω_{1n} to Ω_{Jn} are the same error components included in the utilities of the alternatives, and σ_{Ω_1} to σ_{Ω_J} are parameters to be estimated. By allowing the discrete sub-model and the continuous sub-model to share the same error components, correlation between the sub-models is introduced into the unobserved parts of each model. The error components introduced to the model differ between the utilities to introduce different correlations between each utility and the mileage. Note that the parameters by which the error components are multiplied were not identifiable when also included in the utility equations so they are included only in the regression equation.

3.2.3. The Likelihood Function

In this section we present the derivation of the likelihood function which allows the two sub-models to be estimated simultaneously. Since there is an unobserved correlation between each of the car ownership choice and mileage and the indicators of the latent variables through their dependence on the latent variables and because of the correlation between the discrete sub-model (car ownership) and the continuous sub-model (mileage), the conditional likelihood (conditional on the latent variable and error components), designated as L_n^* for household *n*, is expressed as the product of the conditional choice probability (discrete sub-model), the conditional probability density function of mileage (continuous sub-model), and the conditional joint density function of the indicators of the latent variables, when the chosen car ownership level is not zero. Otherwise, the conditional probability density function of mileage is not included in the likelihood function when the chosen car ownership level is zero because no car mileage is produced by households with zero cars.

$$L_n^* \ (y_n, \mathrm{Y}_{n,reg}, I_n | \mathrm{X}_n, \mathrm{X}_{n,reg}, \mathrm{X}_n^*, \Omega_n; \beta, \beta_{reg}, \lambda, \sigma_{\epsilon,reg,} \textstyle\sum_{\upsilon}, \sum_{\Omega}) =$$

$$\mathrm{P}(y_{n0} | \mathrm{X}_n, \mathrm{X}_n^*, \Omega_n; \beta). \prod_{l=1}^{L} \prod_{r=1}^{R_l} g\left(I_{r,n,l} | \mathrm{X}_{n,l}^*; \lambda_{r,l}, \sigma_{\upsilon_{r,l}}\right). (y_{n0}) + \tag{7}$$

$$\mathrm{P}(y_n | \mathrm{X}_n, \mathrm{X}_n^*, \Omega_n; \beta). f_1\left(\mathrm{Y}_{n,reg} | \beta_{reg}, \mathrm{X}_{n,reg}, \mathrm{X}_n^*, \Omega_n; \sigma_{\epsilon,reg}\right). \prod_{l=1}^{L} \prod_{r=1}^{R_l} g\left(I_{r,l,n} | \mathrm{X}_{n,l}^*; \lambda_{r,l}, \sigma_{\upsilon_{r,l}}\right). (1 - y_{n0})$$

Where $\mathrm{y_n}$ denotes the car ownership choice vector of household *n*, and $\mathrm{y_{n0}}$ can be expressed as:

$$y_{n0} = \begin{cases} 1, & if\ zero\ cars\ is\ chosen \\ 0, & otherwise \end{cases} \tag{8}$$

In equation (7), Ω_n is a vector of error components, $\sum_{\upsilon}$ is a diagonal variance-covariance matrix of the error terms of the indicators, and $\sum_{\Omega}$ is a diagonal variance-covariance matrix of the error components.

$\mathrm{P}(y_{n0} | \mathrm{X}_n, \mathrm{X}_n^*, \Omega_n; \beta)$ denotes the conditional choice probability of household *n* choosing alternative zero.

$\mathrm{P}\ (y_n | \mathrm{X}_n, \mathrm{X}_n^*, \Omega_n; \beta)$ denotes the logit conditional choice probability based on the assumption about the distribution of the disturbance ε being independently and identically distributed Extreme Value Type I for each alternative. Hence, the conditional choice probability of household n choosing alternative *i*:

$$P_{in} = \frac{e^{V_{in} + \Omega_{in}}}{\sum_j e^{V_{jn} + \Omega_{jn}}} \tag{9}$$

$f_1(\text{Y}_{n,reg}|\beta_{reg}, \text{X}_{n,reg}, \text{X}_n^*, \Omega_n; \sigma_{\epsilon,reg})$ denotes the conditional probability density function or the likelihood of the continuous sub-model and can be expressed as:

$$f_1(\text{Y}_{n,reg}|\beta_{reg}, \text{X}_{n,reg}, \text{X}_n^*, \Omega_n; \sigma_{\epsilon,reg}) = \tag{10}$$

$$\frac{1}{\text{Y}_{n,reg} * \sigma_{\epsilon,reg}\sqrt{2\,\pi}} * e^{-\frac{\left(\log(\text{Y}_{n,reg}) \; - f(\text{X}_{n,reg}, \text{X}_n^*; \beta reg) - \sigma_{\Omega_1} * \Omega_{1n} \,....\, \sigma_{\Omega_j} * \Omega_{jn}\right)^2}{2\,\sigma_{\epsilon,reg}{}^2}}$$

$g\left(I_{r,l,n}\middle|\text{X}_{n,l}^*; \lambda_{r,l}, \sigma_{\upsilon_{r,l}}\right)$ is the joint density function of the indicators which takes the form:

$$g\left(I_{r,l,n}\middle|\text{X}_{n,l}^*; \lambda_{r,l}, \sigma_{\upsilon_{r,l}}\right) = \frac{1}{\sigma_{\upsilon_{r,l}}}\, \emptyset\left[\frac{I_{r,l,n} - \text{q}\,(\text{X}_{n,l}^*; \lambda_{r,l})}{\sigma_{\upsilon_{r,l}}}\right] \tag{11}$$

Where $\emptyset\,(.)$ is the standard normal density function. The functional form of g(.) is based on the assumption that the error term υ in the measurement equation is independently and identically distributed (iid) normal.

The unconditional likelihood can be obtained by integrating over the joint density function of the vector of the latent variables X_n^* and the vector of error components Ω_n as shown by the equation below:

$$L_n\,(y_n, \text{Y}_{n,reg}, I_n|\text{X}_n, \text{X}_{n,reg};\, \beta,\, \beta_{reg}, \alpha, \lambda, \sigma_\eta, \sigma_{\epsilon,reg}, \textstyle\sum_\upsilon, \sum_\Omega) = \tag{12}$$

$$\int\limits_{\Omega_n}\int\limits_{\text{X}_n^*} L_n^*\left(y_n, \text{Y}_{n,reg}, I_n\middle|\text{X}_n,\ \text{X}_{n,reg}, \text{X}_n^*, \Omega_n;\ \beta,\ \beta_{reg}, \lambda, \sigma_{\epsilon,reg,}\textstyle\sum_\upsilon, \sum_\Omega\right).$$

$$f_2\left(\text{X}_n^*\middle|\text{X}_n; \alpha, \textstyle\sum_\eta\right).\, f_3(\Omega_\text{n})\; d\Omega_n d\text{X}_n^*$$

Where L_n now designates the unconditional likelihood, and $f_2(\mathrm{X}_n^*|\mathrm{X}_n; \alpha, \sum_\eta)$ and $f_3(\Omega_\mathrm{n})$ denote the joint density function of the all latent variables and the error components, respectively.

Since the disturbance terms η are assumed to be normal, the joint density function of a latent variable *l* takes the form:

$$f_2(\mathrm{X}_{l,n}^*|\mathrm{X}_n; \alpha, \sigma_\eta) = \frac{1}{\sigma_\eta} \, \emptyset \, \left[\frac{\mathrm{X}_{l,n}^* - \mathrm{X}^*(\mathrm{X}_n; \alpha)}{\sigma_\eta}\right] \tag{13}$$

The unconditional likelihood of the sample can be obtained by taking the product of the unconditional likelihood over all individuals as shown in the equation below:

$$L = \prod_{n=1}^{N} L_n \left(y_n, \mathrm{Y}_{n,reg}, I_n | \mathrm{X}_n, \ \mathrm{X}_{n,reg}; \ \beta, \ \beta_{reg}, \alpha, \lambda, \sigma_\eta, \sigma_{\epsilon,reg}, \textstyle\sum_\upsilon, \sum_\Omega\right) \tag{14}$$

Where N is the total number of individuals in the sample.

The log-likelihood of the whole sample can be expressed as:

$$LL = \sum_{n=1}^{N} \ln[\, L_n(y_n, \mathrm{Y}_{n,reg}, I_n | \mathrm{X}_n, \ \mathrm{X}_{n,reg}; \ \beta, \ \beta_{reg}, \alpha, \lambda, \sigma_\eta, \sigma_{\epsilon,reg}, \textstyle\sum_\upsilon, \sum_\Omega)] \tag{15}$$

Therefore, the discrete-continuous model can be estimated by maximizing LL.

3.3. Policy Analysis

The developed model will be used to estimate the potential reduction in car ownership and use levels that may result from (i) improved public transportation quality, and (ii) changes in variables under the planning factors category. The sample enumeration method will be used to evaluate the impact of the defined policy scenarios. These policies provide a tool for policy makers aiming at reducing car ownership and use levels in Lebanon. Next, estimates of reduction in vehicular emissions, fuel consumption, and heat island effects resulting from travel by households in the study area can be obtained based on the reduction in car kilometers traveled and the speed of travel in peak hours, peak shoulder hours, and free flow hours.

CHAPTER 4

MODELING CAR OWNERSHIP AND USE IN GREATER BEIRUT AREA

This chapter is an application of the modeling framework presented in Chapter 3 on the data collected in the study area consisted in this thesis. The first section of this chapter presents the study area. Sections 4.2 and 4.3 describe the survey design, sampling plan and data collection. Section 4.4. reports on the other types of collected data. Section 4.5 presents descriptive statistics about the sample used for modeling. Then, the last section presents the model specification of the discrete-continuous model including modeling estimation and outlier analysis.

4.1. Study Area

The area of interest of this project is the Greater Beirut Area (GBA) extended to Jounieh in the north and Jiyeh in the south (see Figure 2). It is composed of 65 traffic analysis zones (TAZ). Even though GBA is very dense, 80% of motorized trips conducted in the AM peak in Greater Beirut are made by the private auto, and the rest is distributed as follows: 6% by service (or jitney, which is a form of shared taxi), 1% by private taxi, 11% by red plate van and 2% by bus (IBI Group and TEAM International, 2009). The high reliance on the private car is attributed to a number of factors including poor urban planning policies and inefficient public transit facilities and services.

In Lebanon, several recommendations to establish regulated public transport facilities and to increase ridership were presented: increasing the frequency and the route coverage of buses, integrated fare scheme, and increasing bus speed based on transit signal priority or exclusive bus lanes as discussed in a recent study on the revitalization of public transportation in Lebanon (IBI Group and TEAM International, 2009). However, none of these recommendations has been implemented yet. Therefore, the current public transportation in Greater Beirut is perceived to be of low quality and car ownership which is estimated to be 3 persons per car is expected to increase with an annual rate of 1.5% in the next 10 years (MoE et al., 2012).

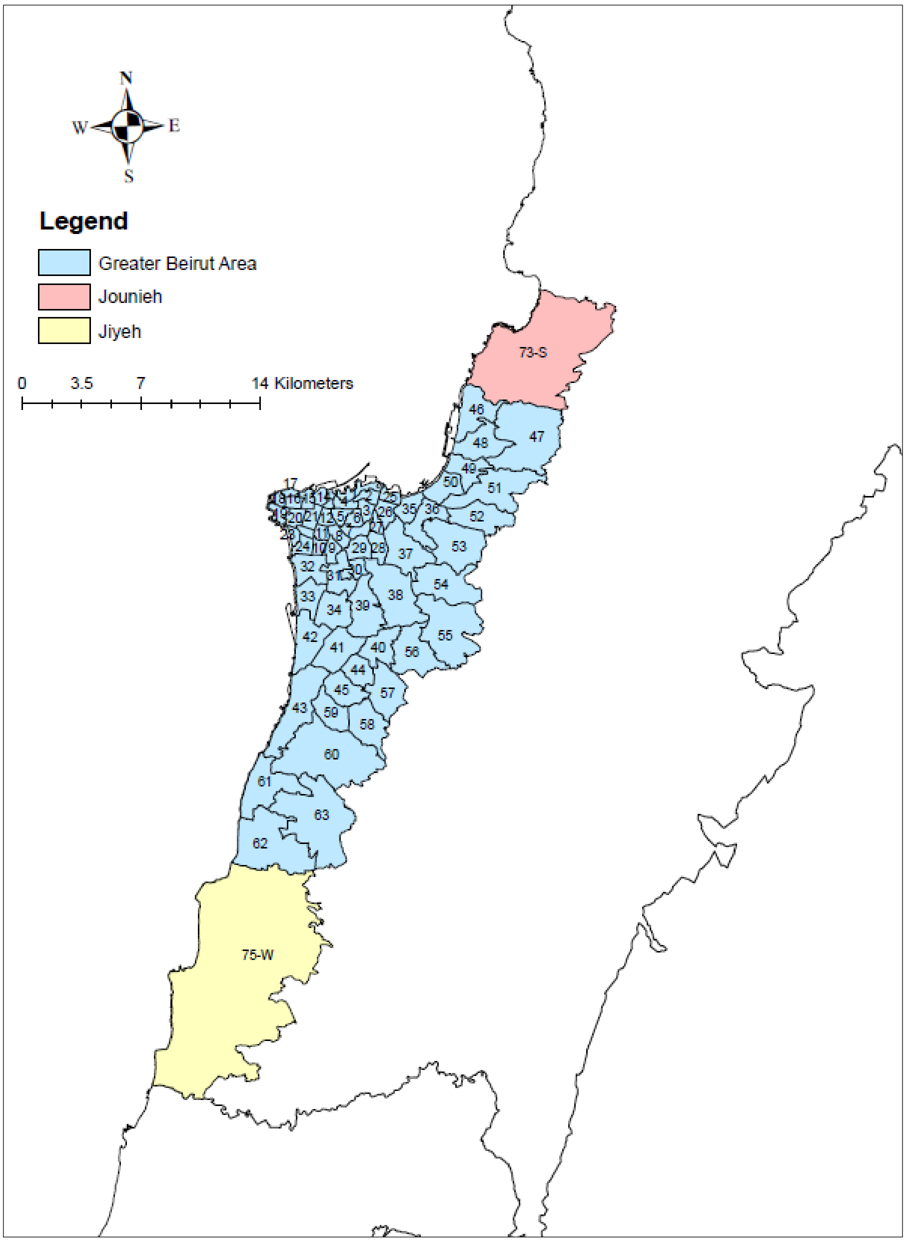

Figure 2: Study Area

4.2. Survey Design

A survey, approved by the Institutional Review Board (IRB) at AUB, was launched in July 2018 targeting households in the study area. The eligibility to participate in the survey relies on three criteria: (1) the household members hold the Lebanese nationality, (2) the household does not own a vehicle with a red plate, and (3) the household owned a car for a period exceeding one year. The survey, attached in Appendix A, was carried by Information International, an experienced survey company in Lebanon. Two types of data were collected: revealed preference (RP) data and stated preference (SP) data.

4.2.1. Revealed Preference Survey

The revealed preference (RP) part of the survey asked about:

- *Household's car ownership and use*

  The first section in the survey asked about car ownership (number of cars owned) and self-reported annual car use (kilometers traveled) for each car owned. It also included questions about the characteristics of each car including fuel efficiency and maintenance costs, etc.

- *Socioeconomic characteristics*

  The second section in the survey asked questions related to the household and the household members such as: gender, age, level of education, occupational level, modes of transport used to reach university/work, place of education/work, and number of licensed drivers in the household.

- *Public transportation characteristics*

  The third section of the survey included questions about public transportation availability in the vicinity of the interviewed member's residence. The interviewed household member was asked about how long he/she has to wait for the bus/service if they were to use it, how much he/she has to walk to catch a bus. Note that in some cases the respondents' answers to these questions were not precise, i.e. the reported headway and the distance to public transportation did not reflect the actual situation.

- *Attitudinal indicators*

  The last section of the survey included attitudinal statements about cars and public transportation services. The respondent stated his/her opinion using a 5-point scale where 1 represents "strongly disagree" and 5 represents "strongly agree". The respondent's attitudes toward public transportation and the car are captured by the indicators defined by their responses.

4.2.2. Stated Preference Survey

As previously mentioned, the survey also included a stated preference part where scenarios related to the purchase of new hybrid or electric vehicles within the next 12 months were presented to respondents. The collected data from this part of the survey was not used for estimating the discrete-continuous model adopted in this thesis; however, it can serve in developing a second model which aims at estimating consumers' willingness to buy clean vehicles in the future as a replacement of their current gasoline cars. Moreover, assuming that respondents are not familiar with alternative fuel vehicles, they were provided with details about each hybrid and electric car along with their operational characteristics and emissions.

In the SP part of the survey, the interviewed member was asked to complete four scenarios. Each scenario presents three types of cars (gasoline, hybrid and electric car), each characterized by the following four attributes: purchase price, range of the car, horsepower, and fuel cost per 100 km. The choice of the attributes was based on extensive literature review of similar studies. Two of the scenarios include financial incentives for purchasing a hybrid or an electric car. Before completing these scenarios, the interviewed member was asked to assume that the government has decided to exempt those who choose to purchase a hybrid or electric car completely or partially from customs and excise taxes. The exemption levels along with the final prices were explicitly shown in the scenarios.

The levels of the attributes are presented in Tables 2, 3, 4 and 5. The following methodology was followed to obtain these levels:

1. The report “Analysis of Lebanon’s Automobile sector” prepared by Bankmed, regarding the most purchased cars by brand in 2014 in Lebanon, was reviewed. Based on these brands, research on different models within each car brand was done, taking into consideration whether each brand offers electric cars, hybrid cars, or both.
2. Purchase prices, ranges, and horse power for several models within each car brand were obtained. The cost per 100 kilometers was also calculated for each car. For gasoline cars, the cost per 100 km was calculated based on car fuel efficiency and the price of fuel in June 2018 (prior to conducting the survey). For hybrid cars, the cost was determined based on rough estimates retrieved from websites of car dealers stating that the cost per 100 km of a hybrid car is 40% to 70% less than the cost of a gasoline car of the same brand. For electric cars, the cost per 100 km was determined based on the battery efficiency and the cost of electricity obtained from Electricité du Liban. This was done for all car brands that manufacture hybrid and/or electric cars along with gasoline cars.

3. The attribute levels of the gasoline car were determined by setting the attribute level boundaries lower and higher than the minimum and maximum values in the market, respectively.

4. For the attributes to be comprehensible by all respondents, values close to those in the market for similar car types were employed. Multiplication factors were thus calculated for each of the hybrid and electric cars. The prices of the hybrid and electric cars within each car brand were divided by the prices of the gasoline cars to obtain the aforementioned multiplication factors. These factors were obtained to calculate the respective prices of the hybrid and electric cars based on the already fixed gasoline car levels; i.e. the multiplication factors represent the levels which were used to obtain different values of the prices of hybrid and electric cars for every level of gasoline car price. It is important to note that the differences in car models within each brand were not taken into consideration since the same car model might not be available as either hybrid or electric. The same methodology was followed for setting all other attributes.

Hence, the levels of the attributes of both hybrid and electric cars are conditional on the attribute levels of the gasoline car and the scenarios presented to each respondent are a random combination of the levels (see for example Walker et al., 2017 for a discussion of the random design approach).

Table 2: Purchase price attribute levels ($)

Gasoline Car	Hybrid Car			Electric Car		
16,660	22,491	24,157	27,489	23,324	25,823	27,656
22,800	30,096	31,464	34,200	30,552	31,920	34,656
29,000	37,700	39,150	40,600	37,700	39,440	41,180
36,220	44,188	45,637	47,086	43,464	47,086	47,810
47,600	49,028	52,360	57,120	49,980	52,360	58,072

Table 3: Cost attribute levels ($/100 km)

Gasoline Car	Hybrid Car			Electric Car		
6	2.4	3.3	4.1	1.8	2.0	2.2
9	3.1	4.4	5.4	2.3	2.5	2.6
11	5.2	6.4	6.8	2.8	3.2	3.8
14	5.9	6.2	6.9	2.6	4.3	4.5

Table 4: Range attribute levels (km)

Gasoline Car	Hybrid Car				Electric Car			
500	425	610	650	875	150	200	215	550
650	520	735	878	1,105	228	241	286	553
760	570	874	912	1,178	228	243	266	562
880	616	950	1,012	1,188	220	264	299	572
1000	650	1,000	1,100	1,250	210	360	400	580

Table 5: Horsepower attribute levels (Hp)

Gasoline Car	Hybrid Car				Electric Car			
130	114	130	189	228	98	107	111	113
160	128	131	216	272	102	107	115	120
185	130	148	228	300	102	109	117	122
230	131	150	255	354	115	120	123	128
270	149	176	297	405	132	138	142	147
320	176	192	352	480	141	147	160	170

A tablet was used to conduct the survey. The software in the tablet was able to choose a different version of the scenarios every time there was a new respondent. The chosen scenarios were presented to the respondents in a table similar to the one presented in Figure 3 below.

Scenario 1:

	Option 1	Option 2	Option 3
Car Type	Gasoline	Hybrid Electric Car	Electric Car
Price ($)	16,660	22,491	25,823
Range (km)	760	570	228
Horsepower (hp)	160	216	115
Cost ($/100km)	6.00	3.30	1.80

Indicate below which car would be your preferred choice.

1. Option 1
2. Option 2
3. Option 3

Figure 3: Example of a stated choice scenario

4.3. Sampling Plan and Data Collection

The determination of the sample size N_s, was guided by the formula used to determine sample size needed to estimate a population proportion as follows:

$$N_s = \frac{Z_{\alpha/2}^2 \, p(1-p)}{d^2} \tag{16}$$

Where p is the proportion of the population having a certain characteristic, α is the level of significance, d is the allowable error, and $Z_{\alpha/2}$ is the Z-value which leaves an area of $\alpha/2$ to the right under the standard normal probability curve. The value of the level of significance α was chosen to be 0.05. The value of the allowable error d was set to be equal to 0.05. Lastly, the value of p was set to be equal to 0.5 given that this value gives the most conservative value for N_s. This results in a sample size of 384.

It is worth noting that the above equation is generally used to obtain the sample size of a proportion of people having a particular characteristic, such as the percentage of households owning a car, rather than estimating the sample size for a choice model.

However, based on common experience in the transportation demand and choice modeling field, a sample size of 400 is generally considered sufficient to estimate standard discrete choice models.

Given the above determination as well as the available budget, a sample size of 400 was adopted. In the absence of updated official statistics about the number of households in the various areas under study, the sample was based on the number of registered voters of the related areas, as per the Ministry of Interior official numbers for the 2018 elections. Therefore, 400 questionnaires were distributed proportionally to the number of voters in the zones to be covered. The number of questionnaires per zone is detailed in Table B1 in Appendix B. The zones from which households were sampled cover most of the study area. In some cases, a zone was excluded because it did not include residential areas. Hence, the questionnaires assigned to that zone were distributed proportionally to nearby zones.

Before fielding the survey, a number of pilot tests were performed on a small sample of individuals of different ages. The main objective of the pilot study is to make sure that the questions and the scenarios are interpreted correctly. None of the respondents reported any problems in understanding the survey questions. Moreover, the time taken to complete the survey was about 30-35 minutes. The time basically depends on the number of people in the household and the number of cars available for use, as the respondent had to provide information about all the household members and all cars owned. Another pilot study was conducted by the survey firm and no significant problems were reported.

During the actual data collection, a two-stage probability sampling was adopted to ensure a random, representative sample for identifying households. The first stage consists of selecting neighborhoods inside each TAZ in a dispersed manner; the second stage consists of selecting households based on a systematic random sample in each selected neighborhood according to the estimated number of buildings in the neighborhood. The chosen sample included households with different level of access to public transportation since the purpose of this research is to investigate the relation between car ownership and public transport accessibility and availability.

Since it is a typical practice in transportation survey research for one adult household member to provide information about all household members, the survey followed this practice whereby information about each household in the sample was collected from an adult household member. This member had to be knowledgeable about the cars owned by the household and available at the time the survey firm arrives to the household. Moreover, the survey firm obtained the exact address of each interviewed household and associated it with the ID of the survey conducted with that specific household. The reason behind obtaining exact addresses is to calculate the access time to public transportation of the geolocated households as discussed in Section 4.4.3.

4.4. Other Collected Data

4.4.1. Land Use/Cover Data

Land use/cover data for Greater Beirut area extending to Jounieh in the North and Jiyyeh in the South were obtained from the National Center for Remote Sensing, a research center under the National Council for Scientific Research (CRNS). The land use data corresponds to year 2015 and has been verified in 2017.

4.4.2. Population and Employment Densities.

Data on residential and employment densities in Lebanon at the zonal level were also obtained from Mr. Rami Semaan, Managing Partner at TMS Consult. The year of the data is 2014.

4.4.3. Public Transportation Data

Given that public transportation services in Lebanon are unorganized (buses and red plate vans have no fixed stops or published schedules), field investigation was a necessity. Field data collection took place in order to obtain data about the buses and vans which operate in Greater Beirut in terms of their trajectories, the areas they cover, headway, number of available buses, operating hours, etc. The tasks in the field consisted of: (1) tracking a round trip for some bus lines to verify the actual bus route and record the trajectory using a GPS, (2) recording the time at which buses of the same line leave a designated area in order to measure the headway. When possible, the bus driver was interviewed and asked about operating hours, number of buses, the number of trips per bus per day, and the fare. In addition, field data was checked against data on bus routes and headways provided by SETS, a leading multidisciplinary engineering and consulting firm.

Based on the collected data, estimates of public transportation accessibility and attributes can then be obtained. The actual bus routes and the bus stops are digitized in GIS format, allowing the calculation of accessibility, i.e. the access time or distance for the geolocated interviewed households. Hence, the nearest bus route to households, the number of bus lines within walking distance, and the approximate waiting time can be determined.

4.5. Descriptive Statistics

A total of 709 households were approached in order to fill in 400 completed surveys; 136 refused to participate in it and 173 were not eligible to take the survey based on the preset selection criteria. This results in a response rate of 56.41%.

The responses were reviewed in order to detect any potential data issues. Three observations had to be eliminated because their total reported annual kilometers were significantly smaller than the total expected kilometers traveled for work trips by car based on the distance between their residence and work place. This was verified by measuring distances on Google maps. Furthermore, ten additional observations were removed based on outlier analysis which is further explained in subsection 4.6.2.2. Accordingly, this section covers the sample demographics and socio-economics, and the relationship between each of the socio-economic variables and distance to public transportation, and car ownership / use for the remaining 387 responses used in the model.

The spatial distribution of the surveyed households is shown in figure 4 below.

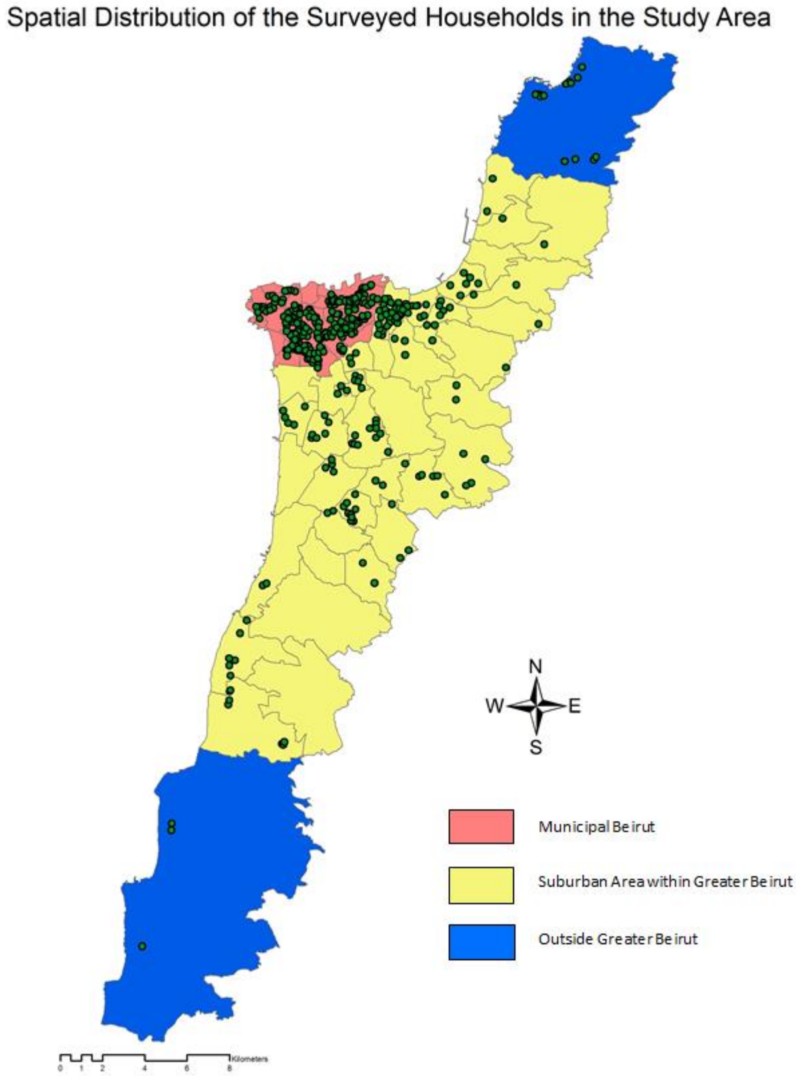

Figure 4: Spatial distribution of the surveyed households

4.5.1. Sample Demographics

The sample demographics and socio-economics are shown in in Table 6 and include the household size, car ownership, household income, education of the household head, and gender of the household head.

Table 6: Distribution of sample demographics (Sample = 387)

Survey question		**Percentage of Households**
Household size	1	4.13
	2	29.72
	3	27.39
	4 or more	38.76
Monthly Household Income	0 - 1,999,000 L.L.	28.42
	2,000,000 L.L. - 3,999,000 L.L.	24.81
	4,000,000 - 5,999,000 L.L.	20.93
	6,000,000 - 7,999,000 L.L.	9.30
	8,000,000 - 9,999,000 L.L.	3.88
	10,000,000 - 14,999,000 L.L.	2.58
	I don`t know / No response	10.08
Education of household head	No formal education	2.33
	Less than secondary/high school diploma	35.14
	Secondary/high school diploma (12 years of schooling)	25.58
	Some college/university	10.08
	Technical or vocational school	9.04
	University undergraduate/bachelor degree or equivalent	15.25
	Postgraduate, master`s degree, doctorate	2.58
Gender of household head	Male	95.35
	Female	4.65
Car ownership	0	8.53
	1	51.94
	2	29.72
	3 or more	9.82

*1 US dollar is equivalent to 1,500 L.L. (Lebanese Pounds).

Only few households in the sample were composed of one individual. The remaining were approximately equally distributed between sizes of two, three and four or more individuals. The average sample household size is 3.26 whereas the value obtained in the Living Conditions Survey conducted by the Central Administration of Statistics (CAS) in 2007 is 4.23. Consequently, weights based on household size will be applied to the categories of household sizes in the forecasting stage.

The income of the majority of the households surveyed is distributed as follows: 53.23% falls below 4,000,000 L.L., and 20.93% between 4,000,000 L.L. and 6,000,000 L.L. A slight percentage of households reported an income higher than 6,000,000 L.L., while 10% preferred not to answer this question.

The sample distribution according to the level of education of the household head is skewed towards lower levels of educational attainment. In fact, two thirds of the sample household heads completed 12 years of schooling or less. Moreover, the gender of the household head is 95% of the time male. It is important to note that the household head was assumed to be the oldest employed individual in the household. In cases where no working adult was found, the oldest household member is considered to be the household head.

The reported car ownership rates differed from the Greater Beirut Transport Plan study prepared by TEAM International (1995). Although the survey results for a car ownership rate of one were in accordance with this study – around 50% -, the sample has a high percentage of households in the two plus car category (39.54% vs. 25% in the 1995 study).

A question about car fuel efficiency was asked for every car owned by the household with the aim of determining the average fuel cost per car for each household and incorporating it later in the model. The resulting sample average is equal to 0.089$/km and the sample standard deviation is 0.022. These figures were obtained using the average price of fuel over the last 12 months before conducting the survey (July 2017 – July 2018). Also, the annual household kilometers for the cars available in the household were obtained. As shown in figure 5, the distribution is concentrated around an average household annual mileage of 15,055 kilometers, excluding households who don't drive (8.52% of the sample). The average annual mileage per car is 9,854 kilometers. This value is 35% less than the average annual kilometers of 15,000 kilometers per car estimated by the Ministry of Environment (MoE et. al 2015). It is suspected that this difference arises from the smaller sample collected outside Municipal Beirut. Conversely, the NAMA study (MoE et al., 2017) analyzed the average annual kilometers per car based on the age of the car; i.e. manufactured in the year 1999 or earlier (pre-2000), or manufactured between 2000 and 2014 (post-1999). It was reported that the average annual kilometers per car are 10,238 and 11,591 kilometers for cars in the pre-2000 and post-1999 category, respectively. These values are obtained based on a local market survey (Ecodit, 2015) and they are close to the average annual kilometers per car (9,845) obtained by our survey.

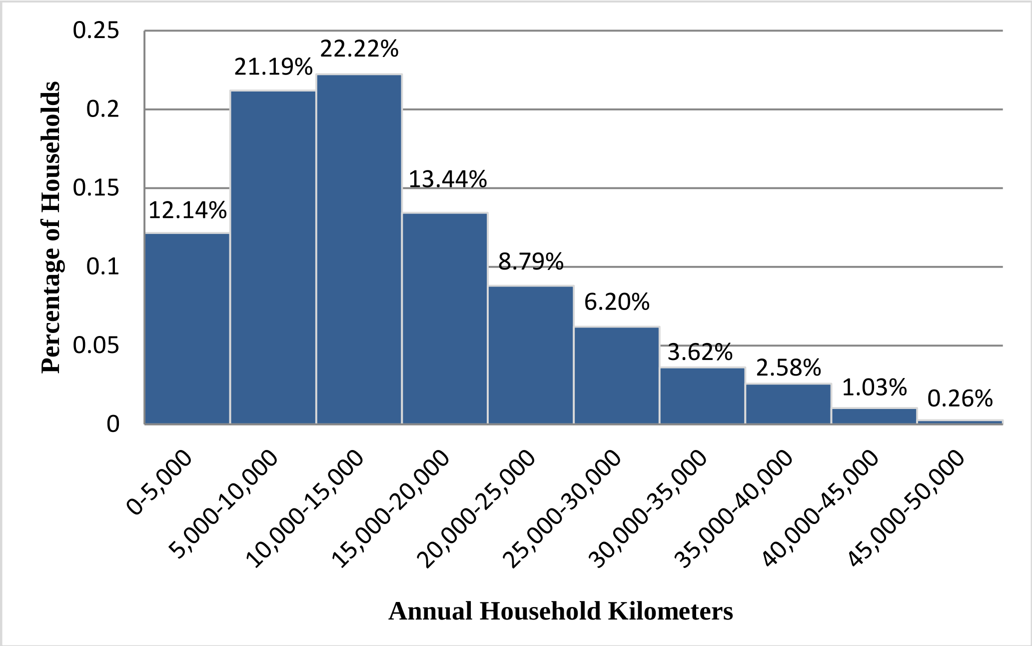

Figure 5: Distribution of households as a function of annual household kilometers

4.5.2. Socio-economic Variables

In this section, the socio-economic variables will be related to the average car ownership and average usage. The distribution of these averages among the three main regions of the study area will be explored. A summary of the results is provided in Tables 7 and 8.

Based on the values presented in Table 7, the sample average car ownership is equal to 1.46. While Municipal Beirut is considered as an area of higher density and mixed land use compared to the other two regions, it displays a higher average car ownership and average usage. This is probably attributed to the fact that Municipal Beirut residents are high income earners who can afford to live in the capital, buy cars, and bear the costs associated with using them.

Table 8 indicates an increasing relationship between the average car ownership and usage and all the socio-economic and demographic variables collected. These include the number of working adults, the number of household members working at a distance greater than 5 kilometers, the number of licensed drivers, the number of children, and household income. This pattern is expected and will be further investigated in the model. Moreover, the correlation between income (treating income as a continuous variable represented by the midpoint of each income range) and household kilometers is 0.595. This value supports the hypothesis of a significant relationship between usage and income.

Table 7: Average car ownership and average usage in the study area

	Average car ownership	Average usage (Km)	Number of households
Municipal Beirut	1.51	14,531	228
Suburban Area within Greater Beirut	1.41	13,044	143
Outside Greater Beirut	1.19	9,453	16
Sample	1.46	13,771	387

Table 8: Socio-economic and demographic variables in relation with average car ownership and usage

Socio-economic variables		Average car ownership	Average usage (Km)
Working adults	0	0.63	7,234
	1	1.07	10,232
	2	1.59	15,970
	3	2.00	19,258
	4 or more	3.00	20,798
Number of workers with job location>5km	0	1.31	11,842
	1	1.65	16,389
	2 or more	2.48	26,194
Licensed Drivers	0	0.18	1,364
	1	0.98	10,309
	2	1.42	14,021
	3	1.88	17,377
	4 or more	2.94	22,200
Number of Children	0	1.40	12,915
	1	1.60	15,263
	2	1.62	16,601
	3 or more	1.48	15,467
Household Income	0 - 1,999,000 L.L.	0.87	8,282
	2,000,000 L.L. - 3,999,000 L.L.	1.32	11,875
	4,000,000 - 5,999,000 L.L.	1.59	17,275
	6,000,000 - 7,999,000 L.L.	2.25	23,167
	8,000,000 - 9,999,000 L.L.	2.60	28,583
	10,000,000 - 14,999,000 L.L.	2.70	29,650

The relationship between car ownership and income is illustrated in Figure 6. The percentage of households that do not own cars decreases with an increase in annual income, while the opposite is true for households that own three or more cars.

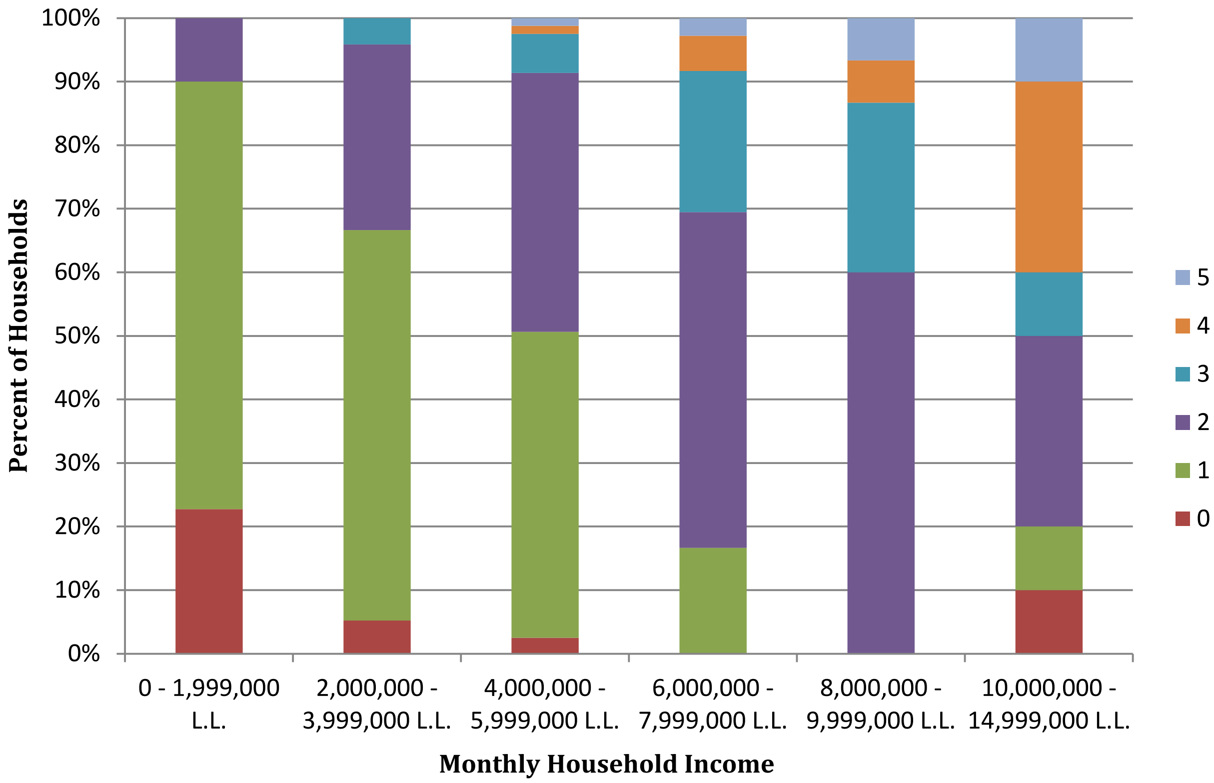

Figure 6: Percent of households owning one or more cars by monthly household income

4.5.3. Relation between Distance to Public Transportation and Car Ownership / Usage

An analysis similar to the one conducted for socio-economic and demographic variables is done for data collected on household perception of public transportation. Accordingly, the perceived distance to service and bus/van is related to the average car ownership and average usage, as shown in Table 9 below.

Table 9: Proximity to public transport in relation with the average car ownership and usage

	Average car ownership	Average usage (Km)	Percentage of households
Distance to service			
Less than 250 meters (less than 4 minutes)	1.50	13,861	83.46
Between 250 and 500 meters (4 to 8 minutes)	1.09	12,543	9.04
Between 501 and 750 meters (9 to 11 minutes)	1.50	14,792	3.10
More than 750 meters (more than 11 minutes)	1.27	13,023	2.84
I don`t know	1.33	15,417	1.55
Distance to bus/van			
Less than 250 meters (less than 4 minutes)	1.41	13,468	55.04
Between 250 and 500 meters (4 to 8 minutes)	1.40	13,293	25.84
Between 501 and 750 meters (9 to 11 minutes)	2.00	19,025	7.75
More than 750 meters (more than 11 minutes)	1.60	13,692	7.75
I don't know	1.14	10,714	3.62

An increase in average car ownership / usage is expected as the distance to public transport increases. While this relationship is true to a certain extent for the distance to bus/van, the sample results did not demonstrate a clear relationship for the distance to service. One explanation might be that the percentage of surveyed households located at a distances larger than 250 meters from service was particularly smaller than those situated at a distance to service less than 250 meters. This category represents 83.46% of the sample. It is interesting to note that the percentage of households who are unaware of their location with regards to available service reported the highest average car usage. A bigger sample size capturing more variability in accessibility to service is needed to reach more conclusive results. However, the effect of distance to service on car ownership / usage will be tested in the model.

Looking more carefully at the relationship between the average car ownership / usage to the distance to bus/van, it is worth mentioning that it no longer follows the expected increasing trend beyond a distance of 750 meters. This could arise from characteristics associated with these households in particular that would make them drive less. The model will account for these characteristics when testing the effect of distance to bus/van on car ownership and usage.

Figure 7 is an illustration of all the bus lines intersecting the study area. Note that in some cases, two or more bus lines take the same route; they overlap and cannot be distinguished on the map. Accordingly, Table 10 provided after Figure 7 contains the characteristics of the bus lines, including the name of each bus line, its total length, and its length inside the study area. All the lines utilize the following fare scheme: 1,000 L.L. inside Greater Beirut and between 2,000 L.L. and 3,000 L.L. outside Greater Beirut. The operating hours for most lines extend between 6:00 am and 8:30 pm. The average headway is 13 minutes.

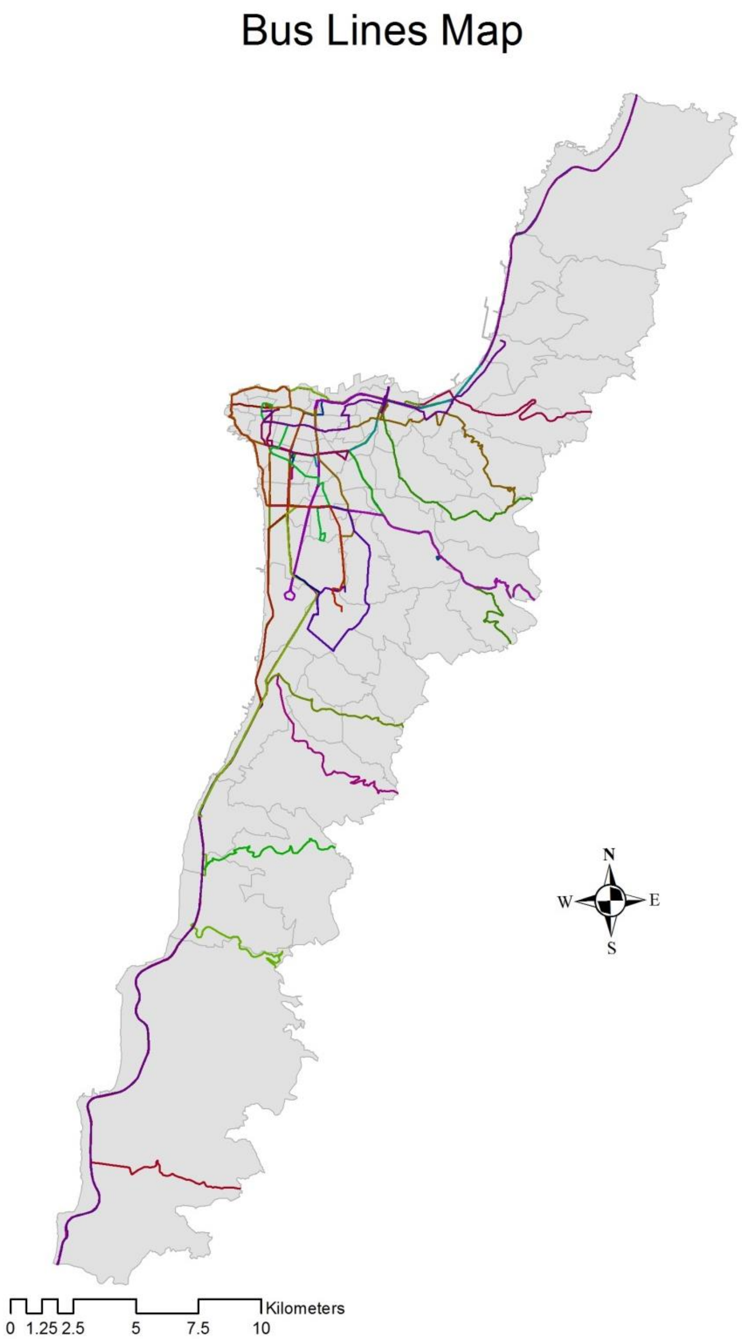

Figure 7: Bus lines map in the study area

Table 10: Bus Lines

Origin	Name	Length (m)	Length in Study Area (m)	Origin TAZ	Destination TAZ	Headway (minutes)
Sultan Ibrahim	Sultan Ibrahim - Hay El Sellom	7,290	7,290	TAZ 32	TAZ 41	2
	Sultan Ibrahim - LU	14,144	14,144	TAZ 32	TAZ 39	2
Hamra	ROUTE 2	15,762	15,762	TAZ 16	TAZ 49	8
	ROUTE 4	10,982	10,982	TAZ 16	TAZ 41	1
	ROUTE 5	18,016	18,016	TAZ 16	TAZ 54	9.5
	ROUTE 12	10,450	10,450	TAZ 20	TAZ 31	11.5
	ROUTE 24	10,749	10,749	TAZ 15	TAZ 7	10
Al Rihab	AL Rihab – Hermel	137,507	12,484	TAZ 31	TAZ 76	20
	Al Rihab – Manara	14,497	14,497	TAZ 31	TAZ 19	5
	AL Rihab - Ramle El Bayda	9,104	9,104	TAZ 31	TAZ 23	5
	AL Rihab - Naameh	14,570	14,570	TAZ 31	TAZ 61	20
	AL Rihab - Raouche	13,330	13,330	TAZ 31	AZ 19	5
Cola	Cola Kayfoun	21,373	18,449	TAZ 10	TAZ 64	12
	Cola – Kfarmatta	27,518	24,900	TAZ 10	TAZ 64	60
	Cola - Qabr Shmoun	22,817	21,404	TAZ 10	TAZ 64	2.5
	Cola – Khalde	11,763	11,763	TAZ 10	TAZ 43	5
	Cola - Tripoli – Aakkar	110,017	24,475	TAZ 10	TAZ 78	3
	Cola – Jbeil	38,534	23,505	TAZ 10	TAZ 78	15
	Cola - Jbeil (minivans)	38,534	23,505	TAZ 10	TAZ 78	2
	Cola – Chehime	43,989	39,747	TAZ 10	TAZ 75-E	45
	Cola - Chouf (Niha)	65,576	27,607	TAZ 10	TAZ 75-E	9
	Cola – Ersal	119,493	14,604	TAZ 10	TAZ 76	35
	Cola – Hasbaya	120,653	15,391	TAZ 11	TAZ 77	45
	Cola – Naameh	15,406	15,406	TAZ 10	TAZ 61	3
	Cola – Qmatiyeh	16,609	15,315	TAZ 10	TAZ 64	10
	Cola – Saida	40,583	37,625	TAZ 10	TAZ 77	5
	Cola – Bhamdoun	21,694	14,685	TAZ 10	TAZ 65	6
	Cola – Chtoura	43,419	14,695	TAZ 10	TAZ 76	15
	Cola – Jezzine	67,901	37,710	TAZ 10	TAZ 77	12
	Cola – Tyre	78,321	37,027	TAZ 10	TAZ 77	10

Table 10 (cont.): Bus Lines

Origin	Name	Length (m)	Length in Study Area (m)	Origin TAZ	Destination TAZ	Headway (minutes)
Dora	Dora - Beirut Airport	25,232	25,232	TAZ 35	TAZ 42	1.5
	Dora – Mrouj	21,379	11,285	TAZ 35	TAZ 72	10
	Dora - Baabdat	21,402	11,898	TAZ 35	TAZ 71	10
	Dora – Baskinta	40,511	11,285	TAZ 35	TAZ 72	5
	Dora – Jbeil	34,237	19,273	TAZ 35	TAZ 78	1.5
	Dora - (Bahri)	15,642	15,642	TAZ 35	TAZ 1	7
	Dora - (Nahri)	19,344	19,344	TAZ 35	TAZ 1	10
	Dora – Arz	110,262	19,273	TAZ 35	TAZ 78	60
Kuwait Embassy	KE- Nabatiyeh	71,150	36,678	TAZ 10	TAZ 77	10.5
	KE – Saida	41,587	36,678	TAZ 10	TAZ 77	1
	KE – Tyre	81,893	36,678	TAZ 10	TAZ 77	9.5
Charles Helou	Charles Helou-Tripoli	79,287	19,593	TAZ 2	TAZ 78	30
Other	Tiro-Airport	3,037	3,037	TAZ 34	TAZ 41	5
	Barbir - Nahr El Mot	9,103	9,103	TAZ 9	TAZ 50	20

4.6. Modeling Car Ownership and Use

The discrete-continuous model described in Chapter 3 is adopted, using the data collected, to model car ownership and use in the study area of this thesis. The following subsections describe the model specification, model development, and the results.

4.6.1. Model

<u>4.6.1.1.</u> <u>Latent Variable Model Specification</u>

It is assumed that car ownership and use is affected by attitudes toward public transportation and the private car. The last section of the survey measures the attitudes of respondents towards public transportation and the private car through respondents' level of agreement with the presented attitudinal and perceptual statements. These are used as indicators of the latent variable. Using these statements, two attitudes were considered. Bus (*BLV*) attitude and Car (*CLV*) attitude. The indicators with their corresponding descriptions are shown in Table 11.

Table 11: Latent variables and their indicators

Designation	Description of Indicator	Latent Variable
$I_{1,BLV}$	I can count on the bus/van to get me to the places I need to go to on time.	BLV
$I_{2,BLV}$	I don't feel comfortable in the bus/van.	BLV
$I_{3,BLV}$	I can get other things done while commuting by bus/van.	BLV
$I_{4,BLV}$	I like the idea of using bus/van as a means of transportation for me.	BLV
$I_{1,CLV}$	I feel stressed when I commute using the vehicle.	CLV
$I_{2,CLV}$	I like the idea of driving as a means of transportation for me.	CLV

The *BLV* and *CLV* were expressed as a function of observed variables as follows:

$$\mathrm{BLV}_n = \alpha_{BLV} + \alpha_{Income\_BLV} \times Income_n + \alpha_{M\_Income\_BLV} \times M\_Income_n + \alpha_{Distance\_Bus\_BLV} \times Distance\_Bus_n + \alpha_{M\_Distance\_Bus\_BLV} \times M\_Distance\_Bus_n + \eta_{BLV,n} \tag{17}$$

$$\mathrm{CLV}_n = \alpha_{CLV} + \alpha_{Income\_CLV} \times Income_n + \alpha_{M\_Income\_CLV} \times M\_Income_n + \eta_{CLV,n} \tag{18}$$

Where η_{BLV} and η_{CLV} are random disturbance error terms which are assumed to be independently and identically distributed (iid) normal, expressed as:

$$\eta_{BLV,n} \sim \mathrm{N}(0, \sigma^2_{\eta_{BLV}}) \tag{19}$$

$$\eta_{CLV,n} \sim \mathrm{N}(0, \sigma^2_{\eta_{CLV}}) \tag{20}$$

Table 12 describes the explanatory variables that were included in the structural equations of the latent variables.

Based on model testing, the *BLV* latent variable was included only in the discrete sub-model while the *CLV* latent variable was included in the continuous sub-model.

Table 12: Explanatory variables employed in structural equations of the latent variables

Variable	**Description**
Income	Continuous variable, the monthly income in million L.L. available for all members living in the household.
M_Income	Dummy variable, equal to 1 if the household did not report its income and equal to 0 otherwise.
Distance_Bus	Continuous variable, the distance in meters that the respondent needs to walk to obtain access to a bus/van. This distance is based on the respondent's answer, i.e. it may not reflect the actual distance to the nearest bus line.
M_Distance_Bus	Dummy variable, equal to 1 if the household head/respondent is not aware of the distance that he/she needs to walk to obtain access to a bus/van, and equal to 0 otherwise.

The measurement equations of the latent variable model are expressed as in equations 21 and 22 below:

$$I_{r,BLV,n} = \vartheta_{r,BLV} + \lambda_{r,BLV}.BLV + \upsilon_{r,BLV,n} \qquad ; r = 1, 2, 3, 4 \tag{21}$$

$$I_{r,CLV,n} = \vartheta_{r,CLV} + \lambda_{r,CLV}.CLV + \upsilon_{r,CLV,n} \qquad ; r = 1, 2 \tag{22}$$

Where $I_{r,BLV,n}$ and $I_{r,CLV,n}$ represent the survey response of respondent *n* for the indicator *r* of the latent variables *BLV* and *CLV*, respectively. The indicators are measured on a scale of 1 to 5 and assumed to be continuous variables.

4.6.1.2. The Discrete Sub-Model Specification

We assume that the car ownership choice set consists of three alternatives; the alternatives of owning zero, one or two+ cars.

The utility equations (U_0, U_1, and U_{2+}) of car ownership levels for household *n* are shown below. It should be noted that several model specifications for the discrete sub-model were also considered, such as including demographics and public transportation quality measures; but did not lead to significant results.

$$U_{0,n} = \quad 0 + \varepsilon_{0,n} \tag{23}$$

$$\begin{aligned} U_{1,n} = \quad & \text{ASC}_{one} + \beta\text{\_Children\_One} \times Presence\_Children_n + \\ & \beta\text{\_Bachelor\_One} \times Bachelor_n + \beta\text{\_Workers \_One} \times \\ & Working\_Adults_n + \beta\text{ \_BLV\_One} \times BLV_n + \Omega_{1n} + \varepsilon_{1n} \end{aligned} \tag{24}$$

$$\begin{aligned} U_{2+,n} = \quad & \text{ASC}_{Two} + \beta\text{\_Children\_Two} \times Presence\_Children_n + \\ & \beta\text{\_Bachelor\_Two} \times Bachelor_n + \beta\text{\_Workers \_Two} \times \\ & Working\_Adults_n + \beta\text{\_Income} \times Income_n + \beta\text{\_M\_Income} \times \\ & M\_Income_n + \beta\text{\_BLV\_Two} \times BLV_n + \Omega_{2n} + \varepsilon_{2n} \end{aligned} \tag{25}$$

Where Ω_{1n} and Ω_{2n} are the error components included in the utilities of U_{1n} and $U_{2+\,n}$, respectively, in order to correlate the decision of owning one and two+ cars with their corresponding usage (regression equation), and ASC$_{one}$ and ASC$_{Two}$ are alternative specific constants. As discussed in Chapter 3, the decision of owning zero cars was not correlated with the usage since mileage was only modeled for those who have cars, i.e. if the household has zero cars then the kilometers traveled is zero. The description of the variables incorporated as explanatory variables is shown in Table 13 below.

Table 13: Description of variables in the discrete sub-model

Variable	Description
Presence_Children	Dummy variable, equal to 1 if there are children in the household and equal to 0 otherwise.
Bachelor	Dummy variable, equal to 1 if there is at least one household member with an education of at least a bachelor's degree and equal to 0 otherwise.
Working_Adults	Ordinal variable, the number of household members working full-time, part-time, or self-employed.
Income	Continuous variable, the monthly income in million L.L. available for all members living in the household.
M_Income	Dummy variable, equal to 1 if the household refused to report its income and equal to 0 otherwise
BLV	Bus latent variable

4.6.1.3. The Continuous Sub-Model Specification

OLS regression was used to model the household total annual kilometers. The reason behind log transforming the dependent variable is to avoid obtaining negative values for the predicted mileage. The model was specified as a function of observed variables (socioeconomic characteristic, demographic factors, etc.) and the latent variable *CLV*. The functional form of this model is:

$$\begin{aligned}\log(Y_{n,reg}) = \; & ASC_{reg} + \beta\_\text{Children\_reg} \times Presence\_Children_n + \\ & \beta\_\text{Workers\_reg} \times Working\_Adults_n + \beta\_\text{Working\_5km} \times \\ & HHM\_5km_n + \beta\_\text{Income\_reg} \times \log(Income_n) + \\ & \beta\_\text{M\_Income\_reg} \times M\_Income_n + \beta\_\text{Cost} \times \log(Cost_n) + \beta\_\text{MDI} \\ & \times \log(MDI_n) + \beta\_\text{CLV} \times CLV_n + \sigma_{\Omega_1} \times \Omega_{1n} + \sigma_{\Omega_2} \times \Omega_{2n} + \varepsilon_{reg,n}\end{aligned} \quad (26)$$

The description of the explanatory variables presented in Table 13 still applies. For all the additional variables included in the regression equation, the description is shown in Table 14.

Table 14: Description of variables in the continuous sub-model

Variable	Description
HHM_5km	Ordinal variable, the number of household members working at a distance greater than five kilometers from the location of the residence.
$Cost$	Continuous variable, the fuel cost per kilometer of driving ($/km)
MDI	Continuous variable, the mixed density index at the traffic analysis zone level.
CLV	Car latent variable.

The above variables were computed as follows:

- HHM_5km , the survey asked about the zone in which the work place of each worker (full-time, part-time, or self-employed) in the household is located. Using the road network on Google maps, the distance between each worker's residence and work place was calculated as the distance between the centroids of the zones in which each is located. Subsequently, the number of household members working at a distance greater than 5 kilometers in each household was determined.
- $Cost$, was calculated by dividing the average price of fuel tank ($/tank) – obtained as discussed in subsection 4.5.1 – by the average fuel efficiency (km/tank) of the owned cars, where a tank has a volume of 20 liters. In some studies in the literature, the cost variable was assumed to be endogenous and therefore estimated using instrumental variables (e.g. Liu and Cirillo, 2014). Endogeneity of the cost variable may arise from the fact that the operating cost of driving the owned vehicles is chosen by the household in tandem with choosing the type of car to own – which is related to fuel efficiency. In this thesis, we adopted an approach similar to that of Holder (2013), by assuming that "households do not change their vehicle fleet". As such, the fuel efficiency of the cars was treated as exogenous in a short-term model.
- *MDI* in zone k, as defined by Chu (2002), is expressed as:

$$MDI_k = \frac{ED_k \times RD_k}{ED_k + RD_k}$$

Where ED_k is the employment density in zone k (number of workers per km^2) and RD_k is the residential density in zone k (number of households per km^2). In the absence of data about the number of households in the zones of our study area, RD_k was replaced by population density (number of persons per km^2) based on the assumption that population density is positively correlated with residential density; i.e. as population density increases, residential space consumption will also increase.

4.6.2. Model Development

4.6.2.1. Model Estimation

Initially, the sample that was used to estimate the model consisted of 397 households. However, estimation results showed that some observations needed to be excluded as will be further explained in the following section. The final sample used for estimation is composed of 387 households.

In order to estimate the model, the factor loadings $\lambda_{1,BLV}$ and $\lambda_{2,CLV}$ of the *BLV* and the *CLV* latent variables, respectively, were fixed to 1 to set the scale of these latent variables.

The model was estimated in PythonBiogeme (Bierlaire, 2016; Bierlaire and Fetiarison, 2009), and maximizing the likelihood function was done through Monte-Carlo integration using "MLHS" draws implemented in the aforementioned software and reported to perform well for discrete choice models (Bierlaire, 2015; Hess et al., 2005). The model was tested from multiple starting points and using different number of draws (increased by increments of 1,000). This procedure was adopted to ensure the stability and precision of the estimated parameters. In the end, 6,000 draws were used to estimate the model because at that stage, the parameter estimates stabilized.

Several model specifications were tested such as including demographics (e.g., age and gender of household head), land use variables, and other measures of public transportation quality; however, none of these variables were found to be significant.

Previous research has identified different ways to measure the service level of public transportation. For instance, Rood (1998) measures the transit service level of an area using the Local Index of Transit Availability (LITA) which correlates the capacity, frequency and the service coverage with the population and the area at which the transit service level is being computed (as cited in Liu and Cirillo, 2015). "Transit Capacity and Quality of Service Manual (TCQSM) (TRB 2003) uses transit data and census tract data along with service coverage measure to evaluate transit accessibility". "The Time-of-Day Tool adopted by Polzine et al. (2002) measures transit service accessibility for each time period". This method necessitates the availability of data on travel demand as well as transit and census data (as cited in Liu and Cirillo, 2014).

In this thesis, several quality measures were developed using the data collected on public transportation, including access time, distance, coverage of bus lines at the zonal level, density of bus lines within a buffer around households, etc. Multiple trials included one or a combination of these measures; however, the presented model was found to outperform any of them in terms of parameter estimates' signs, statistical significance of variables and goodness-of-fit.

4.6.2.2. Outlier Analysis

After the model was estimated on a sample of 397 households, outlier analysis was performed. First, the predicted car ownership choice probabilities of all the observations in the sample were calculated. Next, the predicted values were analyzed whereby those that are below 0.01 were examined. However, none of the observations matched this condition. Five observations were associated with predicted probabilities less than 0.05 and were selected for further inspection. They were checked for data errors but there was not enough information to support eliminating them. Also, removing the observations had a minor effect on the estimation results of the model. Therefore, they were not eliminated from the data set.

For the continuous sub-model, the predicted usage for all the observations in the sample was calculated. Then, the predicted values were compared against the corresponding observed values (the reported household kilometers driven) and the difference between them was obtained. The sources of deviation were investigated for the ten observations with the highest difference with respect to the reported value. These observations were further inspected for data recording errors, but none was found. Moreover, the model was run with and without the 10 observations with the aim of testing the effect of these observations on the estimation results. Eliminating the 10 observations with the highest differences resulted in a model with better goodness-of-fit and more statistically significant variables. Therefore, the 10 observations were removed and the final data set became 387 households.

It is worth noting that outlier analysis allowed some improvements to the model specification through incorporating new variables such as the number of people who work at a distance greater than five kilometers and the level of education in the household.

CHAPTER 5

RESULTS

This chapter presents the results of the discrete-continuous model specified in Chapter 4. It is divided into two sections. The first section describes the model estimation results and compares them to the available literature. The second section analyzes multiple policy scenarios that can serve as a decision tool for reducing car ownership and use levels along with their environmental benefits.

5.1. Model Estimation Results

In this section we present the estimation results and summary statistics of the discrete-continuous model. The latent variable model, the discrete sub-model and the continuous sub-model results are provided in Tables 15, 16, 17, respectively. The model statistics are added in Table 18.

Table 15: Estimation results of the discrete-continuous model (Latent Variable Model)

Structural Model

BLV - Structural Equation

Variable/Parameter	Parameter Estimate	Robust Standard Error	Robust t-test	p-value
α_{BLV}	3.10	0.123	25.12	0.00
Distance_Bus (km/10^3)	-4.97	2.04	-2.43	0.01
Income (ML.L. /10^7)	-0.857	0.176	-4.86	0.00
M_Distance_Bus	-0.988	0.240	-4.11	0.00
M_Income	-0.955	0.165	-5.80	0.00
$\sigma_{\eta_{BLV}}$	0.786	0.0586	13.43	0.00

CLV - Structural Equation

Variable/Parameter	Parameter Estimate	Robust Standard Error	Robust t-test	p-value
α_{CLV}	3.70	0.0459	80.46	0.00
Income (ML.L. /10^7)	0.569	0.0569	10.00	0.00
M_Income	-0.112	0.0163	-6.90	0.00
$\sigma_{\eta_{CLV}}$	-0.424	0.0413	-10.26	0.00

Table 15 (cont.): Estimation results of the discrete-continuous model (Latent Variable Model)

Measurement Model				
BLV - Measurement Equations				
	Parameter Estimate	**Robust Standard Error**	**Robust t-test**	**p-value**
$\vartheta_{1,BLV}$	1.00	-	-	-
$\vartheta_{2,BLV}$	6.03	0.266	22.67	0.00
$\vartheta_{3,BLV}$	1.59	0.211	7.53	0.00
$\vartheta_{4,BLV}$	0.420	0.248	1.70	0.09
$\lambda_{1,BLV}$	1.00	-	-	-
$\lambda_{2,BLV}$	-1.13	0.0999	-11.31	0.00
$\lambda_{3,BLV}$	0.652	0.0784	8.32	0.00
$\lambda_{4,BLV}$	1.04	0.0899	11.56	0.00
$\sigma_{\upsilon_1,BLV}$	0.914	0.0462	19.78	0.00
$\sigma_{\upsilon_2,BLV}$	0.792	0.0680	11.65	0.00
$\sigma_{\upsilon_3,BLV}$	0.940	0.0335	28.08	0.00
$\sigma_{\upsilon_4,BLV}$	0.887	0.0545	16.27	0.00
CLV - Measurement Equations				
Variable/Parameter	**Parameter Estimate**	**Robust Standard Error**	**Robust t-test**	**p-value**
$\vartheta_{1,CLV}$	11.5	0.907	12.65	0.00
$\vartheta_{2,CLV}$	1.00	-	-	-
$\lambda_{1,CLV}$	-2.31	0.224	-10.31	0.00
$\lambda_{2,CLV}$	1.00	-	-	-
$\sigma_{\upsilon_1,CLV}$	0.0331	0.00641	5.17	0.00
$\sigma_{\upsilon_2,CLV}$	0.700	0.0299	23.39	0.00

Table 16: Estimation results of the discrete-continuous model (Discrete Sub-Model)

Discrete Sub-Model					
Variable/Parameter	**Alternative**	**Parameter Estimate**	**Robust Standard Error**	**Robust t-test**	**p-value**
ASC	1 car	2.74	1.07	2.55	0.01
	2+ cars	-0.914	1.15	-0.79	0.43
Bachelor	1 car	1.00	0.503	1.99	0.05
	2+ cars	1.41	0.579	2.44	0.01
Presence of Children	1 car	0.0990	0.507	0.20	0.85
	2+ cars	1.28	0.562	2.29	0.02
Working Adults	1 car	0.115	0.378	0.30	0.76
	2+ cars	1.22	0.395	3.10	0.00
Income (ML.L. /10^7)	1 car	-	-	-	-
	2+ cars	4.66	1.12	4.17	0.00
M_Income	1 car	-	-	-	-
	2+ cars	1.21	0.753	1.61	0.11
BLV	1 car	-0.458	0.307	-1.49	0.14
	2+ cars	-0.905	0.340	-2.66	0.01

Table 17: Estimation results of the discrete-continuous model (Continuous Sub-Model)

Continuous Sub-Model				
Variable/Parameter	**Parameter Estimate**	**Robust Standard Error**	**Robust t-test**	**p-value**
ASC_{reg}	2.68	0.785	3.41	0.00
Presence of Children	0.166	0.0707	2.35	0.02
Working Adults	0.115	0.0351	3.27	0.00
HHM_5km	0.140	0.0414	3.38	0.00
Income (MLBP/10^7)	0.334	0.0499	6.69	0.00
M_Income	4.26	0.763	5.58	0.00
MDI	-0.0513	0.0293	-1.75	0.08
Cost ($/km)	-0.528	0.164	-3.22	0.00
CLV	0.165	0.0804	2.06	0.04
σ_{Ω_1}	0.0464	0.0726	0.64	0.52
σ_{Ω_2}	0.488	0.0596	8.20	0.00
$\sigma_{\epsilon,reg}$	0.380	0.0539	7.05	0.00

Table 18: Estimation results of the discrete-continuous model (Model Statistics)

Model Statistics	
Choice Likelihood at Zero	-425.163
Final Choice Likelihood	-269.575
Final Log-Likelihood	-500.887
Final Gradient Norm	+1.14E-03
Rho bar squared	0.337
Adjusted R^2	0.36

The estimation results are discussed below.

BLV – Structural Equation

The constant α_{BLV} along with all the explanatory variables in the BLV structural equation are statistically significant at the 95% level of confidence.

- The negative sign of the *distance to bus* variable implies that as the distance to the nearest bus line (as perceived by the respondent) increases, the respondent develops a more negative attitude towards the bus as expected.
- The *M_Distance_Bus* variable also has a negative sign suggesting that respondents who are unaware of the distance they need to walk to access a bus/van are also likely to develop a more negative attitude towards the bus.
- The negative sign of the *Income* variable means that an increase in total household income leads to a less favorable attitude towards riding the bus. This result is expected since high income groups tend to rely more on cars for commuting.

CLV – Structural Equation

Similarly, the constant α_{CLV} along with all the explanatory variables in the CLV structural equation are statistically significant at the 95% level of confidence.

- The coefficient of the *Income* variable is positive, indicating that an increase in the monthly household income leads to a more favorable attitude towards the car.
- The *M_Income* has a negative sign.

BLV and CLV – Measurement Equations

The factor loadings of the indicators of the BLV and the CLV latent variables are significant at the 95% level of confidence, and they all have the correct sign. In terms of an increase in the latent variable, a factor loading with a positive sign indicates that the respondent expresses more agreement with more favorable statements, while the opposite behavior is true for a negative factor loading sign.

Discrete Sub-Model

The coefficients of the *Bachelor* variable in the one-car and the two-plus-cars alternatives are positive and significant at the 95% level of confidence implying that a household with at least one member with an education of at least a bachelor's degree is more likely to own more cars. This result is in line with the findings in the literature in terms of the effect of education on car ownership (e.g. Liu, 2010). This may be explained by the fact that highly educated people conduct a higher number of mandatory trips, notably for work and educational purposes, compared to people with lower levels of education. Moreover, they tend to be more active in terms of their community involvement. Consequently, they need more cars to carry out all these activities.

The positive sign of the *Presence of Children* variable suggests that the presence of children has a positive effect on the number of cars owned. It is expected that more cars are needed to satisfy the additional non-work trips generated for children (Potoglou and Kanaroglou, 2008). This variable is not significant in the one-car alternative; however, removing it created estimation issues. Consequently, it was maintained in the utility equation.

The positive sign of the *Working Adults* variable implies that households with more working individuals are associated with higher levels of car ownership due to greater mobility needs. Studies such as those conducted by Potoglou and Kanaroglou (2008) and Kim and Kim (2004) report a similar finding. This variable behaves similarly to the children variable such that it is insignificant in the one-car alternative but is kept in the utility equation.

As for *Income*, the coefficient in the two-plus alternative is positive and significant at the 95% level of confidence, indicating that households with higher income levels are more likely to be associated with higher levels of car ownership. This finding is in accordance with the descriptive analysis (subsection 4.5.2.) that related the effect of income to the number of cars owned in the household. It is also consistent with the findings of theoretical and empirical work on car ownership (e.g. Kim and Kim, 2004; Huang et. al, 2016). Including the *Income* variable in the one-car alternative resulted in model estimation issues, so it was removed from the one-car utility equation.

Finally, the sign of the *BLV* latent variable in the one-car and the two-plus cars alternatives shows that a positive attitude towards the bus has a negative effect on car ownership. This result makes sense such that public transportation services (measured in terms of attitudes and perceptions towards the bus service) affect the decision of the number of cars to own. That is, as the distance to the nearest bus line decreases, one would develop a more positive attitude towards the bus. Consequently, the probability of a household owning more cars decreases. This finding supports the hypothesis of a relationship between public transportation availability and car ownership levels. However, while previous studies have found that accessibility to public transportation directly influences car ownership, in this study we find that the effect is indirect, occurring through the attitude towards public transportation. The coefficients of the *BLV* in the one-car and the two-plus-cars alternatives are significant at the 95% and 80% level of confidence, respectively. The magnitude of the influence of public transportation accessibility on car ownership will be analyzed in the forecasting section below.

Continuous Sub-Model

The estimated coefficients of the explanatory variables in the continuous sub-model have the expected signs and are statistically significant at the 95% level of confidence, except for the *MDI* variable which is significant at the 90% level of confidence.

The coefficient of the *Presence of Children* variable is positive implying that the presence of children has a positive effect on car use. The positive relationship between the presence of children and car usage that was found in the descriptive analysis stage (subsection 4.5.2.) is here confirmed by the model. This result is in accordance with that found in previous studies on car ownership and usage such as Bhat et al. (2009) signifying as expected that the presence of children leads to greater reliance on travel by car.

We also find that as the number of household members who work at a distance greater than five kilometers from the residence increases, car usage increases. This relationship is in line with previous studies claiming that private car is more convenient than public transportation when commuting long distances (Potoglou and Kanaroglou, 2008).

As expected, households drive more as their monthly income increases. The log-log specification of the model allows a fair interpretation for the continuous variables in the regression model. For instance, the coefficient value of Income (0.334) is the income elasticity[1] for annual household kilometers. The income elasticity falls between values estimated by Holder (2013) and Goodwin et al. (2013) which are equal to 0.24 and 0.49, respectively, knowing that the latter estimates have been derived in the context of developed countries.

In terms of the *MDI* variable, the negative sign of the coefficient is in accordance with previous studies (Chu, 2002; Potoglou and Kanaroglou, 2008). An increase in the population and the employment densities within a traffic analysis zone has a negative effect on car usage of a household located in that zone. It is worth noting that the effect of population and employment densities was tested separately in the model; however, combining them using the *MDI* index resulted in more statistically results.

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[1] $\log(\mathrm{Y}_{reg})$ = β_Income_reg × $\log(Income)$ + ….. → $\frac{\partial(\log(\mathrm{Y}_{reg}))}{\partial \mathrm{Y}_{reg}} = \frac{\partial(\beta\_\mathrm{Income\_reg} \times \log(Income))}{\partial Income}$

→ $\frac{1}{\mathrm{Y}_{reg}}\partial \mathrm{Y}_{reg} = \beta\_\mathrm{Income\_reg} \times \frac{1}{Income}\partial Income$ → $\beta\_\mathrm{Income\_reg} = \frac{\partial \mathrm{Y}_{reg}}{\mathrm{Y}_{reg}} \times \frac{Income}{\partial Income} =$ e_{Income}

The negative sign of the *Cost* variable implies that driving cost has a negative effect on car usage. Its coefficient can be interpreted as the elasticity of car usage with respect to driving cost. It is found that a 10% increase in the driving cost leads to a 5.28% decrease in household annual mileage. The effect of driving cost on household mileage is in line with what has been found in previous studies. As for the cost elasticity value itself, it is larger than estimates in the literature, such as 0.45 and 0.18 reported by Liu (2010) on data from 2001 and 2009, respectively, and 0.26 by Holder (2013). Nevertheless, because these estimates were acquired for developed countries, the difference is expected.

The coefficient of the *CLV* latent variable is positive, indicating that as expected, a positive attitude towards the car has a positive effect on the kilometers driven per year per household.

Finally, the coefficient of the error component correlating the decision of owning two cars with their corresponding usage is significant at the 95% level of confidence whereas the coefficient of the error component correlating the decision of owning one car with its corresponding usage is not significant. This signifies that the car ownership and usage decisions are jointly correlated and should be modeled simultaneously.

5.2. Forecasting

This section develops and analyzes policies for reducing car ownership and use levels. Five policies are tested in terms of reduction in kilometers traveled, emissions, fuel consumption and heat generated. The procedure for quantifying these parameters is first elaborated. Then each policy is discussed according to the estimated results.

5.2.1. Procedure

The impact of the suggested policy scenarios on the reduction in car ownership and usage is assessed by the sample enumeration method which utilizes sample predictions to make inferences about the population. In order to account for the unrepresentativeness of the sample household size distribution, weights were applied to the categories of household sizes. The population household size distribution throughout the study area was obtained from the Living Conditions Survey conducted in 2007 by the Central Administration of Statistics (CAS). Weights were then calculated for every household in the sample to match the household size distributions in Municipal Beirut and outside Municipal Beirut, respectively. Weights could have been calculated to match other population characteristics as well; however, there are no joint distributions available at the population level for multiple population characteristics (e.g. household size by household income). Furthermore, we assume that the distribution of households by size has not changed significantly since 2007.

Based on the calculated weights, which are provided in Table C1 Appendix C, the predicted distributions of car ownership levels and the total household kilometers were calculated for the base case and the suggested policy scenarios. The environmental benefits including reduction in emissions, fuel consumption and heat island effect were also determined. Each calculation step is detailed separately in the following.

5.2.1.1.Weights

The weight associated with an observation in Municipal Beirut from household size category g is:

$$W_{\text{MB,g}} = \frac{\text{Number of households in Municipal Beirut from category g}}{\text{Number of households in the sample in Municipal Beirut from category g}} \tag{27}$$

The weight associated with an observation outside Municipal Beirut from household size category g is:

$$W_{\text{OMB,g}} = \frac{\text{Number of households outside Municipal Beirut from category g}}{\text{Number of households in the sample outside Municipal Beirut from category g}} \tag{28}$$

5.2.1.2. <u>Car Ownership and Usage</u>

In this section we elaborate on how the sample enumeration method was used to calculate the predicted car ownership levels and usage.

First, car ownership levels were obtained based on the two steps below:

1- Calculate the number of households in the population, $\widehat{N}_{\text{T}}(i)$, predicted to choose car ownership level i. The population refers to all households living in the study area considered in this thesis.

$$\widehat{N}_{\text{T}}(i) = \sum_{n=1}^{N_s} P(i|\text{X}_n;\beta)\, w_n \tag{29}$$

Where,

$P(i|\text{X}_n;\beta)$ is the probability of household n choosing alternative i, and N_s is the number of households in the sample

$$w_n = \sum_{\text{g}} W_{MB,\text{g}} I_{n,MB,\text{g}} + \sum_{\text{g}} W_{OMB,\text{g}} I_{n,OMB,\text{g}} \tag{30}$$

$$I_{n,MB,\text{g}} = \begin{cases} 1, & \text{if household } n \text{ is in MB and belongs to household category g} \\ 0, & \text{otherwise} \end{cases}$$

$$I_{n,MB,\text{g}} = \begin{cases} 1, & \text{if household } n \text{ is outside MB and belongs to household category g} \\ 0, & \text{otherwise} \end{cases}$$

2- Calculate the share of the households in the population predicted to choose car ownership level *i:*

$$\widehat{W}_{\mathrm{T}}(i) = \frac{\widehat{N}_T\,(i)}{N_T} \tag{31}$$

Where N_T is the number of households in the population.

Second, the total household car kilometers (THHK) generated by households living in the study area were calculated as follows:

$$\text{THHK} = \sum_{n=1}^{N_s} \hat{Y}_{n,reg}\, w_n \tag{32}$$

Where $\hat{Y}_{n,reg}$ is the predicted total annual household kilometers for household *n*. Finally, the average total annual household kilometers per household were calculated as follows:

$$\text{Average kilometers / hh} = \frac{\text{THHK}}{N_T} \tag{33}$$

5.2.1.3. Vehicular Emissions

Vehicular emissions, namely carbon monoxide (CO), and hydrocarbons (HC), were obtained for the base case and for each scenario based on the total vehicle kilometers traveled. This was done by multiplying distances traveled by car emission factors. The latter have been estimated by Sbayti et al. (2002) for Beirut based on the vehicle fleet. This way, the type and amount of fuel used, which are important determinants of CO and HC emissions, were accounted for. The equations of the emission factors, expressed in g/vehicle-mile, are in function of the speed *S* in miles per hour:

$$\text{CO: EF} = 330.37\ S^{-1.0411} \tag{34}$$

$$\text{HC: EF} = 35.492\ S^{-0.9406} \tag{35}$$

Since the car speed varies by time of day, a weighted average emissions approach was adopted in this thesis, where emission factors were calculated for peak hours, peak shoulder hours, and free flow hours. The emissions in each time period were then weighted by the percentage of traffic volume in each period.

$$\begin{aligned}\text{CO emissions (g)} = {} & 330.37\ S_{peak}^{-1.0411} \times (\text{\% of traffic in peak hours}) \times \text{THHK} \\ & + 330.37\ S_{peak\ shoulder}^{-1.0411} \times (\text{\% of traffic in peak shoulder hours}) \times \text{THHK} \\ & + 330.37\ S_{free\ flow}^{-1.0411} \times (\text{\% of traffic in free flow hours}) \times \text{THHK}\end{aligned} \tag{36}$$

$$\begin{aligned}\text{HC emissions (g)} = {} & 35.492\ S_{peak}^{-0.9406} \times (\text{\% of traffic in peak hours}) \times \text{THHK} \\ & + 35.492\ S_{peak\ shoulder}^{-0.9406} \times (\text{\% of traffic in peak shoulder hours}) \times \text{THHK} \\ & + 35.492\ S_{free\ flow}^{-0.9406} \times (\text{\% of traffic in free flow hours}) \times \text{THHK}\end{aligned} \tag{37}$$

Note that THHK should be measured in miles in order for the above equations to apply.

The percentage of traffic volume throughout the day in GBA was obtained from the IBI Group / Team International (2009) study on revitalization of public transportation. As for speed during these time periods, several sources were considered. First, the Ministry of Environment (MoE, 2005) states that the speed in the peak hour equals 10km/h. Second, the calculations in the Beirut Mobility Study Report show that the average speed in the peak hour ranges between 9.4 and 13.5 km/h (Al Hajj Hassan and Abou Zeid, 2016). An assumption within the range of these values was adopted: it corresponds to a speed of 12km/hr during peak hours, i.e. S_{peak} = 7.46 mph. Regarding peak shoulder hours and free flow hours, the assumed speeds were 30 km/hr and 40 km/hr, respectively. Therefore, $S_{peak\ shoulder}$ = 18.64 mph and $S_{free\ flow}$ = 24.85 mph.

For a given policy, reductions in emissions can then be found. For example, CO emissions reduction in response to Policy X can be calculated as:

$$CO\ emissions\ reduced\ (\text{g}) = CO_{Base\ Case}(\text{g}) - CO_{Policy\ X}(\text{g}) \tag{38}$$

5.2.1.4. Fuel Consumption

Fuel consumption, calculated based on the total household kilometers traveled THHK and the average fuel efficiency of the car (assumed to be 170 km per 20 liters according to Danaf et al., 2014) was obtained for both the base case and the proposed scenarios:

$$\textit{Fuel consumption (liters)} = \textit{THHK (km)}\ x\ \frac{1}{Car\ fuel\ efficiency} \tag{39}$$

Reduction in fuel consumption in response to Policy X was calculated as:

$$\textit{Reduction in fuel consumption (liters)} = \tag{40}$$

$$\textit{Fuel consumption (liters)}_{Base\ Case} - \textit{Fuel consumption (liters)}_{Policy\ X}$$

5.2.1.5. Heat Generated

Heat generated due to travel was calculated based on the calorific value of fuel and the fuel consumption obtained by equation 39 for the base case and the policies being tested. Using the density of fuel (0.74 *kg/l* according to Balaji et al., 2017), the amount of fuel consumed was converted from liters to ktonnes. The heat generated was calculated based on the below equation:

$$\textit{Heat generated (TJ)} = \textit{Fuel Consumption (ktonnes)} \times \textit{calorific value of fuel (TJ/ktonnes)} \quad (41)$$

Where, *TJ* = Terajoule, and the calorific value of fuel is equal to 44.8 TJ/ktonnes (MoE et. al, 2015).

Next, the reduction in heat as a result of Policy X was calculated as:

$$\textit{Reduction in heat generated (TJ)} = \textit{Heat generated (TJ)}_{\textit{Base Case}} - \textit{Heat generated (TJ)}_{\textit{Policy X}} \quad (42)$$

5.2.1. Policies

Five policies which target different facets of urban planning and transportation are tested in this section. Two of them tackle public transportation improvement, two others examine the effects of land use development, and the last one focuses on the impact of fuel cost.

5.2.2.1. Policy 1: Changes in the Accessibility of Current Bus Services

Policy 1 aims at improving bus service accessibility for the existing fleet. This is done through reducing the distance between the household and the nearest bus line, denoted as "Distance_Bus" in the model. Even though subjective distance was used in the model, we assumed that subjective distance is correlated with actual distance to the nearest bus line. In fact, the correlation coefficient between the two for the given sample is 0.51.

Three scenarios are tested:

- Scenario 1: for a given household in the sample, the Distance_Bus remains the same if it is already smaller than 500 m, and becomes 500 m otherwise.
- Scenario 2: for a given household in the sample, the Distance_Bus remains the same if it is already smaller than 250 m, and becomes 250 m otherwise.
- Scenario 3: for a given household in the sample, the Distance_Bus remains the same if it is already smaller than 150 m, and becomes 150 m otherwise.

The predicted distributions of car ownership levels are summarized in Table 19. They point at little variation across all levels of car ownership.

Table 19: Predicted car ownership levels in response to Policy 1

	Zero-car hh	One-car hh	Two-car hh
Base Case	8.67%	50.64%	40.69%
Scenario 1 (Distance_Bus max 500)	8.76%	50.69%	40.56%
Scenario 2 (Distance_Bus max 250)	8.91%	50.72%	40.38%
Scenario 3 (Distance_Bus max 150)	9.00%	50.72%	40.28%

One limitation of the model is its inability to predict changes in kilometers traveled in response to changes in public transportation accessibility. Consequently, reduction in emissions, fuel consumption, and heat generated remain unaltered in the context of Policy 1. Given the very limited reduction in car ownership levels, the reduction in emissions and fuel consumption is expected to be limited as well.

5.2.1.2. Policy 2: Major Changes in Bus Service Provision

Policy 2 considers improvements in public transportation services beyond just accessibility. These could result from a single factor or a combination of factors related to the user experience, notably comfort, reliability and safety or to the travel time of the bus (such as a major reduction in travel time due to operating on dedicated bus lanes).

The model accounts for these major changes by modifying the values of the attitudes BLV and CLV. It is assumed that major improvements in bus service provision would result in a more positive attitude towards the bus and possibly a more negative attitude towards the car (particularly if the bus travel time becomes smaller than the car travel time). Using changes in attitudes as a proxy for major public transportation improvements is supported to some extent by findings of El Zarwi (2017) which indicate that travel mode preferences and lifestyles, denoted by the latent variable "modality styles", change over time in response to major changes in the public transportation system. Indeed, he found that after a major change in the system, individuals are more likely to shift to a modality style that includes public transportation in its choice set compared to a modality style that only includes driving in its choice set; the probabilities obtained are 32% and 25%, respectively. These outcomes were developed for a case study of Santiago, Chile, where a complete reform of the public transport took place. A Hidden Markov model was used to estimate the evolution of individual preferences – modality styles – over time. It is important to note that these modality styles differ from the attitudinal latent variables incorporated in our model. Nevertheless, the evolution of modality points at changes in attitudes with regards to improvements in public transport.

In the survey, attitudes and perceptions were measured on a scale of 1 to 5. Therefore, their values (which are computed from their structural equations, expressed in terms of explanatory variables such as household income and proximity to bus) are increased or decreased using this scale. Note that the value of the CLV latent variable is not decreased beyond two units assuming that the attitude of respondents with a high degree of attachment to the car cannot be completely undermined. In addition, given that these attitudes were measured using a 5-point scale, some cases require a restriction on the number of units removed or added.

Three scenarios are analyzed:

- Scenario 1: Increase the value of the BLV latent variable by one unit, and decrease the value of the CLV latent variable by one unit.
- Scenario 2: Increase the value of the BLV latent variable by two units, and decrease the value of the CLV latent variable by two units.
- Scenario 3: Increase the value of the BLV latent variable by three units, and decrease the value of the CLV latent variable by two units.

Table 20 contains the distribution of households according to the values of the CLV and BLV attitudinal latent variables, under the base case and the three scenarios tested. Base case situation shows that the majority of households are more inclined towards the car mode as the value of the CLV latent variable for 97.87% of households is above 3 - which translates into a favorable attitude towards the car mode. On the other hand, only 28.28% of households have a favorable attitude towards the bus mode – the value of BLV latent variable is above 3. Based on the aforementioned assumption, major improvements to the public transportation system can lead to changes in attitudes towards the car and the bus mode. Therefore, the percentage of households with a favorable attitude towards the bus – the value of the BLV latent variable is above 3 – increases to 75.15%, 94.61%, and 99.92% in scenarios 1, 2, and 3, respectively. At the same time, the percentage of households with favorable attitude towards the car – the value of the CLV latent variable is above 3 – decreases to become 42.34% in scenario 1, and 0.09% in scenarios 2 and 3.

Table 20: Distribution of households based on the values of the CLV and BLV latent variables

CLV				
Attitude Value	1 – 2	2 – 3	3 – 4	4 – 5
Base Case	0%	2.12%	55.53%	42.34%
Scenario 1	2.12%	55.53%	42.25%	0.09%
Scenario 2	57.66%	42.25%	0.09%	0%
Scenario 3	57.66%	42.25%	0.09%	0%
BLV				
Attitude Value	1 – 2	2 – 3	3 – 4	4 – 5
Base Case	24.85%	46.87%	21.24%	7.04%
Scenario 1	5.39%	19.46%	46.87%	28.28%
Scenario 2	0.08%	5.31%	19.46%	75.15%
Scenario 3	0%	0.08%	5.31%	94.61%

The predicted distributions of car ownership and average usage levels are summarized in Table 21. The percentage of households owning zero cars increases by 4.61%, 9.94%, and 13.45% in scenarios 1, 2, and 3, respectively, when compared to the base case. In parallel, the percentage of households owning two or more cars decreases by 5.88%, 10.88%, and 13.59% in scenarios 1, 2, and 3, respectively, when compared to the base case. These results are expected, yet the percentage of households owning one car slightly fluctuates across the three scenarios. This is probably due to the fact that the shift from owning one car to none is compensated by a shift from two or more cars to one. Furthermore, the kilometers traveled per household decrease in all scenarios, the most significant reduction, with respect to the base case, being 28.09% under scenarios 2 and 3. The same value of kilometers traveled is predicted for scenarios 2 and 3 because the *CLV* latent variable was modified in a similar manner.

It is worth noting however that under policy 2, scenario 1 is the most realistic; in scenarios 2 and 3, the CLV latent variable for 99.91% of households is below 3 indicating an unfavorable attitude towards the car.

Table 21: Predicted car ownership levels and usage in response to Policy 2

	Zero-car hh	One-car hh	Two-car hh	Average kilometers/hh	% Change (in Ave. kms/hh)
Base Case	8.67%	50.64%	40.69%	13,884.74	
Scenario 1	13.28%	51.91%	34.81%	11,772.65	15.21
Scenario 2	18.61%	51.58%	29.81%	9,984.85	28.09
Scenario 3	22.12%	50.78%	27.10%	9,984.85	28.09

The environmental benefits induced by Policy 2 are summarized in Table 22. It is clear that scenarios 2 and 3 which result in fewer kilometers per household per year compared to scenario 1 contribute to a larger extent to the reduction of emissions, fuel consumption and heat generation. Nonetheless, all scenarios under Policy 2 would potentially alleviate emissions, fuel consumption and heat generation by 15% to 28%.

Table 22: Environmental benefits induced by Policy 2

	Emissions (ton/year)		Fuel consumption (liters/year)	Heat (TJ/year)
	CO	HC		
Base level	*89,380*	*11,910*	*514,134,345*	*17,044*
Scenario 1	75,784	10,098	435,926,244	14,452
Scenario 2	64,275	8,565	369,726,295	12,257
Scenario 3	64,275	8,565	369,726,295	12,257

5.2.1.3.Policy 3: Changes in Land Use Development

Policy 3 simulates increased land development by means of the MDI. This was done by assigning to a certain TAZ the lowest MDI value greater than its own out of the MDI values of its surrounding TAZs. Thematic maps illustrating these modifications are shown in Figures 8 and 9, and the corresponding numerical values are provided in Table C2 in Appendix C.

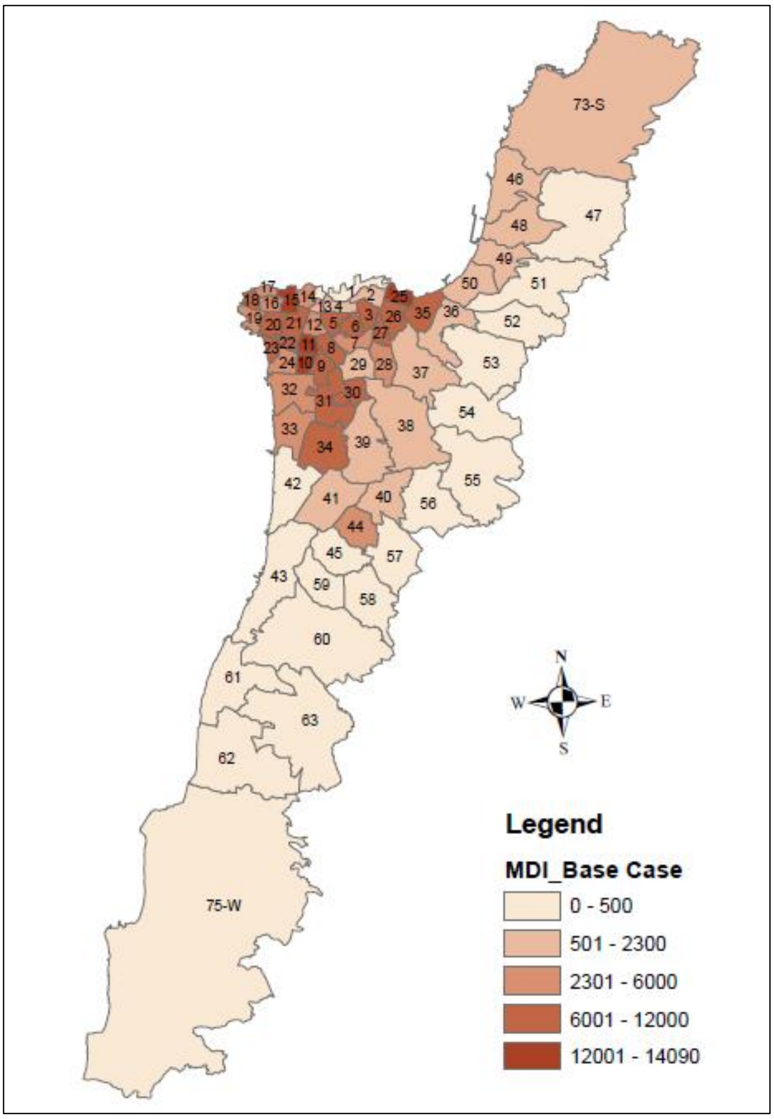


Figure 8: MDI values in the base case

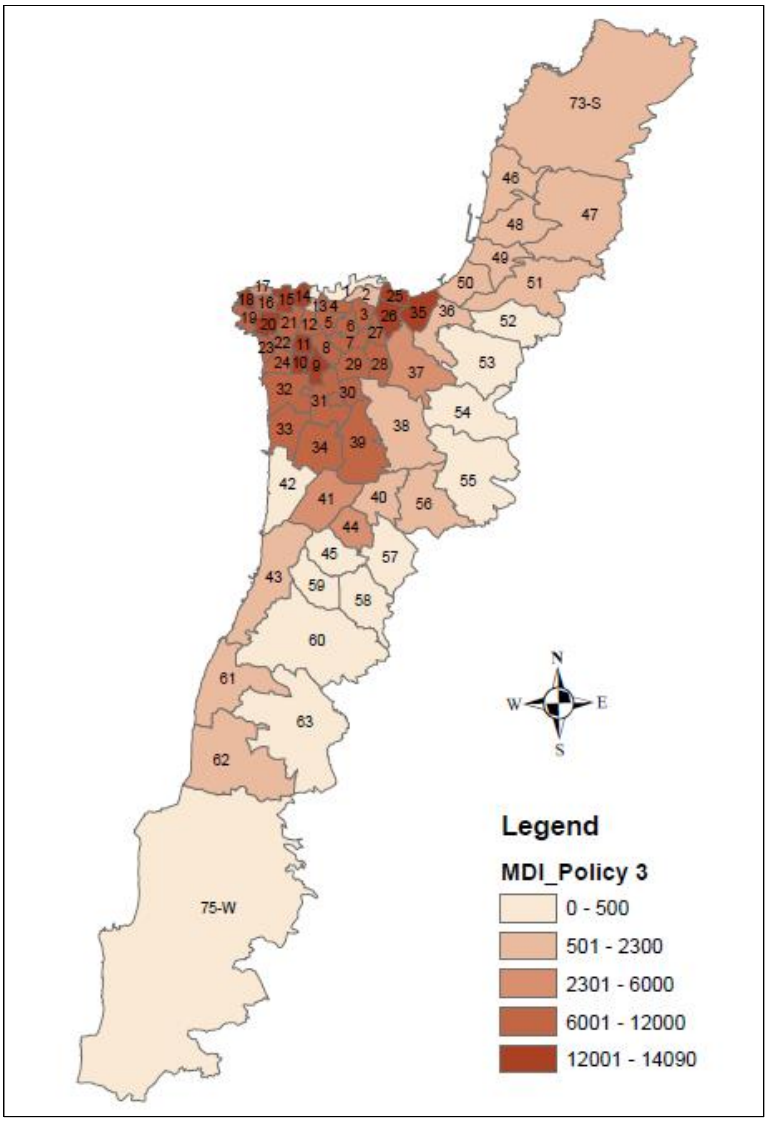


Figure 9: MDI values in Policy 3

The results of the model application are presented for Municipal Beirut and outside Municipal Beirut separately due to differences in the number of households and their characteristics between the two areas. They do not comprise car ownership levels since the discrete sub-model does not draw a relationship between MDI and the number of cars owned. Consequently, Table 23 contains the average kilometers traveled per household for the base case and Policy 3. Table 24 shows the total reduction in kilometers for each of the two areas as well as for the study area as a whole. It is clear that Policy 3 has a limited impact on car usage. The change is as low as 2.16% in

Municipal Beirut and 2.77% outside Municipal Beirut. Note that the total reduction in kilometers is more prominent outside Municipal Beirut since it covers a larger number of households.

Table 23: Predicted car usage in response to Policy 3

	Avg. kilometers/hh	% Change (in Ave. kms/hh)
Municipal Beirut		
Base Case	14,371.54	
Policy 3	14,068.28	2.16%
Outside Municipal Beirut		
Base Case	13,680.92	
Policy 3	13,312.29	2.77%

Table 24: Total reduction in kilometers in response to Policy 3

Region	Base Case	Policy 3	Reduction (km)	Total reduction (km)
Municipal Beirut	1,334,978,981	1,306,809,047	28,169,934	109,952,125
Outside Municipal Beirut	3,035,162,952	2,953,380,762	81,782,191	

The environmental benefits were computed on the basis of the total kilometers reduced. The results are shown in Table 25 below. A decrease of 2.5% in emissions, fuel consumption, and heat generation is expected in case Policy 3 is in action.

Table 25: Environmental benefits induced by Policy 3

	Emissions (ton/year)		Fuel consumption (liters/year)	Heat (TJ/year)
	CO	HC		
Base level	*89,380*	*11,910*	*514,134,345*	*17,044*
Policy 3	87,131	11,610	501,198,801	16,616

5.2.1.4.Policy 4: Major Changes in Land Development

Policy 4 adopts a more aggressive transformation of MDI values across three regions of the study area: Municipal Beirut, Beirut inner suburbs and Beirut outer suburbs. This categorization is based on the assumption that individuals exhibit different behavior in each region while being homogenous within each. The grouping of TAZs is shown in Table 26.

Table 26: Categorization of regions inside the study area

Greater Beirut Area	TAZs
Municipal Beirut	1-24
Beirut Inner Suburbs	25-45
Beirut Outer Suburbs	46-63 including 73-S and 75-W

The TAZs of Municipal Beirut preserved their initial MDI values. A different procedure was employed for the two remaining areas. It consists of assigning the highest MDI value among all TAZs in a region to all the other TAZs within the region. Therefore, each of the inner and outer suburbs has only one value of the mixed density index under this policy. Note that the TAZ that contains the Airport maintained its original MDI value. Thematic maps prior to and post Policy 4 are provided in Figures 10 and 11, and the corresponding numerical values are provided Table C2 in Appendix C.

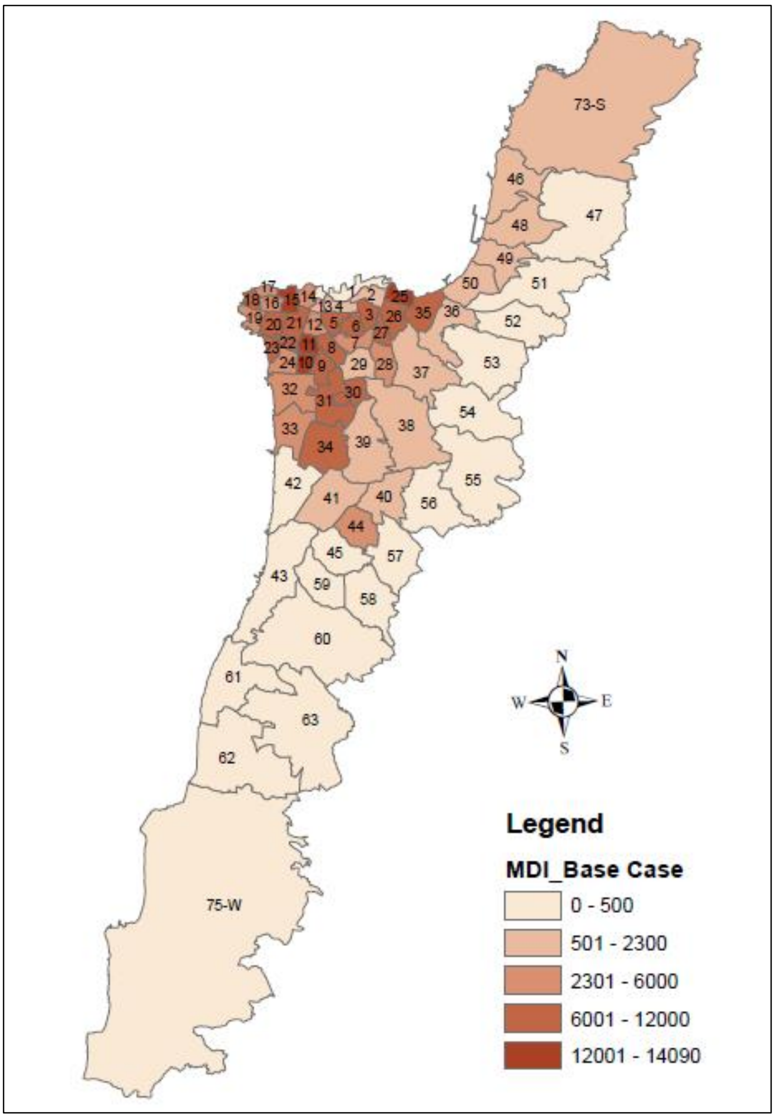


Figure 10: MDI values before applying Policy 4

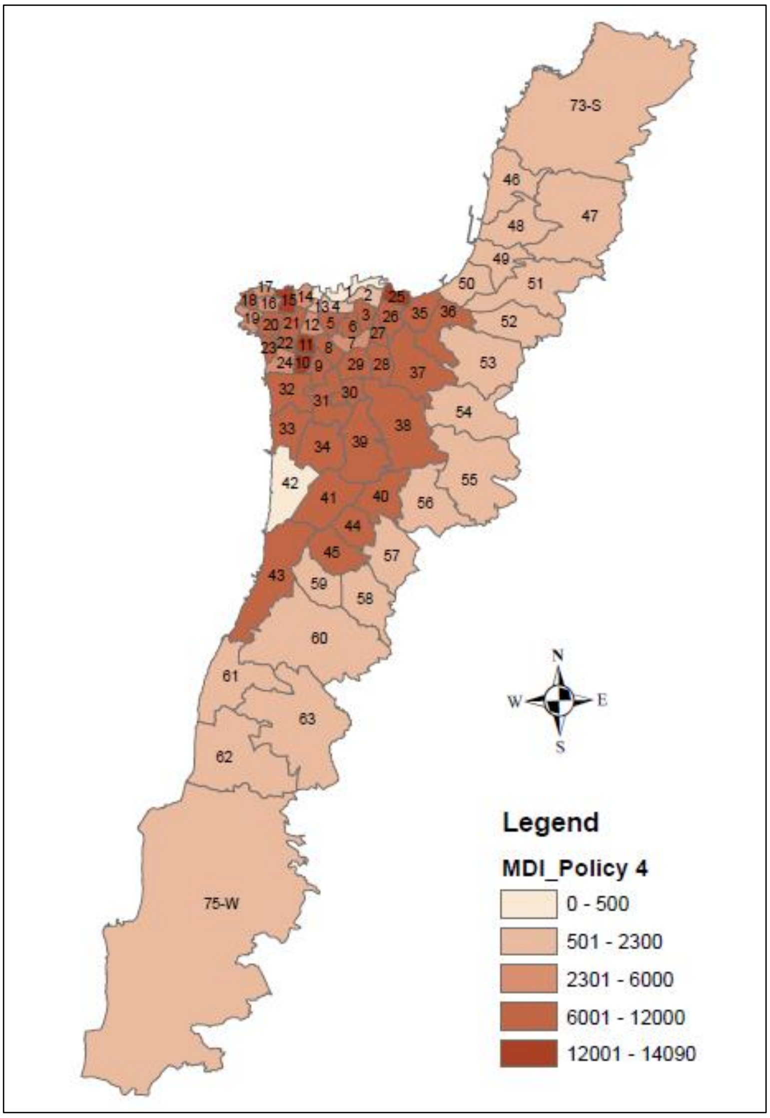


Figure 11: MDI values in Policy 4

Table 27 presents the results for two regions: Municipal Beirut and the inner and outer suburbs jointly (referred to subsequently as outside Municipal Beirut). The merging of these two regions was performed in order to better assimilate the outcomes with respect to the other policies that distinguish between Municipal Beirut and outside Municipal Beirut. Table 28 shows the total reduction in vehicle kilometers traveled in response to Policy 4. Clearly, no change is witnessed in Municipal Beirut since the MDI values were not modified. However, a reduction of 7.08% in the average kilometers traveled per household is observed outside Municipal Beirut.

Table 27: Predicted car usage in response to Policy 4

Municipal Beirut		
	Avg. kilometers/hh	% Change (in Ave. kms/hh)
Base Case	14,371.54	
Policy 4	14,371.54	0%
Outside Municipal Beirut		
	Avg. kilometers/hh	% Change (in Ave. kms/hh)
Base Case	13680.92	
Policy 4	12,776.88	7.08%

Table 28: Total reduction in kilometers in response to Policy 4

Region	Base Case	Policy 4	Reduction (km)	Total reduction (km)
Municipal Beirut	1,334,978,981	1,334,978,981	0	200,564,404
Outside Municipal Beirut	3,035,162,952	2,834,598,548	200,564,404	

The environmental benefits associated with Policy 4 are given in Table 29. They indicate a decrease of 4.58% in emissions, fuel consumption, and heat generation.

Table 29: Environmental benefits induced by Policy 4

	Emissions (ton/year)		Fuel consumption (liters/year)	Heat (TJ/year)
	CO	HC		
Base level	*89,380*	*11,910*	*514,134,345*	*17,044*
Policy 4	85,278	11,363	490,538,533	16,262

5.2.1.5.Policy 5: Change in Fuel Cost

Policy 5 attempts discouraging car usage by means of increasing the fuel cost. Accordingly, the VAT was considered to increase from 11% (the current situation according to the Ministry of Energy and Water) to 15%. Table 30 contains the results solely for kilometers traveled as car ownership is not correlated to fuel cost in the model. Table 31 shows the total reduction in household kilometers in the study area. This policy would reduce the average car usage by 1.89%.

Table 30: Predicted car usage in response to Policy 5

Municipal Beirut		
	Av. kilometers/hh	% Change (in Ave. kms/hh)
Base Case	14,371.54	
Policy 5	14,104.92	1.89%
Outside Municipal Beirut		
	Av. kilometers/hh	% Change (in Ave. kms/hh)
Base Case	13,680.92	
Policy 5	13,427.11	1.89%

Table 31: Total reduction in kilometers in response to Policy 5

Region	Base Case	Policy 5	Reduction (km)	Total reduction (km)
Municipal Beirut	1,310,211,999	1,334,978,981	24,766,983	81,076,312
Outside Municipal Beirut	2,978,853,622	2,834,598,548	56,309,330	

The environmental benefits associated with Policy 5 are given in Table 32. They indicate a decrease of 1.85% in emissions, fuel consumption, and heat generation.

Table 32: Environmental benefits induced by Policy 5

	Emissions (ton/year)		Fuel consumption (liters/year)	Heat (TJ/year)
	CO	HC		
Base level	*89,380*	*11,910*	*514,134,345*	*17,044*
Policy 5	87,721	11,689	504,595,955	16,728

5.2.2. Summary

A summary table that contains the expected results in terms of reduction of annual emissions, fuel consumption and heat generation is provided below.

Table 33: Environmental benefits induced by all policies

Policy		Emissions (ton/year)		Fuel consumption (liters/year)	Heat (TJ/year)
		CO	HC		
Base level		*89,380*	*11,910*	*514,134,345*	*17,044*
Policy 1		-	-	-	-
Policy 2	Scenario 1	75,784	10,098	435,926,244	14,452
	Scenario 2	64,275	8,565	369,726,295	12,257
	Scenario 3	64,275	8,565	369,726,295	12,257
Policy 3		87,131	11,610	501,198,801	16,616
Policy 4		85,278	11,363	490,538,533	16,262
Policy 5		87,721	11,689	504,595,955	16,728

Policy 2, which suggests major enhancements to the public transportation system, is the most promising as it generates the highest environmental benefits in the three scenarios due to a substantial decrease in car usage. In fact, there is a concrete plan for such an improvement: the proposal of a Bus Rapid Transit project was completed in 2017. It consists of linking the northern region to the capital through dedicated lanes of new fuel-efficient buses as well as providing service within Beirut along an Outer Ring and an Inner Ring. The BRT buses operate with a design speed of 80 km/hr on the coastal highway and 50 km/hr within Beirut (CDR and World Bank, 2017). This service would significantly reduce travel time and travel cost along these road segments which suffer from severe congestion. The traffic assessment of the project anticipates a significant modal shift in favor of the BRT system. Consequently, harmful emissions including CO and HC, would be lessened. Ideally, the current bus fleet covering this region would be employed as feeders for the BRT; however, there are no clear strategies for this regard yet. The BRT project would require the collaboration of multiple authorities and the issuance of regulations associated with its construction, implementation, monitoring, and environmental and social aspects.

There are a few limitations to the approach used for the assessment of the environmental benefits. The first one lies in disregarding the type and age of the passenger car fleet as well as the driving patterns in the calculations. The second one concerns the interpretation of the base level emissions. The studies providing data on emissions do not clearly state the methodology followed. Therefore, they cannot be compared to our base level values. The third one is that the emission factors developed by Sbayti et al. (2002) – which are the only source relevant to the context of this thesis – were developed for a vehicular fleet and other trip characteristics that were in effect in 2002, so they are not recent.

On a last note, the heat and the emissions as calculated in the base level are specific to the trips conducted by vehicles of households living in the study area, yet part of these trips (kilometers driven) might have been external trips (outside the study area). Subsequently, the spatial distribution of the heat and the emissions was not considered; a more sophisticated model is required to perform that task. Moreover, the base level calculations do not include emissions and heat induced by vehicles coming from outside the study area.

CHAPTER 6

CONCLUSION

This chapter concludes the thesis. The first section reviews the findings of the research. The second section presents the contributions of the thesis. The third section states the research limitations. Finally, the fourth section suggests directions for future research.

6.1. Summary of Findings

This thesis provided a framework to predict car ownership and usage in car-dominant developing country contexts focusing on the impact of public transportation availability on these travel decisions. A discrete-continuous model that correlates the decision of owning a certain number of cars (discrete sub-model) and usage (continuous sub-model) was estimated. This correlation was achieved by introducing error components which capture the unobserved factors affecting the joint decision. Additionally, the model incorporated a latent variable model for both the discrete and the continuous parts. This type of model allows for a relationship between respondents' attitudes and their choices (number of cars and kilometers driven).

The model was estimated on data from a travel behavior survey conducted with a sample of households in the Greater Beirut area (extended to Jounieh in the north and Jiyeh in the south).

The model results suggest that:

- Car ownership is positively associated with the level of education of the household members, presence of children, number of working adults, and income. However, it is negatively affected by public transportation accessibility as measured through the attitude towards public transportation. In other words, a more favorable attitude towards public transportation, arising partly from better accessibility to public transportation, is associated with lower levels of car ownership.
- Car usage is positively associated with the presence of children, number of working adults, number of household members who work far from residence, and income. Moreover, a positive attitude towards the car increases car usage. Nonetheless, car usage is negatively impacted by driving costs and the MDI index which captures population and employment densities in the neighborhood of a household.

We also aimed at testing the following hypothesis:

The higher the quality and accessibility of public transportation, the less likely it is that households will own more cars and have high vehicle usage, while controlling for socio-economic and demographic characteristics and other built environment attributes.

The model results, specific to bus transport, showed that accessibility has no effect on vehicle usage and that it only influences car ownership through the attitudes towards public transportation; i.e. the effect is indirect, unlike what has been found in previous research studies. This might be justified by the fact that the current public transportation services in Lebanon are largely unregulated and informal, and therefore do not affect households' decision on the number of kilometers to drive. Furthermore, other metrics of public transportation services such as headway, and the number of bus lines in the vicinity of the household do not seem to impact the decisions of car ownership and usage. It is worth mentioning that the other type of public transportation, represented by the "service", was tested for; however, no relationship was found between the latter and the decision of car ownership and usage and was therefore disregarded from the initial stages of the study.

Model estimation was followed by testing five policies for reducing car ownership and use levels that encompass public transportation improvements, increased densities, and higher fuel price.

- Policy 1, which consisted of enhancing the accessibility of the current public transportation system, resulted in minor car ownership changes including a reduction of 0.41% of two plus car households and an increase of 0.33% of zero car households.
- Policy 2, which builds on Policy 1 and suggests further improvements in factors related to user experience or service travel time (captured through more favorable attitude towards public transportation and less favorable attitude towards the car), had the greatest effect on both car ownership and usage. It decreased car ownership and usage by around 14% and 28%, respectively.
- Policy 3, which increases the average MDI values in Municipal Beirut and outside Municipal Beirut by 27.9% and 69.4%, respectively, produced a reduction in kilometers traveled per household of 2.16% and 2.77% in Municipal Beirut and outside Municipal Beirut, respectively.

- Policy 4, which increases the average MDI values outside Municipal Beirut by 186.4%, resulted in a decrease in kilometers traveled per household of 7.08% outside Municipal Beirut.
- Policy 5, which increases VAT on fuel, produced a decrease in kilometers traveled per household of 1.89% in both Municipal Beirut and outside Municipal Beirut.

Under the current situation of public transportation in Lebanon, it is very unlikely that car ownership will be significantly reduced, as confirmed by Policy 1. Major improvements to the service must be implemented in order to achieve lower car ownership levels and usage. Such improvements, which are simulated by Policy 2, would also provide environmental benefits such as a reduction in emissions, fuel consumption and heat generation in the ranges of 15% to 29%. Having that said, we do not find evidence from the collected data that a reduction in both car ownership and usage may be achievable as a result of improvements to the current public transportation system. Another way to reduce car usage is by increasing land development, as simulated by Policies 3 and 4. This can be done by ensuring an adequate job-housing balance in each zone, meaning a fairer distribution of job availabilities. This would result in shorter commute distances, and thus in an increase in the share of non-motorized trips (Cervero, 1988). Moreover, the average total kilometers per household would decrease, leading to a reduction in emissions, fuel consumption and heat generated (as shown by Policies 3 and 4).

6.2. Contributions

This thesis advances the existing literature concerning the effect of public transportation quality on car ownership / use by applying it to a context of informal and unregulated transportation services. As a matter of fact, the numerous studies conducted until now have only examined the relationship between public transportation availability and car ownership / use in cases where the public transportation system is organized. The results reinforce the notion that incremental improvements to low quality public transportation systems are unlikely to result in any noticeable reduction in car ownership and use and their environmental impacts.

The developed model and policy analysis can also be applied in other developing countries with similar public transportation characteristics and lower car ownership rates. Since the policy analysis demonstrated that improving the existing services of public transportation (as simulated in Policy 2) are effective in curtailing car ownership, the model would serve as guidance to these countries. Accordingly, they would plan for a sustainable public transportation system ahead of a significant growth in car ownership that may accompany rising incomes in emerging economies.

6.3. Limitations

There are a few limitations associated with this research. First, the small sample size might have influenced some relationships such as the one between public transportation and car ownership, or the significance of the public transportation measures tested for in the model. Larger samples are needed to validate the conclusions made in this thesis. Second, the mileage predicted by the model is not restricted to being produced within the study area. Therefore, the spatial distribution of the environmental effects (emissions and heat) is not addressed in this thesis. Third, the model does not include explanatory variables beyond those used in the literature, yet car usage could have been further explained by having a better understanding of other variables such as characteristics of non-work travel.

6.4. Recommendations for Future Research

It is recommended that adjustments to the model specification be made. These include drawing a correlation between the *BLV* and the *CLV* attitudes, and incorporating other metrics of public transportation in the model specification such as travel time. The model can also be improved by modeling the choice of car type and accounting for the correlation between the latter and both car ownership and usage. In future prospects, where the public transportation system in Lebanon is improved, the model will eventually have to be recalibrated in order to better capture the effect of public transportation on car ownership and use. Additionally, it would be important to quantify the effects of ridesourcing services, such as Uber, on car ownership and usage in the long term.

APPENDIX A: CAR OWNERSHIP AND USE SURVEY

Survey Description and Consent Form

Hello, my name is [INTERVIEWER'S NAME] from Information International. I am contacting you on behalf of researchers at the American University of Beirut. This research study is being conducted by the Civil Engineering Department to study auto ownership and use decisions of the residents of Greater Beirut as well as the availability of public transportation services. Participants of this research are directly approached by the survey firm to do the interview. Around four hundred participants will take part in this study. The results of this research will be used by researchers and policy makers to suggest improved transportation services in the future.

Your participation should take approximately 30 minutes. Please understand that your participation is completely voluntary: you have the right to choose not to participate or to withdraw anytime without having to give any reason for your withdrawal. Refusal or withdrawal from the study will involve no loss of benefits to which you are otherwise entitled nor will it affect your relationship with AUB or AUBMC. You receive no direct benefits from participating in this research; however, your participation does help researchers better understand auto ownership and use levels. Your participation in this study does not involve any physical or emotional risk to you beyond the risks of daily life.

Participation in this study is completely confidential. Your name or any other identifying information will not be asked, however please note that your home address will be used to study the availability of public transportation in close proximity to your household. For confidentiality purposes, your home address will not be published. A copy of the consent form may be kept with you if you wish.

The collected data from this survey will be stored for a minimum of 3 years on the computer of the principal investigator and the research assistant who will both have access to it. The interview will not be audio recorded.

If you have questions about your rights as a participant, you can contact the AUB Social and Behavioral IRB office at: 01-350000 ext. 5454/5455; and if you have questions about the research study you can contact:

Professor Maya Abou Zeid
Civil and Environmental Engineering
ma202@aub.edu.lb

[NOTE TO INTERVIEWER: ASK TO SPEAK TO THE HEAD OF THE HOUSEHOLD OR AN ADULT WHO KNOWS ABOUT THE CHARACTERISTICS OF EACH CAR IN THE HOUSEHOLD AND HOW MANY KILOMETERS EACH CAR IS DRIVEN PER YEAR ON AVERAGE. IF THERE ISN'T ANYONE AVAILABLE AT THE TIME OF THE INTERVIEW, COME BACK ANOTHER TIME]

Do you voluntarily consent to participate in this survey?

1. Yes
2. No

[NOTE TO INTERVIEWER: IF YES, PROCEED WITH INTERVIEW AND GIVE THE PARTICIPANT A COPY OF THE CONSENT FORM IF HE/SHE ASKS FOR IT. IF NO, THANK RESPONDENT AND TERMINATE THE INTERVIEW.]

Are you Lebanese?

1. Yes
2. No

[NOTE TO INTERVIEWER: IF YES, PROCEED WITH THE INTERVIEW. IF NO, THANK RESPONDENT AND TERMINATE THE INTERVIEW.]

Do you or any member of your household own a red plate?

1. Yes
2. No

[NOTE TO INTERVIEWER: IF THE ANSWER IS YES, THANK RESPONDENT AND TERMINATE THE INTERVIEW]

Have you owned any of your household cars for less than 1 year? Please do not include vehicles of members who usually live somewhere else or just visiting, such as a college student away at school.

1. Yes
2. No

[NOTE TO INTERVIEWER: IF THE ANSWER IS YES, THANK RESPONDENT AND TERMINATE THE INTERVIEW]

Household Address:

Governorate: ………………………………………………………………………………
Caza: ………………………………………………………………………………………
Town/Village: ……………………………………………….…………………………
Neighborhood/Street (if known): ……………………………………………………………
Building: ……………………………………………………………………………………
Nearest intersection: …………………………………………………………………………
Nearest “landmark” (for example: restaurant or pharmacy): ……………………………….

Section 1: Car Ownership and Use Information

The questions in this section ask about the vehicles owned and used by the household members.

1) How many motorized vehicles are owned or available for regular use by all members living in your household? (Including motorcycles and company vehicles). Please do not include vehicles of members who usually live somewhere else or just visiting, such as a college student away at place of education.

0. 0
1. 1
2. 2
3. 3
4. 4
5. 5
6. 6
7. 7
8. 8+

[NOTE TO INTERVIEWER: IF THE ANSWER IS ZERO, GO DIRECTLY TO SECTION 2]

Now we will ask some specific questions about the total number of vehicles reported in the previous question.

<u>Vehicle 1</u>

1.1) What is the type of Vehicle 1?

1. Motorcycle
2. Car

2.1) What is the year of manufacture for Vehicle 1?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.1) What type of fuel does Vehicle 1 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.1) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 1?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.1) How long has Vehicle 1 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.1) On average, how much do you spend on Vehicle 1 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.1) During the past 12 months, how many kilometers was Vehicle 1 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Vehicle 2

1.2) What is the type of Vehicle 2?

1. Motorcycle
2. Car

2.2) What is the year of manufacture for Vehicle 2?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.2) What type of fuel does Vehicle 2 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.2) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 2?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.2) How long has Vehicle 2 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.2) On average, how much do you spend on Vehicle 2 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.2) During the past 12 months, how many kilometers was Vehicle 2 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Vehicle 3

1.3) What is the type of Vehicle 3?

1. Motorcycle
2. Car

2.3) What is the year of manufacture for Vehicle 3?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.3) What type of fuel does Vehicle 3 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.3) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 3?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.3) How long has Vehicle 3 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.3) On average, how much do you spend on Vehicle 3 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.3) During the past 12 months, how many kilometers was Vehicle 3 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Vehicle 4

1.4) What is the type of Vehicle 4?
1. Motorcycle
2. Car

2.4) What is the year of manufacture for Vehicle 4?
1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.4) What type of fuel does Vehicle 4 run on?
1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.4) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 4?
1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.4) How long has Vehicle 4 been owned or available to your household?
1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.4) On average, how much do you spend on Vehicle 4 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.4) During the past 12 months, how many kilometers was Vehicle 4 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Vehicle 5

1.5) What is the type of Vehicle 5?

1. Motorcycle
2. Car

2.5) What is the year of manufacture for Vehicle 5?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.5) What type of fuel does Vehicle 5 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.5) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 5?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.5) How long has Vehicle 5 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.5) On average, how much do you spend on Vehicle 5 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.5) During the past 12 months, how many kilometers was Vehicle 5 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Vehicle 6

1.6) What is the type of Vehicle 6?

1. Motorcycle
2. Car

2.6) What is the year of manufacture for Vehicle 6?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.6) What type of fuel does Vehicle 6 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.6) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 6?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.6) How long has Vehicle 6 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.6) On average, how much do you spend on Vehicle 6 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.6) During the past 12 months, how many kilometers was Vehicle 6 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Vehicle 7

1.7) What is the type of Vehicle 7?

1. Motorcycle
2. Car

2.7) What is the year of manufacture for Vehicle 7?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.7) What type of fuel does Vehicle 7 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.7) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 7?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.7) How long has Vehicle 7 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.7) On average, how much do you spend on Vehicle 7 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.7) During the past 12 months, how many kilometers was Vehicle 7 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

<u>Vehicle 8</u>

1.8) What is the type of Vehicle 8?

1. Motorcycle
2. Car

2.8) What is the year of manufacture for Vehicle 8?

1. 2015-2018
2. 2010-2014
3. 2005-2009
4. 2000-2004
5. 1995-1999
6. 1990-1994
7. 1985-1989
8. 1980-1984
9. 1975-1979
10. 1970-1974
11. Before 1970

3.8) What type of fuel does Vehicle 8 run on?

1. Gasoline
2. Diesel
3. Hybrid
4. Electric
5. I don't know

4.8) What is on average the fuel efficiency in kilometers per tank (20 liters) of Vehicle 8?

1. Less than 120 km/tank
2. 120 – 149 km/tank
3. 150 – 169 km/tank
4. 170 – 199 km/tank
5. 200 – 249 km/tank
6. 250 – 299 km/tank
7. 300 – 399 km/tank
8. 400 km/tank or more
9. I don't know

5.8) How long has Vehicle 8 been owned or available to your household?

1. Between 1 and 5 years
2. Between 6 and 10 years
3. More than 10 years

6.8) On average, how much do you spend on Vehicle 8 per year for costs other than fuel (This includes annual Mecanique fees, repairs and maintenance costs, motor oil costs and insurance costs).

1. US$ 500 or less
2. Between US$ 501 – 750
3. Between US$ 751 – 1,000
4. Between US$ 1,001 – 1,250
5. Between US$ 1,251 – 1,500
6. More than US$ 1,500

7.8) During the past 12 months, how many kilometers was Vehicle 8 driven by all drivers in this household on average?

1. 0 – 2,499 km
2. 2,500 – 4,999 km
3. 5,000 – 7,499 km
4. 7,500 – 9,999 km
5. 10,000 – 12,499 km
6. 12,500 – 14,999 km
7. 15,000 – 17,499 km
8. 17,500 – 19,999 km
9. 20,000 – 24,999 km
10. 25,000 km or more

Section 2: Household Data

The questions in this section are related to your household and household members.

Your answers will help us understand better your mobility choices.

8) Do you own or rent your residence?

1. Own
2. Rent
3. Some other arrangement
4. I don't know
5. I prefer not to answer

9) What kind of housing unit do you currently live in?

1. Apartment
2. Single family house
3. Other, please specify:………………………………

Please provide the following information about yourself and the household members. Please do not include anyone who usually live somewhere else or just visiting, such as a college student away at school. Ordinary housemates/roommates and live-in domestic workers would generally not be considered members of the household.

[NOTE TO INTERVIEWER: IN THE FOLLOWING TABLE, ASK QUESTIONS {13 AND 14} ONLY FOR HOUSEHOLD MEMBERS WHO ARE 18 YEARS OLD OR OLDER.]

	10	11	12	13	14	15
	Relationship to Respondent	**Age group**	**Gender**	**Licensed Driver?**	**Highest degree or level of education completed**	**Occupational status.** You can choose more than one category.
Respondent (A)	0. Respondent	1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:……………………………..	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 1 (B)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:…………………………..	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work

Member 2 (C)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	1. 0 – 17 2. 18 – 29 3. 30 – 39 4. 40 – 49 5. 50 – 59 6. 60 – 69 7. 70 – 79 8. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:……………………………….	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 3 (D)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………………….	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work

Member 4 (E)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………………….	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 5 (F)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………………….	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work

Member 6 (G)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:…………………………………..	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 7 (H)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………………	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work

Member 8 (I)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………………….	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 9 (J)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………………….	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work

Member 10 (K)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:……………………………………	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 11 (L)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:……………………………………	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work
Member 12 (M)	1. Spouse/partner 2. Child 3. Parent 4. Brother/Sister 5. Other relative 6. Non-relative 7. I prefer not to answer	0. 0 – 17 1. 18 – 29 2. 30 – 39 3. 40 – 49 4. 50 – 59 5. 60 – 69 6. 70 – 79 7. 80 and above	1. Male 2. Female	1. Yes 2. No	1. No formal education 2. Less than secondary/high school diploma 3. Secondary/high school diploma (12 years of schooling) 4. Technical or vocational school 5. Some college/university 6. University undergraduate/bachelor degree or equivalent 7. Postgraduate, master's degree, doctorate 8. Other, please specify:………………………..	1. Full-time worker 2. Part-time worker 3. Self-employed 4. Unemployed 5. Full-time student 6. Part-time student 7. Retired 8. Homemaker 9. Unable to work

[NOTE TO INTERVIEWER: QUESTIONS 16.1 TO 17.1 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO THE QUESTION IN COLUMN 15, ROW A (15.A) IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 1. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Respondent

16.1) In which area is your work place/place of education located?

[NOTE TO INTERVIEWER: IF THE RESPONDENT HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/SHE BOTH WORKS AND STUDIES, ASK HIM/HER TO REPORT ABOUT THE WORK PLACE/PLACE OF EDUCATION IN WHICH HE/SHE SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.1.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata

23. UNESCO, Ramlet al-Baida
24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar

60. Aramoun
61. Daouha, Naameh
62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

17.1) What mode of transport do you usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work/university
8. Motorcycle
9. Bicycle
10. N/A: I work from home
11. Other, please specify:…………………………………..

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.A IS 1 OR 2, ASK QUESTION 18.1, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 1. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.1) How flexible is your work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – I arrive when I want to and leave when I want to
2. Partly flexible – I can arrive a bit late but cannot leave before a certain time of day or I have to arrive by a certain time but can leave a bit early.
3. Not flexible – I have to be on time in the morning and cannot leave before a certain time of day, else I would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.2 TO 17.2 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO THE QUESTION IN COLUMN 15, ROW B (15.B) IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 2. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 1

16.2) In which area is Member's 1 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 1 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/PLACE OF EDUCATION IN WHICH MEMBER 1 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.2.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun

61. Daouha, Naameh
62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 1 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.2, OTHERWISE GO TO QUESTION 17.2.1]

17.2) What mode of transport does Member 1 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work/university
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:…………………………………………………

17.2.1) What mode of transport does Member 1 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:………………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.B IS 1 OR 2, ASK QUESTION 18.2, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 2. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.2) How flexible is Member's 1 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.3 TO 17.3 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.C IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 3. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 2

16.3) In which area is Member's 2 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 2 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 2 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.3.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh

62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 2 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.3, OTHERWISE GO TO QUESTION 17.3.1]

17.3) What mode of transport does Member 2 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work/university
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:…………………………………………………………

17.3.1) What mode of transport does Member 2 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:…………………………………………………………

[NOTE TO INTERVIEWER: IF IF THE RESPONSE TO QUESTION 15.C IS 1 OR 2, ASK QUESTION 18.3, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 3. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.3) How flexible is Member's 2 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.4 TO 17.4 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.D IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 4. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 3

16.4) In which area is Member's 3 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 3 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 3 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.4.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida
24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh
62. Damour, Mechref

63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 3 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.4, OTHERWISE GO TO QUESTION 17.4.1]

17.4) What mode of transport does Member 3 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work/university
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………..

17.4.1) What mode of transport does Member 3 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:…………………………………………….

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.D IS 1 OR 2, ASK QUESTION 18.4, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 4. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.4) How flexible is Member's 3 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.5 TO 17.5 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.E IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 5. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 4

16.5) In which area is Member's 4 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 4 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 4 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.5.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun

61. Daouha, Naameh
62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 4 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.5, OTHERWISE GO TO QUESTION 17.5.1]

17.5) What mode of transport does Member 4 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:………………………………………………

17.5.1) What mode of transport does Member 4 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to works/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:………………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.E IS 1 OR 2, ASK QUESTION 18.5, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 5. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.5) How flexible is Member's 4 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day; else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.6 TO 17.6 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.F IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 6. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 5

16.6) In which area is Member's 5 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 5 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 5 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.6.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh

62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 5 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.6, OTHERWISE GO TO QUESTION 17.6.1]

17.6) What mode of transport does Member 5 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:…………………………………………………..

17.6.1) What mode of transport does Member 5 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to works/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:…………………………………………………..

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.F IS 1 OR 2, ASK QUESTION 18.6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 6. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.6) How flexible is Member's 5 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.7 TO 17.7 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.G IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 7. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 6

16.7) In which area is Member's 6 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 6 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 6 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.7.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun

61. Daouha, Naameh
62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 6 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.7, OTHERWISE GO TO QUESTION 17.7.1]

17.7) What mode of transport does Member 6 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………..

17.7.1) What mode of transport does Member 6 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to works/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:……………………………………………..

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.G IS 1 OR 2, ASK QUESTION 18.7, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 7. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.7) How flexible is Member's 6 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.8 TO 17.8 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.H IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 8. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 7

16.8) In which town/city is Member's 7 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 7 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 7 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.8.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun

61. Daouha, Naameh
62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 7 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.8, OTHERWISE GO TO QUESTION 17.8.1]

17.8) What mode of transport does Member 7 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………

17.8.1) What mode of transport does Member 7 usually use to travel to and from work/university?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to works/university
6. Bicycle
7. N/A: He/she lives right next to his/her work/university
8. N/A: He/she works/studies from home
9. Other, specify:……………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.H IS 1OR 2, ASK QUESTION 18.8, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 8. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.8) How flexible is Member's 7 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.9 TO 17.9 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.I IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 9. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 8

16.9) In which town/city is Member's 8 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 8 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 8 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.9.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida
24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh
62. Damour, Mechref

63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 8 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.9, OTHERWISE GO TO QUESTION 17.9.1]

17.9) What mode of transport does Member 8 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………

17.9.1) What mode of transport does Member 8 usually use to travel to and from work place/place of education?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work place/place of education
6. Motorcycle
7. Bicycle
8. N/A: He/she works/studies from home
9. Other, specify:……………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.I IS 1OR 2, ASK QUESTION 18.9, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 9. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.9) How flexible is Member's 8 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.10 TO 17.10 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.J IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 10. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 9

16.10) In which town/city is Member's 9 work place/place of education located?
[NOTE TO INTERVIEWER: IF MEMBER 9 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 9 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.10.1)
Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida
24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh
62. Damour, Mechref

63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 9 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.10, OTHERWISE GO TO QUESTION 17.10.1]

17.10) What mode of transport does Member 9 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………

17.10.1) What mode of transport does Member 9 usually use to travel to and from work place/place of education?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work place/place of education
6. Motorcycle
7. Bicycle
8. N/A: He/she works/studies from home
9. Other, specify:…………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.J IS 1OR 2, ASK QUESTION 18.10, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 10. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.10) How flexible is Member's 9 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTIONS 16.11 TO 17.11 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.K IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 11. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 10

16.11) In which town/city is Member's 10 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 10 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 10 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.11.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida

24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun

61. Daouha, Naameh
62. Damour, Mechref
63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 10 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.11, OTHERWISE GO TO QUESTION 17.11.1]

17.11) What mode of transport does Member 10 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………

17.11.1) What mode of transport does Member 10 usually use to travel to and from work place/place of education?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work place/place of education
6. Motorcycle
7. Bicycle
8. N/A: He/she works/studies from home
9. Other, specify:……………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.K IS 1OR 2, ASK QUESTION 18.11, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 11. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.11) How flexible is Member's 10 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTION 16.12 TO 17.12 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.L IS 1,2,3,5, OR 6, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 12. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

Member 11

16.12) In which town/city is Member's 11 work place/place of education located?
[NOTE TO INTERVIEWER: IF MEMBER 11 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 11 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.12.1)
Municipal Beirut
1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida
24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh
62. Damour, Mechref

63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 11 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.12, OTHERWISE GO TO QUESTION 17.12.1]

17.12) What mode of transport does Member 11 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………

17.12.1) What mode of transport does Member 11 usually use to travel to and from work place/place of education?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work place/place of education
6. Motorcycle
7. Bicycle
8. N/A: He/she works/studies from home
9. Other, specify:……………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.L IS 1OR 2, ASK QUESTION 18.12, OTHERWISE GO TO THE QUESTIONS ABOUT MEMBER 12. IF THERE ARE NO OTHER HOUSEHOLD MEMBERS GO TO QUESTION 19]

18.12) How flexible is Member's 11 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

[NOTE TO INTERVIEWER: QUESTION 16.13 TO 17.13 SHOULD BE ANSWERED ONLY IF THE RESPONSE TO QUESTION 15.M IS 1,2,3,5, OR 6]

Member 12

16.13) In which town/city is Member's 12 work place/place of education located?

[NOTE TO INTERVIEWER: IF MEMBER 12 HAS MORE THAN ONE WORK PLACE/PLACE OF EDUCATION OR IF HE/ SHE BOTH WORKS AND STUDIES, ASK THE RESPONDENT TO REPORT ABOUT THE WORK PLACE/ PLACE OF EDUCATION IN WHICH MEMBER 12 SPENDS THE MOST AMOUNT OF TIME]

1. Municipal Beirut
2. Suburban area within Greater Beirut
3. Outside Greater Beirut

[ACCORDING TO THE RESPONDENT'S CHOICE, ASK HIM/HER TO CHOOSE THE SPECIFIC AREA FROM BELOW]

16.13.1)

Municipal Beirut

1. Port
2. Mar Mikhael, Khodr
3. Geitawi, Karm el-Zeitoun
4. Gemmayzeh, Saifi, Remeil, Tabaris
5. Nasra, Furn al-Hayek, Monot, Sodeco
6. Achrafieh, Mar Mitr, Sassine
7. Sioufi, Aadlieh, Hotel Dieu
8. Ras al-Nabaa, Mathaf, Badaro
9. Horsh, Qasqas, Chatila
10. Tareek al-Jdideh, Fakhani
11. Mazraa, Bourj Abi Haidar
12. Basta Faouka, Basta Tahta
13. Baladieh, Maarad, Riad al-Solh
14. Serail, Minet al-Hosn
15. Ain Mreisseh, al-Zarif
16. Hamra, Wardieh
17. AUB/IC campuses
18. Manara, Jal al-Bahr
19. Rawcheh, Qoreitem
20. Snoubra, Munla, Verdun
21. Moussaitbeh, Zaidanieh, Batrakieh
22. Tallet al-Khayat, Wata
23. UNESCO, Ramlet al-Baida
24. Mar Elias, Dar Mouallimeen

Suburban area within Greater Beirut

25. Bourj Hammoud (North), Dora
26. Bourj Hammoud (South), Nabaa
27. Sin el-Fil
28. Jisr al-Bacha
29. Furn al-Chebbak, Ain al-Roummaneh
30. Chiah
31. Ghobeiry, Haret Hreik
32. Jnah, Bir Hassan, Marriott
33. Ouzai
34. Bourj Brajneh
35. Bouchrieh
36. Jdeideh, Sid Bouchrieh
37. Dekwaneh, Mkalles
38. Hazmieh, Fayadyeh, Baabda
39. Haddath, Laylakeh
40. KfarChima, Boutchay
41. Hay el-Sellom
42. Airport
43. Khaldeh
44. Choueifat
45. Deir Koubel
46. Dbayeh, Aoukar, Haret El Bellan
47. Rabieh, Raboueh, Ain Aar
48. Naccache, Tellel Srour
49. Antelias, Haret El Ghouarneh
50. Jal al-Deeb, Zalka, Deir Salib
51. Bsalim, Nabay, Baikout
52. Roumieh
53. Ain Saade, Fanar
54. Mansourieh, Deychounieh
55. Jamhour, Bsous
56. Wadi Chahrour, Bdadoun
57. Ain Anoub, Bsaba
58. Bchamoun, Sarahmoul
59. Yanar
60. Aramoun
61. Daouha, Naameh
62. Damour, Mechref

63. Baaourta, Dakkoun

Outside Greater Beirut

64. Aley, Souk el-Gharb
65. Bhamdoun
66. Sofar, Charoun
67. Ain Dara, Ain Zhalta
68. Aaraiya, Kahaleh
69. Baalchmay
70. Ras el-Harf, Krayeh
71. Bikfaya, Broummana, Ras el-Metn
72. Hammana, Falougha
73. Tabarja, Safra, Ghadras
74. Jounieh, Kaslik, Jeita
75. Baskinta
76. Chouf, Baakline, Chhime
77. Saadiyat, Jiyeh, Wadi Zeini
78. Bekaa
79. Saida and the South
80. Jbeil, Tripoli and the North

[NOTE TO INTERVIEWER: IF MEMBER 12 IS ABOVE 18 YEARS OLD AND IS A LICENSED DRIVER, GO TO QUESTION 17.13, OTHERWISE GO TO QUESTION 17.13.1]

17.13) What mode of transport does Member 12 usually use to travel to and from work place/place of education?

1. Driving private vehicle (alone)
2. Driving private vehicle with other passengers in the vehicle
3. Dropped off (by family member, friend, colleague, etc.)
4. Bus/van
5. Service
6. Private taxi
7. Walking all the way from residence to work place/place of education
8. Motorcycle
9. Bicycle
10. N/A: He/she works/studies from home
11. Other, specify:……………………………………………

17.13.1) What mode of transport does Member 12 usually use to travel to and from work place/place of education?

1. Dropped off (by family member, friend, colleague, etc.)
2. Bus/van
3. Service
4. Private taxi
5. Walking all the way from residence to work place/place of education
6. Motorcycle
7. Bicycle
8. N/A: He/she works/studies from home
9. Other, specify:……………………………………………

[NOTE TO INTERVIEWER: IF THE RESPONSE TO QUESTION 15.M IS 1OR 2, ASK QUESTION 18.13]

18.13) How flexible is Member's 12 work arrangement in terms of arrival time to work and departure time from work?

1. Completely flexible – He/she arrives when he/she wants to and leaves when he/she wants to.
2. Partly flexible – He/she can arrive a bit late but cannot leave before a certain time of day or he/she has to arrive by a certain time but can leave a bit early.
3. Not flexible – He/she has to be on time in the morning and cannot leave before a certain time of day, else he/she would be penalized.

19) How likely are you or any of your household members to buy a new vehicle in the next 6 to 12 months (even if there are one or more vehicles in your household already)?

1. Very unlikely
2. Somewhat unlikely
3. Undecided
4. Somewhat likely
5. Very likely

20) In case you or any of your household members buys a new vehicle, what would you do with your current household vehicles?

1. Currently we do not have any vehicle in our household
2. We might sell one when we buy a new vehicle
3. We might sell one within two years after we buy a new vehicle
4. We will keep all household vehicles regardless of when we buy a new vehicle

21) What is your household monthly income range (approximately) in Lebanese Liras?

1. 0 – 1,999,000 L.L.
2. 2,000,000 L.L. – 3,999,000 L.L.
3. 4,000,000 - 5,999,000 L.L.
4. 6,000,000 - 7,999,000 L.L.
5. 8,000,000 – 9,999,000 L.L.
6. 10,000,000 - 14,999,000 L.L.
7. 15,000,000 - 29,999,000 L.L.
8. More than 30,000,000 L.L.
9. I don't know / No response

Section 3: Public Transportation Characteristics

The questions in this section ask you about public transportation availability in the vicinity of your residence. Even if you don't use bus/van or service, please answer based on what you know or have heard of.

22) Are you aware of buses or vans that pass within 500 meters from your residence?

1. Yes
2. No

23) How far do you have to walk from your residence to catch a bus/van during the day?

1. Less than 250 meters (less than 4 minutes)
2. Between 250 and 500 meters (4 to 8 minutes)
3. Between 501 and 750 meters (9 to 11 minutes)
4. More than 750 meters (more than 11 minutes)
5. I don't know

24) If you were to use a bus/van during the day, how long would you have to wait for the bus/van to arrive?

1. Up to 5 minutes
2. More than 5 minutes, up to 10 minutes
3. More than 10 minutes, up to 15 minutes
4. More than 15 minutes
5. I don't know

Now we will ask you a few questions about the ‘service’ availability in the proximity of your residence.

25) How far do you have to walk from your residence to find a ‘service’ during the day?

1. Less than 250 meters (less than 4minutes)
2. Between 250 and 500 meters (4 to 8 minutes)
3. Between 501 and 750 meters (9 to 11 minutes)
4. More than 750 meters (more than 11 minutes)
5. I don’t know

26) If you were to use the ‘service’ during the day, how long would you have to wait for it to arrive?

1. Less than 5 minutes
2. More than 5 minutes, up to 10 minutes
3. More than 10 minutes, up to 15 minutes
4. More than 15 minutes
5. I don’t know

Section 4: Alternative Fuel Vehicles

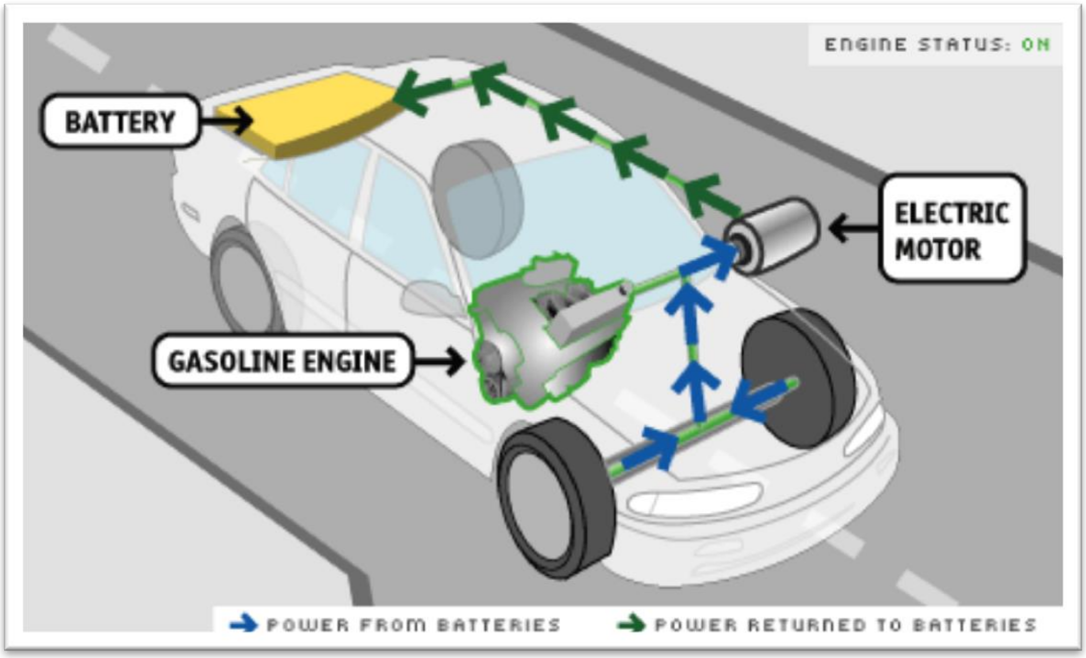
In this section, we are interested in understanding Lebanese citizens' preferences among different types of cars. You will be presented with four scenarios where we will ask you to indicate your preference among three types of cars (gasoline, hybrid, and electric).
Hybrid-electric vehicles (HEVs) and battery electric vehicles (BEVs) are two examples of alternative fuel vehicles which can act as a replacement for conventional gasoline cars.

Hybrid Electric Car

A hybrid electric car (HEV) is a fuel-efficient car which relies on two sources of power to operate - a gasoline motor and a set of rechargeable batteries that can be charged using a special system which stores the braking energy in the batteries (regenerative braking). Hence, hybrid electric cars do not need an external power source to recharge the batteries. The two power sources (gasoline and electric) work together. An electric motor empowered by the batteries on board will be used to run the car at low speed, while at higher speed the car will depend on the gasoline motor to move. Therefore, the amount of gasoline required to move the car as well as the emissions will be reduced.

Who is making HEV?
Honda: Accord, Civic, Clarity
Toyota: Avalon, Prius, Camry, Yaris and Highlander
Nissan: Altima
Kia: Optima, Niro
Hyundai: Sonata
Mercedes: Mercedes Benz GLE55e and Mercedes Benz C350e
And others.

[NOTE TO INTERVIEWER: PLEASE SHOW THE BELOW PICTURE TO THE RESPONDENT]

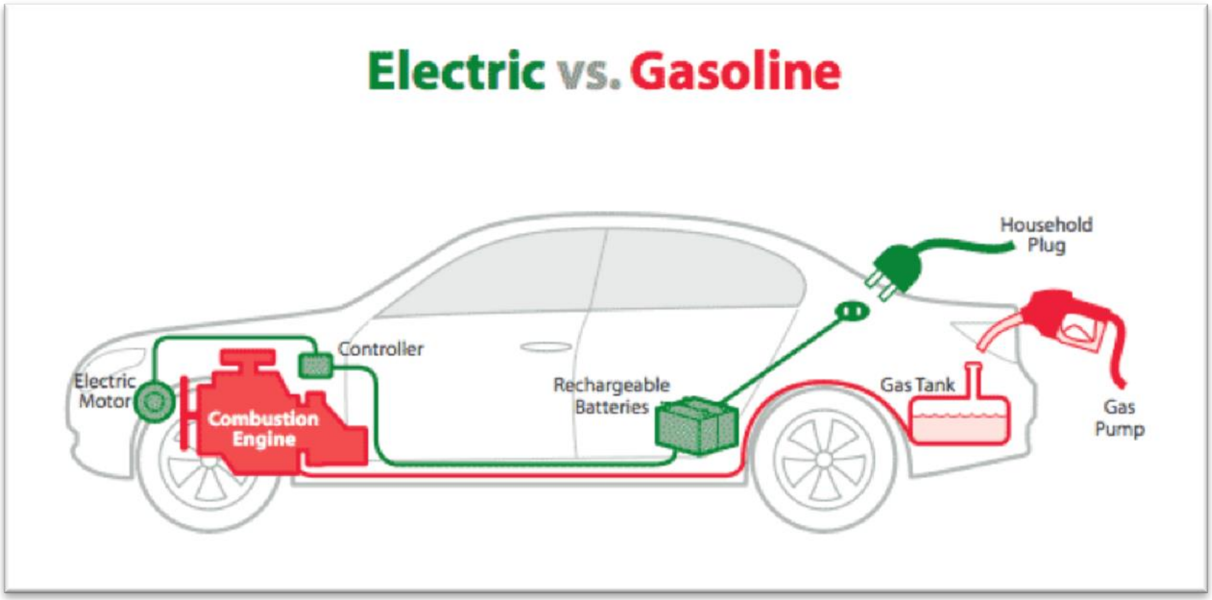

ENGINE STATUS: ON
BATTERY
ELECTRIC MOTOR
GASOLINE ENGINE
POWER FROM BATTERIES
POWER RETURNED TO BATTERIES

Battery Electric Car

A battery electric car (BEV) is a car which relies on an electric motor to operate. The only power source for the electric car is the rechargeable batteries installed inside the car which serve as a “gas tank” and provide the electric motor with the energy required to run the car.
Battery electric cars can be charged at EV charging stations which do not yet exist in Lebanon, but are becoming more prevalent worldwide. Battery electric cars also have the benefit of home or work charging; any 240-volt outlet can be used to charge up an electrical car. Hence, electric cars are cost effective in terms of operation costs because electricity is cheaper than gasoline. However, electric cars need time to charge, i.e. the time to charge an electric car ranges between 30 minutes to 12 hours depending on the size of the battery, the state of the battery (e.g. empty or half full), and the speed of the charging point. Furthermore, electric cars typically have shorter range than conventional gasoline cars and are more expensive.
Electric cars are cleaner than both conventional gasoline cars and hybrid electric cars as they do not emit greenhouse gases given the fact that they operate totally on electrically powered engines.

Who is making BEV?
Honda: Clarity and Fit EV
Nissan: Leaf
Hyundai: Ionic and Kona electric
Chevrolet: Spark EV and Bolt EV
Audi: E-tron Quattro
Mercedes: B-class electric drive and EQ
And others.

[NOTE TO INTERVIEWER: PLEASE SHOW THE BELOW PICTURE TO THE RESPONDENT]


Electric vs. Gasoline
Household Plug
Controller
Electric Motor
Combustion Engine
Rechargeable Batteries
Gas Tank
Gas Pump

Let's consider that your household is willing to buy a medium sized car within the next 12 months.

Examples of medium-sized cars:
Toyota Corolla
Nissan Sunny

In the following part of the survey, we will present you a number of scenarios where you have to make a decision about buying the conventional type (gasoline), the hybrid electric type (gasoline + electric), or the battery electric type (electric) assuming that the last two mentioned types (hybrid electric and battery electric) will be available in the Lebanese market within the next 12 months.
Assume that the presented cars only differ with respect to the presented attributes in the scenarios but are otherwise identical (in terms of quality, luggage space, color, safety, and other specifications), and are from the same manufacturer.
Definition of the attributes:

- Price: is the purchase price (in dollars) of the car including customs and excise, VAT, and registration fees.
- Range: is the driving range (in km) of a car. It represents how far the car can operate before the need to refuel the car for gasoline and hybrid cars or to recharge it for electric cars. For example, a car with three fuel tanks has a longer driving range compared to a car with two fuel tanks, assuming that both cars have the same fuel consumption. Moreover, the range of an electric car increases as the capacity of the batteries in the car increases.
- Horsepower: measured in hp and reflects the performance of the car. The more horsepower a car has, the faster it will be.
- Cost: is the cost of driving 100 km. For example, in the case of gasoline cars, the cost reflects the fuel cost per 100 km.

Please treat each scenario independently and read each one carefully.

27) Scenario 1:

	Option 1	Option 2	Option 3
Car Type	Gasoline	Hybrid Electric Car	Electric Car
Price ($)	16,660	22,491	25,823
Range (km)	760	570	228
Horsepower (hp)	160	216	115
Cost ($/100km)	6.00	3.30	1.80

Indicate below which car would be your preferred choice.
1. Option 1
2. Option 2
3. Option 3

28) Scenario 2:

	Option 1	Option 2	Option 3
Car Type	Gasoline	Hybrid Electric Car	Electric Car
Price ($)	22,800	30,096	30,552
Range (km)	1,000	1,000	400
Horsepower (hp)	160	128	120
Cost ($/100km)	12.00	5.00	4.47

Indicate below which car would be your preferred choice.
1. Option 1
2. Option 2
3. Option 3

Assume now that the government has decided to exempt you completely or partially from customs and excise taxes when purchasing an environmentally friendly car (hybrid or electric car). The below prices included in the table reflect this exemption along with the final price.

29) Scenario 3:

	Option 1	Option 2	Option 3
Car Type	Gasoline	Hybrid Electric Car	Electric Car
Price ($)	29,000	37,000 - 1,690 = 36,010	41,180 – 5,370 = 35,810
Range (km)	600	780	180
Horsepower (hp)	130	189	98
Cost ($/100km)	6.00	3.30	1.98

Indicate below which car would be your preferred choice.
1. Option 1
2. Option 2
3. Option 3

30) Scenario 4:

	Option 1	Option 2	Option 3
Car Type	Gasoline	Hybrid Electric Car	Electric Car
Price ($)	16,660	24,157 – 437 = 23,720	27,656 – 1,866 = 25,790
Range (km)	880	950	264
Horsepower (hp)	130	228	107
Cost ($/100km)	12.00	5.89	2.85

Indicate below which car would be your preferred choice.
1. Option 1
2. Option 2
3. Option 3

Section 5: Opinions about Vehicles and Public Transportation Services

In this section, we would like to know your opinions about vehicles, public transportation in Lebanon, and hybrid and electric cars. There are no right or wrong answers. Even if a subject does not exactly apply to you, we would still like to have your general thoughts about it.

31) Please indicate your level of agreement with the following statements about using the bus/van.

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly Agree (5)
a. I can count on the bus/van to get me to the places I need to go to on time.					
b. I don't feel comfortable in the bus/van.					
c. I can get other things done while commuting by bus/van.					
d. Using the bus/van is affordable.					
e. I like the idea of using bus/van as a means of transportation for me.					

32) Please indicate your level of agreement with the following statements about using the “service”.

		Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
a.	**I can count on the “service” to get me to the places I need to go to on time.**					
b.	**I don’t feel comfortable in the “service”.**					
c.	**I can get other things done while commuting by the “service”.**					
d.	**Using the “service” is affordable.**					
e.	**I like the idea of using “service” as a means of transportation for me.**					

33) Please indicate your level of agreement with the following statements about owning and using a personal vehicle to commute.

		Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
a.	**I feel stressed when I commute using the vehicle.**					
b.	**I like the idea of driving as a means of transportation for me.**					
c.	**Owning and maintaining a vehicle is expensive.**					
d.	**In Lebanon, one is expected to own and use a vehicle.**					

34) For ***each*** of the following statements, please check the response that best expresses your opinion. ***Your impressions are important*** even if you're not very familiar with hybrid or electric cars.

	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
a. I am willing to pay a little more to own an electric car or a hybrid car.					
b. I rarely consider the impact on the environment when deciding what type of car to purchase.					
c. I haven't really thought about buying a hybrid or electric car prior to answering this survey					
d. I am concerned that the electric car might run out of electricity while on the road.					
e. I am quite familiar with the technical and operational characteristics of hybrid and electric cars prior to answering this survey.					
f. Electric cars are less reliable than conventional cars.					
g. I would feel relatively less safe in an electric car.					
h. I would value the ability to refuel my electric car from home.					
i. Electric cars don't offer enough performance.					
j. I think it would be easy for me to find places to plug in an electric car.					
k. I think electric cars would be complicated to use.					
l. I think hybrid cars would be complicated to use.					

Thank you very much for participating in this survey. If you have any comments about this survey or about transportation issues in Lebanon, please feel free to express them now.
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………………………………………………………………………………………………
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APPENDIX B: DISTRIBUTION OF QUESTIONNAIRES PER ZONE

Table B1: Distribution of questionnaires per zone

Zone Number	**Zone Name**	**Number of Questionnaires**
2	Mar Mikhael, Khodr	21
3	Geitawi, Karm el-Zeitoun	10
4	Gemmayzeh, Saifi, Remeil, Tabaris	29
5	Nasra, Furn al-Hayek, Monot, Sodeco	10
6	Achrafieh, Mar Mitr, Sassine	10
7	Sioufi, Aadlieh, Hotel Dieu	10
8	Ras al-Nabaa, Mathaf, Badaro	12
9	Horsh, Qasqas, Chatila	12
10	Tareek al-Jdideh, Fakhani	12
11	Mazraa, Bourj Abi Haidar	12
12	Basta Faouka, Basta Tahta	12
15	Ain Mreisseh, al-Zarif	8
16	Hamra, Wardieh	8
19	Rawcheh, Qoreitem	8
20	Snoubra, Munla, Verdun	8
21	Moussaitbeh, Zaidanieh, Batraki	18
22	Tallet al-Khayat, Wata	18
24	Mar Elias, Dar Mouallimeen	18
26	Bourj Hammoud (South), Nabaa	24
27	Sin el-Fil	7
29	Furn al-Chebbak, Ain al-Roumman	3
30	Chiah	8
33	Ouzai	6
34	Bourj Brajneh	6
35	Bouchrieh	9
36	Jdeideh, Sid Bouchrieh	8
37	Dekwaneh, Mkalles	3
39	Haddath, Laylakeh	11
40	KfarChima, BeitChay	3
41	Hay el-Sellom	4
43	Khaldeh	2
44	Choueifat	9
45	Deir Koubel	2
46	Dbayeh, Aoukar, Haret Bellane	2
47	Rabieh, Raboueh, Ain Aar	1
48	Naccache, Tellel Srour	1
50	Jal al-Deeb, Zalka, Deir Salib	6
51	Bsalim, Nabay, Baikout	2
52	Roumieh	1
53	Ain Saade, Fanar	1
54	Mansourieh, Deychounieh	2
55	Jamhour Kahale, Bsous	4
56	Wadi Chahrour, Bdadoun	5
57	Ain Anoub, Bsaba	3
58	Bchamoun, Sarahmoul	2
61	Daouha, Naameh	6
62	Damour, Mechref	7
73-S	Jounieh, Kaslik, Jeita	13
75-W	Saadiyat, Jiyeh, Wadi Zeini	3
Total		***400***

APPENDIX C: FORECASTING

Table C1: Weights according to household size distrbituion

Municipal Beirut			
Household Size	Households in Sample	Households in Population	Weights
1	8	8,863	1,108
2	68	18,015	265
3	58	17,437	301
4	57	20,616	362
5	25	16,088	644
6	11	9,826	893
7 plus	1	5,491	5,491
Outside Municipal Beirut			
Household Size	Households in Sample	Households in Population	Weights
1	8	17,351	2,169
2	47	36,610	779
3	48	36,518	761
4	23	52,409	2,279
5	19	44,978	2,367
6	12	21,738	1,811
7 plus	2	18,773	9,386

Table C2: MDI values for the base case and for Policies 3 and 4

Zone Number	Zone Name	MDI_Base Case	MDI_Policy 3	MDI_Policy 4
2	Mar Mikhael, Khodr	1,060	1,837	1060
3	Geitawi, Karm el-Zeitoun	11,144	11,968	11144
4	Gemmayzeh, Saifi, Remeil, Tabaris	1,837	10,652	1837
5	Nasra, Furn al-Hayek, Monot, Sodeco	10,652	11,968	10652
6	Achrafieh, Mar Mitr, Sassine	11,968	11,968	11968
7	Sioufi, Aadlieh, Hotel Dieu	4,614	8,286	4614
8	Ras al-Nabaa, Mathaf, Badaro	8,286	10,652	8286
9	Horsh, Qasqas, Chatila	7,861	12,941	7861
10	Tareek al-Jdideh, Fakhani	12,941	12,941	12941
11	Mazraa, Bourj Abi Haidar	12,213	12,941	12213
12	Basta Faouka, Basta Tahta	5,855	6,894	5855
15	Ain Mreisseh, al-Zarif	12,780	12,780	12780
16	Hamra, Wardieh	5,406	7,317	5406
19	Rawcheh, Qoreitem	4,042	7,317	4042
20	Snoubra, Munla, Verdun	10,013	12,780	10013
21	Moussaitbeh, Zaidanieh, Batraki	6,894	9,862	6894
22	Tallet al-Khayat, Wata	9,862	10,013	9862
24	Mar Elias, Dar Mouallimeen	4,108	7,993	4108
26	Bourj Hammoud (South), Nabaa	8,098	14,090	10733
27	Sin el-Fil	7,671	8,089	10733
29	Furn al-Chebbak, Ain al-Roumman	2,299	9,128	10733
30	Chiah	9,128	10,733	10733
33	Ouzai	4,377	8,923	10733
34	Bourj Brajneh	8,923	10,733	10733
35	Bouchrieh	9,167	14,090	10733
36	Jdeideh, Sid Bouchrieh	1,248	2,149	10733
37	Dekwaneh, Mkalles	1,625	3,251	10733
39	Haddath, Laylakeh	1,792	8,923	10733
40	KfarChima, BeitChay	659	1,467	10733
41	Hay el-Sellom	1,467	3,407	10733
43	Khaldeh	281	1,467	10733
44	Choueifat	3,407	3,407	10733
45	Deir Koubel	168	398	10733
46	Dbayeh, Aoukar, Haret Bellane	541	2,149	2149
47	Rabieh, Raboueh, Ain Aar	416	541	2149
48	Naccache, Tellel Srour	698	2,149	2149
50	Jal al-Deeb, Zalka, Deir Salib	2,149	2,149	2149
51	Bsalim, Nabay, Baikout	499	698	2149
52	Roumieh	137	346	2149
53	Ain Saade, Fanar	346	346	2149
54	Mansourieh, Deychounieh	480	1,053	2149
55	Jamhour Kahale, Bsous	34	346	2149
56	Wadi Chahrour, Bdadoun	346	659	2149
57	Ain Anoub, Bsaba	204	398	2149
58	Bchamoun, Sarahmoul	398	398	2149
61	Daouha, Naameh	342	1,467	2149
62	Damour, Mechref	347	1,467	2149
73-S	Saadiyat, Jiyeh, Wadi Zeini	155	347	2149
75-W	Jounieh, Kaslik, Jeita	802	802	2149

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