UNDERSTANDING AND MODELING OF TRAVEL BEHAVIOR IN UNIVERSITY CAMPUSES: A CASE STUDY OF BOĞAZİÇİ UNIVERSITY

by

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To my mother

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ABSTRACT

UNDERSTANDING AND MODELING OF TRAVEL BEHAVIOR IN UNIVERSITY CAMPUSES: A CASE STUDY OF BOĞAZİÇİ UNIVERSITY

University campuses are places with distinctive demographic and travel characteristics. These special characteristics of the campuses necessitate a separate research focusing on understanding the underlying structure and the factors affecting travel to/from university campuses so that the campus transportation facilities are planned properly. Hence the main goal of this study is to understand the general characteristics of the transportation demand and supply for Bogazici University in general and to develop a trip modal-split model, which is one aspect of the general travel behavior. For fulfilling this general goal following objectives were aimed at: (i) to carry out a literature review for campus transportation studies; (ii) to collect and analyze data for understanding the general structure of campus transportation demand and supply; (iii) to develop modal split model for campus trips; (iv) to provide conclusions for transportation characteristics in campuses and provide recommendations for improvements based upon the research findings and finally; (v) to provide recommendations for further research. Bogaziçi University, founded in 1863, is one of the oldest universities in Turkey. It has four main campuses which are located in a hilly area in Istanbul and close to each other. For this study, data were collected through various traffic studies conducted in the campuses, interviews with staff and students and the records obtained from campus administration. Using the collected data campus transportation supply and demand characteristics were studied, a modal split model was calibrated for the University trips and some recommendations were made for transportation demand management through the understanding obtained from the analysis performed. Finally conclusions and recommendations for further research were provided.

ÖZET

UNİVERSİTE KAMPÜSLERİNDE ULAŞIM DAVRANIŞLARININ ANLAŞILMASI VE MODELLENMESİ: BOĞAZİÇİ ÜNİVERSİTESİ VAKA ÇALIŞMASI

Üniversite kampüsleri kendine özgü demografisi ve ulasim davranislari olan alanlardir. Bu özel nitelikler, üniversitelerin ulasim altyapisinin dogru planlanabilmesi için üniversiteye ve üniversiteden ulasiminin temel mekaniklerine ve bunlari etkileyen faktörlere odaklanmis arastirmalari gerekli kilmaktadir. Bu sebeplerle, bu çalismanin ana amaci yolculuk türel seçilim modellerini kullanarak Bogaziçi Üniversitesi'nin genel yolculuk talebi ve üretiminin genel karakteristigini anlamaktir. Bu amaç dogrultusunda: (i) kampüs ulastirma planlaması taranmasi; (ii) kampüs yolculuk talebi ve üretiminin anlasilmasi için veri toplanip analiz edilmesi; (iii) kampüs ulasimi için yolculuk türel seçim modellerinin olusturulmasi; (iv) elde edilen sonuçlar dogrultusunda kampüs ulasiminin degerlendirilmesi ve ulasim iyilestirme çalismalari önerilmesi ve son olarak; (v) gelecek çalismalar için önerilerde bulunulmasi amaçlanmistir. Bogaziçi Üniversitesi 1863'te kurulmus Türkiye'nin en köklü egitim kurumlarindan biridir. Üniversitenin Istanbul'un tepelik alanina kurulmus bir birine yakin dört ana kampüsü bulunmaktadir. Bu çalisma kapsaminda, veri toplamak amaciyla kampüslerde çesitli çalismalar yapilmis, ögrenciler ve üniversite personeliyle anket çalismasi yapilmis ve üniversite yönetiminden veri saglanmistir. Toplanan veriler kullanilarak üniversitenin ulasim üretim ve çekim karakteristikleri arastirilmis, yolculuk türel seçilim modeli olusturulmus ve elde edilen sonuçlar dogrultusunda ulasim iyilestirmesi amaciyla ulasim talep yönetimi odakli öneriler sunulmustur. Son olarak gelecek çalismalara yönelik bir takim önerilerde bulunulmustur.

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LIST OF SYMBOLS

C	Universal choice set
C_k	Choice set of person k
E	Elasticity
$Income_3000$	Dummy variable for income between 2000TL and 4000TL
$Income_4000$	Dummy variable for income higher than 4000TL
i	Mode index
J_k	Number of choices in choice set for person k
k	Person index
L	Likelihood
LL	Log-likelihood
LL	Log-likelihood ratio
$Male$	Dummy variable for gender
$R^2_{McFadden}$	McFadden's Pseudo R^2
$R^2_{Cox\&Snell}$	McFadden's Pseudo R^2
$R^2_{Nagelkerke}$	McFadden's Pseudo R^2
$Ttime$	Travel time
$Tcost$	Travel cost
U	Utility
U_{ik}	Utility of mode i for person k
V_{ik}	Deterministic part of the utility funcntion
ε_{ik}	Error term for utility
$Pr_k(i)$	Probability of choosing mode i fo person k
β	Coefficients for variables in multinomial logit model
δ_{jk}	Choice indicator

LIST OF ACRONYMS/ABBREVIATIONS

AASHE	The Association for the Advancement of Sustainability in Higher Education
IETT	Istanbul Electric Tram and Tunnel Company
HGS	Fast Toll Collection System
TL	Turkish Lira
UCLA	University of California at Los Angeles
USA	United States of America
RFID	Radio frequency identification
SFMTA	San Francisco Municipal Transportation Agency
UC	University of California
UO	University of Oregon
UW	University of Washington

1. INTRODUCTION

1.1. General

A campus is defined as "the ground and buildings of a university or college" in Oxford dictionary. Buildings in a university campus may include lecture halls, libraries, residence halls, dining halls, parking structures and even cinemas, theatres and stadiums. From this definition, it can be said that university campuses function like a small town which has its own planners, a governing body and a distinctive population. Generally university campuses have vibrant academic and social life; as a result, there is a continuous movement between buildings, and campuses attracting large amount of trips during a day. Due to the demographically different population, continuous movement between buildings, and the difference between universities and other institutions in terms of number of trips and distribution of trips during the day, transportation planning literature that focused on cities cannot fully address the transportation planning of university campuses (Toor and Havlick, 2004; Balsas 2003; Shannon *et al.* 2006).

Besides the university's main responsibilities of education and research, universities must lead the society by serving as a model society. Current government administrators were educated in a time that car is the main transportation mode; because of that, administrators may be skeptical about sustainable transportation. With similar logic, if administrators of future is educated in a sustainable environment now, they will be more enthusiastic, at least less skeptical about sustainability. Therefore, universities have the responsibility to promote sustainability for present and future (Balsas, 2003).

1.2. Goals and Objectives of the Study

There is limited literature available that focused on the transportation planning of the universities in Turkey. As mentioned above, campus transportation planning

literature claims that transportation planning efforts of universities must be different from the cities because of the demographical difference of the universities' population. Based on this claim, since Turkey has different demographical properties, it can be said that a study that focused on a Turkish University's transportation problems is needed. Hence the main goal of this study is to understand the general characteristics of the transportation demand and supply for Bogazici University in general and the trip modal-split in particular. For fulfilling this general goal following objectives were aimed at:

(i) to carry out a literature review for campus transportation studies,
(ii) to collect and analyze data for understanding the general structure of campus transportation demand and supply,
(iii) to develop models for travel modal split models for campus trips,
(iv) to provide conclusions and recommendations based upon the research findings and finally,
(v) to provide recommendations for further research.

This study provides an assessment of Bogazici University's current transportation system, and travel behavior of university's population in general and the travel modal choice in particular.

2. LITERATURE REVIEW

Many old universities and newly founded urban universities have limited land because the land surrounding the campus is either too expensive or urbanized. With the increase of car ownership over the second half of the last century (Dargay *et al.* 2007), university campuses began to experience car usage related problems like parking shortage, land use problems and pedestrian mobility and security problems. Because of the problems that have been experienced and lack of literature that fully addresses campus transportation problems, from the early 1990's a campus transportation literature has begun to grow. Many researchers and planners have been focused on transportation demand management strategies to address campus transportation problems. With the increase of the global awareness about sustainability and health in 21^{st} century, goal of the planners and researchers have become to promote active transportation in university campuses (Balsas, 2003; Shannon *et al.* 2006; Whalen *et al.* 2013).

Balsas (2003) used results of survey of eight bicycle and pedestrian friendly campuses (Cornell University, UW Madison, UC Boulder, UC Santa Barbara, Stanford University, UC Davis, UO Eugene and UW Seattle) to investigate how these bicycle and pedestrian friendly campuses encouraged a modal shift from cars to other modes. The researcher suggests that in order to promote active commuting, a highly integrated strategy package must be implemented. These strategies include de-marketing automobile commuting, TDM strategies, organization and planning of facilities, promotion, education and enforcement. The researcher also points that these type of extensive changes are likely to face opposition from the university community.

Shannon *et al.* (2006) investigated potential barriers and motivators affecting active transport decisions in University of Western Australia. They defined 6 different state of behavior change to explain potential for a shift to active transportation modes (walking, cycling, and public transportation). The researchers conducted a survey to identify these stages and reveal possibly effective interventions to increase modal share of the active modes. Results show that most effective interventions are aimed to reduce

travel time barrier, address perception of travel time and improve cost effectiveness of active modes and reducing cost effectiveness of private modes. With a proper intervention package, the researchers believe that 30% of the staff and students will switch to the active modes.

Shoup (2008) proposed a pricing methodology for parking in university campuses. The researcher investigated problems of parking universities in USA. The researcher points that parking management is a vital part of the transportation demand management. He states that there are two main approaches to the parking problem political and economic. Political approach uses rules and regulations (e.g. need based or hierarchic parking permit distribution) to manage parking and parking demand. On the other hand, Economic approach uses market prices to manage parking demand. The researches argues that political approach is not sustainable economically and geographically, and eventually leads to parking space shortage. The researcher also states that enforcing rules and regulations may exceed the jurisdiction of university administrations and even if it do not exceed, it may become too expensive to enforce. The researcher proposes a performance based parking scheme, which have the following principle: "The price is too high if too many spaces are vacant, the price is too low if no spaces are vacant. When a few spaces are vacant everywhere, the price is just right". According to proposed scheme, prices must be set according to centrality of parking space and time of the day and aimed to sustain 85% occupancy throughout the day.

Barata *et al.* (2011) analyzed current parking problems in University of Coimbra, Portugal, which have a historical campus where land use is limited. 45% percent of the parking supply of the university does not involve any charge. The remaining 55% percent is reserved to staff which subject to an annual payment. The researchers modelled parking demand and conducted a survey to examine socio-economic profile of the campus commuters, transportation choices, and willingness to pay for parking on campus. Results show that, 73% of the drivers are willing to reduce their car use if adequate incentive programs applied for public transportation. The researchers suggest that parking facilities are underpriced and they must be priced accordingly to

parking costs. The generated parking revenue can be used in transportation projects or management programs.

Daley and Rissel (2010) stated that public image of cycling and cyclist can impede penetration of cycling into different layers of society. They conducted a focus group research to identify public image of cycling and cyclists and effects of these images on cycling choices. According to results, respondents define cycling as clean, green, healthy, fun, dangerous and serious business; however, cyclists have negative image. Respondents see cyclists as risk takers, law breakers and radical green activists. Due to these negative images associated with cycling and cyclists, researchers suggest that promotional campaigns for cycling must be prepared to make bicycle more mainstream.

Miralles-Guasch and Domene (2010) have examined the challenges that a suburban university (Autonomous University of Barcelona) must face in order to achieve their sustainable transportation goals. A survey was conducted to identify travel behavior of the university community. According to results main motivators for walking are proximity to campus, comfortable and pleasant trip experience and low cost. For cycling, main motivators are low cost, short commute time and comfort. They noted that health and environmental concerns do not motivate people to choose walking and cycling as a mode of transportation. They also proposed interventions to increase mode share of active transportation modes. These are introducing a subsidized public transportation card, increasing parking price, increasing number of in-campus housing and improvement of bicycle paths, increasing number of bicycle parking facilities and intersection treatments.

Steg (2004) investigated psychological motives for car use. The researcher divided these motives into 3 categories. These are instrumental, symbolic and affective motives. Instrumental motives are related to convenience and inconvenience of car use. Symbolic motives are about indicator role of car usage in social position. Affective motives are mood changes that car usage inflicts on people. According to results, for young people symbolic and affective motives are more important than other age groups, people with low-income value symbolic and affective aspects of car use than higher income groups.

The researcher suggests that in transportation demand management strategies should not be only focused on instrumental aspects of car use, they should also be directed on non-instrumental motives of car use.

Since cycling is the ideal mode of transportation for short distance inter-campus and on-campus trips, cycling is a vital part of the sustainable transportation planning in college campuses. Because of the relatively progressive community structure of the universities, promoting cycling as a mode of transportation is relatively easy than in cities (Barata *et al.* 2011). National Bicycling and Walking Study (1994), identified factors affecting bicycle demand and divided into two main group as subjective and objective factors. Distance, traffic safety, convenience, cost, value of time, value of exercise, physical condition, family circumstances, habits, attitudes and values and peer group acceptance are the subjective factors. Climate, topography, presence of bicycle facilities and traffic conditions, access and linkage and transportation alternatives are the objective factors. Among these factors Daley and Rissel (2011), stated that perceived safety is a significant barrier to keep people away from cycling. There are programs in many cities for educating both cyclists and motorists about cyclists' legal rights. However, Pucher *et al.* (2010) claimed that there is no statistical evidence to prove these programs' positive quantitative effects on cyclists' safety but these educational programs increase people's self-confidence for cycling. Jacobsen (2003) introduced "safety in numbers" phenomena to explain factors affecting cyclists' safety. Jacobsen (2003) showed that as the cycling level increases injury rate of cyclists' decreases. According to Elvik (2009) and Jacobsen (2003), increase in number of cyclists' leads to increased visibility of cyclists which is an important factor for cycling safety.

Availability of a bicycle in a household is an important and direct factor that affects cycling choices (Cervero *et al.* 2009). Risk of theft, cost of a bicycle, maintenance and lack of safe parking areas affect bicycle ownership. In order to increase bicycle access, giveaway, loaner and service programs and bicycle sharing systems are used extensively. Researches show that these programs increase overall trip share of cycling effectively. Beside cities, universities in USA also adopt bicycle sharing systems to increase modal share of bicycle. Main problem in bicycle sharing systems is distribution

of bicycles among stations. In order to improve distribution, Velib (Bicycle sharing system in Paris) bicycle sharing system rewards cyclists that use uphill stations with 15 minute extra credit (DeMaio, 2009).

All the studies presented in this section proposes to use transportation demand management strategies for transportation planning of campuses. Transportation demand management (also called Mobility Management) refers to various strategies that change travel behavior (how, when and where people travel) in order to increase transport system efficiency and achieve specific planning objectives.

2.1. Campus Transportation Demand Management Strategies

Transportation demand management in campus transportation planning can be defined as "a package of planning strategies, incentives and disincentives, which emphasize alternatives to single occupant vehicle" (Balsas, 2003). In this part, popular transportation demand management strategies are given.

2.1.1. Transportation Allowance and Parking Cash Out

Transportation allowance programs provide a budget for each individual for their transportation related expenses. People either use them for their transportation needs or cash out the financial incentive. Similarly, parking cash out programs offers money to staff for not using their parking space. However, these strategies may result in spillover parking in surrounding neighborhood. Spillover parking may cause inconvenience among neighborhood's residents.

Analyses show that, in UCLA, capital and maintenance cost of a parking spot in a parking structure is 223$ per space per month (Shoup, 2008). For surface parking, monthly cost is estimated as 83$ per space per month in University of Colorado (Shoup, 2008). However, price of a parking permit is 55$. Because of the high capital and operation cost of parking structures, Stanford University and University of Colorado developed a program that focused on drivers which willing to switch their mode choice.

They offer payment (160$/year and 250$/year in Stanford and Colorado respectively) for not driving for commuting (Toor and Havlick, 2004).

2.1.2. Carsharing and Guaranteed Ride Home

Purpose of these strategies is to reduce the need of vehicle ownership. In carsharing, a vehicle fleet is provided to the members of the sharing program for limited purpose or time. Universities often use services of private car rental companies to provide a vehicle fleet. For example, Zipcar^{TM} offers carsharing service in 300 university campuses in USA. In case of university owned carsharing program, implementation costs are high but it can be recovered from membership payments. Studies show that, 20% of the members of a carsharing program stopped using private vehicle and on average 5 private vehicle were replaced by a shared vehicle (Millard-Ball *et al.* 2005).

Guaranteed ride home is providing a free taxi ride to home in case of emergency. This program could cover all employees, or only those who use alternative modes. Number of free trips can be limited for a certain period to prevent abusing of the program. There is no study on quantitative outcome of guaranteed ride home program. However, guaranteed ride home program is considered a significant factor in making the decision to use alternative modes (Analytics, 1992)

2.1.3. Free or Subsidized Transit Passes

Trip cost is an important factor for people in choosing their preferred mode of transportation. Because of that, in order to increase public transportation usage, free or subsidized transit passes were widely implemented to public transportation systems. Students or employees or both can be subsidized by these programs. Cost of the program can either embedded into tuition or subsidized fully by the universities. BruinGO and UPass are example successful subsidized transit pass programs.

U-Pass is an unlimited access program that participated by 167 (AASHE, 2012) academic institutions in North America. Brown *et al.* (2001) provided the empiri-

cal data for the transit ridership before and after the implementation of the UPass. According to the data, the difference in transit ridership before and after of the implementation of U-Pass is in range between 77% and 200%. BruinGO is similar to U-Pass but only one of the major transit service providers of the Los Angeles is included in the program. Program is mainly used by UCLA students and staff. A before and after analysis in Brown *et al.* (2003), showed that inside the bus service area, BruinGO program increased transit ridership of staff 134% and of students 43%. A significant decrease (9% for staff, 43% for students) in driving alone to the campus was also reported.

2.1.4. Parking Price Regulations

As stated in simple supply and demand relationship, if goods or services are underpriced there will be a supply shortage, yet it is often to see underpriced or free parking in universities. Trip cost generally is a significant factor for people in their decisions on mode choice. Increasing parking cost reduces mode share of driving by simply increasing the trip cost of driving to campus. Toor and Havlick (2004), states that if alternatives are available, increasing parking cost can cause 25% of the drivers to shift their modes to alternative modes; however, if there are no sufficient alternative available, spillover parking to the neighborhood can cause problems. In addition, as people get used to new prices, the effect of increased parking price may lose its effectiveness. A before and after study in Los Angeles showed that an increase of monthly parking price from 0$ to 58$ was decreased the driving alone by 58% and increased carpooling 241% (Wilson and Shoup, 1990).

The other approach using pricing as a TDM strategy is changing pricing period. Fixed costs for semester or annual parking permits reduces marginal cost of parking to zero (Shoup, 2008). Students with semester or annual parking permits have no motivation to not to drive to the campus. Changing semester permits to daily permits creates marginal costs for drivers and encourages people to use alternative transportation modes.

2.1.5. Parking Supply Management

Straightforward approach to manage parking supply is limiting number of parking permits; however, this may result in spillover parking in surrounding neighborhood. As a result of this, it may cause inconvenience among neighborhood's residents. In order to control spillover effect, municipalities and university administrations may collaborate to establish a residential parking zone to prevent university community to park off-campus (Toor and Havlick, 2004).

Imposing restrictions on permit distribution can also be used for parking supply management. For example, restricting students from getting parking permits if they live close to campus (Shoup, 2008). Beside from restrictions based on residence area, academic merit or age based restrictions can also be applied.

Another approach for parking supply management is to limiting parking duration in certain parking areas. Limiting parking duration for guests is an example application. These applications are aimed to meet the short time parking demand without using excessive parking capacity. Necessary information must be given by signs to direct short time parking demand to short time parking zones. Enforcement may be needed to prevent long time parking in these areas.

2.1.6. Cycling Promotion

Cycling promotion includes all types of promotion and marketing campaigns aimed to increase mode share of cycling. There are several popular cycling promotion applications that have been proven to be effective.

Recreational bicycle events are mass cycling events that people participate voluntarily. Event organization generally includes a small incentive (free meal, shopping coupon etc.). Bowles *et al.* (2006) examined travel behavior of mass cycling event participants before and after of the event. They conducted travel surveys to participants before and 1 month after the event. Results show that, low level cyclists (4 cycling

trips per month) increased number of cycling trips to 6.8 trips per month. Also for first-time participants, an increase of 1.6 cycling trips per month was observed.

Bicycle awareness campaigns can be consist of television commercials, newspaper advertisements and community events to promote cycling as a mode of transportation by promoting benefits of cycling. In Western Australia, an extensive campaign package that contains 30 second long public service announcement on television for duration of 4 weeks, free bicycle accessories giveaway and newspaper advertisements, was used to promote cycling. A before and after analysis showed that, number of cyclists were increased from 26% to 36% (Greig, 2001; Pucher *et al.* 2010).

Cycle to school or work days are annual events that people use bicycle for transportation to their workplace or school. Similar to recreational cycling events, generally there is a small incentive to use cycling on event day. Studies show that, cycle to school or work day increases number of cyclists significantly. Rose and Marfurt (2006) examined travel behavior change caused by cycle to work day event. They found that, 27% of the first-time bicycle riders to work were continued to cycle to work after 5 months from the event.

2.1.7. Cycling Education

Educational programs may be focused to improving cycling skills, cyclist safety on traffic, pedestrian safety and traffic rules for cyclists. Cycling communities in universities have a significant role in these programs, they can collaborate with the university administration to prepare a cycling guide for university that shows locker locations, rules and regulations, safety tips and maintenance areas. In addition to cycling guide, an introductory course, that focused on safety and cycling skills, can be conducted by cycling communities at the beginning of each semester. Telfer *et al.* (2005) evaluated the effect of a cycling proficiency course in Central Sydney. They used self-administered surveys conducted before and 2 month after the education program. 56% of the participants of the course reported that, because of the cycling course, their self-confidence and cycling skills were increased.

2.1.8. Carpool Promotion

In order to subsidize carpooling, dedicated carpool parking spaces can be established in the most preferable parking areas. Some form of identification is needed to prevent misuse of these parking spaces. Prioritized parking is used in many university campuses. In addition to prioritized parking, financial incentives (discount in parking permit price) can also be used to promote carpool. Promotion campaigns that used in bicycling promotion can be adapted into carpool promotion (Kimley-Horn and Associates Inc., 2014; Tetra Tech, 2012; Kansas State University, 2012; Sanchez *et al.* 2010).

3. METHODOLOGY

The methodology followed in this study was summarized in the flow chart given in Figure 3.1. First, literature of campus transportation studies was reviewed, then data were collected. The collected datasets are: course schedules and dining hall logs, queue lengths of shuttle bus, campus parking areas and their capacities, parking permit records, personnel shuttle smart card logs and campus transportation questionnaire. After data collection, preliminary analysis of data was done. From dining hall logs and course schedule data, travel demand between campuses was determined; from parking capacities and permit record, parking space supply and potential demand for parking was determined; campus transportation survey and personnel shuttle logs were used for selection of multinomial logit model variables and travel time and cost estimation of alternative mode choices. Then by using these results separate multinomial logit models were calibrated. By using model results and other results obtained from preliminary analysis, transportation system of Bogaziçi University was assessed and finally some recommendations for improving transportation in campuses and future research were made. In this chapter theory of multinomial logit models was explained.

3.1. Multinomial Logit Model

Multinomial logit model is a discrete choice analysis method widely used for transportation demand forecasting and mode choice analysis. Multinomial logit models are used when the choice set consists of three or more discrete choices.

In order to illustrate the theory, assume there is a universal choice set C that contains all possible choices for a population. Each member of this population has a choice set C_k, which is a subset of C, that contain J_k number of choices. Number of elements in individual choice sets and universal choice sets may not be equal. For example, considering universal choice set consists of all possible transport mode choices, a person may live outside of the bus service area or that person's commute trip distance is too long to accept cycling as a mode choice. In multinomial logit modelling, utility

of alternative i is for individual k defined as (Ben-Akiva and Lerman, 1985):

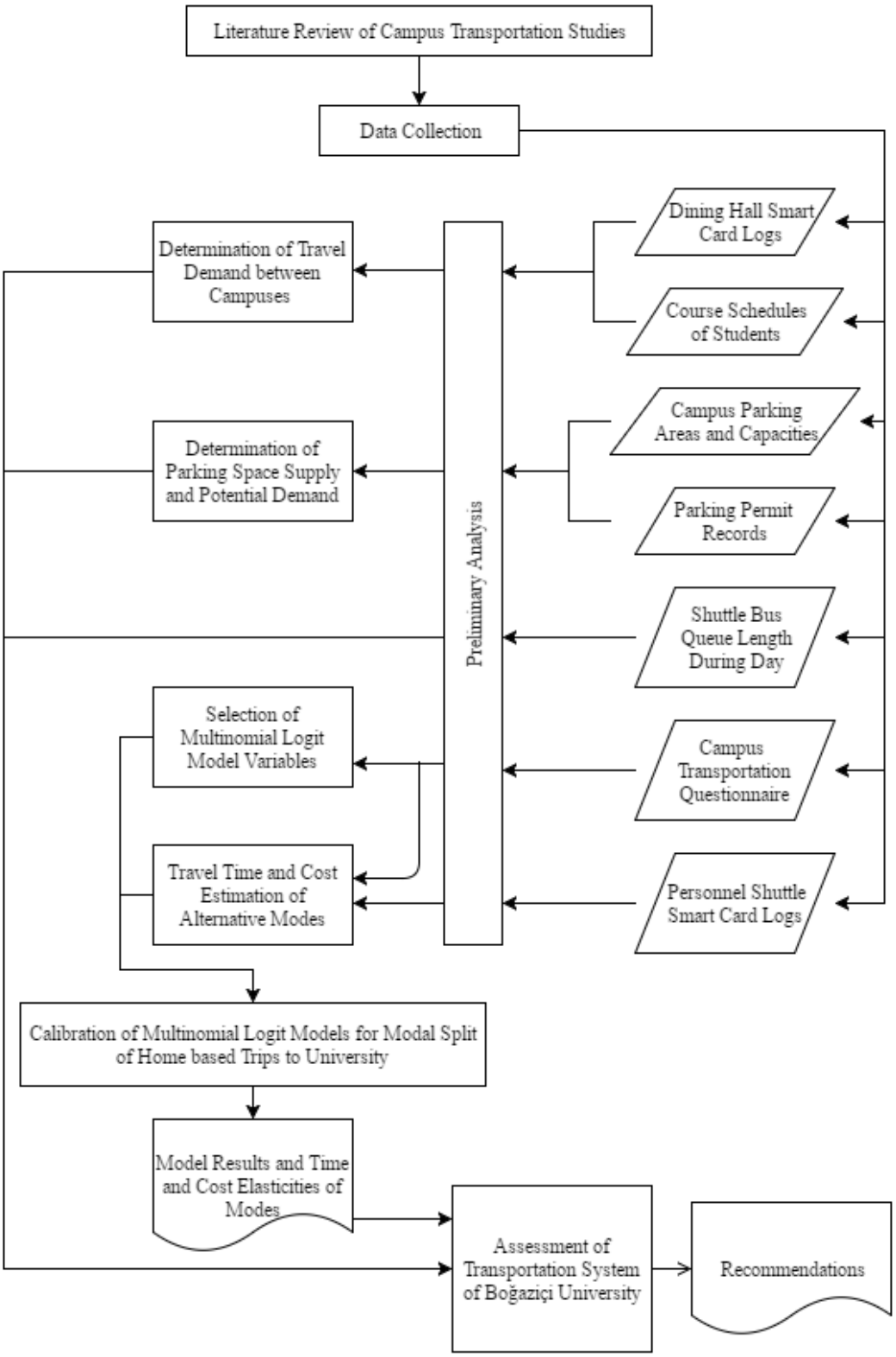

Figure 3.1. Flowchart for the Methodology.

$$U_{ik} = V_{ik} + \varepsilon_{ik} \tag{3.1}$$

ε_{ik} is the error term. It represents the unmeasurable random components in utility assessment of people. Generally, error term assumed to have normal distribution; however, in multinomial logit modelling, for its calculation advantages, it is assumed that error term has Gumbel distribution and identically and independently distributed across observations and alternatives. V_{jk} is the systematic component of the utility function for the person k. Probability of the decision-maker k choosing alternative i is defined as (Ben-Akiva and Lerman, 1985):

$$\Pr_k(i) = \frac{\exp(V_{ik})}{\sum_{j=1}^{J} \exp(V_{jk})} \tag{3.2}$$

Equation 3.2 can also be expressed as:

$$\Pr_k(i) = \frac{1}{1 + \sum_{j \neq i} \exp(V_{jk} - V_{ik})} \tag{3.3}$$

For the calculation of deterministic part of the utility function,V_{ik}, a linear predictor function of the following form is used.

$$V_{ik} = \beta_{0,i} + \beta_{1,i} X_{1,k} + \beta_{2,i} X_{2,k} + \ldots + \beta_{M,i} X_{M,k} \tag{3.4}$$

Where X represents explanatory variables and β represents coefficients of the multinomial logit model. Coefficients can either be alternative specific or generic (constant for each alternative).

Multinomial logit models have two important properties that affect model structure and outcome. First one is the equivalent differences property. As seen in the Equation 3.2, an equal utility difference for all alternatives does not change the probability outcome. Consider the following utility equation set of one individual for alternatives

A, B and C:

$$V_A = \beta_{0,A} + \beta_{1,A}X + \beta_2 Y_A \tag{3.5}$$

$$V_B = \beta_{0,B} + \beta_{1,B}X + \beta_2 Y_B \tag{3.6}$$

$$V_C = \beta_{0,C} + \beta_{1,C}X + \beta_2 Y_C \tag{3.7}$$

Where Y is a continious variable that represents a property of the alternative (e.g., travel time, and trip cost), and X is a dummy variable that reflect a property of the individual (e.g., income, gender and so on). Probability of choosing alternative A can be found from Equation 3.3:

$$\Pr(A) = \frac{1}{1 + \exp(V_B - V_A) + \exp(V_C - V_A)} \tag{3.8}$$

The utility differences between alternatives in Equation 3.8 can be expressed in open form:

$$V_B - V_A = (\beta_{0,B} - \beta_{0,A}) + (\beta_{1,B} - \beta_{1,A})X + \beta_2 (Y_B - Y_A) \tag{3.9}$$

$$V_C - V_A = (\beta_{0,C} - \beta_{0,A}) + (\beta_{1,C} - \beta_{1,A})X + \beta_2 (Y_C - Y_A) \tag{3.10}$$

As seen in Equation 3.8 Equation 3.9, Equation 3.10 a change in the $\beta_{(0,A)}$ or $\beta_{(1,A)}$ does not change the utility differences between the pairs; as a result, probability of selecting the alternative A is not changed. Therefore, estimation of the all model coefficients in Equation 3.5, Equation 3.6, Equation 3.7 is not possible. To overcome this problem, for alternative specific constants, an alternative is selected as reference alternative and alternative specific coefficients for that alternative is assumed to be zero. If alternative

A is selected as reference alternative, utility equation set becomes:

$$V_A = \beta_2 Y_A \tag{3.11}$$

$$V_B = \beta_{0,B-0,A} + \beta_{1,B-1,A} X + \beta_2 Y_B \tag{3.12}$$

$$V_C = \beta_{0,C-0,A} + \beta_{1,C-1,A} X + \beta_2 Y_C \tag{3.13}$$

The notation difference in the coefficients $\beta_{0,B-0,A}$,$\beta_{1,B-1,A}$,$\beta_{0,C-0,A}$ and $\beta_{1,C-1,A}$ represents that these values of these coefficients are determined relative to the selected reference alternative A. Selection of the reference alternative does not change the overall performance of the model; however, it changes the values of the model coefficients.

The other property of multinomial logit model is independence of irrelevant alternatives (IIA). IIA property states that for any individual, the ratio of probabilities choosing two alternatives is independent of the presence or attributes of any other alternative. This property is based on the initial assumption of the error term is independently distributed over alternatives. In short, including a similar alternative to the existing alternatives in a multinomial logit model will lead to erroneous predictions (Ben-Akiva and Lerman, 1985).

3.1.1. Estimation of Model Coefficients

For estimation of the logit model parameters, maximum likelihood method is used. In maximum likelihood method, observed choices of the sample are used to find parameters that maximize the posterior probability (likelihood). Likelihood function with K individuals, each with J alternatives is represented as (Koppelman and Bhat,

2006):

$$L(\beta) = \prod_{k=1}^{K} \prod_{j=1}^{J} (Pr_{jk}(\beta))^{\delta_{jk}} \tag{3.14}$$

δjk is the choice indicator that equals to 1 if individual k chooses the alternative j and 0, otherwise. Pr_{jk} is the probability that individual k chooses alternative j.

In order to maximize the likelihood, fist derivative of the likelihood function must be found and equated to zero. Because logarithm of a function is simpler to differentiate and gives the same result, instead of the differentiating likelihood function, log-likelihood function is differentiated. Logarithm of the likelihood function is:

$$LL(\beta) = Log(L(\beta)) = \sum_{k=1}^{K} \sum_{j=1}^{J} \delta_{jk} ln(Pr_{jk}(\beta)) \tag{3.15}$$

First derivative of the log-likelihood function is defined as:

$$\frac{\partial(LL)}{\partial\beta} = \sum_{k=1}^{K} \sum_{j=1}^{J} \delta_{jk} \frac{1}{Pr_{jk}} \frac{\partial Pr_{jk}(\beta)}{\partial\beta} \tag{3.16}$$

For finding parameters, β, that give maximum likelihood, Equation 3.16 must be solved for β by equating it to zero.

3.1.2. Tests for Multinomial Logit Models

After determination of the model coefficients, model is tested to determine significance and performance of it. In case of multinomial logit models, log-likelihood ratio (LLR) and pseudo R^2 are widely used statistics for this purpose.

Likelihood ratio test performed by determining coefficients for two separate models. First model is the model with explanatory variables. The other model is the basic model with only the alternative specific constants. Ratio of the log-likelihoods of these

two models is defined as (Koppelman and Bhat, 2006):

$$LLR = -2\ln\left(\frac{L\left(nullmodel\right)}{L\left(fittedmodel\right)}\right) \tag{3.17}$$

$$LLR = -2\left(LL\left(nullmodel\right) - LL\left(fittedmodel\right)\right) \tag{3.18}$$

Calculated LLR statistic is assumed to have chi-square distribution with degrees of freedom equal to the difference in degrees of freedoms of compared models. If calculated LLR value is greater than the selected significance value, it can be said that proposed model is an improvement to the null model.

Regular R^2 is a statistic for representing the portion of the variance explained in ordinary least square regression models. For other models including multinomial logit models there are several different pseudo R^2 values defined by different researchers for following purposes:

- To represent explained portion of the variance
- To represent improvement from the null model
- To represent correlation

In multinomial logit modelling, McFadden's pseudo R^2 used for both to estimate explained portion of the variance and to represent improvement from the null model. Formula to calculate McFadden's pseudo R^2 as follows (Domencich and McFadden, 1975):

$$R^2_{McFadden} = 1 - \frac{LL\left(fittedmodel\right)}{LL\left(nullmodel\right)} \tag{3.19}$$

Cox and Snell pseudo R^2 statistic is used for to reflect improvement from the null model. Formula of Cox and Snell pseudo R^2 is as follows (Cox and Snell, 1989):

$$R^2_{Cox\&Snell} = 1 - \left(\frac{L\,(nullmodel)}{L(fittedmodel}\right)^{2/N} \tag{3.20}$$

where, N is the number of observations in the model. Nagelkerke normalized the Cox and Snell pseudo R^2 statistic to the interval between 0 and 1. Nagelkerke pseudo R^2 formula is as follows (Nagelkerke and Nico, 1992):

$$R^2_{Nagelkerke} = \frac{1 - \left(\frac{L(nullmodel)}{L(fittedmodel}\right)^{2/N}}{1 - L(nullmodel)^{2/N}} \tag{3.21}$$

4. DATA COLLECTION AND ANALYSIS

Data used in this study were provided both by Bogaziçi University administration or collected from the field. Provided data were course schedules of the students, dining hall smart card data, parking permit records and personnel shuttle smart card data. Capacities of parking areas, campus transportation survey data, shuttle demand and number of people in shuttle queues are the data collected from the field. In this chapter, data used in this study were explained and preliminary analyses were performed.

4.1. Information about Bogaziçi University

Bogaziçi University, founded in 1863, is one of the oldest educational institutions in Turkey. The university has 6 campuses located in Istanbul. South, North, Hisar and Ucaksavar Campuses are located close to each other in Hisarustu district of Istanbul. Saritepe Campus is located in northern part of Istanbul, and Kandilli campus is located in Asian side of Istanbul. Educational and recreational center of the university is mainly South, North, Hisar and Ucaksavar Campuses. The university's facilities are scattered among aforementioned 4 campuses. For instance, the library is located in North campus, the student clubs are in South Campus, and the gym is in Hisar Campus. Even some departments have classrooms or laboratories in different campuses. Because of this decentralized structure of the university, many students make trips between campuses during the day. Primary transportation modes used for these trips are walking and shuttle buses. As seen in Table 4.1, the distances between main campuses are favorable for cycling. However, hilly topography of the area, where the university is located, discourages people to cycle between or within the campuses.

Trips originated in South Campus suffer the most from this topographic disincentive because of the 350 m long ramp with 9.6% average grade (14.5% max. grade). Therefore, the students have a tendency to prefer to use shuttle busses for their trips originating from South Campus. This, as a result, is causing long queues in the shuttle bus stop in South Campus.

Table 4.1. Distances Between Campuses.

	South Campus	North Campus	Hisar Campus	Uçaksavar Campus	Kandilli Campus	Sarıtepe Campus
South Campus		873 m	1268 m	1340 m	12.3 km	31.6 km
North Campus	873 m		892 m	601 m	11.9 km	30.3 km
Hisar Campus	1268 m	892 m		1240 m	12.5 km	31.4 km
Uçaksavar Campus	1340 m	601 m	1240 m		11.1 km	30.1 km
Kandilli Campus	12.3 km	11.9 km	12.5 km	11.1 km		38.5 km
Saritepe Campus	31.6 km	30.3 km	31.4 km	30.1 km	38.5 km	

4.2. Data Collection

4.2.1. Course Schedules of Students and Dining Hall Smart Card Records

The course schedules and dining hall smart card logs of all undergraduate and graduate students in 2014-2015 academic year were obtained from the Bogaziçi University Registrar Office in order to estimate the number of students in campuses and the number of trips between main campuses during the day. However, graduate students' data were not useful because location and time of the graduate courses were not available in the registration system. As a result of this, this analysis is limited to effects of the movements of the undergraduate students.

4.2.2. Queue Length of Shuttle Stop at South Campus

Because of the ramp located in the South campus. There is a significant demand on shuttle busses in South Campus. To determine volume and capacity of shuttle busses working between campuses, number of passengers and number of people in queue were counted for one week period. Since no queue formation were observed in other shuttle bus stops, only queue lengths of South Campus shuttle bus stop were measured.

4.2.3. Parking Capacity and Parking Permits

Bogaziçi University has no records regarding parking areas and their capacities. Because of that, a land survey in South and North Campus was conducted. In order to determine potential parking demand, records of parking permits were provided by Bogaziçi University Administration. There are only 2 types of parking permits, staff and student, in Bogaziçi University. While staff parking permit grants access to all areas of the campuses, student parking permit grants access only to student parking areas which are student carpark in South campus and parking structure in North Campus.

4.2.4. Interviews with Campus Staff and Students

In order to construct travel demand models in general and travel modal split model in particular as aimed in this study, data must be collected from various sources. Most commonly used method for data collection in transportation mode choice models is conducting transportation surveys. In December 2015, a questionnaire for investigating transportation habits of Bogaziçi University community and community's opinion about certain transportation infrastructure improvements was designed and conducted in South, North, Hisar, Ucaksavar and Kandilli Campuses.

Questionnaire had 28 questions in 6 parts. In these parts, community's transportation habits of home based trips to university, parking problems in campuses, pedestrian and cyclist safety in campuses, transportation habits for trips between campuses, possible improvements of transportation system and demographics of the community were investigated. The questionnaire form was given in Appendix A.

There are two different groups of populations in universities. These are students and staff (both academic and administrative). Because of that, a stratified simple random sampling method was employed for this survey (Richardson *et al.* 1995). Sample was selected randomly (via a random number generator) from university staff and student record. Students' record was provided by the Bogaziçi University Registrar

Office, and personnel record was provided by Bogaziçi University Personnel Administration. Size of the population, selected sample size, assumed response rate, number of collected sample and actual response rate were given in Table 4.2. Sample sizes were selected according to the required number of observations for multinomial logit model. Although required sample size for making inferences about population is much lower than selected sample size (Richardson *et al.* 1995; Franklin and Walker, 2003), relatively large sample sizes were selected in order to have necessary number of mode choice observations after discarding the data that are not suitable for the models. Behavior of the non-respondents were assumed to have same as the respondents (Franklin and Walker, 2003).

Table 4.2. Sample Properties.

Stratum	Population Size	Sample Size	Assumed Response Rate	Number of Collected Samples	Actual Response Rate
Student	15684	2000	70%	1258	62.90%
Staff	1923	700	85%	537	76.70%

Data were collected via personal interviews and e-mails. For interviews with students, questionnaire, a guideline for questionnaire and a confidentiality statement regarding collected data were e-mailed to sampled students asked them to participate the survey study. Collected data were controlled and if an item-non response was detected in first five part of the questionnaire, same questionnaire form sent back the student and kindly asked to fill the necessary fields. For the last part of the questionnaire, which consist of personal questions (gender, income, location of residence), item non-response was permitted to prevent students from opting-out from the survey study. Personal interviews were conducted with university staff. Interviewers were selected from university's students. Interviewers went to offices' of the sampled staffs to conduct interviews. Questions in the first 5 part of the questionnaire were asked by interviewers. For the last part of the questionnaire, to improve the feeling of privacy, questionnaire forms were handed to the interviewees and asked them to answer the

questions. Item non-response was permitted for last part to prevent opting-out.

4.2.5. Personnel Shuttle Smart Card Data

Two weeks of personnel shuttle smart card data is provided by Bogaziçi University Administration. Data consist of boarding time of the staff, boarding location and the number of the shuttle which is boarded on. Data were mainly used for travel time determination of the personnel shuttle users in multinomial logit model.

4.3. Preliminary Analysis of Data

4.3.1. The Analysis of Course Schedules and Dining Hall Smart Card Data

The procedure seen in Figure 3.1 was followed to predict movements of undergraduate students. The assumptions of the followed procedure are:

(i) Time span of the analysis is between 8:00 and 17:00 for 2014-2015 academic year.
(ii) Students do not arrive before their schedule and leave after attended their last lecture of the day.
(iii) In order to simplify analysis, it is assumed that every student lives outside of the campus. Because even if a student lives in a dorm building in main campuses, the student still have to a make a trip to a building to attend a lecture.
(iv) It is assumed that attendance to lectures is 100%.
(v) Students spent their vacant hours between courses in library, study halls, cafes in campuses or cafes in outside of the campuses.
(vi) Every student has a probability to go library regardless of their origin campus.
(vii) If a student do not prefer to go to library, the student prefer the nearest cafe or study hall to spend her/his time between lectures.
(viii) If all cafes and study halls are full in the origin campus, she/he goes to one of the cafes in outside of campus.

It should be noted that the effects of irregular events like concerts, conferences and seminars omitted in this analysis.

In the first part of the analysis, the procedure converts weekly course schedules into a 70-day-long (one semester) schedules. This procedure is required for the determination of locations of the courses in the schedule. After that, each student's record is checked for their lunch time location using dining hall smart card logs. If a student ate lunch in a dining hall, time is matched in the corresponding time slot in the 70-day-long schedule and location of the dining hall recorded. Found dining hall matches are recorded in a location matrix for each student. At this point, all course and dining hall data are converted into hourly location data (70-day-long schedule) and stored in location matrices for each student.

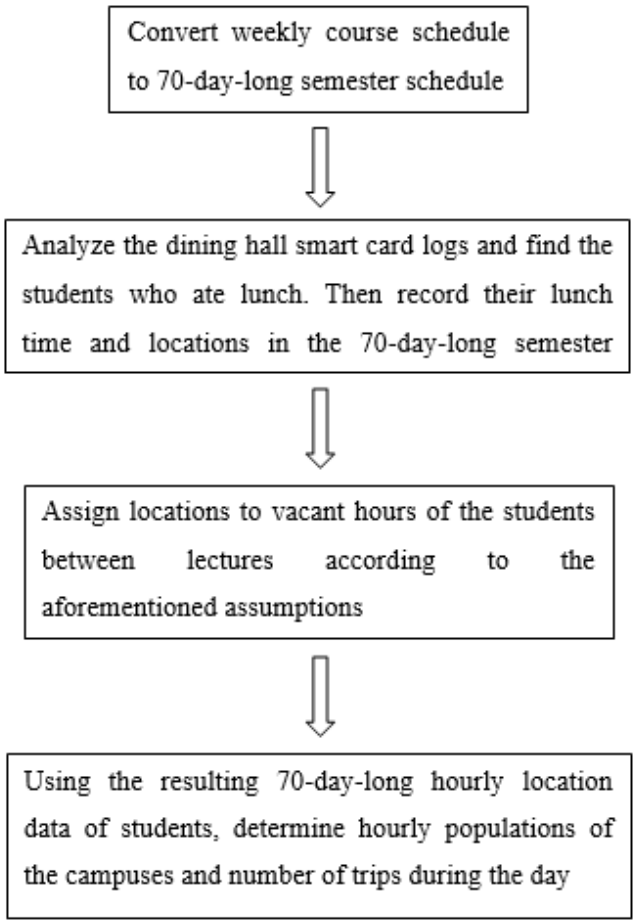

Figure 4.1. Procedure for Analysis of the Course Schedules and Dining Hall Smart Card Logs.

In second part of the analysis, locations are assigned to vacant hours of the students according to the aforementioned assumptions. To calibrate model, capacities of the attractions (library, cafes in and around the campus and study halls) at are measured by counting seating capacities, and a one-question survey with convenience sampling is conducted at the gates of the campuses and the attractions for 1 week at peak hours (11:00-13:00). Interviewers asked "Where do you go?" to the students leaving the campus, and "Where do you come from?" to the students come to the attractions. Resulting data are analyzed and probabilities of destination selection based on the origin campuses are determined. Then, destination campuses are estimated using constant probabilities according to determined origin campuses of the students. Capacities of the facilities and whether the capacity of a facility is full are checked for each hour of each day. If the capacity is full for that hour, the random number is re-rolled to assign new location to that vacant hour. After that, all students' location matrices for all semester is constructed. For the second semester, entire process is repeated.

Finally, average hourly populations of campuses and average hourly inter campus trips are determined. One year average of hourly populations of the campuses were presented in Table 4.3.

Table 4.3. Average Hourly Populations of the Main Campuses.

	South Campus	North Campus	Hisar Campus	Ucaksavar Campus	Total
7:00-8:00	4	39	0	0	43
8:00-9:00	50	255	0	0	275
9:00-10:00	819	1840	216	185	2659
10:00-11:00	1247	2829	457	7	4377
11:00-12:00	1479	3337	536	346	5698
12:00-13:00	1597	3403	478	241	5719
13:00-14:00	1573	3211	316	40	5140
14:00-15:00	1460	2928	357	60	4745
15:00-16:00	1150	2126	394	3	3673
16:00-17:00	924	1482	266	9	2681

Origin and destination campuses of trips were found from trips between 33 locations in university. In Table 4.4, average number of origins and destinations of trips for one day is listed. The term "outside" refers to all locations that are outside of campuses (home, cafes). Home originated or destined trips are included (as outside) in the table.

Table 4.4. Origin and Destinations of Trips in One Day.

		Destination					
		South Campus	North Campus	Hisar Campus	Ucaksavar Campus	Outside	Origin Total
Origin	South Campus	1888	1521	148	97	2416	6070
	North Campus	1456	6153	330	201	5343	13483
	Hisar Campus	194	310	7	5	777	1293
	Ucaksavar Campus	200	355	9	0	196	760
	Outside	2329	5104	799	457	0	8689
Destination Total		6067	13443	1293	760	8732	

From Table 4.3 and Table 4.4, it can be seen that South and North Campuses are most crowded campuses and majority of inter-campus traffic is between these campuses. Analysis showed that, there are average 6652 (outside trips that are not home originated or destined counted as intercampus trips) trips per day between campuses. Table 4.5 and Table 4.6 shows average number of trips originated from South and North Campus during day.

Table 4.5. Trips Originated From South Campus During A Day.

	South Campus	North Campus	Hisar Campus	Ucaksavar Campus	Outside	Total
9:00-10:00	33	12	1	1	1	48
10:00-11:00	69	46	10	0	7	132
11:00-12:00	320	295	17	51	86	769
12:00-13:00	339	231	14	34	92	710
13:00-14:00	544	414	22	5	318	1303
14:00-15:00	333	276	33	3	239	884
15:00-16:00	193	188	48	1	439	869
16:00-17:00	52	54	3	2	306	417

Table 4.6. Trips Originated From North Campus During A Day.

	South Campus	North Campus	Hisar Campus	Ucaksavar Campus	Outside	Total
9:00-10:00	17	152	6	7	4	186
10:00-11:00	18	409	11	0	20	458
11:00-12:00	213	1201	46	59	311	1830
12:00-13:00	134	1081	13	34	367	1629
13:00-14:00	294	1381	44	34	659	2412
14:00-15:00	202	878	61	29	459	1629
15:00-16:00	189	673	86	1	561	1510
16:00-17:00	77	227	5	6	317	632

4.3.2. Shuttle Demand and Shuttle Stop Queue Length

Results of measurements were summarized in Figure 4.2-Figure 4.6. As mentioned in the Section 4.1 students may have consecutive courses in different campuses. As a result, as seen in the Figure 4.2-Figure 4.6, shuttle demand peaks at break times between classes and cause queuing in the shuttle bus stop. Shuttle busses do not have a fixed schedule. They operate according to a maximum waiting time of 10 minutes. If shuttle bus reaches its capacity before 10 minute, it departs. Results of the preliminary analysis showed that average frequency of shuttle busses is 3.82 minute and currently shuttle busses work at 96.9% of their daily capacity.

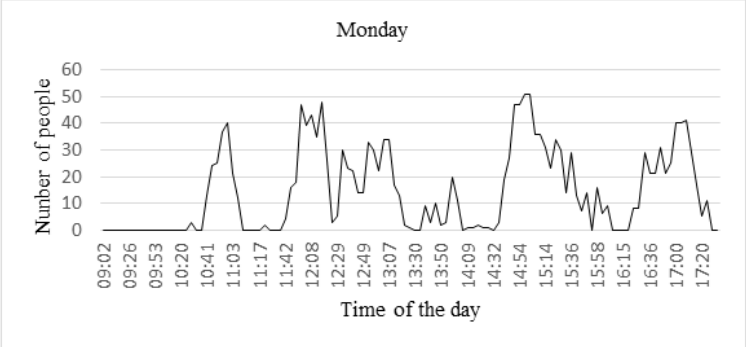

Figure 4.2. Queue Length during Day on Monday.

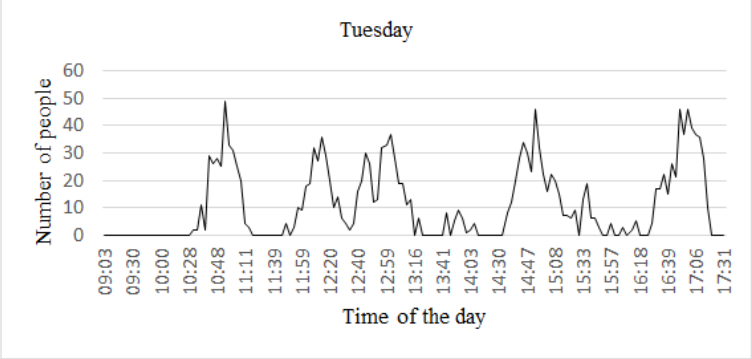

Figure 4.3. Queue Length during Day on Tuesday.

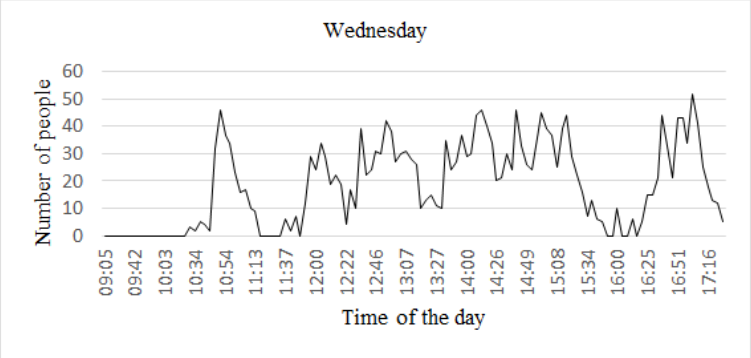

Figure 4.4. Queue Length during Day on Wednesday.

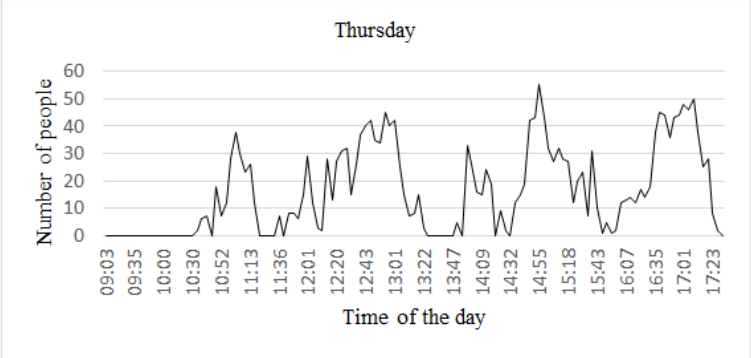

Figure 4.5. Queue Length during Day on Thursday.

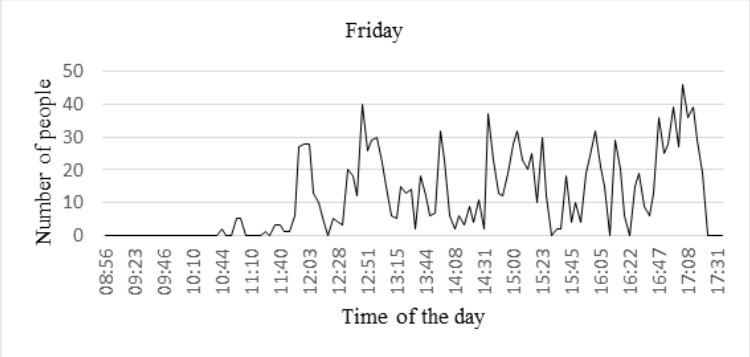

Figure 4.6. Queue Length during Day on Friday.

4.3.3. Parking Capacity and Parking Permits

Due to the limited land area in North and South Campuses, there are limited dedicated parking areas available to community. Majority of the parking capacity come from the roadside parking. It is observed that most of the roadside parking areas were not properly marked. Because of that, illegal parking can be observed in the campuses. As a result of the land survey, parking areas and their capacities were determined. Results were summarized in Table 4.7 and Table 4.8.

Table 4.7. Parking Areas and Capacities in South Campus.

South Campus	
Parking Area	Capacity (passenger car)
Student carpark	120
Engineering Faculty	53
IT center car park	5
Infirmary car park	10
Guest car park	40
Rectorate car park	10
Roadside near Hulya Bozkurt fine arts studio	11
Theodorous Hall car park	11
Roadside between nursery and Kale gate	20
Roadside between infirmary and basketball court	10
Area near Asiyan museum	3
Area between Hamlin Hall and Albert Long Hall	3
Roadside around the Dodge Hall	5
Roadside northwest of the Washburn Hall	5
Area between Rectorate and Registrar office	5
Total	306

Table 4.8. Parking Areas and Capacities in North Campus.

North Campus	
Parking Area	Capacity (passenger car)
Parking Structure	122
Carpark behind New Hall	35
Carpark between ETA/A and library	20
Roadside near engineering laboratories	3
Roadside behind ETA/A	3
Roadside between New Hall and male dorm	12
Roadside around Faculty of Education	6
Roadside between Faculty of Education and male dorm	16
Roadside around School of Foreign Languages	7
Total	224

In total, there are 306 parking spots (57 of them is on roadside) in South Campus and 224 parking spots (47 of them is on roadside) in North Campus. A preliminary analysis was conducted to make a rough estimate of demand on staff and student parking areas. In total, there were 1586 student and staff parking permits that distributed in 2014-2015 academic year. Distribution of this parking permits among students and staff was presented in Table 4.9. Only full-time staff's permits were divided into campuses which the office of the staff is located. Since students and part-time staff are more mobile during the day than full time staff, their permits were not divided into campuses.

Table 4.9. Distribution of Parking Permits.

	Total Number of Permits	
Full-time staff	South Campus	North Campus
	420	350
Part-time staff	172	
Student	355	

In consideration of limited South and North Campuses' parking capacity (530 including students' parking areas), there is an obvious and significant parking capacity shortage in these campuses. Parking capacity cannot sustain even full-time staff. However, by observation, it can be seen that parking problem is not as significant as seen in parking permit data. Possible explanation of this situation are:

- A part of the academic staff does not come to university every day.
- Due to some reasons (fuel prices, parking problem in university, traffic congestion in Istanbul), a part of the permit holders do not choose to drive to university although they have parking permit.

These possible explanations were investigated in the university transportation questionnaire.

4.3.4. Descriptive Results of the Campus Transportation Survey

There were in total 1795 respondents to questionnaire study. 537 (29.92%) of the respondents were university staff (both academic and administrative) and the remaining part was students. Table 4.10-Table 4.32 gives descriptive results of survey study for students and staff separately.

4.3.4.1. Demographic Results. As mentioned earlier, for questions regarding gender, income, residence area and age, item non-response was permitted. Table 4.10 shows gender distribution of the respondents. Although, information of actual gender distribution of all staff is unknown, gender distribution of faculty and administrative staff is published in "Fact and Figures: Boğaziçi University 2014". According to the figures in the published report, there is a probability that females were overrepresented in the sample.

Table 4.10. Gender Distribution of the Respondents.

Gender	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Male	243	45.30%	626	49.80%
Female	263	49.00%	600	47.70%
Did not answered	31	5.80%	32	2.50%
Total	537	100.00%	1258	100.00%

Age distributions of the respondents were presented in the Table 4.11. As expected, age distribution of the students was concentrated between 20 age and 24 age. For age distribution of staff, 54.38% of the staff was under the age of 40. It can be said that, majority of the staff consists of young and middle aged people. It gives some flexibility for consideration of the demand management strategies.

Table 4.11. Age Distribution of the Respondents.

Age	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Did not answered	26	4.84%	10	0.79%
Under 20	2	0.37%	351	27.90%
20-24	24	4.47%	775	61.61%
25-29	84	15.64%	107	8.51%
30-34	95	17.69%	10	0.79%
35-39	87	16.20%	3	0.24%
40-44	72	13.41%	1	0.08%
45-49	65	12.10%	1	0.08%
50-54	43	8.01%	0	0.00%
55-59	19	3.54%	0	0.00%
60-64	18	3.35%	0	0.00%
65 and more	2	0.37%	0	0.00%
Total	537	100.00%	1258	100.00%

Table 4.12 shows income distribution of the respondents. An unexpected result is the vast majority of the students (81.64%) are below 1500 Turkish Liras.

Table 4.12. Income Distribution of the Respondents.

Income	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Did not answered	37	6.89%	17	1.35%
Under 1000TL	3	0.56%	627	49.84%
1000-1499TL	28	5.21%	400	31.80%
1500-1999TL	42	7.82%	128	10.17%
2000-2499TL	136	25.33%	36	2.86%
2500-2999TL	66	12.29%	20	1.59%
3000-3499TL	94	17.50%	8	0.64%
3500-3999TL	65	12.10%	7	0.56%
4000-4499TL	22	4.10%	2	0.16%
4500-4999TL	13	2.42%	1	0.08%
5000-5499TL	6	1.12%	1	0.08%
5500-5999TL	6	1.12%	2	0.16%
6000-6499TL	6	1.12%	0	0.00%
6500-6999TL	4	0.74%	1	0.08%
More than 7000TL	9	1.68%	8	0.64%
Total	537	100.00%	1258	100.00%

Residence area of the respondents was investigated to determine number of people that lives close to university's main campuses. Table 4.13 shows number of respondents that lives close (max distance is 4.5km) to the campus.

Table 4.13. Number of Respondents that Live Close to the Main Campuses.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Did not answered	108	20.11%	36	2.86%
Lives close to main campuses	80	14.90%	521	41.41%
Does not live close to main campuses	349	64.99%	701	55.72%
Total	537	100.00%	1258	100.00%

From Table 4.11-Table 4.13, it can be seen that item-nonresponse for staff interviews was much higher than student interviews. Possible explanation for this is the data were collected from staff by personal interviews. Although the questionnaire form was handed to the interviewee and the interviewee self-answered the question, the interviewee may have not felt private enough to answer these questions.

4.3.4.2. Results about Habits of Transportation to/from University. In this part of the questionnaire, vehicle ownership, number of campus parking permit holders, preferred transportation mode choice for trips to university, arrival times from university, departure times from university, reasons not to use personnel shuttle and reasons not to use private vehicle were investigated. In Table 4.14 vehicle ownership percentages were given.

Table 4.14. Vehicle Ownership of the University Respondents.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Owns a car	228	42.46%	119	9.46%
Does not own a car	309	57.54%	1139	90.54%
Total	537	100.00%	1258	100.00%

Table 4.15 shows parking permit ownership. Since staff parking permits are free of charge, majority of the staff has parking permits. Because of the limited parking space in the campuses, student parking permits are not free. To manage the student

parking demand on campuses, price of the semester parking permits are 350 TL. As seen in the Table 4.14, this pricing strategy is effective.

Table 4.15. Parking Permit Ownership of the Respondents.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Has a parking permit	200	87.72%	42	35.29%
Does not have a parking permit	28	12.28%	77	64.71%
Total	228	100.00%	119	100.00%

Respondents' preferred transportation mode choices were shown in Table 4.16. It can be seen that from Table 4.14 and Table 4.16 not all the people who have vehicles use private vehicle as preferred mode of transportation. Also as seen in the Table 4.5 and Table 4.16, since some of the students do not hold a parking permit, they park their cars in the neighborhood surrounding the university.

Table 4.16. Preferred Transportation Mode Choice of the Respondents.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Walking	44	8.19%	405	32.19%
Private Vehicle	141	26.26%	75	5.96%
Personnel Shuttle	271	50.47%	0	0.00%
Public Transportation	81	15.08%	778	61.84%
Total	537	100.00%	1258	100.00%

Reasons not to use private vehicle as preferred mode of transportation were investigated. Most possible reasons were listed and asked to respondents who do not prefer private vehicle despite having a vehicle. Results were listed in Table 4.17.

Table 4.17. Reasons for Not Using Private Vehicle.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
High fuel prices	27	31.03%	11	25.00%
Parking space shortage in and around campus	9	10.34%	8	18.18%
Traffic congestion	27	31.03%	13	29.55%
Environmental concerns	7	8.05%	1	2.27%
Other	17	19.54%	11	25.00%
Total	87	100.00%	44	100.00%

Personnel shuttle is a comfortable (everybody is sitting) and free of charge (except for contracted personnel) transportation alternative. Shuttle make only two trips (one morning and one evening) per day. Personnel shuttle routes are determined according to demand. There are 62 different shuttle routes. Some of the staff do not prefer to use this mode. Reasons for not using this mode were investigated and results were presented in Table 4.18.

Table 4.18. Reasons for Not Using Personnel Shuttle.

	Frequency	Percentage
Preferred transportation mode is faster	79	35.59%
Price is too high	4	1.80%
Routes are not favorable	53	23.87%
Not comfortable	7	3.15%
Service times are not convenient	45	20.27%
Other	34	15.32%
Total	222	100.00%

The high percentage of unfavorable service routes indicates there are some planning problems in route planning of shuttles.

Number of days that respondents go to university, arrival times and leaving times were also investigated. Results were shown in Table 4.19, Table 4.20 and Table 4.21.

Table 4.19. Number of Days that Respondents go to University.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
1 day per week	0	0.00%	6	0.48%
2 days per week	4	0.74%	17	1.35%
3 days per week	28	5.21%	53	4.21%
4 days per week	22	4.10%	295	23.45%
5 days per week	483	89.94%	887	70.51%
Total	537	100.00%	1258	100.00%

As seen in the Table 4.19, majority of the respondents go to university every weekdays.

Table 4.20. Average Arrival Time of the Respondents.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Before 8:00	43	8.01%	46	3.66%
8:00-9:00	385	71.69%	245	19.48%
9:00-10:00	65	12.10%	455	36.17%
10:00-11:00	31	5.77%	319	25.36%
11:00-12:00	7	1.30%	122	9.70%
12:00-13:00	2	0.37%	54	4.29%
13:00-14:00	4	0.74%	7	0.56%
After 14:00	0	0.00%	10	0.79%
Total	537	100.00%	1258	100.00%

As expected, distribution of the arrival time and leaving time of the staff is more concentrated than students' arrival time distribution.

Table 4.21. Average Departure Time of the Respondents.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Before 11:00	5	0.93%	0	0.00%
11:00-12:00	1	0.19%	0	0.00%
12:00-13:00	4	0.74%	6	0.48%
13:00-14:00	1	0.19%	90	7.15%
14:00-15:00	9	1.68%	201	15.98%
15:00-16:00	58	10.80%	302	24.01%
After 17:00	459	85.47%	659	52.38%
Total	537	100.00%	1258	100.00%

4.3.4.3. Results about Parking Problems in University Campuses. In this part of the questionnaire, parking capacity problems were investigated. Staff and students questions were separated; because, parking areas of students and staff were separated. Students can only park their cars to designated student parking areas. These questions were asked to people whose choice is car as preferred mode of transportation. Questions and the responses were summarized in Table 4.22.

Table 4.22. Questions and Responses about Parking Problems in University Campuses.

(Asked to staff) Can you find available (space in the parking space that closest to your office?		
	Frequency	Percentage
Yes	107	75.89%
No	34	24.11%
Total	141	100.00%
(Asked if respondent is staff and answered "No" to the previous question) If you cannot find available space in the closest parking area to your office, can you easily find a parking space in the campus that you worked in?		
	Frequency	Percentage
Yes	14	41.18%
No	20	58.82%
Total	34	100.00%
(Asked if respondent student and has a parking permit) Can you find available parking space in the student parking areas?		
	Frequency	Percentage
Yes	21	80.77%
No	5	19.23%
Total	26	100.00%

According to respondents' statements shown in Table 4.22, a parking capacity problem is available in Boğaziçi University's campuses. Staff have different options for parking spaces. Because of that, the major problem for staff parking is finding an available parking spot close to their offices. For students, since they are only permitted to park student parking areas, major problem is finding an available spot in the campus. As mentioned before students pay considerable amount of money for semester parking permits. Because of that, parking shortages cause "not getting service for a pre-paid service". It naturally frustrates students who experience this problem.

4.3.4.4. Results about Inner Campus Traffic and Security. Not only the actual state of traffic in university's campuses is important, but also people's perception of the current traffic situation have an important role in transportation planning and policy making. In this part people's perception of pedestrian safety and traffic amount were investigated. Table 4.23 presents number of people who think that there is an excessive amount of vehicle traffic in campuses.

Table 4.23. Opinions of Respondents about Amount of Traffic in Campuses.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Amount of vehicle traffic is excessive in campuses	293	54.56%	447	35.53%
Amount of vehicle traffic is not excessive in campuses	244	45.44%	811	64.47%
Total	537	100.00%	1258	100.00%

As seen in the Table 4.23, opinions of staff and students are different. Staff experiences more parking space problems (Table 4.22). They might linked their parking problems to excessive vehicle traffic in campuses.

Table 4.24 shows the number of people who think intersection areas, which motor vehicles and pedestrians and cyclists meet, at campuses do not have adequate safety

measures.

Table 4.24. Opinions of Respondents about Intersection Security.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Security measures are inadequte in intersections	289	53.82%	648	51.51%
Security measures are adequte in intersections	248	46.18%	610	48.49%
Total	537	100.00%	1258	100.00%

As stated in the Section 4.3.3, a significant share of parking is roadside parking. Illegal roadside parking may affect pedestrian and cyclist mobility. Opinion of respondents about this issue is given in Table 4.25.

Table 4.25. Opinions of Respondents about Effect of Parking on Pedestrian/Cyclist Mobility.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Parking spaces affect pedestrian and cyclist mobility	265	49.35%	537	42.69%
Parking spaces do not affect pedestrian and cyclist mobility	272	50.65%	721	57.31%
Total	537	100.00%	1258	100.00%

4.3.4.5. Results of Inter-campus Transportation Part. Decentralized structure of the Boğaziçi University is explained in Section 4.1. Because of the decentralized structure of the university, significant number of inter-campus trips are made each day. There are several alternative modes for this trips. These are carpooling, cycling, shuttle bus, private vehicle, hitchhiking and walking. Table 4.26 shows modal split for these trips.

Table 4.26. Modal Split for Inter-Campus Trips.

	Carpooling	Cycling	Shuttle	Private vehicle	Hitchhiking	Walking
Staff	3.30%	0.60%	44.61%	11.60%	1.15%	38.75%
Student	0.63%	0.80%	45.13%	1.47%	1.61%	50.35%

Because of the vehicle ownership difference between staff and students, as expected mode share of private vehicle and carpooling is much higher for staff. Distances between main campuses are favorable for both cycling and walking; however, mode share of shuttle bus is significantly large. Factor affecting shuttle use for South campus originated trips were investigated. Some possible factor were listed respondents selected the all factors that affect their transportation mode choice. Table 4.27 presents the number of people and the percentages of the population that selected each factor.

Table 4.27. Factors Affecting Shuttle Use for the South Campus Originated Trips.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Bad weather conditions	390	72.63%	1072	85.21%
Queues at the shuttle bus stop	313	58.29%	790	62.80%
Consecutive courses at different campuses	-	-	846	67.25%
Ramp located in South Campus is exhausting	246	45.81%	821	65.26%
There is no fixed schedule for shuttle bus	159	29.61%	454	36.09%
Shuttle busses are free of charge	196	36.50%	868	69.00%

Perceived safety is an important factor that affects the decision to use bicycle for transportation purposes. Nispetiye Street connects all 4 main campuses to each other. Respondents were asked whether Nispetiye Street is safe for cycling or not. Results are shown in Table 4.28.

Table 4.28. Respondents' Opinion about Safety of Nispetiye Street for Cycling.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Safe	22	4.10%	111	8.82%
Does not safe	515	95.90%	1147	91.18%
Total	537	100.00%	1258	100.00%

As seen in the Table 4.28, vast majority of the respondents believe that Nispetiye Street is not safe for cycling.

Boğaziçi University has a vibrant social life and beautiful campuses. Because of that, many students spent time after or between their classes in the campuses. Amount of time they spent in which campuses was investigated. In Table 4.28, number and percentage of students spent their free time in campuses, and on average how much time they spent are given.

Table 4.29. Amount of Time Spent in Campuses.

	Frequency	Percentage	Average time they spent (hours per week)
North Campus	1089	86.57%	14.9
South Campus	1098	87.28%	9.2
Hisar Campus	109	8.66%	5.8
Uçaksavar Campus	116	9.22%	4.8

Also students were asked to grade (1 is most frequent reason, 6 least frequent) their reasons to spent their time in a campus. Results are presented in Table 4.30.

Table 4.30. Reasons of Respondents to Spend Time in Campuses.

	Average score
Studying	2.64
Spending time between classes	2.52
Spending time	2.61
Excersize and training	4.79
Social events	3.53
Other	4.91

As seen in the Table 4.29, there are more people spent time in South Campus; however, amount of time they spent is less than North Campus average. A probable explanation can be inferred from Table 4.30. As seen in the table, main reasons to spent time in a campus are studying and spending time between classes. Since there are much more students in North Campus, as expected average time spent in North Campus is higher than other campuses.

4.3.4.6. Results of Transportation System Improvements. Aim of this part is to measure the public opinion about certain changes in transportation system of university, and understand the priorities of the campus population. The respondents were asked to grade (1 is most prioritized, 5 is least prioritized) some general ideas of improvements. Priorities of the campus population were summarized in Table 4.31.

Table 4.31. Average Priority Scores of the General Ideas.

Priorities of the campus population	Staff	Student
	Average score	Average score
Improvement of pedestrian mobility and safety	2.1	2.31
Increasing parking capacity	3.38	4.28
Subsidizing and promoting cycling	3.22	3.07
Improvement of shuttle bus service	2.89	2.15
Preserving campus	3.41	3.19

Carpooling for commuter trips is cost and comfort effective; however, carpooling is not popular in Turkey (Tezcan and Tanis, 2011). Since people are not familiar with the mode, an incentive and information mechanism must be applied to newly emerging mode. A stated preference question were asked to respondents. Table 4.32 shows the results of this question.

Table 4.32. Stated Preferences of the Respondents on Incentivized Carpooling System.

	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Yes I will use carpool	290	54.00%	858	68.20%
No I will not use carpool	247	46.00%	400	31.80%
Total	537	100.00%	1258	100.00%

There is no traffic enforcement in Boğaziçi University. This leads to frequent illegal parking (e.g., parking in front of a fire hydrant) and speeding in the campuses. Different types of enforcements are asked to respondents. Results can be seen on Table 4.33. The results indicate that only a small portion (8.57% of staff and 7.15% of students) of the population is against the traffic enforcement in the university.

Table 4.33. Enforcement Preferences of the Respondents.

Enforcement type	Staff		Student	
	Frequency	Percentage	Frequency	Percentage
Penalty fine	261	48.60%	769	61.13%
Banning the vehicle from entering campus for a period of time	297	55.31%	761	60.49%
For repeated illegal behavior, banning the vehicle for all semester	262	48.79%	606	48.17%
There should not be any enforcement	46	8.57%	90	7.15%

Results of the campus transportation survey provided necessary insights of the transportation problems in Boğaziçi University and data for the discrete choice anal-

ysis. Results of the habits of transportation to/from university part of the survey showed that, vehicle ownership of staff is significantly higher than the students; as a result of this, modal share of private vehicle for staff is higher than for students. Also personnel shuttle is the most preferred transportation mode for staff. As expected, students predominantly prefer walking and public transportation. Along with the results of the parking capacity analysis, campus transportation survey indicates some level of parking capacity problems. For security of pedestrian and cyclists, answers of respondents are almost evenly divided except security of Nispetiye Street for cyclists. For inter-campus transportation, as expected it is found that shuttle busses and walking are predominantly used modes. Respondents stated that the most significant barrier against shuttle use is the long queues at the shuttle bus stop. About transportation improvements, priority improvements for staff is improvement pedestrian mobility and safety, for students, priority improvement is improvement of shuttle bus service. About carpooling, majority of the respondents state that they will willing to use a incentivized carpooling service.

4.3.5. Personnel Shuttle Smart Card Data

There are 62 different personnel shuttle routes available, and 1166 personnel of Boğaziçi University are registered for the personnel shuttle service. In Figure 4.7, addresses of all staff registered to the service is marked on the map.

As seen from the figure residence locations of the staff is widely spread across Istanbul, and the shuttle service area is wide enough to capture this area. Data are analyzed to estimate actual usage of the shuttle busses. For the two week long period, there were 871 staff used the personnel shuttle. 25.3% of the registered users did not use the personnel shuttle.

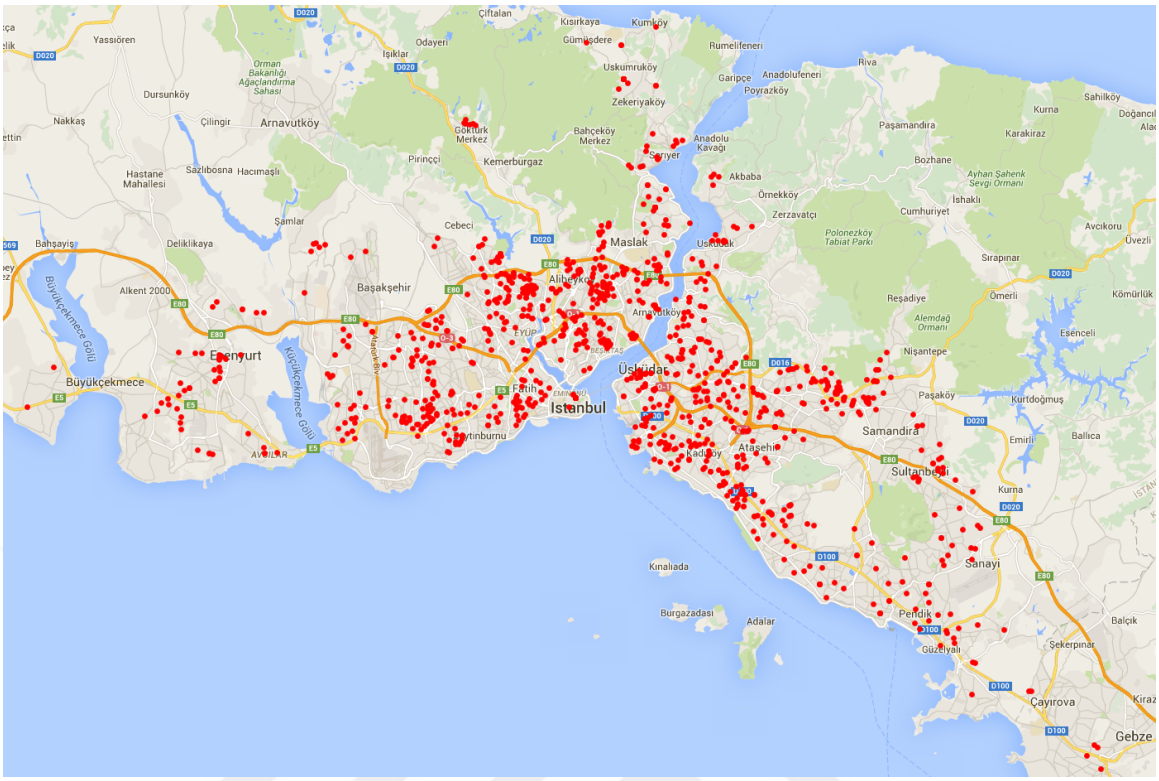

Figure 4.7. Addresses of the Staff Registered to Personnel Shuttle.

5. DISCRETE CHOICE ANALYSIS AND RESULTS

Using the survey data, multinomial logit models for population of Boğaziçi University were calibrated. In these models, travel mode choice behavior of the students and staff in main campuses of Boğaziçi University were analyzed. Students and staff were analyzed separately because of the difference between numbers of available modes for these two groups. Staff have access to 4 different modes. These are public transportation, walking, private vehicle and personnel shuttle. Students do not have access to personnel shuttle.

The survey data has 1795 observations; however, some part of these data cannot be used in this model. Questionnaires with item non-response (unanswered questions) were discarded. Limited number of data were collected from campuses other than main campuses, and some of these data were defective because of the item-nonresponse. In addition, these campuses are in remote locations, and do not have as good public transportation access as main campuses, so behavioral differences between populations of main campus and other campuses are possible. Because of these, data from campuses other than main campuses were discarded. Also some people do not have an alternative mode to choose. For example, a student, who lives far from the university and do not own a car, has no alternatives other than using public transportation. At least two alternative choices are needed to construct a choice model; therefore, the observations with insufficient number of mode alternatives are discarded from the data. The assumed conditions leading to insufficient number of alternatives are listed below:

(i) A student who does not own a car and lives far from university has only public transportation alternative.

(ii) A student or staff who lives in or very close to the campus and does not have a car. Definition of very close is limited to Hisarüstü district. Public transportation from this district is not an option because the bus stop of the district is very close to the campus gate.

(iii) The personnel shuttle service runs only for morning and evening commute, and shuttles make only one trip for each commute time. Because of that, staff who lives far from university, does not own a car and arrives at the campus after 9:00 has only public transportation alternative.

In the survey study, preferred mode of transportation and location of the residence were asked to respondents. Using these data, travel time and travel cost of alternatives were estimated.

For private vehicles, Google Maps is used for distance and travel time estimation. Using user data, Google Maps makes travel time estimates by taking traffic congestion into account. For travel cost of the private vehicle, fuel cost of 0.34TL/km (Gökaşar and Günay, working paper) was used. In models, private vehicle alternative was only provided to people who own a car.

TRAFI is used for travel time and travel cost estimation of public transportation. TRAFI is a web application that provides public transportation trip plan with alternatives. For travel time estimation, TRAFI takes into account transfer times and traffic congestion. Alternative trip plans provided by TRAFI was selected according to the respondents' revealed preferences in questionnaire (Question 3 in Appendix A). Travel costs (full price without any discounts) were provided by TRAFI. Student and teacher discounts are applied manually according to the price scheme of the IETT (Istanbul Electric Tram and Tunel Company) presented in Table 5.1, Table 5.2 and Table 5.3. In models, public transportation alternative was provided to everyone except people living in campus housing and Hisarüstü district.

Table 5.1. Prices of Different Types of Public Transportation Tickets in Istanbul.

Ticket type	Price (TL)
Full-fare one trip	2.3
Student one trip	1.15
Faculty one trip	1.65
Full-fare monthly	185
Student monthly	80
Faculty monthly	110

Table 5.2. Transfer Prices of Public Transportation in Istanbul (Prices in Turkish Liras).

	Full-fare	Student	Faculty
First transfer	1.65	0.5	0.95
Second transfer	1.25	0.45	0.75
Third transfer	0.85	0.4	0.5
Fourth transfer	0.85	0.4	0.5
Fifth transfer	0.85	0.4	0.5

Table 5.3. Metrobus Ticket Fares (Prices are in Turkish Liras).

Number of travelled stops	Full-Fare	Student	Faculty
1-3	1.8	1	1.3
4-9	2.8	1.15	1.65
10-15	3	1.2	1.7
16-21	3.15	1.2	1.8
22-27	3.25	1.2	1.8
29-33	3.4	1.2	1.9
34-39	3.55	1.2	1.9
40+	3.55	1.2	1.9

For personnel shuttle, travel times were estimated using smart card data of personnel shuttles. In the smart card data, only boarding times are recorded. Arrival times of personnel shuttles are not recorded in the smart card data. Average arrival times of shuttle busses to the university were asked to shuttle drivers. Travel times were found by matching the survey respondents' residence area and the smart card location data and subtracting boarding time of the matched data from arrival time of the shuttle bus. Since personnel shuttles are free of charge, travel cost was taken as zero. In models, personnel shuttle alternative was provided to staff.

Walking travel time was estimated using preferred walking speed of 1.33 m/sec (Transport for London, 2010). Travel cost of walking was taken as zero. In models, walking alternative was only provided to people who live in the area of 1 hour walking distance (4.8 km) from the university.

NLOGIT version 4 was used for the estimation of the model coefficients. NLOGIT is an econometrics and statistical analysis software which specialized in discrete choice models (Greene, 2009).

5.1. Staff Multinomial Logit Model

537 staff were interviewed during the survey study. Number of discarded data are given in Table 5.4.

Table 5.4. Number Discarded Data and Their Reasons.

Reason to discard	Number of discarded observation
Workplace is not in main campuses	52
Insufficient number of alternatives	64
Item non-response	143

44 of 64 insufficient number of alternative cases belong to staff who live in Hisarüstü District or in campus and do not have a car. Their only option is to walk to

the university. Remaining insufficient number of alternative cases are belong to staff who lives too far to walk to the campus, do not have a car and arrive campus after 9:00. Public transportation is the only alternative they have.

The resulting dataset consisted of 314 observations. As mentioned in Section 5, all alternatives are not available for all people. Table 5.5 shows number of removals of alternatives and removal reasons.

Table 5.5. Number of Removals of Alternatives and Removal Reasons.

Removed alternative	Removal reason	Number of removals
Walking	Living outside of walking distance	269
Private vehicle	Does not own a car	165
Public Transportation	Living in or very close to university	12
Personnel shuttle	Living in or very close to university	12
	Arrives university after 9:00	25

After the removal of invalid alternatives from people's choice set, in resulting data, there are 181 observations with 2 choice alternatives, 118 observations with 3 choice alternatives and 15 observations with 4 alternatives. Table 5.6 shows observed mode choices of 314 people.

Table 5.6. Observer Mode Choices.

Mode	Frequency	Percentage
Walking	11	3.50%
Private Vehicle	67	21.34%
Public Transportation	59	18.79%
Personnel Shuttle	177	56.37%
Total	314	100.00%

5.1.1. Preliminary Analysis of Model Data

Gender, age and income data were collected as categorical data. In order to select model variables, relationship between these variables and people's mode choices was investigated by using cross tabulation and chi square test. Cross tabulation and chi square test result of gender and mode choices are shown in Table 5.7.

Table 5.7. Cross Tabulation Chi-Square Test of Mode Choice and Gender.

			Mode Choice				Total
			Walking	Private Vehicle	Public Transport	Personnel Shuttle	
Gender	Male	Count	3	33	38	84	158
		Percent	1.90%	20.89%	24.05%	53.16%	100.00%
	Female	Count	8	34	21	93	156
		Percent	5.13%	21.79%	13.46%	59.62%	100.00%
	Total	Count	11	67	59	177	314
		Percent	3.50%	21.34%	18.79%	56.37%	100.00%
Chi-Square Test							
Value			Degree of freedom			Significance	
7.631			3			0.054	

Results indicate that, there may be relationship (at a 0,054 significance level) between gender and mode choice. From the cross table it can be seen that, males prefer public transportation more than females.

Table 5.8. Cross Tabulation Chi-Square Test of Mode Choice and Age.

			Mode Choice				Total
			Walking	Private Vehicle	Public Transport	Personnel Shuttle	
Age	<29	Count	1	7	21	28	57
		Percent	1.75%	12.28%	36.84%	49.12%	100.00%
	30-39	Count	2	23	17	75	117
		Percent	1.71%	19.66%	14.53%	64.10%	100.00%
	40-49	Count	2	21	11	45	79
		Percent	2.53%	26.58%	13.92%	56.96%	100.00%
	>50	Count	6	16	10	29	61
		Percent	9.84%	26.23%	16.39%	47.54%	100.00%
	Total	Count	11	67	59	177	314
		Percent	3.50%	21.34%	18.79%	56.37%	100.00%
Chi-Square Test							
Value			Degree of freedom			Significance	
27.635			9			0.001	

Results presented in Table 5.8 shows a significant relationship between age and mode choice. According to the results, elder people prefer private vehicle, and people in the age group 30-39 prefer personnel shuttle more than the rest of the sample.

Table 5.9. Cross Tabulation Chi-Square Test of Mode Choice and Income.

			Mode Choice				Total
			Walking	Private Vehicle	Public Transport	Personnel Shuttle	
Income (TL)	<2000	Count	3	3	14	23	43
		Percent	6.98%	6.98%	32.56%	53.49%	100.00%
	2000-3000	Count	2	14	10	101	127
		Percent	1.57%	11.02%	7.87%	79.53%	100.00%
	3000-4000	Count	5	20	23	47	95
		Percent	5.26%	21.05%	24.21%	49.47%	100.00%
	>4000	Count	1	30	12	6	49
		Percent	2.04%	61.22%	24.49%	12.24%	100.00%
	Total	Count	11	67	59	177	314
		Percent	3.50%	21.34%	18.79%	56.37%	100.00%
Chi-Square Test							
Value			Degree of freedom			Significance	
95.591			9			0	

Table 5.9 shows significant relationship between mode choice and income level. People with high income favors private vehicle more than the other income groups. The people in income level of 2000TL-3000TL prefer to use personnel shuttle.

Table 5.10 shows the relationship between age and income. As suspected the relationship between age and income is significant. Because of that, although both variables were significant only income variable (as the inclusion of the other did not yield a better model) was included in the model.

Table 5.10. Cross Tabulation Chi-Square Test of Income and Age.

			Income (TL)				Total
			<2000	2000-3000	3000-4000	>4000	
Age	<30	Count	11	18	26	2	57
		Percent	19.30%	31.58%	45.61%	3.51%	100.00%
	30-40	Count	17	61	31	8	117
		Percent	14.53%	52.14%	26.50%	6.84%	100.00%
	40-50	Count	11	29	25	14	79
		Percent	13.92%	36.71%	31.65%	17.72%	100.00%
	>50	Count	4	19	13	25	61
		Percent	6.56%	31.15%	21.31%	40.98%	100.00%
	Total	Count	43	127	95	49	314
		Percent	13.69%	40.45%	30.25%	15.61%	100.00%
Chi-Square Test							
Value			Degree of freedom			Significance	
53.442			9			0	

5.1.2. Model Specifications and Results

For multinomial logit mode two continuous explanatory variables, travel time (T_{time}) and travel cost (T_{cost}), were used. Coefficient of these variables were chosen to be generic (choice invariant). It means that a change in the explanatory variable affects all modes the same. Income and gender variables were used as dummy variables. These variables were specified as follows:

- $\text{Income} - 3000 = \begin{cases} 1, \text{if income is between 2000TL and 3000TL} \\ 0, \text{otherwise} \end{cases}$
- $\text{Income} - 4000 = \begin{cases} 1, \text{if income is larger than 4000TL} \\ 0, \text{otherwise} \end{cases}$

- Male $= \begin{cases} 1, \text{if biological gender is male} \\ 0, \text{otherwise} \end{cases}$

Gender dummy was included to utility functions of all modes, but found significant only for public transportation. Because of this, gender dummy was included to only utility function of public transportation for the final model. Following utility function set was used for model:

$$U\left(walking\right) = \beta_{TT} Ttime + \beta_{TC} Tcost \tag{5.1}$$

$$\begin{aligned} U\left(PrivateVehicle\right) &= \beta_{PV} + \beta_{TT} Ttime \\ &+ \beta_{TC} Tcost + \beta_{inc1} Income\_4000 \end{aligned} \tag{5.2}$$

$$\begin{aligned} U\left(PublicTransport\right) &= + \beta_{TT} Ttime \\ &+ \beta_{TC} Tcost + \beta_{gen} Male \end{aligned} \tag{5.3}$$

$$\begin{aligned} U\left(PersonnelShuttle\right) &= \beta_{PS} + \beta_{TT} Ttime \\ &+ \beta_{TC} Tcost + \beta_{inc2} Income\_3000 \end{aligned} \tag{5.4}$$

Model was calibrated by using NLOGIT software. Calibrated model coefficients are presented in Table 5.11. All variables are significant at 95% confidence level, except private vehicle and public transportation intercepts. Significance of travel cost variable is important, because it means that university can use strategies targeted to travel cost (e.g. parking pricing, financial incentives) to manage demand of a transportation mode.

Table 5.11. Calibrated Model Coefficients.

Variable Code	Explanation	Value of the Coefficient	Standard Error	Significance
Ttime	Travel time	-0.04154	0.01434	0.0038
Tcost	Travel cost	-0.36357	0.07703	0.0000
Income-4000	Income dummy 1 (for income larger than 4000TL), used for private car	146.457	0.4975	0.0032
Income-3000	Income dummy 2 (for income between 3000TL and 4000TL) used for personnel shuttle	173.686	0.32156	0.0000
Male	Dummy variable for Males	0.85924	0.33079	0.0094
β_{PV}	Constant for private vehicle	0.50617	0.45616	0.2672
β_{PT}	Constant for public transportation	-0.33241	0.46083	0.4707
β_{PS}	Constant for personnel shuttle	-131.691	0.48855	0.007

Predictions are made by calibrated model is given in Table 5.12. Rows are actual observations, columns are model predictions. As seen in Table 5.12, model was correctly predicted 62.74% of the observations.

Table 5.12. Predictions of Calibrated Model.

		Prediction					Percentage of correct prediction
		Walking	Private Vehicle	Public Transport	Personnel Shuttle	Total	
Observation	Walking	5	3	2	1	11	45.45%
	Private Vehicle	4	40	7	16	67	59.70%
	Public Transport	1	9	21	29	59	35.59%
	Personnel Shuttle	1	15	30	131	177	74.01%
	Total	11	67	59	177	314	62.74%

In order to assess overall model significance log-likelihood ratio test is performed. Result presented in Table 5.13. Result indicates that model is significant.

Table 5.13. Result of the Log Likelihood Ratio Test.

Model	Log-Likelihood	Number of parameters	Log-Likelihood ratio test		
			Log-Likelihood ratio	Degrees of freedom	Significance
Null model	-2.494.909	8	1.064.134	5	0.0000
Fitted model	-1.962.842	3			

Pseudo R^2 measures are given in Table 5.14.

Table 5.14. Pseudo R^2 Measures.

Cox and Snell	0.2874
Nagelkerke	0.3611
McFadden	0.2133

5.1.3. Elasticity Analysis for Travel Time and Travel Cost

Elasticity of a transportation mode can be defined as percent change in the share of the mode when one of the explanatory variables changes one percent. Elasticity can be expressed as (Ben-Akiva and Lerman, 1985):

$$E_H(P) = \frac{H}{P}\frac{\partial(P)}{\partial(H)} \tag{5.5}$$

Where H is the explanatory variable, and P is the probability outcome which the elasticity to be determined. For multinomial logit models, elasticity can be found from the following formula:

$$E_{H_{jkq}}^{P_{iq}} = \beta_{jk} H_{jkq} (\delta_{ij} - P_{jq}) \tag{5.6}$$

Where, P_{iq} is the the probability of individual q selecting mode, H_{jkq} the value of the variable for individual q, alternative j and variable k,β_{jk} is the coefficient of the variable k for the utility function of alternative j, P_{jq} is the probability of individual q selecting mode j δ_{ij} is the 1, for direct elasticity 0 otherwise

Travel time and travel cost elasticities of modes were presented in Table 5.15 and Table 5.16 respectively. Average travel cost, average travel time and current percentages of mode choices were used for the elasticity analysis. Since travel cost of personnel shuttle and walking is zero, travel cost elasticities of these modes were not calculated.

Table 5.15. Travel Time Elasticities of Modes.

1% travel time change of	Elasticity of			
	Walking	Private Vehicle	Public Transport	Personnel Shuttle
Walking	-0.65%	0.14%	0.13%	0.38%
Private Vehicle	0.05%	-1071%	0.26%	0.77%
Public Transport	0.09%	0.52%	-1984%	1377%
Personnel Shuttle	0.07%	0.40%	0.35%	-0.81%

Table 5.16. Travel Cost Elasticities of Modes.

1% travel time change of	Elasticity of			
	Walking	Private Vehicle	Public Transport	Personnel Shuttle
Private Vehicle	0.062%	-1391%	0.332%	0.997%
Public Transport	0.049%	0.297%	-1.132%	0.785%

Results indicate that, personnel shuttle is the most cost elastic mode. It means that any percent change in cost for any mode increases market share of personnel shuttle more than the other modes. Personnel shuttle is also highly time elastic in case of a change of the travel time of public transportation.

Boğaziçi University can affect the travel cost of private vehicle by using parking pricing. According to results, 1% travel cost increase of private vehicle will lead to -1.391% decrease of private vehicle usage and 0.062%, 0.332%, 0.997% increase in walking, public transport and personnel shuttle usage respectively.

5.2. Student Multinomial Logit Model

1258 students were interviewed during the survey study. Number of discarded data are provided in Table 5.17.

Table 5.17. Number Discarded Data and Their Reasons.

Reason to discard	Number of discarded observation
Does not study in main campuses	90
Insufficient number of alternatives	946
Item non-response	59

398 of 946 insufficient number of alternative cases belong to students who live in Hisarüstü District or in campus and do not have a car. Their only option is to walk to the university. Remaining insufficient number of alternative cases are belong to students who lives too far to walk to the campus and do not have a car. Public transportation is the only alternative they have.

The resulting dataset consist of 170 observations. Table 5.18 shows number of removals of alternatives and removal reasons.

Table 5.18. Number of Removals of Alternatives and Removal Reasons.

Removed alternative	Removal reason	Number of removals
Walking	Living outside of walking distance	60
Private vehicle	Does not own a car	89
Public Transportation	Living in or very close to university	15

After the removal of invalid alternatives from people's choice set, in resulting data, there are 162 observations with 2 choice alternatives and 8 observations with 3 choice. Table 5.19 shows observed mode choices of 170 people.

Table 5.19. Observer Mode Choices.

Mode	Frequency	Percentage
Walking	78	45.88%
Private Vehicle	38	22.35%
Public Transportation	54	31.77%
Total	170	100.00%

5.2.1. Preliminary Analysis of Model Data

Relationships between gender, income and age categorical variables were investigated. Table 5.20, Table 5.21 and Table 5.22 show this relationships. None of the investigated relationships was found significant.

Table 5.20. Cross Tabulation Chi-Square Test of Mode Choice and Age.

			Mode Choice			Total
			Walking	Private Vehicle	Public Transport	
Age	<20	Count	7	4	5	16
		Percent	43.75%	25.00%	31.25%	100.00%
	20-24	Count	64	25	42	131
		Percent	48.85%	19.08%	32.06%	100.00%
	>25	Count	7	9	7	23
		Percent	30.43%	39.13%	30.43%	100.00%
	Total	Count	78	38	54	170
		Percent	45.88%	22.35%	31.76%	100.00%
Chi-Square Test						
Value			Degree of freedom			Significance
5.055			4			0.282

Table 5.21. Cross Tabulation Chi-Square Test of Mode Choice and Income.

			Mode Choice			Total
			Walking	Private Vehicle	Public Transport	
Income (TL)	<1000	Count	21	9	10	40
		Percent	52.50%	22.50%	25.00%	100.00%
	1000-2000	Count	50	18	34	102
		Percent	49.02%	17.65%	33.33%	100.00%
	>2000	Count	7	11	10	28
		Percent	25.00%	39.29%	35.71%	100.00%
	Total	Count	78	38	54	170
		Percent	45.88%	22.35%	31.76%	100.00%
Chi-Square Test						
Value			Degree of freedom			Significance
8.657			4			0.07

Table 5.22. Cross Tabulation Chi-Square Test Oof Mode Choice and Gender.

			Mode Choice			Total
			Walking	Private Vehicle	Public Transport	
Gender	Male	Count	34	24	29	87
		Percent	39.08%	27.59%	33.33%	100.00%
	Female	Count	44	14	25	83
		Percent	53.01%	16.87%	30.12%	100.00%
	Total	Count	78	38	54	170
		Percent	45.88%	22.35%	31.76%	100.00%
Chi-Square Test						
Value			Degree of freedom			Significance
4.118			2			0.128

5.2.2. Model Specifications and Results

The same two continuous explanatory variables with staff model, travel time ($Ttime$) and travel cost ($Tcost$), were used in student multinomial logit model. Constants for these variables were chosen to be generic. For dependent variables, since students do not have access to personnel shuttle, personnel shuttle is not presented in this model. Gender dummy variable was not found significant in this model. For income dummy variables, high income dummy (greater than 4000TL) was used in the model, and other dummy variable is discarded because mode which the other dummy used was also discarded. Following utility function set was used for the model:

$$U\left(walking\right) = \beta_{TT} Ttime + \beta_{TC} Tcost \tag{5.7}$$

$$\begin{aligned} U\left(PrivateVehicle\right) &= \beta_{PV} + \beta_{TT} Ttime \\ &+ \beta_{TC} Tcost + \beta_{inc1} Income\_4000 \end{aligned} \tag{5.8}$$

$$U\left(PublicTransport\right) = \beta_{PT} + \beta_{TT} Ttime + \beta_{TC} Tcost \tag{5.9}$$

Model was calibrated by using NLOGIT software. Calibrated model coefficients are presented in Table 5.23. All variables are significant at 90% confidence level.

Table 5.23. Calibrated Model Coefficients.

Variable Code	Explanation	Value of Coefficient	Standard Error	Significance
Ttime	Travel time	-0.0702	0.01716	0.0000
Tcost	Travel cost	-0.22254	0.10408	0.0325
Income-4000	Income dummy 1 (for income larger than 4000TL), used for private car	260.629	138.682	0.0602
β_{PV}	Constant for private vehicle	-194.638	0.5138	0.0002
β_{PV}	Constant for public transportation	-115.135	0.26383	0.0000

Predictions are made by calibrated model is given in Table 5.24. Rows are actual observations, columns are model predictions. As seen in Table 5.24, model was correctly predicted 63.06% of the observations.

Table 5.24. Predictions of Calibrated Model.

		Prediction				Percentage of correct prediction
		Walking	Private Vehicle	Public Transport	Total	
Observation	Walking	61	1	16	78	78.21%
	Private Vehicle	6	19	13	38	50.00%
	Public Transport	11	17	25	54	46.00%
	Total	78	38	54	170	61.76%

In order to assess overall model significance log-likelihood ratio test is performed. Result presented in Table 5.5. Result indicates that model is significant. Pseudo R^2 measures are given in Table 5.6.

Table 5.25. Result of the Log Likelihood Ratio Test.

Model	Log-Likelihood	Number of parameters	Log-Likelihood ratio test		
			Log-Likelihood ratio	Degrees of freedom	Significance
Null model	-1.097.745	5	21.3178	3	0.0000
Fitted model	-991.156	2			

Table 5.26. Pseudo R^2 Measures.

Cox and Snell	0.1179
Nagelkerke	0.1625
McFadden	0.0971

5.2.3. Elasticity Analysis for Travel Time and Travel Cost

Travel time and travel cost elasticities of modes were presented in Table 5.27 and Table 5.28 respectively. Since travel cost of walking is zero, Elasticity of the walking was not calculated.

Table 5.27. Travel Time Elasticities of Modes.

1% travel time change of	Elasticity of		
	Walking	Private Vehicle	Public Transport
Walking	-0.63%	0.26%	0.37%
Private Vehicle	0.83%	-1404%	0.57%
Public Transport	0.85%	0.41%	-1259%

Table 5.28. Travel Cost Elasticities of Modes.

1% travel cost change of	Elasticity of		
	Walking	Private Vehicle	Public Transport
Private Vehicle	0.35%	-0.60%	0.25%
Public Transport	0.18%	0.09%	-0.27%

As seen in the Table 5.27 and Table 5.28, none of the modes are highly elastic for travel cost or travel time.

As mentioned in Section 5.1.3, Boğaziçi University can affect the travel cost of private vehicle by using parking pricing. According to results, 1% travel cost increase of private vehicle will lead to -0.600% decrease of private vehicle usage and 0.354% and 0.245%, increase in walking and public transport usage respectively.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The results of this study revealed parking capacity shortage of the South and North Campus, inter-campus travel demand of main campuses, capacity shortage of the shuttle bus service between South and North Campus and access mode choice behavior of students and staff of the Boğaziçi University. In this study, multinomial logit modelling was used for the modelling transportation mode decisions for home based trips to university. Travel cost and travel time elasticities of the transportation modes were determined. Since data were collected to represent only the population of Boğaziçi University, validity of the results are limited to population of Boğaziçi University. This study also revealed some problems in transportation system of Boğaziçi University. The main conclusions of this study are summarized below:

- The inefficiency of shuttle busses against high demand of inter-campus trips was shown by the collected data. Resulting queues cause lead to an increase of the service times of the shuttle busses. 26.61% of staff and 36.09% of the students stated that inconsistent departure time of shuttle buses affect their choices to use shuttle busses for inter-campus transportation (Section 4.3.2 and Section 4.3).
- Parking capacity problem was also investigated. Although according to the number of parking permits and parking capacity, a parking capacity seems to exist, transportation survey revealed that 38% of staff and 34% of students who own a car, do not use their private vehicle as preferred mode of transportation. Because of that, parking capacity problem is not as serious as was revealed by parking capacity and permit data (Section 4.3.4).
- As mentioned in Section 4.3.5, there are 1166 staff registered to personnel shuttle service; however, in two-week long period, 25.3% of the staff registered to service did not use the personnel shuttle. Also 23.87% of the staff, who do not prefer to use personnel shuttle, stated that shuttle routes are not favorable. Both data indicate that, there might be a planning problem in the route planning of the

shuttle busses.

- Perceived safety is an important factor that affects people's cycling decisions (Daley and Rissel, 2011; Clarke and Dornfeld, 1994). 95.9% of staff and 91.18% of students stated that, the streets connecting the main campuses were not safe for cycling. Another barrier for cycling is the hilly topography of the area that main campuses are located.
- Modal split for trips between main campuses was determined from the revealed responses of the transportation survey respondents. Results presented in Table 4.26. As expected from the higher vehicle ownership rate of staff, staff prefer private vehicle and carpooling more than students.
- Boğaziçi University has rules and regulations for transportation and parking in campuses; however, either there are no punishments involved for the violation of these rules or university does not enforce these rules. Transportation survey revealed that only 5.56% of staff and 7.15% percent of students were against some kind of punishment for people who break these rules.
- Separate multinomial logit models were created for students and staff. Preliminary analysis of the model data showed that 16.36% of the staff and 78.9% of the students do not have an alternative mode to choose. After discarding the data that has item non-response, insufficient number of alternatives and data belong to people who do not work or study in main campuses, relationship between demographical variables and observed mode choices were investigated. For staff, gender, income and age was found significant; however, the relationship between age and income was also found significant. Because of that, only gender and income demographic variables were included in the model. For, students, relationships between demographical variables and mode choices were found insignificant.
- Staff multinomial logit model results indicate that travel time and travel cost are significant for all modes, gender is significant for public transportation, average income (2000TL-3000TL) is significant for personnel shuttle and high income (higher than 4000TL) is significant for private vehicle. For students, travel time and travel cost are significant for all modes. Since demographical variables were not found significant in preliminary analysis, they are not included in student

multinomial logit model.

6.2. Recommendations

In this study, some problems in transportation system of Boğaziçi University are determined. In case of parking and inter-campus shuttle bus problems, the cause of these problems were determined as supply shortage of these services. For supply shortage problems, one option is to increase supply which may be expensive if it involves infrastructure improvements. The other option is to manage demand by using strategies (e.g. pricing, incentives or punishments). In this study, for the sake of the sustainability, recommendations do not involve infrastructure improvements related to private vehicle usage. Instead of increasing convenience of using a car, demand management strategies are recommended to decrease private vehicle usage. Recommendations based on the results of the analyses and the campus transportation planning literature are presented below:

- Demand management strategies listed in Section 2.1 are based on incentives and punishments. However, in order to prevent abuse of incentives and enforce the punishments, there must be some kind of monitoring system. Current infrastructure of Boğaziçi University does not have that kind of system. Radio frequency identification (RFID) based campus entrance systems offers monitoring of entering and leaving of vehicles. RFID based entering systems are widely used by many universities (e.g. Kansas State University, Wright State University, University of North Carolina, University of Arizona, University of Texas at El Paso, University of Wisconsin-Madison, Duke University). RFID based HGS (Fast Toll Collection System) system are currently in use for the toll collection of Turkey's freeways and bridges. Because of that, majority of vehicles has already RFID tags that necessary for a RFID based entrance system. Current campus entrance gates are controlled by security guards. Guards allow entrance according to availability of a parking permit sticker on the vehicle's windshield. These stickers can be easily counterfeited. With this system, gates will be automatically opened to users identified in the system. Since RFID tags are unique, counterfeiting will not be a

problem. In addition, an automated system will eliminate possible human errors. Rest of the recommendations are made based on the assumption that Boğaziçi University have some kind of monitoring system.

- The most straightforward approach to solve parking capacity problems is to increase parking capacity; however, because of the limited free space in main campuses and the financial cost of building a parking structure, building a parking structure is not an option for Boğaziçi University. A minor increase in parking capacity can be achieved by inspection of current parking spaces. There are no markings for parking spots in most of the parking spaces in the university. This may result in inefficient use of parking space.
- The other solution for parking problems of Boğaziçi University is to manage parking demand. Currently Boğaziçi University uses pricing as a demand management tool for students' parking demand. Students pay 350 TL/semester, which is a considerable amount for a student, for semester parking permit. As stated in Shoup (2008), changing parking permit pricing period from semester or annual to daily pricing will create a marginal cost for parking, and motivate students to consider alternative modes. For staff, there are currently no demand management measures applied. Results of the multinomial logit model showed that travel cost is a significant variable in people's mode choices. Also elasticity analysis showed that, an increase 1% in the travel cost of private vehicle will increase the usage of the personnel shuttle by 0.997%. Since already personnel shuttles are working under their capacity, starting to charge staff for parking will lead to a decrease in private vehicle usage, effective usage of money spent on personnel shuttles and generate revenue from parking spaces dedicated to staff. Parking fee collection can be easily done by the monitoring system recommended before.
- Promoting carpooling can also be beneficial for solving parking problems. As shown in Table 4.31 people are willing to use carpool. A web base application can match people who have parking permits and want to carpool. Carpooling can be promoted by making parking free or discounted to carpoolers. Enforcement and pricing of this can be done by the monitoring system that recommended before.

In order to solve queuing problem in shuttle busses, cycling can be promoted as an alternative to shuttle bus. In order to, promote cycling bicycle sharing systems, improvement of bicycle parking and cycling education can be considered.

- Bicycle sharing systems consists of a station of bicycles ready to use. People registered to system use smart cards to take the bikes in the station. Martens (2007) report that bicycle sharing system increases market share of cycling. Gokasar and Bayrak (2016) investigated stated cycling preferences of students of Boğaziçi University, in case of certain pro-cycling investments are made to campus. In this study, it is found that bicycle sharing system will increase the bicycle usage in the campuses; however, it is also found that students will use bicycle for South Campus originated trips but not as much as for South Campus destined trips. This will create operational difficulties like distribution of bikes among stations during day. A Bicycle sharing system that consists of electrical bikes can be considered to eliminate the difficulties of the distribution of bikes among campuses.
- An increase in number of parking spaces for bicycle increases modal share of cycling (Hunt and Abraham, 2007; Noland and Kunreuther, 1995; Wardman *et al.* 2007). A rule of thumb for bicycle parking is bicycle parking units must support bicycle from two points on the frame to prevent damages from falling and must be in a visible area to increase security (SFMTA, 2015; City of London, 2011; Bristol City Council, 2005). In current cycling parking units in Bogazini University, bicycles are locked from their wheel. Since, majority of modern bicycles have easy wheel release handles, they are prone to bicycle theft. Improvement of existing parking facilities and increasing the number of parking facilities will improve cycling between campuses.
- As stated before, Nispetiye Street is not perceived safe for bicycles. Education programs can be beneficial for increasing people's confidence for cycling (Telfer *et al.* 2005; Pucher *et al.* 2010). A cycling course focused of cycling in vehicle traffic and a cycling handbook will be beneficial for both security of cyclists and level of cycling.

Recommendation for future studies are given below:

- This study is mainly focused on instrumental utilities of the travel modes for explaining travel choice of people and evaluation of the demand management strategies; however, as Steg (2004) and Daley and Rissel (2010) stated that, symbolic and affective motives are also significant for travel choice behavior of people. Inclusion of these variables into analysis will lead to better understanding of the transportation behavior of the university students and staff, and better evaluation of the improvement strategies.
- Literature on quantitative effects of transportation improvements on university communities is limited. If the recommended improvements and strategies are applied to Boğaziçi University, a follow up research can be conducted to determine quantitative effects of the applied improvements.

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APPENDIX A: CAMPUS TRANSPORTATION SURVEY

BOĞAZİÇİ ÜNİVERSİTESİ ULAŞIM ANKETİ

Anketör:		Tarih:	
Anketin Yapıldığı Kampüs:		Anket No:	

1. Bölüm: Üniversiteye Ulaşım

S1. Özel aracınız (motorsiklet, otomobil) var mı?

Var		Yok	

S2. *(Soru 1 "Yok" olarak yanıtlandıysa bu soruyu atlayınız)* Aracınızın Boğaziçi Üniversitesi amblemi var mı?

Var		Yok	

S3. Üniversiteye gelirken genellikle hangi ulaştırma türlerini kullanıyorsunuz? *(Eğer tek yolculukta farklı türler kullanılıyorsa hepsi işaretlenmelidir)*

Bisiklet		Özel Araç	
Dolmuş		Servis (Öğrenci)	
Metro		Servis (Personel)	
Metrobüs		Taksi	
Minibüs		Vapur/Deniz Otobüsü/Motor	
Otobüs		Yürüme	

S4. Üniversiteye hafta içi hangi sıklıkla geliyorsunuz?

1 gün		4 gün	
2 gün		Her gün	
3 gün			

S5. Üniversiteye hafta içi genellikle hangi saat aralığında geliyorsunuz?

	Pazartesi	Salı	Çarşamba	Perşembe	Cuma
8:00'dan önce					
8:00-9:00					
9:00-10:00					
10:00-11:00					
11:00-12:00					
12:00-13:00					
14:00-15:00					
15:00'dan sonra					

S6. Üniversiteden hafta içi genellikle hangi saat aralığında ayrılıyorsunuz?

	Pazartesi	Salı	Çarşamba	Perşembe	Cuma
11:00'dan önce					
11:00-12:00					
12:00-13:00					
14:00-15:00					
15:00-16:00					
16:00-17:00					
17:00'dan sonra					

S7. *(Bu soru S1 "var" olarak S3 ise "özel araç" dışında cevaplandıysa sorulacaktır)* Özel aracınız olmasına rağmen üniversiteye gelişinizde neden özel aracınızı kullanmıyorsunuz? *(Eğer birden fazla neden var ise anket yapılan için en önemli olan seçilmelidir)*

Akaryakıt ücretleri	
Üniversite ve civarında park yeri bulma sorunu	
Trafik yoğunluğu	
Çevresel duyarlılık	
Diğer	

S8. *(Bu soru S3'e Servis (Personel) ve yürüme dışında cevap veren personellere sorulmalıdır)* Personel servisini neden kullanmıyorsunuz? *(anket yapılan için en önemli seçenek seçilmeli)*

Tercih ettiğim ulaşım yöntemi servisten daha hızlı	
Servis ücretleri pahalı	
Servislerin rotaları uygun değil	
Servisler konforlu değil	
Servis saatleri uygun değil	
Diğer	

Figure A.1. Campus Transportation Survey, Page 1.

2. Bölüm: Park Yeri Problemleri *(Bu bölümdeki sorular sadece S3'e özel araç cevabını verenlere sorulacaktır)*

S9. *(Öğrencilere sorulmayacaktır)* Üniversiteye geldiğinizde çalıştığınız yere en yakın park yerinde genellikle park alanı bulabiliyormusunuz?

Evet		Hayır	

S10. *(Öğrencilere sorulmayacaktır, S9'a hayır cevabı verenlere sorulacaktır)* Çalıştığınız yere en yakın park yeri bulamadığınızda kampüsün herhangi bir yerinde kısa sürede park yeri bulabiliyormusunuz?

Evet		Hayır	

S11. *(Öğrencilere ve S2'ye var yanıtını verenlere sorulacaktır)* Üniversiteye geldiğinizde öğrenci otoparklarında genellikle park yeri bulabiliyormusunuz?

Evet		Hayır	

3. Bölüm: Kampüs İçi Trafik ve Yaya/Bisikletli Güvenliği

S12. Bulunduğunuz kampüste sizce araç trafiği fazlalığı var mı?

Var		Yok	

S13. Bulunduğunuz kampüste sizce motorlu taşıtların ve yaya/bisikletlilerin karşılaştığı yerlerde güvenlik eksikliği var mı?

Var		Yok	

S14. Bulunduğunuz kampüste sizce araç park yerlerinin yaya/bisikletli hareketliliğine olumsuz etkileri var mı?

Var		Yok	

4. Bölüm: Kampüsler Arası Ulaşım

S15. Merkez kampüsler (Hisar, Kuzey, Güney, Uçaksavar) arasında ulaşım için aşağıdaki yöntemleri hangi oranda kullanıyorsunuz? *(Oranlar "%" cinsinden yazılmalıdır. Değerlerin toplamının %100 olmasına dikkat edilmelidir)*

Araç paylaşımı (örn. arkadaşınızın aracı ile ulaşım)	
Bisiklet	
Shuttle servisi	
Özel araç	
Otostop	
Yürüme	

S16. Güney Kampüsten diğer merkez kampüslere ulaşımınızda shuttle kullanma tercihinizi aşağıdakilerden hangileri olumlu veya olumsuz etkilemektedir?

Kötü hava şartları	
Shuttle durağında oluşan kuyruk	
Art arda olan derslerin farklı kampüslerde olması	
Güney Kampüs yokuşunun yorucu olması	
Shuttle servislerinin belirli saatlerde değil de dolduğunda hareket etmesi (Shuttle servisinin ne zaman geleceğinin belirsizliği)	
Shuttle servislerinin ücretsiz olması	

S17. Merkez kampüsleri birbirine bağlayan Nispetiye Caddesi sizce bisiklet kullanımı için yeterince güvenli mi?

Güvenli		Güvenli değil	

****18-19-20 numaralı sorular sadece öğrencilere sorulacaktır*

S18. Derslerinizin çoğunluğu hangi kampüstedir?

Hisar Kampüsü		Kandilli Kampüsü	
Güney Kampüsü		Kilyos Kampüsü	
Kuzey Kampüsü			

S19. Ders saatleri ve ikamet dışında aşağıdaki kampüslerde, bir hafta boyunca kaç saat vakit geçiriyorsunuz?

Kuzey Kampüsü	
Güney Kampüsü	
Hisar Kampüsü	
Uçaksavar Kampüsü	

Figure A.2. Campus Transportation Survey, Page 2.

S20. Ders saatleri ve ikamet dışında kampüslerde harcadığınız vakit için aşağıdaki nedenler arasında sıralama yapabilir misiniz? *(1: en sık, 6:en az, sıralamaya her madde katılmalıdır)*

Ders çalışmak	
Gün içinde ders aralarındaki boş saatleri değerlendirmek	
Vakit geçirmek	
Spor	
Sosyal etkinlikler	
Diğer	

5. Ulaşımda Yapılacak Geliştirmeler

S21. Ulaşımda yapılacak olan iyileştirme çalışmalarında aşağıdaki maddelerin öncelik sıralaması nasıl olmalıdır? *(1: en öncelikli, 5: en az öncelikli, sıralamaya her madde katılmalıdır)*

Yaya hareketliliğinin ve güvenliğinin iyileştirilmesi	
Park kapasitesinin arttırılması	
Bisiklet kullanımının kolaylaştırılması/desteklenmesi	
Mekik servislerinin iyileştirilmesi	
Kampüs estetiğinin korunması	

S22. Çeşitli teşviklerle desteklenen bir araç paylaşım sistemi kurulsa üniversiteye gelirken araç paylaşım sistemini kullanmayı düşünürmüsünüz?

Kullanırım		Kullanmam	

S23. Kampüs içinde belirlenecek trafik kurallarına uymayan araçlar için sizce ne çeşit bir yaptırım uygulanmalıdır? *(Birden fazla seçenek seçilebilir)*

İdari para cezası	
Araçla kampüse girişinin geçici bir süre için yasaklanması	
Tekrarlanan ihlallerde araçla kampüse girişinin dönem boyunca yasaklanması	
Yaptırım uygulanmamalıdır	

6. Bölüm: Demografik Veriler *(Bu bölümün cevaplanmasını anket yaptığınız kişiye bırakın)*

S24. Cinsiyetinizi alttaki boşluğa lütfen yazınız?

S25. Aşağıdaki aralıklardan yaşınız için uygun aralığı lütfen işaretleyiniz

20'den küçük		45-49	
20-24		50-54	
25-29		55-59	
30-34		60-64	
35-39		65'ten büyük	
40-44			

S26. Aşağıdaki yurtlardan/lojmanlardan birinde ikamet ediyorsanız işaretleyiniz. Eğer kampüs içinde ikamet etmiyorsanız lütfen ikamet ettiğiniz mahalle ve ilçeyi belirtiniz.

Kilyos Kampüsü Yurtları/Lojmanları		Kandilli Kampüsü Lojmanları	
Uçaksavar Kampüsü Yurdu/Lojmanı		Mahalle:	
Kuzey Kampüs Yurtları		İlçe:	
Güney Kampüs Yurtları/Lojmanları			

S27. Boğaziçi Üniversitesi'ndeki konumunuzu ifade eden seçeneği işaretleyiniz

Tam Zamanlı Akademik Personel		İdari Personel	
Yarı Zamanlı Akademik Personel		Öğrenci	
Araştırma Görevlisi			

S28. Aylık geliriniz aşağıdaki aralıklardan hangisi arasındadır?

<1000TL		2500-2999TL		4500-4999TL		6500-6999TL	
1000-1499TL		3000-3499TL		5000-5499TL		>7000TL	
1500-1999TL		3500-3999TL		5500-5999TL			
2000-2499TL		4000-4499TL		6000-6499TL			

Figure A.3. Campus Transportation Survey, Page 3.