GROUND ACCESS MODE CHOICE MODELS OF İSTANBUL AIRPORTS

by

Onur Ilgen

B.S., Civil Engineering, Yildiz Technical University, 2011

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Civil Engineering
Boğaziçi University
2016

ACKNOWLEDGEMENTS

I would first like to thank my thesis advisor Assist. Prof. Ilgin Gökasar for her guidance and attention. Without her support and tolerance, I would not be able to finish this study.

I would like to thank also the member of thesis committee, Prof. Safa Bozkurt Coskun an d Assoc. Prof. Nilüfer Özyurt Zihnioglu for their valuable guidance.

I should also thank Gürkan Günay for his contribution to my thesis and friends who help me for survey study. Last but not least, I want to thank my wife for her sincere and continuous support.

ABSTRACT

GROUND ACCESS MODE CHOICE MODELS OF İSTANBUL AIRPORTS

One of the important parameter of airport landside planning is providing access alternatives to air passengers. As a result of the characteristics of the travellers, duration of the travel and differences in the current modes and, the factors in airport travel are importantly different from those in the urban transportation models for the regular travels. Most of the travel is conducted by the visitors to airports; in comparison to other urban travels, passengers prefer to travel in groups. Also, their trips for airport access purposes have lesser frequency than the other urban trips. They carry their luggage with them and they are mostly away for a couple of days or sometimes for weeks. In this study, two airport in İstanbul; S.A.W., I.S.T. were investigated and access mode choice models were built by using the air passenger survey data. Multinomial Logit Model was used to analyze mode choice. Passenger characteristics and trip characteristics are the major parameters of models. Results of the analysis show that travel time, trip purpose (Business/Nonbusiness), travel cost, flight route (Domestic/International) are the most important parameters of access mode choice. For instance, being international or business passenger for SAW model and number of passenger for IST model decreases probability of choosing public transit relative to auto. Also, distance has a negative effect on choosing taxi relative to auto for both airport. So, if distance increases, proportion of choosing taxi decreases. Furthermore, in this study, two factors which did not used for any models in literature, were used for mode choice models. One of them is seasonal effect (winter/summer) which was used for IST model and winter increases choosing taxi compare to auto. Other one is Weather effect (rainy/not rainy) which was used for SAW model and if weather is rainy choosing public transit rate relative to auto decreases.

ÖZET

İSTANBUL HAVALIMANLARININ ULAŞIM TÜREL SEÇİM MODELLERİ

Havalimanı kara alan planlamasının önemli parametrelerinden biri havalimanı yolcularının havalimanına ulaşım alternatiflerinin sunulmasıdır. Yolcu profinin, seyahat süresinin ve ulaşım modları arasındaki farkların bir sonucu olarak, havalimanına ulaşımı etkileyen faktörler havalimanı yolcuları için kentiçi ulaşım modellerinden önemli ölçüde farklıdır. Kentiçi seyahat ile karşılaştırıldığında havalimanına yapılan seyahatlerde genellikle yolcular grup halinde seyahat etmeyi tercih ederler. Havalimanı seyahatleri kent içi seyahatlerden daha az sıklıktadır. Yolcular yanlarında bavullarını taşırlar ve seyahatleri birkaç günlük veya birkaç haftalıktır. Bu çalışmada havalimanı yolcuları ile yapılan anketler kullanılarak İstanbul'da bulunan iki havalimanı; S.A.W. ve A.H.L. araştırılmış, havalimanı ulaşım türel seçim modelleri oluşturulmuştur. Oluşturulan modeller için Multinomial Logit Model yöntemi kullanılmıştır. Yolcu özellikleri ve seyahat özellikleri, modellerin ana parametreleridir. Analiz sonuçlarına göre havalimanı ulaşımı mod seçiminin en önemli parametreleri seyahat süresi, seyahat amacı(Iş seyahati/Iş dışı seyahatler), seyahat ücreti, uçuş rotasıdır(Iç hat/Dış Hat). Örneğin SAW modeli için iş seyahati veya dış hat yolculukları, İST modeli için yolcu sayısı otomobile oranla toplu taşımanın tercih edilmesini azaltmaktadır. Buna ek olarak otomobile oranla uzaklık her iki havalimanı için taksi tercihi üzerinde negatif bir etkiye sahiptir. Uzaklık arttıkça taksinin tercih edilmesi oranı azalmaktadır. Ayrıca bu çalışmada ulaşım türel modeli için literatürde herhangi bir çalışmada kullanılmamış olan iki faktör kullanılmıştır. Bunlardan birisi İST modelinde kullanılan mevsimsel etki(yaz/kış)dir. Kış, otomobile oranla taksi tercihini arttırmaktadır. Bir diğer faktör SAW modeli için kullanılan hava durumu (yağışlı/yağışsız) etkisidir, hava yağışlıysa, otomobile oranla toplu taşımanın tercih edilmesi artmaktadır.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

C	Choice Set
J	Number of component
U	Utility
V	Deterministic part of utility
ε	Error
γ	Euler constant

LIST OF ACRONYMS/ABBREVIATIONS

ACI	Airports Council International
ACRP	Airport Cooperative Research Program
ATL	Atlanta Hartsfield-Jackson International Airport
CLE	Cleveland Hopkins International Airport
HKG	Hong Kong International Airport
IST	İstanbul Atatürk International Airport
JFK	New York John F. Kennedy International Airport
MNL	Multinomial Logit Model
OSL	Oslo Gardermoen International Airport
SAW	Sabiha Gökçen International Airport
SFO	San Francisco International Airport
ZRH	Zurich International Airport

1. INTRODUCTION

Globalization, development of technology and depending on these, changing of people's travel behaviour increases necessity of fast and safe transportation. Increasing needs have affected air transportation market in the last decades. Today, airports are the main transport centers of most cities. According to the Airports Council International (ACI) statistics, the number of total passengers for top 50 airports in the world is 1.95 billion in 2009. In 2014, that number has become 2.44 billion, so that a 25.5% growth in 5 years has brought a lot of problems and thus, management of airports has become one of the most important issues for transportation engineering. At the same time, managing airports is not only about preparing flight schedules, organizing employees, taking safety measures but also establishing facilities to provide an easy access to the airport for passengers. According to ACRP(Airport Cooperative Research Program) report, share of using public transportation (rail and bus) for airport access is 23% for San Francisco International Airport (SFO), 19% for New York John F. Kennedy International Airport (JFK), 14% for Atlanta Hartsfield-Jackson International Airport (ATL), 6% for Cleveland Hopkins International Airport (CLE), 64% for Oslo Gardermoen International Airport (OSL), 63% for Hong Kong International Airport (HKG), 47% for Zurich International Airport (ZRH) and 40% for Paris Charles de Gaulle International Airport (CDG). According to airport facilities, passenger access behaviour is different from each other (Gosling, 2008).

An important analytical element of airport landside planning and airport system planning is generated by the mode choice decisions of the air passenger for their transportations to airport or the other way around. However, it has to be found well-defined and verified process to design how airport users will alter their transportation modes to airport depending on the changes at the ground transportation system in the airport. As a consequence of the characteristics of the travellers, time and duration of the travel and differences in the current modes and services, the factors in airport travel are different from those in the regional transportation models for the regular travels. It is very perplexing to predict how changes in the airport ground transportation system will affect the airport travellers for their mode choice decisions seeing that these decisions depend both on price and characteristics of the individual travellers (Gosling, 2008). There are more transportation modes in terms of airport ground access than the general urban travel demand models (Gosling, 2008). Airport access trips of the air passengers are significantly distinctive from those of the urban travel. Most of the travel is conducted by the visitors to the region; in comparison to other urban travels, passengers prefer to travel in groups and their trips for airport access purposes have lesser frequency than the other urban trips, they carry their luggage with them and they are mostly away for a couple of days or sometimes for weeks and thus affected by the cost and parking due to the economical reasons.

1.1. Goals and Objectives of the Study

The goal of this study is to analyze airport passenger behaviour and to build a ground access mode choice model using with passenger survey data for the two airports in İstanbul, Turkey; Sabiha Gökçen International Airport (SAW) and Atatürk International Airport (IST).

One of the objectives of this study is to understand which parameters affect ground access mode choice to airport and how demographic characteristics such as gender, age specify mode choice behaviour. Other objective is investigating similarities and differences between passenger mode choice behaviours of two airports in a city. Two airport in İstanbul, Sabiha Gökçen International Airport and Ataturk International Airport were selected for study. The survey data was collected via face to face interview with air passengers on both airports. The last objectives of this study is create a model for each airport by using survey data and to investigate the statistical relation based on important parameters between access alternatives for each airport.

1.2. Thesis Outline

Chapter 1 presents introduction and motivation of this study.

Chapter 2 includes general theoretical information about mode choice behaviour and models. The chapter also contains previous studies about airport ground access mode choice model.

In Chapter 3, methodology of the research is presented. The chapter includes the survey study, data collection, demographic information of the passengers, analysis of the passenger mode choice behaviour and ground access mode choice model of IST and SAW.

Chapter 4 includes the conclusion and recommendation for the future studies.

2. TRAVEL DEMAND FORECASTING

Demand forecasting is a key member of transportation systems. During the 1960s and 1970s there had been a shift conversion to transportation organization investigations from unimodal inquiry of big central decisions against multinomial system's terms of value, operative policies, and developments and addition of transportation estimation and analytic access. Because of considerable modernization in the analysis of the need for transportation systems, the travel demand models, upon various choice analysis practices, were developed. Separating the geographic area under two study zones would be the familiar systematic approach. In the geographical centroid the roots and destinations of all travelers in the area are represented by a single point within the area. Aggregate travel demand models are estimated straight forwardly with date on travel attitude with some level of accumulation within a geographical area that serves as an observational unit for the person carrying out the investigation. At the disaggregate, or smaller scale level, the conduct of the distinctive individual, family unit or firm can best be portrayed with discrete variables. The order of family units, as an example, into car owner and non-car owner infer a binary yes or no-reliant variable. The essential issue stood up to by discrete choice analysis is the displaying of decision from an arrangement of totally unrelated things considered thorough options. Discrete choice issues have been of enthusiasm to scientists for a long time in an assortment of controls. The sources of probabilistic decision models are in mathematical psychology.

2.1. Theories of Individual Choice Behaviour

The behaviour of substantial number of people or associations is the result of individual choices. Therefore, the displaying of individual behaviour is either explicitly or certainly at the center of every single prescient model of total conduct. With a theory of behaviour that is descriptive, in the sense that it shows hypothesizes of how individuals act and does not endorse on how they should act, unique, as it can be formalized in wording which is not particular to specific circumstances, and operational, as it results in models with parameters and variables that can be measured or assessed.

There does not exist a universally accepted decision theory that fulfills these necessities. Alternative theories contrast fundamentally in the level of detail because they idealize the thought processes that procedure observed behaviour.

A decision can be seen as a result of a consecutive choice making that incorporates the accompanying steps;

(i) Definition of the choice problem,
(ii) Generation of alternatives,
(iii) Evaluation of attributes of the alternatives,
(iv) Choice,
(v) Implementation

A worker selecting a model of trip to work would be an illustration of a substitute downside. His or her surroundings and the transportation administrations affirm the decision modes reachable for the trip; however he or she may not take personality into consideration to be a main priority in the considerable number of chances. A particular theory of decision is an accumulation of techniques that characterizes the accompanying components:

(i) Decision Maker: The unit of choice making can be based on a unique individual or a gathering of people, for example, a family or family unit. It can likewise be an association, for example, a firm or government office. Decision maker will be accepted as an individual.
(ii) Alternatives: Any decision is produced using a nonempty set of options. The setting of the decision maker pins down what should be called the widespread arrangement of choices. Any single decision maker considers a subset of this widespread set, termed as the decision set. This recent set incorporates the choices that are both attainable to the leader and known at the time of the choice procedure. It will be valuable to recognize two general sorts of decision sets. In the first sort, the decision set is persistent and the second set is where the options are normally intermittent.

(iii) Alternative Attributes: The engaging quality of an option is assessed in terms of the vectors of property estimations. The characteristic qualities are measured on a size of pleasantness. For instance, travel time via vehicles in congested urban territories may be a questionable property for model decision in light of its extraordinary variability from day to day. This part of auto travel would be spoken to as a property of the alternative.

(iv) Decision rule: A decision from a decision set containing two or more choices requires a choice principle. It portrays the inward components utilized by the decision maker. These principles can be grouped into four classifications:

- Dominance: an option is predominance concerning another on the off chance that it is better for minimum one characteristic and no more terrible for every other single quality.
- Satisfaction: For each property accept a level that serves as a fulfillment criteria in view of the leader's desire of feasible, encountered from his or her present data and past encounters.
- Lexicographic rules: Suppose that the traits are rank requested by their level of 'significance'. The decision maker picks the option that is the most alluring for the most imperative quality.
- Utility: The engaging quality of an option communicated by a vector of ascribes qualities is reducible to a scalar. Utility is a measure that the decision maker endeavours to expand through his or her decision (Ben-Akiva, Lerman and Discrete, 1985).

2.1.1. Economic Consumer Theory

The essential way to deal with the mathematical theories individual inclinations is by the microeconomic consumer theory. The goal of the theory is to give way to the change of suspicion about wishes into an interest capacity communicating the activity of consumer under given circumstances. An individual consumer is choosing a consumption bundle

$$Q = \{q_1, ...q_2\} \tag{2.1}$$

where $q_{1,........}q_L$ are amounts of each of the products and assistances, L =1, 2,..., L. In consumer theory these amounts are, for the most part, thought to be nonnegative never stopping variables. The numerical investigations utilized by this hypothesis to deliver its vital results are subject to this supposition.

The buyer is confronted with a financial plan that characterizes the utilization of potential outcomes or decisions of sets. For a settled income, $p_{1,}p_{2,........}p_L$, and settled prices, $p_{1,}p_{2,........}p_L$ the financial backing imperative is

$$\sum_{l=1}^{L} p_1 q_1 \leq \mathrm{I} \tag{2.2}$$

In the traditional way to deal with customer theory there is no way to express the unequivocal treatment of ascribes notwithstanding the amounts $q_1, ..., q_L$ that characterize an option (Layard, Walter, 1978).

2.1.2. Discrete Choice Theory

A continuous space of options expected in the consumer theory permits the utilization of analytics to infer interest capacities. Notwithstanding, if the utilization of one or more things can be zero, the expansion issue might have a corner arrangement, a point where the standard first-request conditions for an ideal don't hold.

Utilization of this theory to anticipate how the commuter will react to changes requires giving allocate numerical qualities to the parameters. The methodology taken to this estimation issue is called "revealed preferences".

2.1.3. Probabilistic Choice Theory

The main advancements of probabilistic decision theories were in the field of psychology. The advancement of these speculations emerged from the need to clarify test perceptions of conflicting and non-transitive inclinations. In decision tests people have been watched not to choose the same option in reiterations of the same transitive inclinations supposition. In addition, by changing decision sets, infringements of the transitive inclinations presumption are also watched.

2.2. Binary Choice Theory

For an assortment of reasons the utility of any option is, from the viewpoint of investigator, best saw as a random variable. This leads specifically to the thought of random utility models in where the issues of probability options i being chosen by individual n from a decision set Cn, is given by the following:

$$P(i|C_n) = Pr(U_{in} \geq U_{jn}, \forall j \in C_n) \tag{2.3}$$

Formally, if the appropriations of and U_{jn} can be portrayed by a probability density function,

$$Pr(U_{in} = U_{jn}) = 0 \tag{2.4}$$

In this theory the essential thought is to consider the unique situation where C_n contains precisely two options. Such circumstances lead to what are termed as paired decision models. The probability of individual n choosing i is

$$P_n(i) = Pr(U_{in} \geq U_{jn}) \tag{2.5}$$

the probability of picking option j is $P_n(j) = 1 - P_n(i)$ The objective of this method is to build up the essential theory of random utility models into a class of operational binary choice models.

The improvement of any binary decision model would be divided into three essential steps:

(i) The partition of aggregate utility into deterministic and random segments of the utility function.

(ii) The determination of the deterministic part.
(iii) The determination of the random part.

2.2.1. Deterministic and Random Utility Components

U_{in} and U_{jn} are random variables, starting by separating each of the utilities into two added substance parts as follows:

$$\begin{aligned} U_{in} &= V_{in} + \varepsilon_{in} \\ U_{jn} &= V_{jn} + \varepsilon_{jn} \end{aligned} \tag{2.6}$$

V_{in} and V_{jn} are known as the systematic parts of the utility of i and j; ε_{in} and ε_{jn} are the random parts and are called disturbances.

2.2.2. Common Binary Choice Models

The binary decision models which are normally utilized as a part of interest determining are;

(i) The Linear Probability Model ($\varepsilon_{jn} - \varepsilon_{in}$ uniform)
(ii) Binary Probit ($\varepsilon_{jn} - \varepsilon_{in}$ normal)
(iii) Binary Logit ($\varepsilon_{jn} - \varepsilon_{in}$ logistic)

The ladder two models are numerically comparative, however logit is analytically the more tractable.

2.3. Multinomial Choice

In the advancement of models for more broad cases, the decision set of Cn comprises more than two options. In such cases the induction of helpful decision models and proper estimation systems turn out to be significantly more intricate than for binary decision investigations. Specifically, it is not adequate just to indicate the invariable dispersion of the distinctions in unsettling influences.

2.3.1. Theory of Multinomial Choice

Starting by accepting the issue being concentrated on, that the one making the analysis can characterize set C that incorporates every single potential decision for some population. C called be the general, or ace, decision set, and characterize J to be number of components in it. Every individual from the population has some subset of C as his or her decision set. For instance, in a mode decision model, C might comprise of six components: automobile, taxi, transit bus, motorcycle, bicycle, walking.

However, for a specific explorer the genuine decision set, C_n, may be extensively smaller. Clearly what constitutes a practical option for a specific individual may be troublesome for the investigator to decide. We should acknowledge, then again, that this attribution of the decision set by the examiner is basically a conceivably unrefined model of mind boggling cooperation between an individual leader and his or her surroundings. It is conceivable to configure decision models that unequivocally represent decision set era, but at great expense as far as intricacy.

$J_n \leq J$ is the quantity of possible decisions. The probability that any component i in C_n is picked by the decision n is given by

$$P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n) \tag{2.7}$$

The utility of every option is separated into a deterministic and random segment:

$$\begin{aligned} &P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n, j \neq i) \\ &= \Pr(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}, \forall j \in C_n, j \neq i) \\ &= \Pr(\varepsilon_{jn} \leq V_{in} - V_{jn} + \varepsilon_{jn}, \forall j \in C_n, j \neq i) \end{aligned} \tag{2.8}$$

A specific multinomial decision model can be inferred utilizing mathematical statement Equation 2.7 that gives particular suspicions on the joint distribution of the disturbances. Let $f(\varepsilon_{1n}, \varepsilon_{2n}, ..., \varepsilon_{Jn})$ mean the joint density function of the disturbances terms. Without loss of any inclusive statements consider option i to be the first option in C_n. Then

$$P_n(1) = \int\limits_{\varepsilon_{1n}=-\infty}^{\infty} \int\limits_{\varepsilon_{2n}=-\infty}^{V_{1n}-V_{2n}+\varepsilon_{1n}} ... \int\limits_{\varepsilon_{2n}=-\infty}^{V_{1n}-V_{2n}+\varepsilon_{1n}} f(\varepsilon_{1n}, \varepsilon_{2n}, ..., \varepsilon_{J_n n}) d\varepsilon_{J_n n} d\varepsilon_{J_n-1,n} d\varepsilon_{1n} \tag{2.9}$$

Clearly, on the off chance that we are keen on cases other than Cn, the decisions can be reordered properly to utilize the Equation 2.8. Note that the integration is continued a subspace of disturbances where

$$U_{in} = \max\{U_{1n}, U_{2n}, ..., U_{J_n n}\} \tag{2.10}$$

In spite of the fact that the Equation 2.8 is the most direct method for communicating the decision probability in theory, it is frequently not the most advantageous approach to determine $P_n(i)$ for a specific circumstance. Two different structures for the decision probability can also be utilized. In the first, $F_i(\varepsilon_{1n}, \varepsilon_{2n}, ..., \varepsilon_{Jn})$ is meant as the partial derivate of F (the cumulative distribution function of the disturbances) as for ε_{in}. Utilizing this system, $P_n(i)$ can be expressed:

$$P_n(1) = \int\limits_{\varepsilon_{1n}=-\infty}^{\infty} F_1(\varepsilon_{1n}, V_{1n} - V_{2n} + \varepsilon_{1n}, V_{1n} - V_{3n} + \varepsilon_{1n}, V_{1n} - V_{J_n n} + \varepsilon_{1n}) d\varepsilon_{1n} \tag{2.11}$$

In words, Equation 2.10 can be interpreted as follows. Set the disturbances ε_{1n} at some value. The integrand is then the probability that ε_{1n} breaks even with that esteem and the various disturbances fulfill the condition. $V_{1n} + \varepsilon_{1n} \geq V_{jn} + \varepsilon_{jn}, \forall j \in C_n$. By integrating every possible values of ε_{1n}, the aggregate probability that option 1 is chosen. The third and maybe the most savvy approach to express $P_n(i)$ is to lessen the multinomial decision problem to binary. To do this, the condition is noted

$$U_{in} \geq U_{jn}, \quad \forall j C_n, j \neq i \tag{2.12}$$

is in fact equivalent to

$$U_{in} \geq \max_{\substack{j \in C_n \\ j \neq i}} U_{jn} \tag{2.13}$$

In this manner we can make what is called a "composite" option out of the considerable number of components other than i and we utilize the utility of the best option in the composite to represent the whole composite. In the event that the utility of the composite is surpassed, then i is picked; otherwise, it is definitely not. Thus

$$P_n(i) = \Pr\left[V_{in} + \varepsilon_{in} \geq \max_{\substack{j \in C_n \\ j \neq i}} (V_{jn} + \varepsilon_{jn})\right] \tag{2.14}$$

To use comparison Equation 2.13, the distribution of the utility part of the composite option will be derived from the fundamental distribution of the disturbances, F.

<u>2.3.1.1. Definition of Multinomial Logit.</u> The multinomial logit (MNL) model is expressed as

$$P_n(i) = \frac{e^{V_{in}}}{\sum_{j \in C_n} e^{V_{jn}}} \tag{2.15}$$

This reduces to binary logit when $J_n = 2$ and the Equation 2.19 characterizes as an appropriate probability mass function since $0 \leq P_n(i) \leq 1$, for all $i \in C_n$ and

$$\sum_{i \in C_n} P_n(i) = 1 \tag{2.16}$$

To conclude that $U_{in} = V_{in} + \varepsilon_{in}$ for all $i \in C_n$, and that all the disturbances ε_{in} are independently distributed, identical distributed, and Gumbel-distributed with a location parameter η, and a scale parameter $\mu > 0$ then,

$$P_n(i) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}} \tag{2.17}$$

As opposed to determining mathematical statement 2.32 specifically, expressing a few properties of Gumbel distribution will be given.

2.3.1.2. The Gumbel Distribution: Basic Properties. ε is Gumbel distributed (Domencich, McFadden, 1975). Then

$$F(\varepsilon) = \exp\left[-e^{-\mu(\varepsilon-\eta)}\right], \quad \mu > 0 \tag{2.18}$$

$$f(\varepsilon) = \mu\varepsilon^{-\mu(\varepsilon-\eta)} \exp\left[-e^{-\mu(\varepsilon-\eta)}\right] \tag{2.19}$$

where η is a location parameter and μ is a positive scale parameter.

This distribution has the following properties:

(i) The mode is η,
(ii) The mean is $\eta + \gamma/\mu$, where γ is Euler constant(0.577)
(iii) The variance is $\pi^2/6\mu^2$
(iv) If ε is Gumbel distributed with parameters (η, μ) and V, and $\alpha > 0$ are any scalar constants, then $\alpha\varepsilon + V$ is Gumbel distributed with parameters $(\alpha\eta + V, \mu/\alpha)$
(v) If ε_1 and ε_2 are independent Gumbel-distributed variates with parameters (η_1, μ) and (η_2, μ), respectively, then $\varepsilon^* = \varepsilon_1 - \varepsilon_2$ is logically distributed:

$$F(\varepsilon^*) = \frac{1}{1 + e^{\mu(\eta_2-\eta_1-\varepsilon^*)}} \tag{2.20}$$

(vi) If ε_1 and ε_2 are independent Gumbel appropriated with parameters (η_1, μ) and, subsequently, then max $(\varepsilon_1, \varepsilon_2)$ is Gumbel appropriated with parameters

$$\left(\frac{1}{\mu} In(e^{\mu\eta_1} + e^{\mu\eta_2}), \mu\right) \tag{2.21}$$

(vii) As a culmination to recommendation 6, if $f(\varepsilon_1, \varepsilon_2, .., \varepsilon_3,)$ are J independent Gumbel- distributed random variables with parameters $(\eta_1, \mu), (\eta_2, \mu), ..., (\eta_J, \mu)$ subsequently, then $\max(\varepsilon_1, \varepsilon_2, ..., \varepsilon_J)$ is Gumbel distributed with parameters

$$\left(\frac{1}{\mu} In \sum_{j=1}^{J} e^{\mu\eta j}, \mu\right) \tag{2.22}$$

<u>2.3.1.3. Derivation of Multinomial Logit.</u> Using the given parameters, the multinomial logit model can be derived. η=0 is assumed for all disturbances.

$$P_n(i) = \Pr\left[V_{1n} + \varepsilon_{1n} \geq \max_{j=2,\ldots,J_n} (V_{jn} + \varepsilon_{jn})\right] \tag{2.23}$$

$$U_n^* = \max_{j=2,\ldots,J_n} (V_{j_n} + \varepsilon_{jn}) \tag{2.24}$$

From substance 7, U_n^* is Gumbel distributed with parameters

$$\left(\frac{1}{\mu} In \sum_{j=2}^{J_n} e^{\mu V_{jn}}, \mu\right) \tag{2.25}$$

Using substance 4, the equation can be written $U_n^* = V_n^* + \varepsilon_n^*$ where

$$V_n^* = \frac{1}{\mu} In \sum_{j=2}^{J_n} e^{\mu V_{jn}} \tag{2.26}$$

and ε_n^* is Gumbel distributed with parameters $(0, \mu)$. Since

$$\begin{aligned} P_n(1) &= \Pr(V_{1n} + \varepsilon_{1n} \geq V_n^* + \varepsilon_n^*) \\ &= \Pr\left[(V_n^* + \varepsilon_n^*) - (V_{1n} + \varepsilon_{1n}) \leq 0\right] \end{aligned} \tag{2.27}$$

by substance 5

$$
\begin{aligned}
P_n &= \tfrac{1}{1+e^{\mu(V_n^* - V_{1n})}} \\
&= \tfrac{e^{\mu V_{1n}}}{e^{\mu V_{1n}} + e^{\mu V_n^*}} \\
&= \tfrac{e^{\mu V_{1n}}}{e^{\mu V_{1n}} + \exp(In \sum_{j=2}^{J_n} e^{\mu V_{jn}})} = \tfrac{e^{\mu V_{1n}}}{\sum_{j=1}^{J_n} e^{\mu V_{jn}}}
\end{aligned}
\qquad (2.28)
$$

The scale parameter is not identifiable so it's value is accepted 1.

2.3.2. Specification of a Multinomial Logit Model

The particular of a multinomial logit model comprises various unmistakable steps. To begin with, all the inclusive decision sets C should be characterized for the problem study. This stride might require some judgment about which options can be disregarded. The following step is to characterize the decision set for every person. This is, for the most part, done by applying sensible judgments about what constitutes the attainability of an option in a specific circumstance. Finally, the specific variables going into the utility capacities must be characterized.

Most issues brought up in talking about the determination of binary models stretch out specifically to multinomial decisions. For instance, in binary decision models, it appeared well and good to have only one constant. Its coefficients reflect the relative utility of the option in which the constant was incorporated when contrasted with the one from which it overlooked.

2.3.3. Other Multinomial Choice Models

Multinomial logit is the most generally utilized multinomial decision model. However there are different models that have been produced and connected. These models be separated two classes. The first may be termed logit extensions, in that they are generalization of multinomial logit. The second class is nonlogit-based models. These models are: Random Coefficient Logit, Ordered Logistic, The Generalized Extreme Value (GEV) Model, Multinomial Probit.

The multinomial logit model depends on the accompanying presumptions about the unsettling influence terms of the utilities of:

(i) Gumbel distributed
(ii) They are identical
(iii) They are independent

One valuable type of multinomial logit model has linear-in parameters efficient utilities.

2.4. Previous Studies in Literature

The studies with respect to the ground access to airport are conducted under three study areas such as, funding ground access and airport choice in multiple airport region and ground access mode choice. What's more, the studies about the access mode choice are conducted at two study fields; air passengers access and airport employees access. The focus of this study is on the mode choice of airport passengers to access airport.

There has been 30 years of study on the ground access mode choice. Sobieniak (Sobieniak,Westin, Rosapep and Shin, 1979) developed MNL model for intercity coach stations including but not limited to the airports in Ottawa-Hull and vicinity in Canada in access mode choice field. According to the results of the model, there are dominant factors influencing the access mode choice such as walking time and baggage handling which are the variable of convenience. Then, Harvey (Harvey, 1986) used MNL modes and singled out the travellers as two groups such as business and non-business travellers. Analyses have shown that air travellers were greatly sensitive about the travel time for accessing the airport, the sensitivity between the business passengers and non business passengers was compared, business passengers more sensitive than the those of non-business. Furthermore, Tam and Lam (Tam, Lam, and Lo, 2008) have used the MNL model and according to the results of the model, travel time and safety margin for ground access to Hong Kong International Airport (HKG) are more important for business air passengers than the those of the non-business ones.

To analyse the mode choice model, Multinominal Logit model is conducted, however, there are different ways for model analysis, as well. To analyse three airports passengers in the Bay Area of San Francisco, Pels (Pels, Nijkamp and Rietveld, 2003) has conducted Nested Logit Model. When business passengers compared with non-business passengers, the result was the same and it showed that access time is more decisive than the access cost in terms of airport access mode choice. Choo, You and Lee (Choo, You, and Lee, 2013) has conducted an analysis on the Gimpo International Airport (GMP) and Daegu International Airport (TAE) in Korea by using Nested Logit Model. According to the results of the model, travel features such as business and non-business and socio demographic variables such as age, income and education considerably affect the choice for airport access mode. What's more, by stating the demographic characteristics of non-business passengers comparably more affect the access mode choice than the business passengers, this study measured the access mode choice models for business and non-business travel.

For the some airports, there are not many options for accessing the airports, therefore the model is used for two major modes. To assess the access mode choice, Alhussein (Alhussein, 2011) has developed a binary logit model. According to the analysis, it was shown that the mode choice was highly influenced by the variables such as income, luggage, travel access time, and nationality to access Riyadh King Khaled International Airport. Akar (Akar, 2013) has used binary logit models to have a better understanding of the interest of passengers to take alternative transportation modes. According to the results, the individuals travelling for business purposes, flying alone (or with fewer people), and try not to use auto, will probably take alternative modes to go to airport. Furthermore, ground access mode decisions of individuals, which are considerably influenced, are presented for travellers for business trips and non-business trips.

According to the findings of the Dresner (Dresner, 2006) by comparing the leisure and business passengers at BWI airport, passengers of the two groups are considerably similar to each other for mode choice to airport access, their parking needs and number of bags they checked. Basing on the collected data at ATH, Tsamboulas and Nikoleris (Tsamboulas and Nikoleris, 2008) has conducted an analysis with regard to the willingness of passengers to pay for the trips to the airport. 42% of the passengers do not want to pay for such trips to airport and the remaining part highly wants to pay to shorten travel time to access ATH by using public transport. Koster, Kroes and Verhoef (Koster, Kroes and Verhoef, 2011) has conducted an analysis for the influence of travel time variability for airport access on the access travel cost. According to the results of the study, the variability cost for business passengers is between 0% and 30% of the expected access travel cost. This figure is between 0% and 25% for the non-business passengers.

According to the study of Chang (2013), if elder air passengers make distinctive mode choice for airport ground access and study showed that elder passengers prefer to use private transport rather than public transport. The elders prefer to use private transport for factors such as "possessing a car in their household", "carrying more luggage", "spending more time spent in the vehicle", and "higher ticket prices for public transport".

A model is developed by Psaraki and Abacoumkin (Psaraki and Abacoumkin, 2002), from the Athens International Airport' (ATH) existing mode of share to estimate the mode share access for the relocation of the airport. The mode share rate has been changed upon arranging the model for the relocated airport. For example, while the drive and park mode rates have been increased, the drop off mode rate for domestic passengers have been decreased. Having been generating the mass rapid transit system (TIA MRT) Jou, *et al.* (2011) has conducted a study on the change of the mode choice by using factors such as same passenger characteristics, airport locations and facility changes. It was expected from the hybrid logit model to identify the air passengers preference for the new mode. According to the results, out-of-vehicle travel time and in-vehicle travel time are the two significant factors to influence the choice of traveller for airport access mode.

Castillo and Manzona (2011) has conducted a research to better understanding the differences between the low cost carrier (LLC) passenger and network carrier passenger rather than making classification on business-non-business passengers. The target population of the study was 7 airports in Spain, all of which are at secondary position in terms of airport and none have effective rail public transportation connection. The results indicate that while LLC passenger is less likely to choose taxi to go to airport by 5.85%, but he chooses about 4% and 2% a rented car or public transportation.

In an another study, Keumi and Murakami (Keumi and Murakami, 2012) has conducted an analysis to have a better understanding of the access mode choice behaviour of the passengers, coming from local regions to hub airport. They have selected Kansai International Airport (KIX) as a hub airport and Takamatsu and Tokushima as local areas. KIX is by far the nearest international airport for both local areas. To access KIX from Takamatsu and Tokushima, one has to take a bus, which takes 3.5 hour drive from Takamatsu and 2.75 hour from Tokushima. This study includes a different mode from others which has air access to airport from both of the local areas. While air and bus are selected as alternative mode, rail and car have been excluded. The results show that travellers choose to use air modes for international flights.

The technique of Shafabakhsh, *et al.* (2014) is different from the logit model. They made use of the method of Mikhailov for fuzzy analytical hierarchy process to have the most suitable public transportation system to go to Sari International Airport. The results show that for airport access, safety, reliability, access time, access cost are the most efficient parameters and to access the airport, train system is appeared as the most suitable public transportation mode.

3. CASE STUDY

3.1. General Information about the Airports in İstanbul

There are two airport in İstanbul; Sabiha Gökçen International Airport (SAW), Atatürk International Airport (IST).

3.1.1. İstanbul Sabiha Gökçen International Airport (SAW)

Sabiha Gökçen International Airport (SAW) is one of the two international airports serving İstanbul, Turkey. Figure 3.4 shows the location of SAW. Airport is located 35 km southeast of central İstanbul, it is on the Asian side of the city. There are several ways to travel SAW:

- Public Transit IETT: There are nine bus line to access SAW. These are 130H (SAW - Tuzla), KM22 (SAW - Kartal), 18H (SAW - Sultanbeyli), 16S (SAW - Yenisehir), E9 (SAW - Bostanci), E3 (SAW - 4.Levet), E10 (SAW - Kadiköy), E11 (SAW - Kadiköy), 16S (SAW - Uzunçayir).
- The shuttle services are operated by Havatas. The busses go to Taksim and Kadikoy from Airport. Also Akmis Seyahat has scheduled services nearly cities which are Sakarya and Kocaeli.

In Table 3.1 total passengers of SAW is given. In 2015, number of total passenger is 28 million. 18.5 million is domestic passenger, 9.5 million is international passenger. In Figure 3.1 increasing of total passenger is given. It shows that passenger capacity of SAW significantly increases year by year.

Table 3.1. Passenger Statistics at SAW.

Year	Domestic	International	Total	% change
2015	18.525.649	9.583.089	28.108.738	20%
2014	15.008.600	8.499.541	23.508.141	27%
2013	11.947.424	6.694.418	18.641.842	27%
2012	9.486.469	5.000.773	14.487.242	10%
2011	8.704.249	4.420.421	13.124.670	17%
2010	7.435.158	3.694.314	11.129.472	71%
2009	4.547.673	2.092.285	6.639.958	52%
2008	2.764.856	1.516.337	4.281.193	15%
2007	2.528.549	1.191.946	3.720.495	28%
2006	2.153.561	762.893	2.916.454	186%
2005	559.824	459.922	1.019.746	315%
2004	10.323	235.278	245.601	56%
2003	2.826	154.346	157.172	-

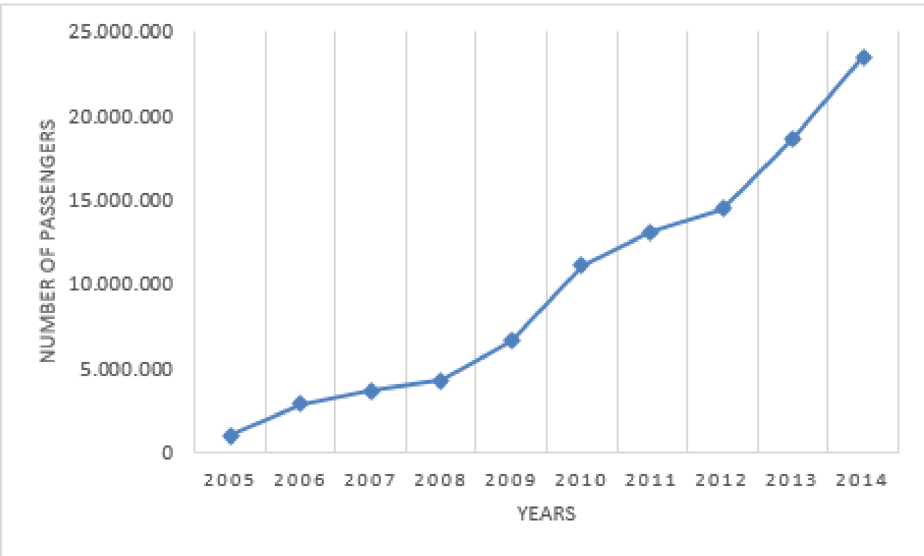

Figure 3.1. Number of Passenger (SAW).

3.1.2. İstanbul Ataturk International Airport (IST)

İstanbul Atatürk International Airport is the biggest international airport in Turkey. The location of IST is shown in Figure 3.4. It is located in Yesilköy, on the European side of the city, it is located 24 km west of the city centre. There are several ways to travel Atatürk International Airport:

- Subway Service: Figure 3.2 shows that the İstanbul railway network. M1A is between Yenikapi and Atatürk International Airport.

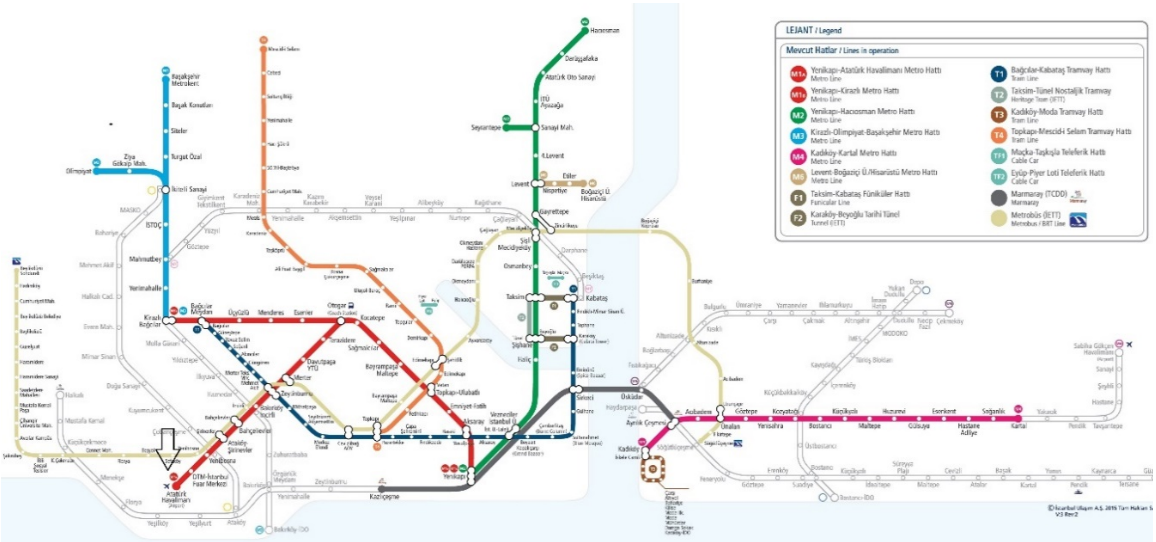

Figure 3.2. İstanbul Railway Network.

- Airport Shuttle Service: The shuttle services are operated by Havatas. The buses run half-hourly to Yenikapi, Taksim Square.
- Transit Bus: TH-1 (Taksim-IST),YH-1(Yenikapi-IST)

In Table 3.3 total passengers of IST is given. In 2015, number of total passenger is 61.3 million. 19.3 million is domestic passenger and 41.9 million is international passenger. Figure 3.3 shows that increasing of total passengers IETT.

Table 3.2. Passenger Statistics at IST.

Year	Domestic	International	Total	% change
2015	19.375.402	41.947.324	61.322.729	8%
2014	18.754.002	38.200.788	56.954.790	11%
2013	17.224.105	34.096.770	51.320.875	14%
2012	15.281.321	29.717.196	44.998.508	20%
2011	13.604.352	23.847.835	37.452.187	17%
2010	11.800.999	20.344.620	32.145.619	8%
2009	11.393.645	18.363.739	29.757.384	4%
2008	11.484.063	17.069.069	28.553.132	23%
2007	9.595.923	13.600.306	23.196.229	9%
2006	9.091.693	12.174.281	21.265.974	10%
2005	7.512.282	11.781.487	19.293.769	24%
2004	5.430.925	10.169.676	15.600.601	29%

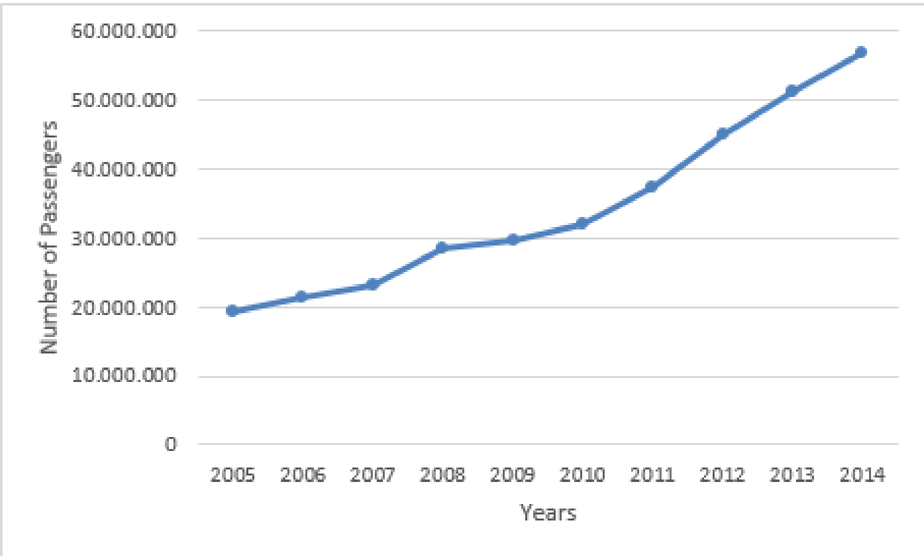

Figure 3.3. Number of Passengers (IST).

Figure 3.4. Location of IST and SAW in İstanbul.

3.2. Data Collection and Survey Study

Face-to-face interviews were performed for the survey at both airports in two stages: the first one on January 5, 2015, on January 12, 2015 and the second one on June 1, 2015. The surveys were made between the hours 10.00-13.00 and 17.00-20.00 on Mondays. The reason why Monday was preferred is not only the fares are more affordable on that day but also it is the first working day for travelers going on a business trip. The surveys were conducted with adult passengers in the terminals of domestic arrival/departure and international arrival/departure. The passengers to be interviewed were selected randomly. The surveys at Sabiha Gökçen Airport were conducted with passengers passing through the checkpoints in both domestic and international departure terminals and waiting for the boarding procedure. The surveys made with arrival passengers were conducted with those who were waiting for their luggage and were about to leave the terminal. For the survey study at Atatürk Airport, the surveys were conducted in the passenger waiting hall following the checkpoint for domestic departure and in front of the checkpoint for international departure passengers because we could not get permission for security purposes. For the arrival passengers, the surveys were conducted in the luggage area and in the exit area of the terminal. Departure and arrival totally 507 passengers at IST and 365 passengers at SAW were surveyed. Departure passenger number is 248 at IST, 258 at SAW. In models, data of departure passengers was used and characteristics of passengers are given. Data of arrival passengers was only used in factor analysis. The surveys made with transit passengers were not included in the study. In models evaluating, only departure passenger data were used. The demographics of the passengers are shown proportionally in the following tables.

Table 3.3. Travel Route.

	IST (Unit%)	SAW (Unit %)
Characteristics		
Number of respondents	248	258
	N=248	N=258
International	41.4	20.5
Domestic	58.6	79.5

Table 3.3 gives the percentages of the surveyed passengers based on their flight routes. 58.6% of the IST passengers participated in the study are domestic, 79.5% of the passengers participated in the survey at SAW are domestic.

Table 3.4. Gender.

	IST (Unit%)	SAW (Unit%)
Characteristics		
Number of respondents	248	258
Gender	N=248	N=258
Male	61.3	72.1
Female	38.7	27.9

Percentage distributions of the survey passengers based on gender is given in Table 3.4. According to survey data, 61.3% of the IST passengers are male, 38.7% are female. 72.1% of the SAW passengers are male, 27.9% are female.

Table 3.5. Demographic Specification.

	IST (Unit%)	SAW (Unit%)
Characteristics	N =248	N =258
Age		
22 or younger	18.5	15.1
23-29	26.2	29.7
30-39	23.2	30.1
40-49	15	15.5
50-59	13.7	7.1
60 or older	3.4	2.5
Total	100.0	100.0
Education		
Primary school	11.4	4.7
High school	24.7	12.4
Graduate	51.7	68.5
Master	7.6	12.5
PhD	4.6	1.9
Total	100	100
Monthly Income (TL)		
0-1500	38.3	28.3
1500-4000	36.7	39.4
4000-7000	19.1	19.7
7000-10000	4.3	6.7
10000+	1.6	5.9
Total	100.0	100.0

In Table 3.5, percentages of passengers' age, educational status and incomes in TRY are given. About 70% of the passengers have a monthly income of under TRY 4000 at both airports. The rate of passengers who graduated from a university is 63.9% at IST, 82.9% at SAW. The age average of the IST passengers is 34.8; it is 32.85 for the SAW passengers.

Table 3.6. Trip Purpose.

	IST (Unit%)	SAW (Unit%)
Characteristics		
Trip purpose	N=248	N=258
Business	34.5	39.1
Leuisure	53.8	53.9
Education	11.7	7.0
Total	100.0	100.0

Table 3.6 presents the percentages of passengers based on travel purposes. The rate of business passengers is 34.9% for IST and 39.1% for SAW.

Table 3.7. Mode Choice.

	IST	SAW
Airport Access Mode	N=248	N=258
Car	13.9	10.1
Drop-off	18.8	15.9
Public	38.3	23.4
Service	4.5	29.3
Taxi	24.4	21.1
Total	100.0	100.0

Table 3.7 presents the percentages of passengers' mode choice. Public Transit has the highest proportion with 38.3% for IST passengers. If car and drop-off is summed, the proportion of using car is 32.7% .While 24.4% of IST passengers used taxi for access to airport, only 4.5% of passengers used airport service. 29.3% of SAW passengers chose airport service and using car (self driving + drop-off) proportion is 26%. Proportion of using public transit is 23.4% and using taxi is 21.1%. If the mode shares of airports were compared, the highest using mode is public transit for IST passenger.

3.2.1. Travel Time and Waiting Time

It is expected from the passengers to arrive at the airport a certain period of time before the flight. This is 60 minutes and above for domestic passengers, 120 minutes and above for international passengers. The passengers were asked how many minutes ago they arrived at the airport before the departure time. The margin between their time of arrival to the airport and the departure time was defined as Waiting Time (WT), spent time from home/work to airport defined as Travel Time (T), and the passenger behaviours were compared according to the times.

According to the survey data, the rates between travel times and waiting times are shown in Table 3.8 for IST, in Table 3.9 for SAW:

Table 3.8. Wating Time -Travel Time IST.

Waiting Time (minutes)						
Travel Time(min)	WT=30	30¡WT=60	60¡WT=90	WT¿90	Total	No. of respondent
Travel Time(min)	WT=30	30¡WT=60	60¡WT=90	WT¿90	Total	
T=30	0.0%	14%	24.6%	61.4%	100%	57
30¡T=60	1.4%	28.3%	9.7%	60.7%	100%	145
60¡T=90	11.1%	19.4%	16.7%	52.8%	100%	36
T¿90	0.0%	19.6%	10.9%	69.6%	100%	46

Table 3.9. Wating Time -Travel Time SAW.

Waiting Time (minutes)						
Travel Time(min)	WT=30	30¡WT=60	60¡WT=90	WT¿90	Total	No. of respondent
Travel Time(min)	WT=30	30¡WT=60	60¡WT=90	WT¿90	Total	
T=30	4,4%	22,2%	40,0%	33,3%	100%	45
30¡T=60	1,9%	35,5%	19,6%	43,0%	100%	107
60¡T=90	10,6%	23,4%	34,0%	31,9%	100%	47
T¿90	1,8%	28,5%	26,2%	41,4%	100%	57

It is observed that:

- for both IST and SAW, approximately 70% of the passengers whose have travel time (T) which defined as duration of travel(from origin to airport) is between 30 minutes and 60 minutes, experience more than 1 hour of waiting time at the airport.
- 80% of IST passengers who have more than 90 minutes travel time, have more than 1 hour waiting time. Close value of percentages is also observed in SAW, where the percentage of passengers who have more than 1 hour waiting time is 67,8

3.3. Data Analysis

3.3.1. Principal Component Analysis

In the survey study conducted in January 2015, we asked the passengers questions about factors that determined their preference modes and requested them to state the significance order of the factors for them. Departure and arrival passenger data were used together in the component analysis.

For the analysis of the questions, the SPSS 20 statistics software was used. The Principal Component Analysis was utilized to categorize the questions. The results are shown below.

As a result of the analysis, component groups were set for values of which eigenvalues were over 1. For significant components were accordingly established. When grouping the factors, the biggest values as a result of the analysis were taken into consideration. Because the biggest value indicates the most significant answers. As seen in the table, components values were assigned to each factor after the analysis. The biggest values present the component class they belong to.

Table 3.10. Components based on important factors affecting mode choice.

	Component			
	1	2	3	4
Eigenvalues	3.826	1.751	1.430	1.224
Proportion	29.43	13.47	11.00	9.42
Factor Loading				
Cost of Parking	0.912	0.048	-0.142	-0.016
Cost of Fuel	0.917	0.103	-0.09	-0.121
Cost of travel	0.582	-0.067	0.248	0.013
Parking consideration	0.544	-0.103	0.172	0.279
Time of current flight	0.007	-0.035	0.903	-0.073
Time of return flight	-0.053	-0.037	0.93	-0.045
Weather Conditions	0.092	0.215	0.485	0.105
Travel time	0.061	0.321	0.29	0.098
Concern of environment	0.041	0.737	0.077	-0.008
Safety and security	0.043	0.87	-0.034	-0.132
Comfort	-0.05	0.784	-0.047	0.176
Number of luggage	-0.024	0.231	-0.005	0.705
Number of people	0.003	-0.123	-0.056	0.887

- Component 1
  - Cost of parking
  - Cost of fuel
  - Cost of travel (if vehicle does not belong to passenger)
  - Parking consideration

The proportion of Component 1 factors over the all factors is 29.43%.

- Component 2
  - Travel time
  - Concern of environment,
  - Safety and security
  - Comfort

The proportion of Component 2 factors over the all factors is 13.47%.

- Component 3

  - Time of current flight
  - Time of return flight,
  - Weather conditions

The proportion of Component 3 factors over the all factors is 11.00%.

- Component 4
  - Number of luggage
  - Number of people

The proportion of Component 4 factors over the all factors is 9.42%.

Sample size (N) in the tables are different from each other, the reason of this situation is some passengers did not give answer some questions so while factors were being interpreted, proportion of answers was used.

Table 3.11. Cost of Parking.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	25.30	41.10	12.10	21.50	297
SAW	31.50	41.80	10.30	16.40	165
ALL	27.50	41.30	11.50	19.70	462

The cost of parking factor shown in Table 3.11 is important and very important in determining the mode alternatives for 297 IST passengers at the rate of 66.40%. In addition, 21.5% of the passengers stated that the cost of parking is not important. The cost of parking is important and very important for 165 SAW passengers at the rate of 73.30%. The rate of passengers who gave the answer 'not important' is 16.40%. When one takes the passengers of both airport into consideration, the rate of the answers 'very important' and 'important' is 68.80% for 462 passengers. The rate of passengers who gave the answer 'not important' is 19.70%. There is no distinct difference between the passengers of both airports for the cost of parking factor and the rates of the answers are close to each other.

Table 3.12. Cost of Fuel.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	28.50	46.00	6.40	19.10	298
SAW	23.00	46.10	11.50	19.40	165
ALL	26.60	46.00	8.20	19.20	463

The cost of fuel factor is shown in Table 3.12 is important and very important for 298 IST passengers at the rate of 74.5%. The rate is 19.10% which the passengers find the cost of fuel not important. This factor is very important and important for 165 SAW passengers at the rate of 69.10%. The rate of passengers who gave the answer 'not important' is 19.40%. When one takes the passengers of both airports into consideration, the answers 'very important' and 'important' were given by 463 passengers at the rate of 72.60%. The rate of those who gave the answer 'not important' is 19.20%. There is no distinct difference between the IST and SAW passengers for the cost of Fuel factor.

Table 3.13. Cost of Travel.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	24.50	44.40	15.00	16.10	286
SAW	17.70	50.60	15.80	15.80	158
ALL	22.10	46.60	15.30	16.00	444

For the cost of travel factor shown in Table 3.13, the answer "If you are coming to the airport via someone else's car, how the cost of travel affects your determining the mode alternatives?" was asked. The answers 'important' and 'very important' were given by 286 IST passengers at the rate of 68.90%. The rate of passengers who gave the answer 'not important' is 16.10%. The rate of the answers 'important' and 'very important' for 158 SAW passengers is 68.30%. The rate of those who gave the answer 'not important' is 15.80%. Taking the passengers of both airports into account, the rate of those who gave the answers 'very important' and 'important' is 68.70% for 444 passengers. The rate of the answer 'not important' is 16%. There is no distinct difference between the passengers of both airports for this factor.

Table 3.14. Time of Current Flight.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	51.90	38.60	2.90	6.50	308
SAW	48.80	42.80	4.90	3.70	164
ALL	50.80	40.00	3.60	5.50	472

The time of current flight factor shown in Table 3.14 is important and very important for 308 IST passengers at the rate of 91.60%. The rate of passengers who gave the answer 'not important' is 6.5%. The rate of the answers 'important' and 'very important' for 164 SAW passengers is 91.40%. The rate of those who gave the answer 'not important' is 3.70%. When one takes the passengers of both airport into consideration, the rate of the answers 'very important' and 'important' is 90.80% for 472 passengers. The rate of those who gave the answer 'not important' is 5.5%. As can be understood, the time of current flight factor is important in determining the transportation alternatives for almost all IST and SAW passengers.

Table 3.15. Time of Return Flight.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	42.00	44.20	5.30	8.50	283
SAW	44.00	44.80	6.40	4.80	125
ALL	42.60	44.40	5.60	7.40	408

The time of return flight factor shown in Table 3.15 is important and very important for 283 IST passengers at the rate of 86.20%. The rate of passengers who gave the answer 'not important' is 8.50%. The rate of the answers 'important' and 'very important' for 125 SAW passengers is 88.80%. The rate of passengers who gave the answer 'not important' is 4.80%. Taking the passengers of both airports into account, the rate of those who gave the answers 'very important' and 'important' is 87% for 408 passengers. The rate of those who gave the answer 'not important' is 7.40%. Like the time of current light factor, the time of return flight factor is important in determining the transportation mode.

Table 3.16. Weather Conditions.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	38.40	45.10	8.80	7.60	328
SAW	34.50	40.40	17.00	8.20	171
ALL	37.10	43.50	11.60	7.80	494

The weather conditions factor shown in Table 3.16 is important and very important for 328 IST passengers at the rate of 83.50%. The rate of those who gave the answer 'not important' is 7.6%. The rate of the answers 'important' and 'very important' for 171 SAW passengers is 74.90%. The rate of those who gave the answer 'not important' is 8.20%. Even though the rates of the IST and SAW passengers who gave the answer 'not important' for the weather conditions factor are close to each other, total rate of the passengers who gave the answers 'very important' and 'important' is higher than those of the SAW passengers who gave the same answer. The rate of SAW passengers who gave the answer 'somewhat important' is about two times more than the rate of IST passengers who gave the same answer. It can be said that weather conditions is of importance for the passengers of both airports; however, the order of importance is different between the IST and SAW passengers.

Table 3.17. Travel Time.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	44.40	44.40	8.60	2.50	324
SAW	30.60	55.90	8.20	5.30	170
ALL	39.70	48.40	8.50	3.40	494

For the travel time factor shown in Table 3.17, the question "How much important is the total travel time taken when going to the airport effective on your determining the transportation alternatives?" was asked to the passengers. The rate of the answers 'important' and 'very important' for 324 SAW passengers is 88.80%. The rate of passengers who gave the answer 'not important' is 2.5%. The rate of the answers 'important' and 'very important' for 170 SAW passengers is 86.50%. The rate of those who gave the answer 'not important' is 5.30%. When the answers given by the IST and SAW passengers are compared, although the answers 'not important' and 'a little important' have similar rates, the rate of the answer 'important' is higher among the SAW passengers while the answer 'very important' has a higher rate among the IST passengers.

Table 3.18. Concern of Environment.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	40.30	43.60	12.70	3.30	330
SAW	27.70	41.60	22.00	8.70	173
ALL	36.00	42.90	15.90	5.20	503

The concern of environment factor shown in Table 3.18 is important and very important for 330 IST passengers at the rate of 80.90%. 3.30% of them gave the answer 'not important'. The rate of the answers 'important' and 'very important' for 173 SAW passengers is 69.30%. The rate of those who gave the answer 'not important' is 15.80%. When one compares the passengers of both airports, it is seen that the concern of environment factor is important for the preferences of the IST passengers.

Table 3.19. Safety and Security.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	58.90	34.10	4.20	2.70	331
SAW	38.20	45.10	12.70	4.00	173
ALL	51.80	37.90	7.10	3.20	504

The safety and security factor shown in Table 3.19 is important and very important for 331 IST passengers at the rate of 93%. The rate of those who gave the answer 'not important' is 2.70%. The rate of the answers 'important' and 'very important' for 173 SAW passengers is 83.3%. The rate of those who gave the answer 'not important' is 4%. When one compares the passengers of both airports, the safety and security factor is more effective for the IST passengers at the rate of 10% compared to the SAW passengers.

Table 3.20. Comfort.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	42.30	41.40	12.30	3.90	333
SAW	18.40	44.80	28.20	8.60	174
ALL	34.10	42.60	17.80	5.50	507

For the comfort factor shown in Table 3.20, the question "How much important is the comfort factor effective on choosing the transportation mode you use to access to the airport?" was asked to the passengers. The rate of the answers 'important' and 'very important' for 333 SAW passengers is 83.70%. The rate of those who gave the answer 'not important' is 3.90%. The rate of the answers 'important' and 'very important' for 174 SAW passengers is 63.2%. The rate of those who gave the answer 'not important' is 8.60%. When one compares the IST and SAW passengers, the comfort factor is more effective for the IST passengers on determining their transportation preferences at the rate of 20

Table 3.21. Number of Luggage.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	24.80	46.50	17.50	11.20	331
SAW	14.10	42.40	26.50	17.10	170
ALL	21.20	45.10	20.60	13.20	501

The luggage factor shown in Table 3.21 is important and very important for 331 IST passengers at the rate of 71.30%. 11.20% of the passengers gave the answer 'not important'. The rate of the answers 'important' and 'very important' for 170 SAW passengers is 56.50%.The rate of passengers who gave the answer 'not important' is

17.10%. When one compares the passengers of both airports, it is seen that the luggage factor is important for the preferences of the IST passengers.

Table 3.22. Number of People.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	20.10	36.50	18.20	25.20	329
SAW	17.30	35.30	17.90	29.50	173
ALL	19.10	36.10	18.10	26.70	502

For the Number of people factor shown in Table 3.22, the question "How much important is the number of passenger travel with you when going to the airport effective on your determining the transportation alternatives?" was asked to the passengers. Important and very important for 329 IST passengers at the rate of 56.60%. The rate of passengers who gave the answer 'not important' is 25.20%. For 173 SAW passengers, the answers 'very important' and 'important' have the rate of 52.60%. The rate of passengers who gave the answer 'not important' is 29.50%. This factor has almost the same rates for the passengers of both airports.

Table 3.23. Parking Consideration.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
IST	28.80	35.50	13.40	22.40	299
SAW	33.50	33.50	14.00	18.90	164
ALL	30.50	34.80	13.60	21.20	463

The parking consideration factor shown in Table 3.23 is important and very important for 299 IST passengers at the rate of 64.3%. The rate of passengers who gave the answer 'not important' is 22.40%. The rate of the answers 'important' and 'very important' for 164 SAW passengers is 67%. The rate of those who gave the answer 'not important' is 18.90%. The parking consideration factor has almost the same rates for the passengers of both airports. Taking the passengers of both airports into account, the rate of those who gave the answers 'very important' and 'important' is 65.30% for 463 passengers. The rate of those who gave the answer 'not important' is 21.20%.

To sum up the comparison results after the compared examination of the factors for both airports:

(i) Even though there are differences between the importance order of the factors for both airports, the rates of the answer 'not important' are very similar for both IST and SAW passengers for all the factor questions.

(ii) The number of people factor is the least important factor for both IST and SAW passengers in determining the transportation alternative (25.20% for IST, 29.50% for SAW).

(iii) For the IST passengers, the factors in which the answer 'not important' was given are in the following order with the number of people factor being the primary one: parking consideration (22.40), cost of parking (21.50%), cost of fuel (19.10%), cost of travel (16.10%). The order of the factors in which the answer 'not important' was given for the SAW passengers is as follow the number of people factor being the primary one: cost of Fuel (19.40), parking consideration (18.90%), Number of luggage (17.10%), cost of parking (16.40%), cost of travel (15.80%).

(iv) The factor which is considered important and very important in the first place for the IST passengers is the safety and security factor at the rate of 93.00%. It is followed by the factors time of current flight (90.50%), travel time (88.80%), time of return flight (86.20%), concern of environment (83.90%), comfort (83.70%), and weather conditions (83.50%).

(v) The factor in which the answers 'very important' and 'important' given by the SAW passengers most is the time of current flight factor at the rate of 91.60%. It is followed by the factors time of return flight (88.80%), travel time (86.50%), safety and security (83.30%) respectively.

(vi) In comparison of the answers 'very important' and 'important' given by the IST and SAW passengers, the biggest difference is observed in the comfort factor (20.5%).It is followed by the factors luggage (14.8%), concern of environment (14.6%), safety and security (9.7%), weather conditions (8.6%), cost of parking (6.9%).

(vii) When compared, the factors in which the answers 'very important' and 'important' are proportionally very similar for both IST and SAW passengers include cost of travel, time of current flight, travel time, time of return flight, parking consideration, and number of people (the factors listed are those in which the difference between IST and SAW rates is less than 5%).

Table 3.24. Factors Affect Travel Mode to the Airports (All Passengers Include SAW and IST).

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
Cost of Parking	27.50	41.30	11.50	19.70	462
Cost of Fuel	26.60	46.00	8.20	19.20	463
Cost of travel	22.10	46.60	15.30	16	444
Time of current flight	50.80	40.00	3.60	5.50	472
Time of return flight	42.60	44.40	13.00	7.40	408
Weather Conditions	37.10	43.50	11.60	7.80	499
Travel time	39.70	48.40	8.50	3.40	494
Concern of environment	36.00	42.90	15.90	5.20	503
Safety and security	51.80	37.90	7.10	3.20	504
Comfort	34.10	42.60	17.80	5.50	507
Number of luggage	21.20	45.10	20.60	13.20	501
Number of people	19.10	36.10	18.10	26.70	502
Parking consideration	30.50	34.80	13.60	21.20	463

Table 3.25. Factors Affect Travel Mode to the Airports IST.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
Cost of Parking	25.30	41.10	12.10	21.50	297
Cost of Fuel	28.50	46.00	6.40	19.10	298
Cost of travel	24.50	44.40	15.00	16.10	286
Time of current flight	51.90	38.60	2.90	6.50	308
Time of return flight	42.00	44.20	5.30	8.50	283
Weather Conditions	38.40	45.10	8.80	7.60	328
Travel time	44.40	44.40	8.60	2.50	324
Concern of environment	40.30	43.60	12.70	3.30	330
Safety and security	58.90	34.10	4.20	2.70	331
Comfort	42.30	41.40	12.30	3.90	333
Number of luggage	24.80	46.50	17.50	11.20	331
Number of people	20.10	36.50	18.20	25.20	329
Parking consideration	28.80	35.50	13.40	22.40	299

Table 3.26. Factors Affect Travel Mode to the Airports SAW.

	Very Important (%)	Important (%)	Somewhat important (%)	Not Important (%)	N
	Very Important	Important	Somewhat important	Not Important	N
Cost of Parking	31.50	41.80	10.30	16.40	165
Cost of Fuel	23.00	46.10	11.50	19.40	165
Cost of travel	17.70	50.60	15.80	15.80	158
Time of current flight	48.80	42.80	4.90	3.70	164
Time of return flight	44.00	44.80	6.40	4.80	125
Weather Conditions	34.50	40.40	17.00	8.20	171
Travel time	30.60	55.90	8.20	5.30	170
Concern of environment	27.70	41.60	22.00	8.70	173
Safety and security	38.20	45.10	12.70	4.00	173
Comfort	18.40	44.80	28.20	8.60	174
Number of luggage	14.10	42.40	26.50	17.10	170
Number of people	17.30	35.30	17.90	29.50	173
Parking consideration	33.50	33.50	14.00	18.90	164

Table 3.27. Factors to Consider in Alternative Modes(Business-Nonbusiness).

Very Important					
Business Passengers					
Cost of Parking	27.80	40.70	13.00	18.50	162
Cost of Fuel	27.20	43.20	9.90	19.80	162
Cost of travel	24.50	40.60	14.80	20.00	155
Time of current flight	44.80	44.20	4.20	6.70	165
Time of return flight	40.90	43.90	8.30	6.80	132
Weather Conditions	28.80	53.50	9.40	8.20	170
Travel time	34.30	51.20	9.60	4.80	166
Concern of environment	37.40	43.30	12.90	6.40	171
Safety and security	46.20	42.10	7.60	4.10	171
Comfort	31.80	45.10	15.60	7.50	173
Number of luggage	15.30	45.30	21.20	18.20	170
Number of people	13.5	38.2	14.7	33.5	170
Parking consideration	22.50	43.80	14.40	19.40	160
Non-business passengers					
Cost of Parking	27.40	41.80	10.70	20.10	299
Cost of Fuel	26.30	47.70	7.30	18.70	300
Cost of travel	20.20	50.20	5.70	13.90	287
Time of current flight	54.10	38.00	3.00	4.90	305
Time of return flight	43.40	44.90	4.00	7.70	274
Weather Conditions	41.50	38.10	12.80	7.60	328
Travel time	42.60	42.60	8.00	2.80	326
Concern of environment	35.20	43.00	17.30	4.50	330
Safety and security	54.70	36.00	6.90	2.40	331
Comfort	35.50	41.60	18.70	4.20	332
Number of luggage	24.30	45.30	20.10	10.30	329
Number of people	22.10	35.20	19.70	23.00	330
Parking consideration	34.90	29.90	13.30	21.90	301

When we examine the effective factor in determining the alternative for airport access as business and non-business passengers, the responses for the actors are close to each other. When we compare the proportional basis of the responses of very important and important for business and non-business passengers, the rates are very close to each other for factors other than the cost of travel, travel time, number of people.

When we compare the not important response for business and non-business passengers, while cost of travel, number of luggage, number of people factors show difference, not important option for other factors has close rates for the business and non-business passengers.

Time of current flight factor is the factor, which the responses of important and very important have been given the most proportionally for both of the business passengers and non-business passengers. Business passengers answered 'not important' for the cost of travel factor at the rate of 20%. Non-business passengers gave the answered 'not important' for the same factor at the rate of 13.90%. Number of the people factor is the factor, to which business passengers answered most as not important at the rate of 33.50%. Even though number of the people factor has got the most not important response from the non-business passengers at the rate of 23%, the biggest difference between the business and non-business passengers is the number of the people factor.

3.3.2. Multinomial Logit Model (MNL)

Using the survey data, ground access mode choice models have been created for both airports. Models were made using multinomial logit model method. SPSS Statistics software was used to create the model. SPSS is a widely used program for statistical analysis in social science. It is also used by market researchers, health researchers, survey companies, education researchers, market organizations and others. In this study SPSS statistics version 20 was used.

3.3.2.1. IST MNL Model. Assumptions for the developed access choice model for IST are following:

(i) Public transit (bus and rail) cost is 2.15 TL, Metrobüs price is between 1.75 TL and 3.40 TL based on travel distance, in İstanbul, in 2015. Also transfer cost is 1.45 TL for first time and 1.15 TL for second one in 2 hour. Cost of public transit was assumed to be 5 TL.

(ii) Airport shuttle service from Taksim and Yenikapi and the fee is 11 TL for Taksim and 9 TL for Yenikapi. Even though airport shuttle is fast and comfortable, its use rate for IST is 4.9%. When we compare it with SAW, it is too low. The reason is that Taksim and Yenikapi regions have connection with subway. Airport shuttle for the IST is ignored and not included in the model.

(iii) The taxi cost, Tc, was calculated according to the following formula; which is the taxi rate tariff in 2015 for İstanbul:

$$T_c = 3.2 + 2(Distance) \tag{3.1}$$

(iv) The cost for auto is assumed to be 0 when the passenger is dropped off at SAW by someone else. When the passenger drove himself/herself to SAW, the auto cost was taken 50 TL for car park fee.

(v) The distances between the districts and IST were measured in km using Google Maps. District center is assumed to be origin. When distance was measured using Google Maps, it shows all alternative routes. The mean of all alternative routes was taken to be distance.

(vi) Survey was done on January 05, on January 12 and on June 01 of the year 2015. The weather was cold but not rainy on January 05, was snowy on January 12 and was sunny on June 01. Hence a season factor was created. Data was collected in January 05 and January 12 is to be winter group, in June 01 is to be summer group for Season.

The three covariates were to be used in the MNL analysis; Cost of access (Cost), Number of passengers (NP) and Velocity (V). Because distance and travel time variables are not significant in ANOVA analysis, using these variables, Velocity (Distance/Travel Time) variable was calculated for every passenger. ANOVA tests were used to check the means of covariates. If the means of covariates were equal for modes, the covariate would not to be adequate to use for model. The results are given in Table 3.28. The significance level of three covariates are less than 0.005 and these are suitable for MNL model.

Table 3.28. ANOVA for the Covariates Between the Mode Types.

		Sum of Squares	Degrees of Freedom	Mean Square	F-statistic	Significance
Velocity	Between Groups	0.93	2	0.465	6.346	0.002
	Within Groups	18.128	248	0.073		
	Total	19.112	250			
Cost	Between Groups	64.481.856	2	32.240.928	80.701	0
	Within Groups	100.277.808	251	399.513		
	Total	164.759.664	253			
Number of passenger	Between Groups	14.362	2	7.181	5.840	0.003
	Within Groups	308.634	251			
	Total	322.996	253			

The survey data had 248 observations. The MNL model for airport access mode choice of SAW, was calibrated using the 208 observations, and it was validated using the remaining 40 observations. The percent shares of the used factors and mode choice types in modelling are shown in Table 3.29.

Table 3.29. Add captionShares of Variables in Overall, Calibration and Validation Data.

Variable		% Share		
		Overall	Calibration	Validation
Mode	Auto	34.3	35.7	26.8
	Public Transport	40.2	39.4	43.5
	Taxi	25.6	24.9	29.3
	Total	100.0	100.0	100.0
Auto ownership	Yes	53	52.7	54.5
	No	47	47.3	45.5
	Total	100.0	100.0	100.0
Destination (D)	International	41.4	42.8	34.1
	Domestic	58.6	57.2	65.1
	Total	100.0	100.0	100.0
Travel Type (B)	Business	34.5	34.5	34.1
	Holiday	53.8	53.2	56.8
	Education	11.7	12.3	9.1
	Total	100.0	100.0	100.0
	Total	100.0	100.0	100.0

In the MNL model, in addition to the four factors (Destination-D, Travel Type and Auto Ownership-Auto, Season), Cost, Velocity, and Number of Passengers (NP) were used as covariates. To investigate the seasonal effect, data in January was used to be winter, data in June was used to be summer.

Table 3.30 indicates that the model fitting information about the model. The chi-square statistics tests can be calculated by -2*[LL(0)-LL(B)] = 452.849-300=152.190. The significance value of 0.000 of the chi squared test show that there is a significant relationship between mode types and independent variables.

Table 3.30. Model Fitting Information.

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2*LL	Chi-Square	Degrees of Freedom	Significance
Null model	452.849			
Fitted model	300.659	152.190	16	0

Pseudo R^2 measures are given in Table 3.31. It shows Goodness of fit of the model, higher value indicates greater model fit. This measure can be maximum 1. If we interpret the R^2 measures, goodness of fit of the model is acceptable.

Table 3.31. Pseudo R^2 Measures.

Cox and Snell	0.517
Nagelkerke	0.584
McFadden	0.336

Table 3.32. Test of Overall Effects of Variables.

Variable	Likelihood Ratio Tests		
	Chi-Square Test Statistic	Degrees of Freedom	Significance
Num. of pas	12.603	2	0.002
Cost	97.561	2	0
Velocity	14.825	2	0.001
Auto ownership	7.663	2	0.022
Trip purpose	16.406	4	0.003
Destination	6.990	2	0.03
Season	6.269	2	0.044

The overall effects of the variables on the model are shown in Table 3.32. As can be observed from the significances of the chi-squared test statistics, all variables are statistically significant at 95% level of confidence.

Table 3.33. Parameter Estimates.

		Coefficient	Wald Statistic	Significance
Public Transit	Intercept	1.323	3.332	0.068
	Num. of pas	-0.698	11.013	0.001
	Cost	-0.078	12.896	0
	Trip pur.(Busi.)	1.512	6.081	0.014
	Trip pur(Vaca.)	1.764	8.986	0.003
	Intercept	-3.175	8.175	0.004
Taxi	Cost	0.053	22.760	0
	Velocity	-3.313	9.709	0.036
	Trip pur.(Busi.)	2.442	6.812	0.009
	Trip pur(Vaca.)	2.561	7.523	0.006
	Season(Winter)	0.992	4.090	0.043

Table 3.33 shows the coefficient estimates, their Wald statistics and significances. Only the significant variables for each mode at 95

Predictions by the calibrated model on calibrated data are given in Table 3.34. It can be seen that the model has an overall 64.1% correct prediction. In detail, auto mode is correctly predicted by 51.3%, and other percentage is 81.2 for public mode and 56.6 for taxi mode.

Table 3.34. Predictions on Calibration Data.

	Correct	Wrong	% Correct
Auto	39	37	51.3
Public Transit	65	15	81.2
Taxi	30	22	56.6
Overall			64.1

Predictions by the validation model on the validation data are given in Table 3.35. It can be seen that the model has an overall 65% correct prediction. In detail, auto mode is correctly predicted by 27.3%, and these percentages are 82.4 and 75 for public transit and taxi modes.

Table 3.35. Predictions on Validation Data.

	Correct	Wrong	
Auto	3	8	27.3
Public Transit	14	3	82.4
Taxi	9	3	75
Overall			65%

3.3.2.2. SAW MNL Model. Assumptions for the developed access choice model for SAW are following:

(i) Public transit (bus and rail) cost is 2.15 TL, Metrobüs price is between 1.75 TL and 3.40 TL based on travel distance, in İstanbul, in 2015. Also transfer cost is 1.45 TL for first time and 1.15 TL for second one in 2 hour. Cost of public transit was assumed to be 5 TL.

(ii) The airport shuttle cost is 9 TL from Kadiköy and 14 TL from Taksim. The shuttle cost was taken 12 TL for both district. Also airport shuttle cost from other cities (Kocaeli, Sakarya) is 23 TL. If passenger came from other cities cost was taken 23 TL.

(iii) The taxi cost, Tc, was calculated according to the following formula; which is the taxi rate tariff for İstanbul:

$$T_c = 3.2 + 2(Distance) \tag{3.2}$$

(iv) The cost for auto is assumed to be 0 when the passenger is dropped off at SAW by someone else. When the passenger drove himself/herself to SAW, the auto cost was taken 50 TL for car park fee.

(v) The distances between the districts and IST were measured in km using Google Maps. District center is assumed to be origin. When distance was measured using Google Maps, it shows all alternative routes. The mean of all alternative routes was taken to be distance.

(vi) Survey was done on January 05, on January 12 and on June 01 of the year 2015. The weather was cold but not rainy on Jan 05, was snowy on Jan. 12 and was sunny on June 01. Hence a weather factor was created. Data which was collected in January 12 is rainy group, data which collected in January 05 and June 01 is normal group for Weather factor.

The testing was done by ANOVA, and the results are given in Table 3.36. Three covariates were to be used in the MNL analysis; cost of access (Cost), time difference between the flight time and departure time to SAW (Departure), and distance between district center and SAW (Distance). The significance level of three covariates are less than 0.005 and these are suitable to use for MNL model.

Table 3.36. ANOVA for the Covariates Between the Mode Types.

		Sum of Squares	Degrees of Freedom	Mean Square	F-statistic	Significance
Cost	Between Groups	133.572.737	3	44.524.246	132.607	0.000
	Within Groups	84.611.636	252	335.760		
	Total	218.184.373	255			
Distance	Between Groups	36.680.589	3	122.226.863	7.217	0.000
	Within Groups	426.947.439	252	1.694.236		
	Total	463.628.027	255			
Departure	Between Groups	7.318.710	3	2.439.570	4.464	0.004
	Within Groups	134.986.032	247	546.502		
	Total	142.304.742	250			

The survey data had 251 observations. The MNL model for airport access mode choice of SAW, was calibrated using 211 observation and it was validated using the remaining 40 observations. The percent shares of the used factors and mode choice types in modelling are shown in Table 3.37.

Table 3.37. Shares of Variables in Overall, Calibration and Validation Data.

Variable		% Share		
		Overall	Calibration	Validation
Mode	Auto	26.2	26.3	25.6
	Public Transport	23.4	22.1	30.8
	Service	29.3	29.5	28.2
	Taxi	21.1	22.1	15.4
	Total	100	100	100
Auto ownership	Yes	58	59.4	50
	No	42	40.6	50
	Total	100	100	100
Gender(G)	Male	72.1	71.6	75
	Female	27.9	28.4	25
	Total	100	100	100
Destination (D)	International	20.5	19.3	27.5
	Domestic	79.5	80.7	72.5
	Total	100	100	100
Travel Type (B)	Business	39.1	39	40
	Non-Business	60.9	61	60
	Total	100	100	100
	Total	100	100	100

In the MNL model, in addition to the five factors (Gender-G, Destination-D, Travel Type-B, Automobile Ownership-Auto, Weather), Cost, Distance, and Departure were used as covariates.

Table 3.38 indicates that the model fitting information about the model. The chi-square statistics tests can be calculated by -2* [LL (0) - LL(B)] = 581.769 - 264.572= 317.196. The significance value of 0.000 of the chi squared test show that there is a significant relationship between mode types and independent variables.

Table 3.38. Model Fitting Information.

l	Model Fitting Criteria	Likelihood Ratio Tests		
	-2*LL	Chi-Square	Degrees of Freedom	Significance
Null model	581.769			
Fitted model	264.572	317.196	24	0

Pseudo R^2 measures are given in Table 3.39. It shows Goodness of fit of the model, higher value indicates greater model fit. If we interpret the R^2 measures, model has a good fit because as the R^2 measures are close to 1.

Table 3.39. Pseudo R^2 Measures.

Cox and Snell	0.778
Nagelkerke	0.83
McFadden	0.545

When we compare other studies R^2, the value of Akar's model(Akar, 2013) is 0.116, the value of Alhussein's model (Alhussein, 2011) is 0.127, the value of Tam and Lam's study (Tam, Lam and Lo, 2008) is 0.612.

The overall effects of the variables on the model are shown in Table 3.40. As can be seen that all variables are statistically significant at 95% level of confidence.

Table 3.40. Test of Overall Effects of Variables.

Variable	Likelihood Ratio Tests		
	Chi-Square Test Statistic	Degrees of Freedom	Significance
Cost	212.468	3	0.000
Departure	21.795	3	0.000
Distance	25.375	3	0.000
Domes.-Int.	8.566	3	0.036
Auto ownership	29.184	3	0.000
Gender	8.000	3	0.046
Whether	10.211	3	0.017
Business	17.666	3	0.001

Table 3.41 shows the coefficient estimates, their Wald statistics and significances. Only the significant variables for each mode at 95% confidence level were included. It should be noted that automobile mode was the reference category.

Table 3.41. Parameter Estimates.

		Coefficient	Wald Statistic	Significance
Public Transit	Intercept	-2.204	2.666	0.103
	Cost	-0.252	17.535	0
	Departure	0.034	12.324	0
	[G-Male]	1.722	6.285	0.012
	[D-International]	-1.797	5.741	0.017
	[B-Business]	-1.999	9.268	0.002
	Autoowner	-2.896	18.500	0
	Whether	1.922	6.863	0.009
Airport Shuttle	Intercept	-0.418	0.205	0.65
	Cost	-0.029	4.172	0.041
	[D-International]	-1.312	5.379	0.02
	Autoowner	-1.094	4.548	0.033
	Whether	0.987	4.403	0.036
Taxi	Intercept	-3.620	0.648	0.421
	Cost	0.331	10.418	0.001
	Distance	-0.34	7.206	0.007
	Business	-3.626	5.185	0.023

Table 3.42 shows that predictions by the calibrated model. It can be seen that the model has an overall 75.4% correct prediction. Auto mode is correctly predicted by 59.3%, and other percentages are 73.9, 74.6 and 95.8 are for public transit, airport shuttle and taxi modes.

Table 3.42. Predictions on Calibration Data.

	Correct	Wrong	% Correct
Auto	32	22	59.3
Public Transit	34	12	73.9
Airport Shuttle	47	16	74.6
Taxi	46	2	95.8
Overall			75.4

Table 3.43. Predictions on Validation Data.

	Correct	Wrong	% Correct
Auto	5	5	50
Public Transit	9	3	75
Airport Shuttle	5	6	45.5
Taxi	6	0	100
Overall			64.1

Predictions by the validation model on validation data are given in Table 3.43. It can be seen that the model has an overall 64.1% correct prediction. In detail, auto mode is correctly predicted by 50.0%, and these percentages are 75.0, 45.5 and 100.0 are for public transit, airport shuttle and taxi modes, respectively.

3.3.2.3. Analysis Results. Two different MNL models were built for SAW and IST. Although there are four mode choice alternatives for SAW airport; Auto(self driving and drop-off), public transit(rail and bus),airport shuttle and taxi, IST mode choice alternatives are car(self driving and drop-off), public transit(bus) and taxi. Auto mode was selected to reference category for both models.

First of all, results of SAW model are evaluated, for public transit relative to auto, it can be said that being international and business passenger and having automobile decreases its probability of choice to access SAW. Also cost has a negative impact on choosing public transit compared to auto. However weather condition (if the weather is rainy) decreases choosing public transit compare to auto and male passengers are more likely to choose public transit to auto compared to female passengers.

For Airport Shuttle, it can be said that cost has negative impact to choose airport shuttle compared to auto. Being international passenger and having automobile decrease probability of choosing airport shuttle compared to auto. However, as public transit mode, rainy weather increases choosing airport shuttle.

For taxi compared to auto, distance has a negative effect choosing taxi probability, if distance between airport and origin increases, choosing taxi probability decreases but if passenger's willingness to pay increases, choosing taxi probability decreases. Also being business passenger has a negative effect choosing taxi compare to auto.

Secondly IST model results are evaluated, for public transit compare to auto when number of passenger increases, choosing public transit proportion decreases also cost has negative impact to choosing public transit. Trip purpose separated three group in IST model; business, vacation and education. Being business or vacation passenger increases choosing public transit compare to auto.

For taxi compare to auto, cost has positive impact on choosing taxi. Velocity (Distance/Travel Time) has a negative impact on choosing taxi compare to auto. As public transit, being business or vacation passenger increases proportion of choosing taxi mode. Furthermore, winter has a positive impact choosing taxi compare to auto.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

This study has investigated air passengers' ground access mode choice and develops ground access mode choice models for SAW and IST in İstanbul, Turkey, by using survey data in 2015. Firstly according to data, important factors which affect the mode choice were found. Although there are some differences between SAW and IST passenger, important factors closed each other. Results are generally coherent with the existing literature. Akar's study which investigates passenger mode choice of Port Columbus International Airport (Akar, 2013) shows that time of current flight, travel time, flexibility in departure time are most important factor for passengers. In our study, the most important factors are safety and security, time of current flight, travel time for both SAW and IST passenger.

After that, characteristics of passengers were analysed. ANOVA and Chi-squared tests used to identify whether the key variables such as travel cost, travel distance, departure time, number of passenger are significantly different among airport access mode choice. But in this step, we could not use same covariates, except Travel Cost, for IST and SAW models. While Departure Time and Distance are suitable variables for SAW model; Velocity and Number of Passengers are suitable variables for IST model. However, in contrast to other studies we could not use some variables because these were not significantly different among modes in ANOVA tests. For instance although Age and Income (mountly) are the significant variables for mode choice Models of Daegu Airport and Gimbo Airport in Choo's study (Choo, You and Lee, 2013), Akar, 2013, also used these in her model, these were not suitable for our models. Number of luggage which was used in model of King Khaled International Airport in Alhussein's study (Alhussein, 2011) and in model of Hong Kong International Airport in Tam' study (Tam, Lam and Lo, 2008), education level which was used in model of Imam Klomeini International Airport in Mamdoohi's study, in Akar's study (Akar, 2013) and in Tam's study were another insignificant factors to our models.

Multinomial Logit (MNL) Model was carried out with four mode alternatives in SAW model; Auto (Self Driving and Drop-Off), Public Transport, Airport Shuttle and Taxi. Other MNL model was proposed with three mode alternatives in IST model; Auto (Self Driving and Drop-Off), Public Transport and Taxi. The model results indicate that the ground access mode choice is significantly affected by travel distance, trip purpose and trip destination for both airport. When we compare with the previous studies travel distance was used by (Choo, You and Lee, 2013) and destination(domestic/international) was used by (Psaraki and Abacoumkin, 2002) to Athen International Airport Model. Trip purpose was used to be a factor by most studies however some researchers such as (Harvey, 1986) and (Choo, You and Lee, 2013) did different models for business passenger and non-business passenger. In our study, different groups of trip purpose was used for IST and SAW models. Two groups (Business/nonbusiness) were used in SAW, three groups (Business/Vacation/Education) were used for IST model.

According to passenger answers, although Number of passenger factor has the least proportion of 'Very Important' and 'Important' answers, it was the significant variable for IST model. When number of passengers increases, using public transport decreases compare Auto for IST passengers.

In this study, we used two different factors from existing studies; Weather effect for SAW model and Seasonal effect for IST model. If weather is rainy, using public transit and airport shuttle increase compare to Auto. Seasonal effect changes using taxi proportion. In winter using taxi increases compare to Auto.

To sum up, Taxi, Auto (self driving/drop-off), airport shuttle are the same access alternatives but public mode is different. Transit bus is public mode of SAW, rail system is public mode of IST. Although SAW has a lot of bus line, using public transit rate is less than IST because of rail system. First of all, modes affect the mode choice decisions. Then the other parameters begin to be important. Two airports of Istanbul, have different mode choice behaviour because of existing mode alternatives. So we create different models for each airport and used different parameters were used for models. Travel cost, travel distance, trip purpose, gender, automobile ownership, destination (domestic/international) and weather/season effects important parameters of this study.

4.2. Recommendation

Airport access mode choice models are not only important to predict what mode travelers choose to get to the airport, but also play a critical role in the planning process. The results of this study can provide useful insight for airport planners, policy makers, designing and operating airport facilities, as well as managing airport access traffic. The models are also important for airport car park planning. Using the models to accurately predict which travelers will use auto can determine the size and capacity of these facilities needed.

Further researches are suggested so that a larger sample with sufficient representations of less-used modes like rented car. This would make possible the effects of different explanatory variables to be explained.

Owing the limited sample size, business and non-business passenger data were used together in MNL models. Trip purpose could be categorized and it was used being a factor. By collecting larger sample, separate models can be analyzed for departing with different trip purpose or types of ticket so as to allow a more identification of sub-market.

Also, other types of logit models such as Nested Logit, Mixed Logit, are used to more investigate on the behaviour of passengers on each modes choice.

Seasonal and weather effect can be investigated more detailed. Long term survey study in different weather conditions can explain exact effects of weather or season on mode choice. “

REFERENCES

Akar, G., 2013, “Ground Access to Airports, Case Study: Port Columbus International Airport”, *Journal of Air Transport Management*, Vol. 30, pp. 25-31.

Alhussein, S.N., 2011, “Analysis of Ground Access Modes Choice King Khaled International Airport, Riyadh, Saudi Arabia”, *Journal of Transport Geography*, Vol. 19, No. 6, pp. 1361-1367.

Akiva, M.E., and S.R. Lerman, 1985, “Discrete choice analysis: Theory and application to travel demand”, Massachusetts Institute of Technology Press, Cambridge, Massachusetts.

Chang, Y.C., 2013, “Factors Affecting Airport Access Mode Choice for Elderly Air Passengers”, *Transportation Research Part E: Logistics and Transportation Review*, Vol. 57, pp. 105-112.

Choo, S., S. You, and H. Lee, 2013, “Exploring Characteristics of Airport Access Mode Choice: A Case Study of Korea”, *Transportation Planning and Technology*, Vol. 36, No. 4, pp. 335-351.

Devlet Hava Meydanlari Isletmesi Genel Müdürlügü, Airport Statistics. Available from: *http://www.dhmi.gov.tr/istatistik.aspx*, accessed at July 2016.

Domencich, T., and L. McFadden, 1975, “Urban Travel Demand-A Behavioral Analysis”, North Holland, Amsterdam.

Dresner, M., 2006, “Leisure Versus Business Passengers: Similarities, Differences, and Implications”, *Journal of Air Transport Management*, Vol. 12, No. 1, pp. 28-32.

Gosling, G.D., 2008, “Airport Ground Access Mode Choice Models”, Airport Cooperative Research Program Synthesis, Washington, District of Columbia.

Harvey, G., 1986, "Study of Airport Access Mode Choice", *Journal of Transportation Engineering*, Vol. 112, No. 5, pp. 525-545.

Istanbul Elektrik Tramvay ve Tünel Isletmeleri, Access to Airport. Available from: $http://www.iett.gov.tr/en/main/pages/access-to-airports/798$, accessed at July 2016.

Keumi, C. and H. Murakami, 2012, "The Role of Schedule Delays on Passengers' Choice of Access Modes: A Case Study of Japan's International Hub Airports", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 48, No. 5, pp. 1023-1031.

Koster, P., E. Kroes, and E. Verhoef, 2011, "Travel Time Variability and Airport Accessibility", *Transportation Research Part B: Methodological*, Vol. 45, No. 10, pp. 1545-1559.

Layard, P. and A. Walter, 1978, "Microeconomic Theory", McGraw Hill, New York.

Pels, E., P. Nijkamp and P. Rietveld, 2003, "Access to and Competition Between Airports: A Case Study for the San Francisco Bay Area", *Transportation Research Part A: Policy and Practice*, Vol. 37, No. 1, pp. 71-83.

Psaraki, V. and C. Abacoumkin, 2002, "Access Mode Choice for Relocated Airports: the New Athens International Airport", *Journal of Air Transport Management*, Vol. 8, No. 2, pp. 89-98.

Shafabakhsh, G., M. Hadjihoseinlou, and S. Taghizadeh, 2014, "Selecting the Appropriate Public Transportation System to Access the Sari International Airport by Fuzzy Decision Making", *European Transport Research Review*, Vol. 6, No. 3, pp. 277-285.

Sobieniak, J., R. Westin, T. Rosapep and T. Shin, 1979, "Choice of Access Mode to Intercity Terminals", *Transportation Research Record*, Vol. 728, pp. 47-53.

Tam, M. L., W.H.K. Lo, 2005, "Analysis of Airport Access Mode Choice: A Case Study in Hong Kong", *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, pp. 708 - 723.

Tam, M.L., W.H.K. Lam, and H.P. Lo, 2008, "Modelling Air Passenger Travel Behavior on Airport Ground Access Mode Choices", *Transportmetrica*, Vol. 4, No. 2, pp. 135-153.

Tsamboulas, D.A. and A. Nikoleris, 2008, "Passengers' Willingness to Pay for Airport Ground Access Time Savings", *Transportation Research Part A: Policy and Practice*, Vol. 42, No. 10, pp. 1274-1282.