MODELING TRAVEL CHOICES OF STUDENTS AT A PRIVATE, URBAN UNIVERSITY: INSIGHTS AND POLICY IMPLICATIONS

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ABSTRACT

This study investigates differences between the mode choice patterns of students of the American University of Beirut (AUB) and the general population of the Greater Beirut Area in light of the socioeconomic background of these two groups, the fragmented public transport system in Beirut, and the high reliance on the private auto. Discrete choice models are developed to model the choice among car, bus, and shared taxi (or jitney). It is found that travel time, cost, income, auto ownership, gender, and residence location (whether within Municipal Beirut or not) are the main factors affecting mode choice, and that AUB students who come from wealthier families have a significantly higher value of time than the general population. The models are used to forecast students' commute mode shares under alternative scenarios to support the development of policies that would encourage students to switch towards more sustainable modes. It is found that increasing parking fees and decreasing bus travel time (e.g. through exclusive bus lanes) could be promising strategies for mode switching from car to public transport for AUB students. The study contributes to the emerging literature on students' travel patterns and its findings are particularly relevant in travel contexts characterized by high congestion levels, high auto ownership rates, and low quality public transport system.

Keywords: Mode choice, Value of time, University students, sustainable transportation

INTRODUCTION

University students have complex and unique travel behavior *(Limanond et al., 2011)*, and they are underrepresented in most travel studies although they comprise a significant proportion of the traveling public *(Khattak et al., 2011)*. Understanding the travel behavior of university students, and particularly their reliance on the private auto for commuting, can help universities and other stakeholders work towards improvements to policies, programs, and infrastructure that encourage students' use of public transport or non-motorized modes of travel *(Shannon et al., 2006)*. This is critical especially in the context of large universities since student travel directly affects the levels of congestion in adjacent streets with impacts on the well-being of students and employees, as well as that of residents and businesses in the university neighborhood.

This study is motivated by the case of the American University of Beirut (AUB), a private university in a developing country, and whose students mostly come from wealthy families. This research analyzes the commute mode choice of AUB students and investigates the extent to which their travel patterns differ from those of the general population in light of their socioeconomic background and the fragmented public transport system in the Greater Beirut Area (GBA). AUB students are very dependent on private cars instead of other modes such as public transit. The study contributes to the emerging literature on understanding student travel behavior, by developing discrete choice models for the travel mode choice of two population groups in Beirut: AUB students and the general GBA population. The study then considers the possible role of different interventions and policy measures in encouraging shifts by AUB students towards more sustainable transport modes.

The findings of this paper are useful in assessing the effectiveness of transportation related policies in the neighborhood of AUB (and similar educational institutions). The mode choice models are used in forecasting the market shares of the considered modes (car, bus, and jitney) in response to changes in different variables such as parking cost, bus and jitney fares, and travel times. These policies can help provide a more sustainable environment for students and a higher quality of life in AUB's neighborhood and nearby areas through easing congestion and promoting public transportation. Non-motorized modes are not modeled in this study as non-motorized travel was not measured in the general population dataset, while for AUB students the data reveals that most students living within walking distance of AUB commute on foot.

This paper is organized as follows. The second section provides a background of Beirut and its current transportation conditions and especially in the AUB neighborhood. The third section presents a literature review discussing the findings of similar student-related transportation studies. The following section presents the data sets, the assumptions, and the methods used in developing the models. The fifth section shows the estimation results of the models for AUB students and the general population, including the values of time calculated for each group, as well as forecasting results under various scenarios. And the last section concludes the paper and discusses the study limitations and recommendations for future research.

STUDY CONTEXT

This section provides the study context, starting first with a description of socio-demographics and travel patterns in Beirut followed by a description of AUB's location and students' characteristics and modal split.

Beirut: Socio-Demographics and Travel Patterns

The Greater Beirut Area (GBA) extends over an area of close to 200 square kilometers and its population (approximately 1.5 million) is estimated to be one third of the total Lebanese population. Different economic activities taking place in Beirut at different times of the day (businesses, schools, universities, retail, etc.) cause traffic to be spread throughout the whole day, without any significant AM or PM peaks, except for the hour between 7:00 and 8:00 AM, which accounts for approximately 6.71% of the daily traffic *(IBI Group and TEAM, 2009)*.

Public transport services are currently provided by many operators running different services (e.g. public buses, private buses, minibuses, etc.). However, these services are inefficient due to their unreliability and the lack of appropriate waiting facilities *(IBI Group and TEAM, 2009)*. Public and private buses and minibuses account for only 10% of the trips in Greater Beirut *(Kaysi et al., 2011)*. The inefficiency and limited coverage of bus lines encouraged jitneys (locally known as service, which are a form of shared taxis) to compensate for the shortage of public transportation in Beirut. Jitneys are mostly privately owned cars operated by single owners seeking random demand for transport *(Kaysi et al., 2011)*. These jitneys do not follow defined routes or paths, and they may or may not serve potential customers on the road depending on their destination and other passengers' destinations. Therefore, travel time by jitney can be highly variable. However, these provide a better level of service and comfort than buses, even though they operate at higher fares (2000 L.L.[1] ($1.3) currently compared to 1000 L.L. ($0.7) charged by buses). Jitneys serve 19% of the overall transport demand in Greater Beirut *(Kaysi et al., 2011)*. The rest of the transport demand is covered by private cars.

Private cars are heavily relied on not only due to the inefficiency of public transport but also due to inexpensive parking, generally ranging from $2 to $4 in Beirut central area. The average vehicle occupancy for private cars in Beirut was estimated to be 1.7, compared to 1.9 for all modes in Beirut *(IBI Group and TEAM, 2009).*

AUB: Location and Characteristics

The American University of Beirut is a private university located in Ras Beirut (one of the most luxurious areas in the city) and having a total area of 250,000 square meters (refer to Figure 1 below). AUB overlooks the Mediterranean Sea on one side and Bliss Street on the other. The adjacent road on the sea side suffers considerable congestion in the afternoon to evening periods. On the curbside, parking is free of any charge, so it is difficult to find an empty parking spot; therefore, parking lots adjacent to the street are almost always full. As for the southern neighborhood (Bliss Street and nearby streets), curbside parking is charged, and several parking facilities operate in this area. Most of these parking facilities are used by AUB students during the day.

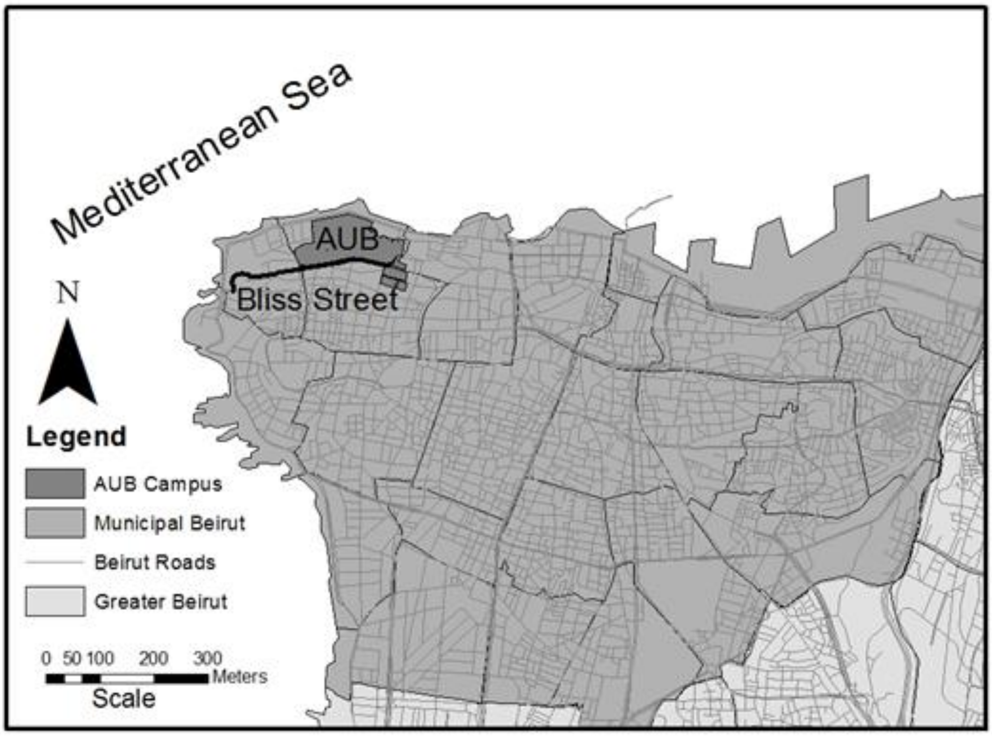

Figure 1 – Municipal Beirut and location of AUB

[1] 1 US dollar is equivalent to 1500 Lebanese Liras (L.L.).

Many AUB students originate from wealthy families. The average household monthly income of AUB students is $5000 compared to the national average of $800 *(Khattab et al., 2012, Central Administration of Statistics, undated)*. Students' families also have a higher auto ownership rate of 1 car for every 2 persons, compared to the national average of 1 car for every 3 persons *(MOE, undated)*. The overall distribution of the mode of commute of AUB students does not substantially differ from that of the general population except for students living near AUB who mostly walk. For motorized trips, auto is the most dominant mode, followed by jitneys and then bus *(Khattab et al., 2012)*.

LITERATURE REVIEW

A number of studies have been conducted to analyze university student travel patterns including trip making levels and mode choice. A small number of studies have also touched upon the policy measures which may influence such travel patterns. This section gives an overview of these studies.

Student Trip Making Levels

A few studies have attempted to characterize student trip making levels, and the extent to which they differ from trip making levels by the general public. The two studies below have addressed such question by considering student travel at universities in Virginia.

Khattak et al. *(2011)* studied student travel behavior at four universities in Virginia and compared this behavior to that of the general population, since they believed that students were often missed or underrepresented in national surveys. They used a modified version of the National Household Travel Survey (NHTS), which includes several sections concerned with personal characteristics, vehicle ownership, commute, a trip diary, and work and parking information. The survey results showed that university students have higher daily trip rates compared to the general population. However, although car is the most dominant mode used by these students, they substantially make more non-motorized trips than the general population. Students also perform more trips in off-peak periods. Students living on campus tend to generate more trips compared to students living off campus; however, they rely more on non-motorized modes such as walking and bicycle *(Khattak et al., 2011)*.

In a related study, Wang et al. *(2011)* modeled the travel demand of students at Old Dominion University in Virginia using the same survey mentioned above in *(Khattak et al., 2011)*. They used a Poisson/Negative Binomial model with the dependent variable being the natural logarithm of the total number of daily trips, and the independent variables included personal characteristics, living conditions (on campus, near campus, or far from campus), and academic status (graduate, full time, working student, etc.). Moreover, trips were segmented into auto trips or walking/bicycle trips using a binary logit model. The authors concluded that undergraduate, full time, and working students make more daily trips than other students, while students who reside off campus make fewer daily trips. Unlike the general population of Hampton Roads based on the 2009 National Household Travel Survey

Virginia add-on, trip frequencies were not affected by the number of vehicles available to students or their income levels. However, the number of vehicles had a significant positive effect on the number of auto trips and a significant negative effect on the number of walking/bicycle trips. Residential location was the primary factor affecting mode choice. Students living near campus on average make 90% more auto trips compared to students living on campus, while students living far from campus make on average 3 times more auto trips. This situation is reversed for walking/bicycle trips.

Determinants of Student Mode Choices

The choice of travel mode by students has an impact on the level of congestion and the parking requirements in the university neighborhood; these considerations are of particular importance in the context of large, urban universities. Several studies have assessed the determinants of student mode choices, including a number which have developed models of such choices.

Limanond et al. *(2011)* conducted a descriptive study of the travel behavior of students living on campus at the Suranaree University of Technology in Thailand using trip diaries filled out by students. They concluded that this behavior does not differ across genders. Mode choice was mostly affected by car ownership, as students who owned a car were most likely to use it while others would resort to ride sharing or using the bus, which is the only public transport mode available there. However, car ownership did not affect the number of trips performed by students or the total distance traveled.

After analyzing the spatial and temporal distribution of trips performed by students of University of Idaho via a descriptive study, Delmelle and Delmelle *(2012)* reckoned that the availability of parking permits for university students is the key predictor of commuting by car even for short trips, and especially in winter. They also found out that safety and road topography are main elements affecting the use of non-motorized modes, especially for females.

Zhou *(2012)* studied the commute and residential location choice of students from the University of California, Los Angeles (UCLA) using a travel and housing survey. The major questions Zhou wanted to find an answer to were whether being embedded in Los Angeles makes university students drive alone more than students in other places, what the main factors influencing the use of alternative modes are, and whether these factors differ between Los Angeles and other places. Zhou first performed descriptive analysis of the survey results and concluded that being embedded in LA does not increase the odds of driving alone. He then developed a logit model studying different alternatives such as solo driving, transit, carpool, biking or walking, and telecommuting. The explanatory variables used were the proximity to bus lines, being multimodal (using more than one primary commute mode), time of travel, residence type, whether students have classmates or friends living nearby, having a parking permit or a discounted transit pass, age, gender, and status (whether the student is graduate or undergraduate) in addition to commute time and distance and the days spent at UCLA. Zhou concluded that being multimodal, having a discounted transit pass, and having classmates living nearby favor the use of alternative modes, while having a parking permit favors driving solo. In addition, commute distance has a positive effect on carpooling and telecommuting. As for demographics, Zhou concluded that females are less likely to bike or walk compared to males. Similarly, older students are less likely to use alternative modes (public transit, biking, or walking). Zhou also concluded that undergraduates are more likely to bike or walk while graduates are more likely to telecommute.

Maneesh et al. *(2007)* developed a mode choice model for students at Texas A&M University considering a choice set that includes walking, biking, driving alone, carpooling, and taking a bus. They concluded that travel time and travel cost were the key attributes affecting mode choice, in addition to individual characteristics such as income, expenses, household type, number of hours in school, gender, and ethnicity. They also stated that the parking permit fee applied in the university was an important factor in lessening the use of personal vehicles. They calculated the value of time for students to be $2.18/hour.

Akar et al. *(2012)* studied the mode choice behavior of university students at Ohio State University. They applied factor analysis to survey questions measuring respondents' attitudes towards auto and the factors encouraging them to use alternative modes, and came up with four principal factors labeled as "Safety and Weather", "Cost and Environment", "Travel Time and Departure Flexibility", and "Travel Time and Making Stops". These factors were then used with other alternative attributes (travel time, availability of bus stops, and availability of bike routes) and individual characteristics (gender and status such as faculty, occupation, year, etc.) to develop a logit choice model taking into consideration a universal choice set of walking, biking, carpooling, bus, and private car. Travel time was the most significant factor affecting mode choice. The presence of a bus stop within 0.5 miles from a student's residence location appeared to have a significant positive effect on choosing to use bus. Similarly, the presence of a bicycle path within 0.5 miles appeared to have a positive effect on bicycle usage. As for individual characteristics, females were more likely to use car compared to bus and bicycle. Undergraduate students were more likely to take the bus, walk, or use the bicycle compared to car. Graduate students were also more likely to use all other modes compared to car.

Whalen *(2012)* studied the travel patterns of students at McMaster University located in Hamilton, Canada. Whalen used a survey including questions about the chosen mode of travel and the availability of other modes, the travel time by these modes, socioeconomic variables, and questions regarding attitudes of respondents towards travel, land use, and the environment. The studied modes were private automobile, public transit, and active modes (walking and bicycle). Whalen also asked students about their actual and ideal commute times. She concluded that most students are not satisfied with their current commute time, and that a typical student would prefer it to be 32.2% less than his/her current travel time. She then developed a regression model having as dependent variable the percentage difference between the actual and ideal commute times, and the independent variables composed of socio-demographic variables and binary variables for the used mode (car, bus, or active). From this model, she concluded that students who drive a car or ride public transit wish to spend less time in their commute compared to those who walk or use the bicycle. She then verified these results using a mode choice model, whereby she concluded that travel time, owning a parking permit, living arrangement, and street density are all significant factors affecting students' mode choice.

De Guzman and Diaz *(2005)* analyzed the mode choice behavior of students in Ateneo De Manila University and Miriam College in Philippines. The students were asked to fill out a survey ranking the factors considered in the choice of mode. Travel time was ranked first, followed by convenience and then travel cost. De Guzman and Diaz then developed a binary logit model to predict the choice of commuting by car or by a mode other than car. The key factors were car ownership, parking access, and the effectiveness of the Unified Vehicle Volume Reduction Program applied in Manila.

Based on the above literature, the major determinants of student mode choice can be summarized in Table I below:

Table I – Major determinants of student mode choice

Determinant of Mode Choice	Supporting Literature
Travel Time	Maneesh et al., 2007, Akar et al., 2012, De Guzman and Diaz, 2005
Travel Cost	Akar et al., 2012, De Guzman and Diaz, 2005, Maneesh et al., 2007
Parking Access	Delmelle and Delmelle, 2012, Zhou, 2012, Maneesh et al., 2007, Whalen, 2012, and De Guzman and Diaz, 2005
Transit Pass	Zhou, 2012
Car Ownership	Limanond et al., 2011
Travel Environment/Context	Delmelle and Delmelle, 2012, Whalen 2012, Akar et al., 2012
Gender	Zhou, 2012, Akar et al., 2012, Maneesh et al., 2007
Age	Zhou, 2012
Educational Status	Zhou, 2012, Akar et al., 2012
Income	Maneesh et al., 2007

Policy Measures to Influence Student Travel

Understanding student travel patterns, and their mode choices in particular, is a precondition for developing effective policy measures that are meant to mitigate impacts of student travel and steer such travel towards more sustainable patterns. A few studies have considered this dimension, as discussed next.

Shannon et al. *(2006)* studied the commuting patterns of students at the University of Western Australia via an online survey whereby respondents reported their trip patterns during a certain week, their self efficacy regarding walking, bicycle, and public transport (how confident students are in undertaking these activities), and to what extent certain barriers, motivators, or interventions can affect their mode choice. They concluded that reducing the actual and perceived travel time by bus and bicycle has the greatest effect on commuting patterns. Other policies appeared to have significant effects too, such as the implementation of a subsidized public transport pass, increased student housing on or near campus, increased cost of parking, and improved bus services and cycle networks.

In a study of students' mode choice at the North Dakota State University, Ripplinger et al. *(2005)* developed a mixed logit model with the independent variables being travel time, automobile cost, and a dummy variable representing the previous use of transit, and found that students prefer walking and biking to automobile or transit. Using that model, they predicted that an increase in fuel prices will only result in modest increases in transit ridership and pedestrian travel. An express bus service between campus and off-campus areas with high student populations could attract a significant number of transit riders from other modes. Students considered cost savings, convenience, and reducing traffic congestion and parking demand as the primary benefits of transit.

Summary

The studies reviewed above concluded that although students are more likely to use non-motorized modes compared to the general population, they still rely heavily on their private cars. Travel time, car ownership, and parking availability are significant predictors of mode choice by students. In addition, other factors affect students' mode choice such as their residence location, the context of their followed routes (safety, topography, etc.), and their socioeconomic characteristics. These studies emphasized the importance of studying student travel behavior, and pinpointed that students are an underrepresented *(Khattak et al., 2011, Wang et al., 2011)*, though significant, group of commuters and have different travel characteristics compared to the general population *(Limanond et al., 2011)*. Understanding student travel behavior will help university officials and other stakeholders in developing a more sustainable environment within and near campus areas, with less air pollution, congestion, and car dependence *(Delmelle and Delmelle, 2012)*.

The current study utilizes discrete choice logit models in order to compare the mode choice behavior of AUB students and the general population, to obtain insights about the different factors affecting the choices of both groups, and to estimate the monetary value of time (VOT) for students and for the general population. Very few studies have estimated the VOT of university students; this indicator may prove to be critical in explaining differences in travel behavior between the two groups. Moreover, this study utilizes the developed model for students in forecasting changes in market shares due to different scenarios which helps assess the effectiveness of transportation policies aimed at encouraging switching towards sustainable modes.

METHODS

This section is divided into three parts. The first part describes the two available data sets used in this study for modeling the mode choices of AUB students and the general population. The second part states the assumptions utilized in calculating travel time and travel cost by different modes as well as some additional assumptions. The third part presents the models that were developed for the two data sets.

Data Sets

General Population Data Set

The first set of data was collected from a survey of the general population of Beirut conducted in 2000 as part of the Beirut Suburban Mass Transit Corridor Feasibility Study *(DMJM + Harris and IBI Group, 2003)*. The survey included questions about regular trip origins, destinations, modes (excluding non-motorized travel), door-to-door travel times, frequencies, and purposes in addition to parking location and expenses. It also included questions about socioeconomic characteristics such as age, gender, monthly income, car availability, and employment status.

The data set used in this paper was limited to motorized trips (bus, car, and jitney) within Greater Beirut area (Zones 1-63). Motorcycle trips were excluded. The number of usable observations was 164. Distances between zone pairs were calculated using GIS Network Analyst tool. Descriptive statistics of the general population data set are provided in Table I. The survey oversampled individuals traveling by modes other than the private car.

Student Data Set

The second data set included only trips performed by AUB students to AUB. It was collected from a survey performed in 2010 as part of the Neighborhood Initiative Congestion studies *(Khattab et al., 2012)*. The survey included questions regarding usual trip mode, door-to-door travel time, parking location and expenses, and socioeconomic characteristics such as age, gender, family income, academic year, faculty, major, family size, and the number of cars available to the family. Non-motorized trips and motorcycle trips were excluded, and only trips originating from Greater Beirut area (zones 1-63) were considered in this study. The final number of observations was 594. Descriptive statistics of the student data set are summarized in Table II.

Table II – Descriptive statistics of the two data sets: counts and percentages

	General Population				AUB Students		
Gender	Male		Female		Male	Female	
	98 (59.8%)		66 (40.2%)		278 (46.8%)	316 (53.2%)	
Travel Mode	Private Car	Bus	Jitney		Private Car	Bus	Jitney
	93 (56.7%)	34 (20.7%)	37 (22.6%)		373 (62.8%)	62 (10.4%)	159 (26.8%)
Trip Purpose	Work	Shopping	Education	Other Purposes	Commuting to AUB		
	137 (83.5%)	3 (1.8%)	16 (9.8%)	8 (4.9%)			

In the models developed below, only motorized trips were considered, and these were limited to travel by car, bus, and jitney. Motorcycle and private taxi trips were disregarded since they only constitute 1.9% of the total trips performed by AUB students, and bicycle trips only constitute 0.2%. Walking trips were also disregarded even though they constituted 17.8% of the total trips since students will only walk to AUB if they live in the dorms or in very close residences, and therefore they are less likely to shift to other modes. Indeed, the survey results indicated that almost all students living within the same zone as AUB travel to AUB on foot. On the other hand, students traveling by motorized modes travel a distance of at least 1600 meters (see Figure 2) and are therefore unlikely to commute on foot.

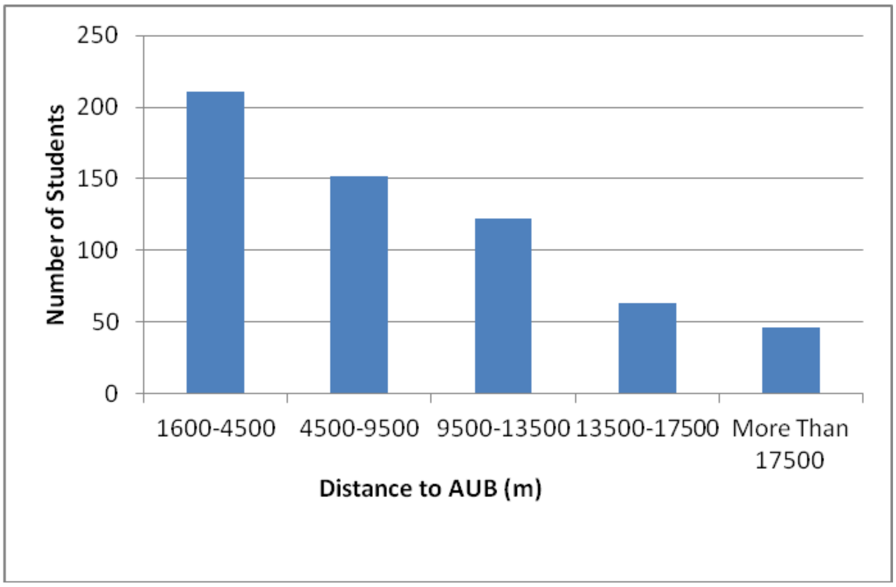

Figure 2 – Distribution of motorized trips by distance

Assumptions

Travel Cost

The fuel economy for private cars was assumed to be 170 km/tank. The fuel cost was considered to be 16,000 L.L. /tank for the general population data set (in year 2000) and 33,000 L.L./tank for the student data set (in year 2010). Given the distance between each origin-destination (O-D) pair from GIS, the fuel cost could then be calculated. The one-way car travel cost was then calculated as the sum of the fuel cost of a one-way trip and half the daily parking cost. In case of monthly parking subscriptions, the daily parking cost was estimated to be equal to the monthly subscription fee divided by 22. For bus and jitney users, the assumed parking cost if they were to use the car is equal to half the average fee paid daily by car drivers in order to account for one- way trips (950 L.L. for year 2000 and 2800 L.L. for year 2010). For the general population data set, the survey did not collect information on whether car users have other passengers in their cars. Therefore, it was assumed that the whole cost is incurred by the driver. However, for the student data set, students were asked whether they drive alone, take other passengers in their car, or are dropped off by other drivers. In case of ride sharing, students were assumed to incur half of the total travel cost. In case car was not the utilized mode, the cost of using the car was calculated as the cost of driving alone reduced by a factor to account for the possibility of ride sharing, based on the existing fraction of carpoolers.

Bus and jitney travel costs are the prevailing fares of 250 L.L. for bus and 1000 L.L. for jitney for the general population data set in year 2000, and 1000 L.L. for bus and 2000 L.L. for jitney for the student data set in year 2010. However, if the one-way trip is longer than 10 km, double the fare is assumed for bus and jitney.

Travel Time

Reported travel times are used in the models as travel times derived from a transportation model are not available for all modes considered. Both surveys asked individuals about their travel time by the chosen mode only. Travel times by other modes were estimated by finding the average operating speed of these modes for a given origin district to destination district pair. Two major districts were defined; the first includes Municipal Beirut and the nearby suburbs, and the second includes all other zones within GBA. This resulted in four district combinations for the general population data set and two combinations for the students' data set since students have a common destination, which is AUB. The average operating speed of each mode was calculated for each of these combinations. It was not possible to use a larger number of districts due to the small number of trips by certain modes for certain district pairs. The average speed by mode for each origin district to destination district pair is shown in Table III below.

Table III – Average operating speeds (km/hr) for different modes for each OD district pair (Major District 1 = Municipal Beirut and nearby suburbs; Major District 2 = all other zones within GBA)

	General Population Data Set			Students Data Set		
Origin – Destination	Car	Jitney	Bus	Car	Jitney	Bus
Major District 1 - Major District 1	22.5	12.2	7.2	15.3	12.8	10.8
Major District 2 -Major District 1	13.3	9.8	9.1	21.2	16.4	12.8
Major District 1 - Major District 2	31.2	17.4	13.4	N/A	N/A	N/A
Major District 2 -Major District 2	23.8	14.6	13.2	N/A	N/A	N/A

Other Assumptions

Car availability for each individual is obtained directly from the survey responses in the general population data set (the survey includes a question asking whether car is available for that individual or not). In the student data set, car was assumed to be available to everyone since students can always share a ride. This was also reflected in the data set, as some students reported that although they do not have any car at home, they still commute to AUB by car with their friends.

As for bus and jitney, several maps showing the distribution of bus trips and jitney trips were produced. The maps implied that bus and jitney are almost available in each of the 63 zones in GBA. For zones where no bus or jitney trips were observed, it was also concluded by spatial continuity that these two modes are always available since they were available in surrounding zones.

Income was used as a continuous variable, and a specific value was used for each income range (taken as the midpoint of the range in the survey).

Model Specification

Two nested logit mode choice models were estimated for the general population and for AUB students, either with car and jitney in the same nest, or with jitney and bus in the same nest. However, the nest coefficients were not statistically different from one. Therefore, logit models were developed instead. Various model specifications were tried. The specifications and estimation results shown below were selected based on the reasonableness of the parameter signs and the statistical significance of the variables included. The systematic utility equations for the general population are as follows:

$$V_{car} = ASC_{car} + \beta_{cost} \times Cost_{car} + \beta_{time} \times Time_{car} + \beta_{CarFrequency} \times Frequency \quad (1)$$

$$V_{Jitney} = ASC_{jitney} + \beta_{cost} \times Cost_{jitney} + \beta_{time} \times Time_{jitney} + \beta_{JitneyFrequency} \times Frequency \quad (2)$$

$$V_{bus} = \beta_{cost} \times Cost_{bus} + \beta_{time} \times Time_{bus} \quad (3)$$

The systematic utility equations for the students are as follows:

$$V_{car} = ASC_{car} + \beta_{cost} \times Cost_{car} + \beta_{time} \times Time_{car} + \beta_{CarIncome} \times Income + \beta_{CarMissingIncome} \times MissingIncome + \beta_{CarGender} \times Male + \beta_{OneCar} \times OneCar + \beta_{MultipleCars} \times MultipleCars \quad (4)$$

$$V_{jitney} = ASC_{jitney} + \beta_{cost} \times Cost_{jitney} + \beta_{time} \times Time_{jitney} + \beta_{JitneyIncome} \times Income + \beta_{JitneyMissingIncome} \times MissingIncome + \beta_{JitneyGender} \times Male + \beta_{JitneyZone} \times Beirut \quad (5)$$

$$V_{bus} = \beta_{cost} \times Cost_{bus} + \beta_{time} \times Time_{bus} + \beta_{BusZone} \times Beirut \quad (6)$$

where travel time was expressed in minutes and cost was expressed in Lebanese Liras. Income represents the monthly household income in US Dollars. Frequency represents the number of times an individual performs his/her trip per week. Male represents a dummy variable equal to one if the individual is a male and zero otherwise. Beirut represents a dummy variable equal to one if the individual lives inside Municipal Beirut (zones 1-24) and zero otherwise (zones 25-63). The dummy variable “OneCar” takes a value of one if one car is available to the student’s household and zero otherwise. Similarly, the dummy variable “MultipleCars” takes a value of one if the student’s household has two or more cars and zero otherwise. For individuals who did not specify their family income (48.5% of the students’ data set), a value of zero is assigned for the income variable, and the dummy variable (MissingIncome) is assigned a value of one. This dummy is assigned a value of zero for all other individuals who reported their family income.

RESULTS

The models specified above were estimated in Biogeme *(Bierlaire, 2003)* using maximum likelihood. This section shows the estimation results for the general population and the students and an analysis of value of time derived from these models.

General Population

The estimation results for the 164 observations are presented in Table IV along with model fit statistics.

Table IV – Model estimation results for the general population

Variable	Parameter Estimate	Robust Std err	Robust t-test
Car Constant	5.87	2.22	2.64
Jitney Constant	4.08	1.97	2.07
Time (minutes)	-0.0874	0.0301	-2.9
Cost (L.L.)	-0.0019	0.000454	-4.11
Frequency - Car	-0.668	0.343	-1.94
Frequency - Jitney	-0.529	0.323	-1.64
Final log-likelihood	-73.934		
Adjusted rho-squared	0.488		

All variables are significant at the 90% level of confidence. The coefficients of time and cost are both negative as expected.

Individuals performing frequent trips are more likely to use the buses since they follow exact routes. Moreover, these individuals become familiar with the bus service. Another explanation for avoiding the car in frequent trips is the unavailability of parking spaces in many zones in Greater Beirut. Gender, age, income, and residence location were not significant at the 90% level of confidence.

Students

For the student data set, the estimation results for 594 observations are presented in Table V.

Table V – Model estimation results for AUB students

Variable	Parameter Estimate	Robust Std err	Robust t-test
Car Constant	-3.05	0.836	-3.64
Jitney Constant	-1.16	0.466	-2.49
Time (minutes)	-0.0962	0.0194	-4.96
Cost (L.L.)	-0.00057	9.29E-05	-6.13
Income - Car (USD)	0.00031	0.000109	2.86
Income - Jitney (USD)	0.0002	0.000108	2.25
Missing Income - Car	2.65	0.506	5.23
Missing Income - Jitney	1.92	0.501	3.83
Male - Car	-0.916	0.342	-2.68
Male - Jitney	-0.45	0.342	-1.32
One Car - Specific to car	1.69	0.589	2.87
Multiple cars - Specific to car	3.27	0.551	5.93
Beirut - Jitney	1.08	0.271	3.99
Beirut - Bus	-1.40	0.420	-3.35
Final log-likelihood	-363.275		
Adjusted rho-squared	0.422		

All variables are significant at the 95% level of confidence except for the male dummy variable in the jitney utility equation.

The coefficients of time and cost are negative. Students with higher family income are more likely to use car compared to bus and jitney, and to use jitney compared to bus. Compared to females, males are more likely to use the bus and have a lower preference for car than for jitney.

Age and frequency were not included in the model due to the homogeneity across the data set; the majority of AUB students are below 25 years old, and AUB students usually visit AUB once per day. Since car availability (for every student) was not provided in the data set, the number of cars per household was used in the model. Students with a car available to their family are more likely to commute to AUB by car, and students having multiple cars are more likely to use car compared to those having only one car or no cars available to their household. The coefficient of Beirut in the jitney utility equation is positive, indicating that students living in Municipal Beirut are more likely to use the jitney compared to students living in other zones. This can be explained by the fact that jitneys, although available, are not easily accessible to residents of distant zones within Greater Beirut. On the other hand, this coefficient is negative in the bus utility equation. This is because bus services in Municipal Beirut have deteriorated over the past ten years. On the other hand, privately operated mini-vans significantly increased in the zones outside Municipal Beirut, and especially in the southern suburbs.

Value of time (VOT) Analysis

Based on the mode choice models presented above, the value of time for the general population is 2760 L.L./hour (in year 2000 L.L.) while that for students is 10,144 L.L./hour (in year 2010 L.L.).

Accounting for inflation from year 2000 to year 2010 (using rates obtained from Bank Audi annual reports for years 2006 -2009 *(Audi Saradar Group, 2007-2010)* and from a report presented to the Senate Ad hoc committee at LAU for previous years *(LAU, 2007)*), the VOT for the general population is 3928 L.L./hour (in year 2010 L.L.) compared to 10,144 L.L./hour for AUB students. In a previous transportation study in Lebanon conducted in 2008, the VOT for the Lebanese population was found to be 5,500 L.L./hour *(IBI Group and TEAM, 2009),* which when inflated to year 2010, becomes 6261 L.L./hour which is greater than the value obtained in this study for the general population.

The VOT of general trip makers is significantly lower than that of AUB students, despite the fact that 137 observations out of 164 (84%) in the general population data set correspond to work trips. This contradicts the general belief that employees usually have a higher VOT, as it is considered that self-employed travelers and private employees show the highest interest for fast options, while public employees and students come in the second place *(Antoniou et al., 2007)*. Some explanations can be given for this finding:

1. Compared to typical Lebanese citizens, AUB students originate from wealthy families as mentioned earlier.
2. University students have tight schedules compared to general trip makers. A late employee may generally lose an amount of money proportional to the time belated or spend an additional amount of time at work in case he/she arrives late, while a late student will miss a class.
3. AUB students pay relatively high tuition fees. A class session with duration of one hour costs AUB students much more than what a typical employee earns per hour.

The t-test test was also used to study the significance of the difference in ratios of the time to cost parameters representing the value of time *(Hess et al., 2012)*, and the difference in the VOT was statistically significant at the 95% level of confidence (t-statistic = 2.38). Therefore, we can reject the hypothesis of equality of VOT for both groups.

FORECASTING

The estimated model for AUB students was then used for forecasting (using sample enumeration) the new market shares of each of the three modes taking into consideration changes in several variables such as travel time by bus (representing for instance the introduction of exclusive bus lanes), parking cost, jitney fare, or bus fare. Aggregate elasticities were also calculated *(Ben-Akiva and Lerman, 1985)*. Figure 3 presents changes in market share with respect to changes in different variables.

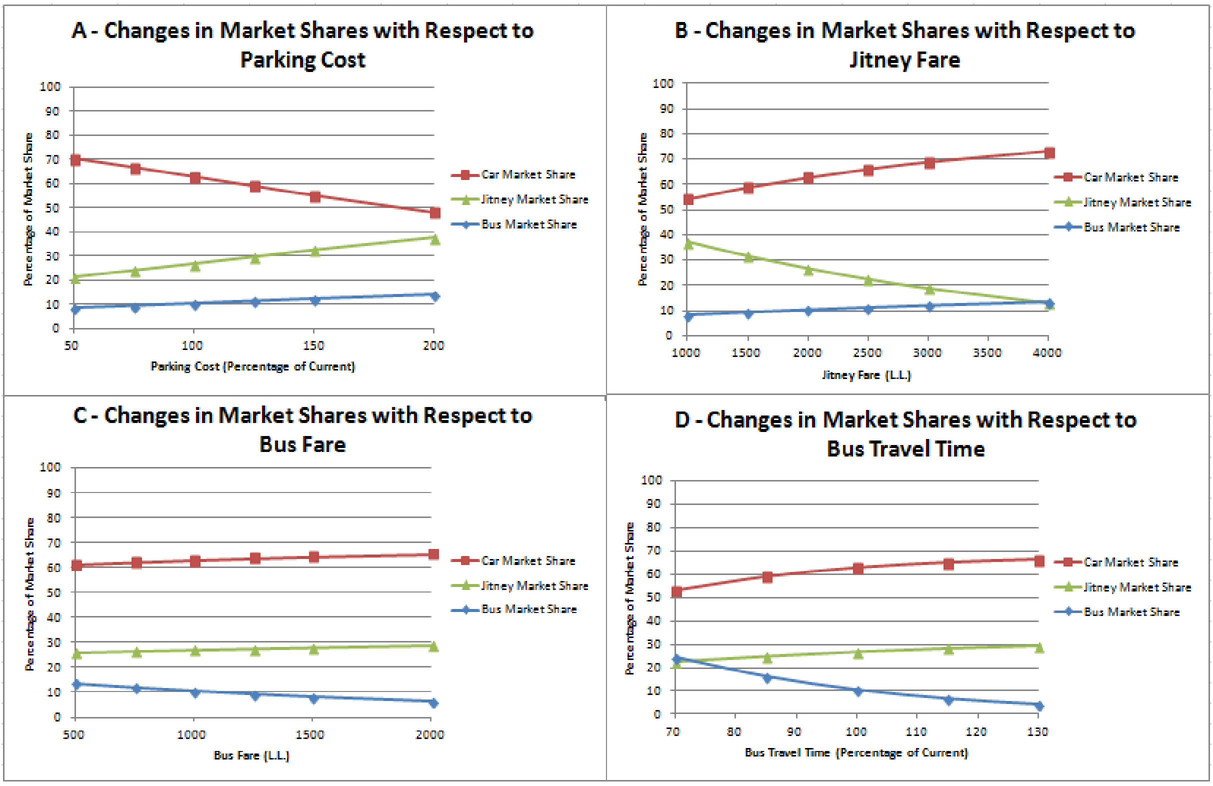

Figure 3 – Changes in market shares as a result of changes in independent variables

As shown in Figure 3-A, the car market share decreases drastically as parking cost increases with most students shifting to jitneys and not to bus. The elasticity of car market share with respect to changes in parking cost is approximately -0.25, while the cross elasticity values for bus and jitney market shares are 0.39 and 0.43, respectively. According to TRACE *(1999)*, the typical values of car demand elasticity with respect to parking price for educational trips are close to -0.1 for car drivers and 0 for car passengers.

The jitney market share elasticity with respect to jitney fare was about -0.68. The cross elasticity of the car market share was 0.23 and that of the bus market share was 0.39. The jitney elasticity with respect to jitney fare was also high compared to typical values. According to Litman *(2012)*, the elasticity of transit services with respect to transit fare was found by Dargay and Hanly *(1999)* to be ranging between -0.3 to -0.54 in the short run and -0.59 to -0.75 in the long run in France and England. Observing the plots in Figure 3-B, we notice again that the car option is absorbing most of the effect of changes in jitney market share (since the plot of car is steeper than that of bus) although the bus cross elasticity is higher than the car cross elasticity, which is mainly due to the low market share of bus *(Berman et al., 2011)*.

The elasticity of the bus market share with respect to changes in bus fare was approximately -0.51. The values of cross elasticity of car and jitney market shares were very low (0.05 and 0.08, respectively), implying that the demand for travel by car and jitney is very inelastic with respect to changes in bus fare. The obtained value of the bus market share elasticity with respect to bus fare was high compared to typical elasticity values found by similar studies. Dargay and Hanly *(1999)* found this value to be ranging between -0.2 to -0.3 in the short run and -0.4 to -0.6 in the long run. Luk and Hepburn *(1993)* found the elasticity of bus demand with respect to bus fare in Australia to be equal to -0.29. Goodwin *(1992)* obtained a value of -0.28 in the short run and -0.55 in the long run *(Litman, 2012)*. Again we notice that people shifting from the bus service are approximately equally distributed between the car and jitney options, and people changing to the bus option are shifting from both car and jitney options approximately equally since both plots of car and jitney market shares have approximately equal slopes (Figure 3-C).

The bus market share appeared to be highly elastic with respect to travel time by bus. The elasticity value is approximately -3.03. According to Litman *(2012)*, Small and Winston *(1999)* found the bus elasticity with respect to in-vehicle travel time to be equal to -0.6. The high elasticity obtained in this study is not only due to the reaction of commuters; it is also due to the low market share of bus. Observing the plots in Figure 3-D, we notice that the plot of car market share is approximately as steep as that of jitney, which implies that users switching from bus are equally distributed among the two other options, car and jitney. The obtained elasticity value is very high compared to typical values.

The estimated elasticity values are all greater than the typical values but generally closer to the long-term predicted elasticities, which suggests that the responses seem to be related to the long-term mode choice/switching behavior.

POLICY IMPLICATIONS

Universities always aim at creating a sustainable campus for students. Students' travel patterns do not only play a role in shaping the sustainability of the campuses themselves, but also contribute to the overall sustainability of a university's environment *(Delmelle and Delmelle, 2012)*. The major concern for decision makers is to reduce the usage of private cars in order for students to shift to public transport or non-motorized modes of travel. The forecasting analysis indicates that in the case of AUB, two policies/interventions may help achieve this modal shift. First, the high elasticity of the bus market share with respect to bus travel time suggests that a major factor causing students to refrain from using the bus is the long travel times suffered. If fast and reliable public transport modes could be provided (dedicated bus lanes, traffic signal priorities for buses, etc.), students would start shifting to this service. On the other hand, reductions in bus fare are unlikely to have a major effect on modal shifts as indicated by the elasticity values obtained and the students' high value of time. Second, the significant decrease in car market share with increases in parking pricing indicates that, as a short term solution, parking pricing can be a key factor affecting the use of car, in accordance with the findings of Shannon et al. *(2006)* and Delmelle and Delmelle *(2012)*. Iing expensive parking fees will result in less dependence on private automobiles and will reduce the parking friction in nearby streets. However, increases in parking pricing coupled with scarcity of parking supply in the vicinity of AUB may not be justifiable unless a more organized and higher quality public transport system becomes available.

The reduction in auto travel resulting from the above two policies/interventions will improve the flow conditions near the university campus leading to significant economic benefits in terms of reduced travel time and congestion relief for AUB students and employees as well as neighborhood residents and businesses.

CONCLUSION

This research investigates the extent to which the commute mode choice of AUB students differs from the mode choice behavior of the general population in light of their socioeconomic background and the fragmented public transport system in the Greater Beirut Area. Discrete choice models were developed to study the mode choice of AUB students. Results showed the travel time, travel cost, income, gender, and residence location are all important factors affecting the choices made by students. In accordance with the findings of similar studies, parking costs appeared to have a significant effect on students' mode choice. AUB students appeared to have a higher value of time compared to the general population due to their tight schedules and classes.

Future extension of this work would benefit from a more detailed data set which would enable us to relax some of the assumptions made regarding travel time and travel cost. A richer data set would also measure factors that were unavailable to us in the current study, including the availability of each of the three modes and qualitative factors affecting mode choice such as comfort, privacy, and habits through for instance attitudinal and perceptual rating statements. In addition, using the zone dummy in the model can lead to bias in parameter estimates due to the possibility of self-selection; i.e. it may be that an individual chooses a certain mode since he/she lives in a certain area, or that he/she chooses living in that area because he/she prefers that specific mode (Mokhtarian and Cao, 2008). Finally, comprehensive models should focus on ride sharing, maybe to be considered as a fourth option in addition to the three modes studied in this research, as well as non-motorized modes such as walking and biking to arrive at certain policies that could encourage the use of these modes.

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