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Mode choice behavior modeling of ground access to airports: A case study in Istanbul, Turkey

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The increase in air transportation mode share, thereby the passenger traffic at airports has made the ground access to the airports more important in recent years. The aim of this study is to analyze the ground access mode choice to airports by using Multinomial Logit (MNL). In particular, our focus is on how transit areas of influence affect the mode choice for travelling to airports. Atatürk International Airport (IST) in Istanbul, Turkey was selected for the analyses and the investigated modes to access IST were automobile, drop-off, public transit, and taxi. The results showed that significant factors and variables included the trip distance to access IST, type of destination, trip cost to IST, automobile ownership status, employment status, travelling group size, location of the trip origin with respect to public transit influence, and time difference between the flight time and departure time to IST. It is also concluded that if the trip origin to IST was inside the influence areas of public transit, then public transit would be more likely to be chosen over other modes for accessing IST.

1. Introduction and background

There has been a rise in international and domestic air travel (or mode share of air travel) over the past ten years with a growth rate of 5.6 per cent (IATA: International Air Transport Association, 2015). This was due to the surge in number of airlines and the decrease in ticket prices due to the competition among them. Similarly, in Turkey, in terms of the number of passengers, the overall increase in 2015 was 9.4 per cent and the increases in domestic and international traffic were 14.1 and 4.4 per cent, respectively. Also, an increase with 8.2 per cent was observed in the overall commercial aircraft traffic. The percentages of the increase in this category for domestic and international traffic have been recorded as 10.7 and 5.6, respectively (General Directorate Of State Airports Authority of Turkey., 2016).

The growth of passenger traffic in air travel causes an increase in the ground traffic to airports. Therefore, understanding the issues in ground access traffic to airports and providing solutions for related problems are important. In this study, the ground access mode choice of Atatürk International Airport (IST) in Istanbul, Turkey was analyzed. IST is the largest airport in Turkey and the international hub for Turkish Airlines (THY). In 2015, passenger movements increased in IST by 8.0, 4.0 and 10.0 per cent in overall, domestic and international traffic categories, respectively. In terms of commercial aircraft traffic in IST, the increases for the same categories were 6.0, 0.3 and 9.0 per cent (General Directorate Of State Airports Authority of Turkey., 2016).

In the studies regarding mode choice for airport access, discrete choice models (Ben-Akiva and Lerman, 1985) were used to estimate the shares. Among them, the most widely used model was Multinomial Logit (MNL), yet a small amount of studies used Binary Logit (BL) and Mixed Logit (ML) as well.

The main concerns of passengers for selecting the mode for airport access are time and cost of travel to the airports (Harvey, 1986; Monteiro and Hansen, 1996; Psaraki and Abacoumkin, 2002; Hess and Polak, 2006; Gupta et al., 2008; Tam et al., 2008; Alhussein, 2011; Jou et al., 2011; Akar, 2013; Choo et al., 2013). Harvey (1986) and Tam et al. (2008) reported that sensitivity to travel time is higher for passengers travelling for business purposes; i.e., business passengers. Hess and Polak (2006) developed a simultaneous airline, airport and airport access mode choice in Bay Area, United States, and reported that travel time was a crucial factor for the choices.

Demographics of passengers are also essential for airport access

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mode choice though the demographic properties considered in each study vary (Harvey, 1986; Gupta et al., 2008; Tam et al., 2008; Alhussein, 2011; Akar, 2013; Choo et al., 2013). Harvey (1986) reported that gender and income level were important factors for airport access mode choice of non-business passengers. However, the same could not be said for business passengers. Tam et al. (2008) had only considered the age of the passengers in their choice model for Hong Kong International Airport (HKG). Gupta et al. (2008) had found out that gender, age and income level had affected airport access mode choice in New York City. Alhussein (2011) used only income level and nationality of the passengers as demographic properties in the choice model between automobile (auto) and taxi. Akar (2013) used the age of the passengers in addition to their incomes as a demographic property. However, Choo et al. (2013) had the most extensive demographic variables including age, gender, occupation and income level of the passengers in their airport access mode choice models for Gimpo (GMP) and Daegu (TAE) International Airports in Korea.

Separation of passengers in terms of trip purposes as business and non-business were considered to be essential in several studies (Harvey, 1986; Psaraki and Abacoumkin, 2002; Pels et al., 2003; Hess and Polak, 2006; Gupta et al., 2008; Tam et al., 2008; Akar, 2013; Choo et al., 2013). Tam et al. (2008) and Akar (2013) applied this separation by including separate variables for business passengers in their models. Harvey (1986), Psaraki and Abacoumkin (2002), Hess and Polak (2006), Gupta et al. (2008), and Choo et al. (2013) developed different mode choice models for business and non-business travelers.

Safety margin is one of the fundamental factors for airport access mode choice, especially for passengers travelling for business purposes. Passengers usually prefer to arrive earlier to the airports in order not to arrive late and miss their flights. Thus, safety margin is described as the time difference between the preferred and expected arrival time of passengers (Tam et al., 2008). Tam et al. (2008) also revealed that each access mode had different safety margin measures. This is due to the fact that different access modes have different travel time reliability. Koster et al. (2011) determined the factors affecting preferred arrival time to the airport, which also has an effect upon safety margin. Those factors were listed as the number of luggage to be checked-in, purpose of the trip, age (elderly or not), the number of flights per year, flight time, check-in type (online or not), expected travel time to the airport and flight duration.

Other factors affecting airport access mode choice can be listed as the number of luggage each passenger is carrying (Harvey, 1986; Akar, 2013; Budd et al., 2014) and the travelling group size (Tam et al., 2008; Akar, 2013). Harvey (1986) stated that carrying luggage would make passengers avoid public transit. Likewise, Akar (2013) also explained that the number of luggage was an important factor in choosing other transportation modes than automobile for airport access. However, Budd et al. (2014) found a contradictory result. In their study, the group which used public transit more often to access airports was made of passengers with checked-in luggage. In terms of group size, both Tam et al. (2008) and Akar (2013) revealed that an increase in group size would discourage passengers from using non-automobile transportation modes.

Use of public transit for airport access has been recommended or its evidence has been presented by several studies (Monteiro and Hansen, 1996; Gupta et al., 2008; Budd et al., 2011). Monteiro and Hansen (1996) had recommended the local authorities to extend the Bay Area Rapid Transit (BART) network to San Francisco International Airport (SFO), and it was indeed extended to SFO in 2003. Similarly, Gupta et al. (2008) had revealed that there was a tendency to use AirTrain to connect rail stations from airports in New York City. Budd et al. (2011) explained that share of private car trips to airports, both as drop-off and as auto, should be reduced and this strategy could be implemented with the help of airport managers. Similarly, Merkert and Beck (2016) explained that integrated air bus services in Australia would reduce the private car usage for regional travel, especially by leisure travelers.

Taking public transit use for airport access as a starting point, it was observed that there was a research gap about the effects of transit areas of influence (or catchment areas) on mode choice access to airports, and that has been covered in this study. Specifically, transit areas of influence is defined as the area around a given public transit station which has the potential to generate trips on the corresponding transit line (APTA Standards Development Urban Design Working Group, 2009). The concept of transit area of influence has been used in literature, such as walking distances to/from transit stations (O'Sullivan and Morrall, 1996). In that study, it was found that pedestrians preferred to walk more for light-rail stops than for bus stops.

Hence, it was aimed to obtain the following:

(1) Effects of transit areas of influence on mode choice for airport access;
(2) Estimation of the airport access mode choice for the passengers departing from IST, and determination of the factors affecting the mode choice.

2. Data and methodology

2.1. Data

Data was collected via a passenger survey conducted at IST. IST was opened in 1953, and has expanded since then. In 2015, the airport handled 41,947,327 international and 19,375,402 domestic passengers, more than its annual capacity (25,500,000 international and 12,800,000 domestic passengers per year) (General Directorate Of State Airports Authority of Turkey., 2016). It is located at the west of central Istanbul, in Bakırköy district of the European side of the city. The distance between IST and Beyoğlu district, which is the city center, is 22 km.

There are 99 districts in the data, with varying distances to IST. 19 of these districts are located on the Asian side of the city and have longer distances to IST. This is because passengers coming from the districts on the Asian side and using highways need to access the bridges first (15th July Martyrs' Bridge or the Fatih Sultan Mehmet Bridge); and therefore, the length of the trip to IST increases. Alternatively, those passengers can also use ferries and Marmaray rail to cross the Bosphorus.

Different studies have considered different ground modes since the alternatives of access mode varied among the airports. In this study, the types of access modes considered were automobile, drop-off, public transit, and taxi. In auto mode, passengers drive on their own and drop-off mode is the case where they are driven to IST by others. There is direct access by public transit to IST via semi-rapid rail, which is the M1A line. It runs from Yenikapi district to IST and passengers can connect to this line from other semi-rapid rail lines at several stations. It should be noted that the transit modes investigated in this study are the semi-rapid transit lines in Istanbul. Furthermore, Istanbul transit network is provided (Fig. 1) to clearly show the transit network structure and location of IST for the convenience of the reader. The final mode considered in this study is the regular taxi service. Given the limited budget for this study, the percentage of passengers who have taken shuttle services to IST was not high enough to obtain a choice model for that mode (4.2%). There is also the option of renting a car to/from IST, but none of the respondents in data used that service.

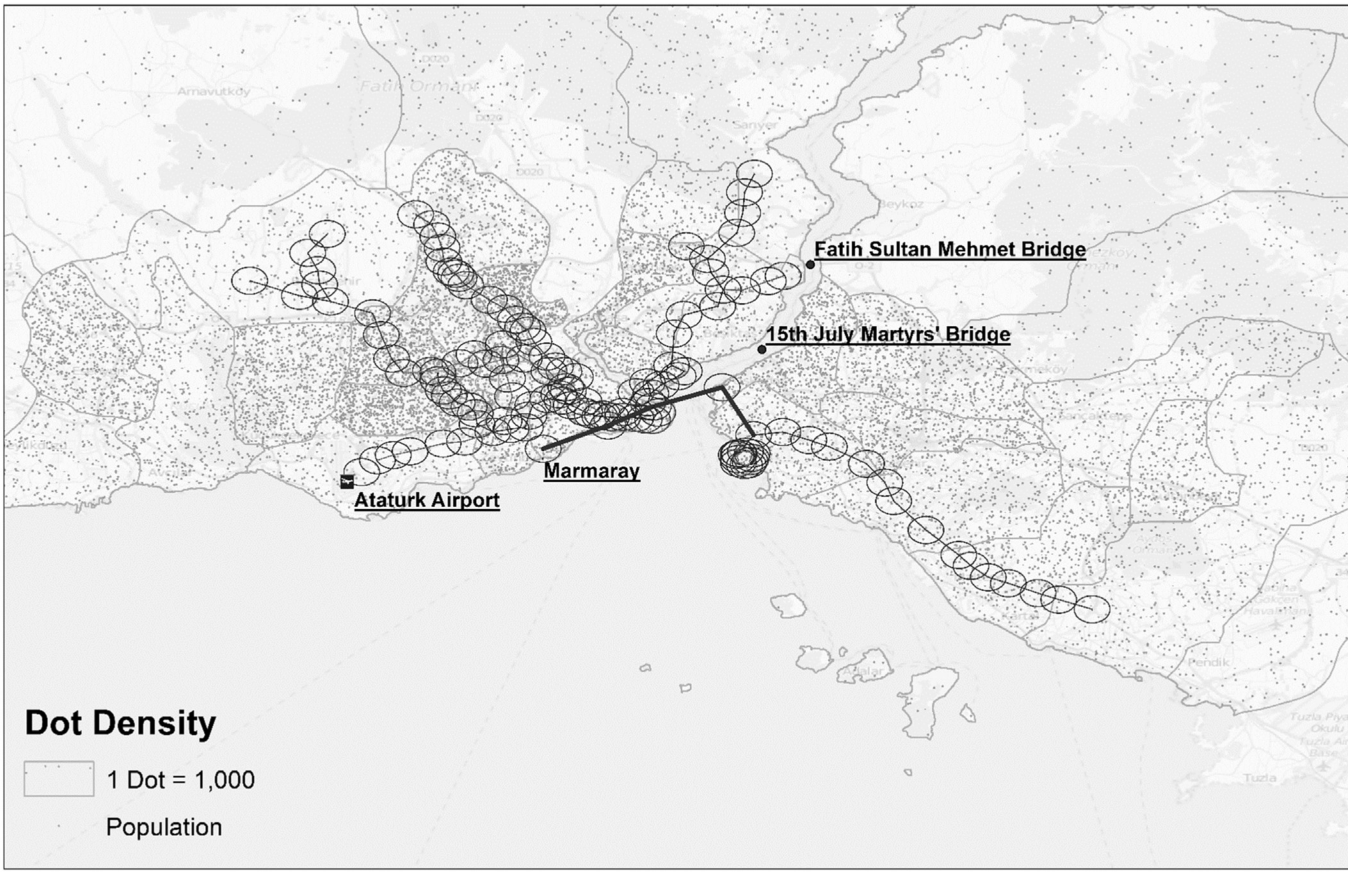

Fig. 1. Istanbul transit network, where the circles show transit areas of influence and the dots represent 1000 people.

No future plan has been officially revealed about the ground transportation between IST and Istanbul city center, since a third airport is under construction at the moment at north of Istanbul. Hence, the future of IST is unknown after the new airport starts operating. Nevertheless, our aim for this work was using IST as a case to investigate the transit areas of influence in airport access mode choice.

546 responses were collected during four days in January 2015. On each day, two sessions were held, each lasting 3 h. Respondents were both domestic and international travelers, selected using convenience sampling method.

In the survey, respondents were asked about their demographics such as their age, gender, income level and whether they owned an automobile and driving license, trip purposes as business or non-business, trip destinations as domestic or international, the number of luggage, trip cost and the districts of their origin of the trip to IST and the amount of time difference between their flight time and their departure time to IST in minutes. The last variable included the travel time to the airport and the additional allowed time of the respondents as "safety margin". Collected revealed preferences data was coded and the models were developed using NLOGIT software.

2.2. Methodology

The MNL model was developed to estimate the mode choice behavior. Ben-Akiva and Lerman (1985) explained the MNL theory. Given that each individual has a feasible choice set, denoted byC_n, $J_n \leq J$ are defined to be the number of feasible choices. The probability of any element i in C_n being chosen by individual n is given by:

$$P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n), \tag{1}$$

where

$$U_{in} = V_{in} + \varepsilon_{in}. \tag{2}$$

In Eq. (2), V_{in} is the systematic component and ε_{in} is the random part of the utility function of the element i, U_{in}. V_{in} can be expressed as:

$$V_{in} = \boldsymbol{\beta}_n \mathbf{x}_{in}, \tag{3}$$

where $\boldsymbol{\beta}$ is the coefficient matrix and $\mathbf{x}$ is the vector of independent variables. Then $P_n(i)$ can be formulated as the following:

$$P_n(i) = \frac{\exp(V_{in})}{\sum_{j \in C_n} \exp(V_{in})}, \tag{4}$$

with conditions:

$$0 \leq P_n(i) \leq 1, \tag{5}$$

and

$$\sum_{i \in C_n} P_n(i) = 1. \tag{6}$$

Other than the MNL model, direct and cross elasticities were also estimated. Direct elasticity is the change in share of a mode when a 1% change is observed in the value of a certain variable of that mode. When changes in other modes' shares are investigated under the same change in that variable, then the elasticity becomes cross elasticity. The elasticities are calculated using Eq. (7) (Ben-Akiva and Lerman, 1985):

$$E^{P_{in}}_{H_{jxn}} = \beta_{jx} H_{jxn} (\delta_{ij} - P_{jn}). \tag{7}$$

where P_{in} is the probability of individual n choosing mode i, H_{jxn} is the value of variable x for alternative j and individual n, β_{jx} is the coefficient value of variable x for alternative j, P_{jn} is the probability of individual n choosing mode j. δ_{ij} is equal to 1 in case of a direct elasticity (where $i = j$) and it is equal to 0 for cross elasticity (where $i \neq j$).

This study contributes to the literature by introducing the effect of transit areas of influence on mode choice, which had not been covered in other studies within this field. For this purpose, influence areas of each station of all public transit lines in Istanbul have been investigated. Thus, a factor was included in the model reflecting the influence area of stations. If the district of a specific passenger was in the influence area of a station, then the variable was set to 1; and 0 otherwise. The influence area of the stations was determined by drawing a circle with the station being the center. Radius of the circle for semi-rapid transit mode is used as 1/2 miles, which is the primary catchment area (APTA Standards Development Urban Design Working Group, 2016) (Fig. 1). As well as the transit areas of influence, Fig. 1 also shows the population density in Istanbul with the dots. Each dot represents 1000 people. As it can be observed, central-west of Istanbul has the highest population density, and this region is covered by rail-public-transit service.

The facts and assumptions for the developed MNL model are listed as below:

1) Cost of public transit is not fixed for users in Istanbul, and it changes with respect to fare type and number of connections made on the transit network. The public transit rates and their types for users shown in Table 1, in Turkish Lira (TL) (1 USD = 2.4598 TL, February 25th, 2015) (IETT, 2015). Users pay the public transit fee either by buying tokens or using a transit card named "IstanbulKart", a type of a pre-paid payment system (Gokasar et al., 2015).
2) The taxi cost, R (in TL), was calculated according to Eq. (8) which is the taxi rate tariff for Istanbul (Istanbul Metropolitan Municipality Directorate of Public Transportation Services, 2016):

$$R = 3.2 + 2(\text{Distance in km}) + 0.325(\text{Travel time in minutes}). \tag{8}$$

It should be noted that the travel time information was collected from the respondents during the interviews.

3) The cost for auto is assumed to be 0 when the passenger is dropped off at IST by someone else. When the passenger drove to IST, the cost for auto was taken as the fuel cost. The fuel consumption in Istanbul was taken as 0.095 lt/km (Biggs and Akçelik, 1986). The average fuel cost in 2015 was 3.58 TL (EMRA-Republic of Turkey Energy Market Regulatory Authority, 2016). Therefore, the fuel cost per kilometer was computed as 0.34 TL in Istanbul.
4) The distances between the districts and IST were measured in kilometers using Google Maps.
5) Passengers arriving IST from other cities via inter-city buses first arrive at the Esenler Bus Terminal in Istanbul, which is 19 km from IST. The bus terminal has a direct rail transit access to IST, and passengers from outside of Istanbul reported that they have used this rail transit to arrive IST. Thus, the start of their trips to IST was assumed as the bus terminal and their mode choice was assumed as public transit.

Table 1
Public transit rates (TL) in Istanbul (IETT, 2015).

	Full	Elderly Passenger	Student
First Ride	2.30	1.65	1.15
1st Connection	1.65	0.95	0.50
2nd Connection	1.25	0.75	0.45
3rd Connection	0.85	0.50	0.40
4th Connection	0.85	0.50	0.40
5th Connection	0.85	0.50	0.40

3. Analysis and results

3.1. ANOVA for covariates

Five covariates were to be used in the MNL analysis; cost of access (Cost), time difference between the flight time and departure time to IST (DepMargin), distance from the trip origin to IST (Distance), number of luggage of each passenger (Luggage) and number of people travelling together with the respondent (Group Size). Equality of means of the covariates over the mode types had to be tested first because if the means of a covariate were equal for mode types, then that covariate would not be suitable to use. The testing was done by ANOVA, and the results are given in Table 2. From the significances of the F-statistics, for all covariates except Luggage, it can be said that at least two of the modes have different means with 95% level of confidence. Luggage, on the other hand, had a significance value of 0.268 and thereby was insignificant at 95% level of confidence and was omitted from the MNL model. Hence, among the covariates, Cost, DepMargin, Distance and Group Size were suitable to be used in the MNL model.

In order to find out the DepMargin differences between terminal types and trip purposes, two ANOVA analyses were carried out to understand if there are any. Table 3 shows that DepMargin did not depend on the trip purpose (significance 0.857) but the terminal type, which is also the destination type (significance 0.000). Both DepMargin and terminal type were included in the MNL model as shown in Section 3.2.

3.2. MNL model results

3.2.1. Model calibration

The survey data had 546 observations. The MNL model for airport access mode choice of IST was calibrated by using 75% of the data (410 observations) and it was validated with the remaining 25% (136 observations). The percent shares of the factors used and mode choice types in modeling were shown in Table 4. Among data types, it can be observed that the distributions are similar. Public transit has the highest share with 40.8%, followed by taxi which has 30.6%. Most of the travelers are domestic (63.9%) and they own at least one automobile (55.1%). Passengers are mostly from the districts which are covered with public transit, with 57.5%. In addition, 69.4% of the passengers reported that they were employed.

Table 5 shows the model fitting information, goodness of fit of the model and coefficient estimates with their significances. The chi-square test statistic for model fitting information, shown in Table 5, tests the null hypothesis that all of the coefficient estimates are equal to zero. The statistic is equal to $-2^*[\text{LL(C)-LL(B)}]$, where LL(C) and LL(B) are the log-likelihood of the model with only the constants and the fitted model, respectively. In Table 5, the

Table 2
ANOVA for the covariates between the mode types.

		Sum of Squares	Degrees of Freedom	Mean Square	F-statistic	Significance
Cost	Between Groups	195,756	3	65,252.1	290.135	0.000
	Within Groups	121,897	542	224.903		
	Total	317,654	545			
DepMargin	Between Groups	150,938	3	50,312.6	5.789	0.001
	Within Groups	4,710,289	542	8690.57		
	Total	4,861,226	545			
Distance	Between Groups	1893.51	3	631.171	5.298	0.001
	Within Groups	64,566.4	542	119.126		
	Total	66,459.9	545			
Luggage	Between Groups	3.635	3	1.212	1.318	0.268
	Within Groups	498.489	542	0.92		
	Total	502.125	545			
Group Size	Between Groups	38.662	3	12.887	4.501	0.004
	Within Groups	1551.843	542	2.863		
	Total	1590.505	545			

Table 3
ANOVA for DepMargin between trip purposes and terminal types.

		Sum of Squares	Degrees of Freedom	Mean Square	F-statistic	Significance
Trip Purpose	Between Groups	289.463	1	289.463	0.032	0.857
	Within Groups	4,860,937.035	544	8935.546		
	Total	4,861,226.498	545			
Destination	Between Groups	332,354.343	1	332,354.343	39.922	0.000
	Within Groups	4,528,872.155	544	8325.133		
	Total	4,861,226.498	545			

Table 4
Shares of variables in overall, calibration and validation data.

Variable		% Share		
		Overall	Calibration	Validation
Mode	Auto	12.8	12.8	13.2
	Drop-off	15.8	16.6	14.0
	Public Transit	40.8	40.8	40.4
	Taxi	30.6	29.8	32.4
	Total	**100**	**100**	**100**
Public Transit Influence (P)	Yes	57.5	58.8	53.7
	No	42.5	41.2	46.3
	Total	**100**	**100**	**100**
Destination (D)	International	36.1	37.1	33.1
	Domestic	63.9	62.9	66.9
	Total	**100**	**100**	**100**
Automobile Ownership (A)	Yes	55.1	54.9	55.9
	No	44.9	45.1	44.1
	Total	**100**	**100**	**100**
Employment Status (E)	Yes	69.4	71.5	63.2
	No	30.6	28.5	36.8
	Total	**100**	**100**	**100**

significance value of 0.000 of the chi squared test statistic indicates that at least one of the coefficient estimates in the MNL model is not equal to zero. Thus, the overall fitted model is significant.

Goodness of the fit of the model is evaluated using McFadden R^2 measures. This measure in this study was calculated using the log likelihoods of the constants-only model and fitted model. Even though McFadden R^2 measures should be interpreted with caution since they are subjective, measures given in the literature review indicated that only Choo et al. (2013) reported McFadden R^2 measures for their models, and the value in this study, 0.264, is higher than the values they reported using log likelihoods of the constants-only model and fitted model.

In terms of the model coefficients, only the significant variables for each mode at 90% confidence level were included, but none of the intercepts were excluded from the models. It should be noted that taxi mode was the reference mode category.

The generic variable, cost, was observed to be significant at 5% level of significance and it has a negative coefficient. It implies that as the cost of a given mode increases, the probability of choosing that specific mode decreases. It should be noted that the utility function for taxi mode only has the cost variable since taxi is the reference mode.

In terms of the mode-specific variables, destination type as domestic or international (D), is significant at 10% level of significance for auto and public transit modes, and insignificant for drop-off mode. When travelling to a domestic destination, one is less likely to choose auto as the coefficient for D is negative. However, this situation is opposite for public transit mode; choosing that mode is more likely if the destination is domestic. DepMargin is significant at 5% level of significance for auto and drop-off modes. The coefficient for both modes is -0.011, which implies that as the DepMargin increases, the choice probability of these modes decreases. Furthermore, distance is significant for all three modes at 5% level of significance, and the coefficients are negative. Hence, distance decreases the probability of choosing these three modes. Employment status (E) of a passenger is significant at 5% and 10% levels of significance for drop-off and public transit modes, respectively. This variable has negative coefficient in both cases; having a job decreases the choice of choosing these modes and thus increases choice of the other two. Auto ownership (A) has a positive effect on choosing auto, as expected. It is significant at 95% level of confidence. On the other hand, this variable affects the choice of public transit negatively due to the negative coefficient, and is also significant at 95% level of confidence. Group Size is significant only for public transit mode, with significance of 0.004. The coefficient for this variable is negative, passengers travelling together are likely to avoid public transit. Most importantly, accessing the airport from an area which is covered by public transit (P) increases the choice of public transit and this variable for that mode is significant at 95% level of confidence. In addition, when a passenger is located within the transit area of influence, auto and drop-off

Table 5
Model fitting information, McFadden R^2 measures and model coefficients.

Model Information				
Number of Observations		410	Likelihood Ratio Test	
Log-likelihood - Constants Only		−527.317	Chi-squared Test Statistic	278.283
Log-likelihood - Fitted Model		−388.125	Significance	0.000
McFadden R^2		0.264		
Adjusted McFadden R^2		0.247		
Model Coefficients				
Generic Variables		Coefficient	Significance	
Cost		−0.190	0.000	
Variables Specific to Alternatives		Coefficient	Significance	
Auto	Constant	−2.493	0.009	
	D	−0.695	0.083	
	P	−0.934	0.018	
	DepMargin	−0.011	0.001	
	Distance	−0.334	0.000	
	A	2.102	0.000	
Drop-off	Constant	0.109	0.877	
	P	−0.597	0.097	
	DepMargin	−0.011	0.001	
	Distance	−0.408	0.000	
	E	−1.400	0.000	
Public Transit	Constant	−1.375	0.022	
	D	0.572	0.081	
	P	0.646	0.049	
	Group Size	−0.408	0.004	
	Distance	−0.422	0.000	
	E	−0.644	0.074	
	A	−0.761	0.014	

modes are less likely to be chosen since the coefficients are negative. This variable is significant for these modes at 5% and 10% level of significance, respectively.

Elasticity analysis of travel cost is given in Table 6. In terms of direct elasticities, it can be observed that cost affects the choices on Auto and Taxi more than other modes. 1% increase in costs of auto and taxi results in 1.083% and 8.738% decrease, respectively. For cross elasticities, it can be said that 1% increase in taxi cost causes a 2.571% increase in other mode shares.

3.2.2. Model validation

The calibrated model was then validated using the remaining 136 cases from data. The results are given in Table 7. The overall correct prediction is 55.9%, a little lower than one of the calibration data. Percentages for correct predictions are 52.9, 36.8, 52.7 and 70.5 for auto, drop-off, public transit and taxi, respectively.

4. Conclusions

In this study, ground access mode choice for IST in Istanbul, Turkey was investigated using MNL modeling. Four types of modes were included in the study: Auto, drop-off, public transit, and taxi. As being different from other studies in the literature, investigation of the effects of influence areas of public transit systems in Istanbul on mode choice for airport access was made. To understand these potential effects, public transit influence was added to MNL model as a factor. It was seen that origin of the trip to airport is a determining factor for choosing the public transit. If a specific origin is in the influence area of a public transit system, then the passenger is more likely to choose public transit over the other modes.

The results indicated a 55.9% correct mode prediction obtained with MNL model using the validation data. Travel cost to IST has a negative effect on mode choice probabilities as expected. Furthermore, it was seen that there were differences with regard to explanatory variables on mode choice for access to IST. For instance, time difference between the flight time and departure time to the airport (DepMargin) was significant for auto and drop-off modes with negative effects on their choice probabilities. This result is similar to the findings of Tam et al. (2008). Furthermore, destination type as domestic or international is particularly important for the choices of public transit and auto. Also, passengers are less likely to use public transit if they are employed. In addition, ownership status of an automobile had an effect on choosing public transit and auto. Logically, travelling group size had a negative effect on choice of public transit mode. Interestingly, contrary to some other studies (Choo et al., 2013; Tam et al., 2008; Alhussein, 2011; Akar, 2013), age, number of luggage, trip purpose (business/non-business) and income level did not have an effect on the mode choice in this study. The ANOVA procedure on the number of luggage among the ground access modes revealed that the expected means of luggage number related to the modes might be

Table 6
Elasticities of travel cost (in %).

	Auto	Drop-off	Public Transit	Taxi
Auto	−1.083	0.000	0.265	2.571
Drop-off	0.180	0.000	0.265	2.571
Public Transit	0.180	0.000	−0.418	2.571
Taxi	0.180	0.000	0.265	−8.738

Table 7
Predictions on validation data.

	Correct	Wrong	% Correct
Auto	9	9	50.0
Drop-off	7	12	36.8
Public Transit	29	26	52.7
Taxi	31	13	70.5
Overall	76	60	55.9

equal to each other, and thus, number of luggage did not have any effect on mode choice.

Results of this study also reveal important implications for policy makers. For passengers originating outside the transit areas of influence, using public transit should be promoted for accessing to IST with the help of certain incentives. Findings of Monteiro and Hansen (1996), Gupta et al. (2008) and Budd et al. (2011), which were explained in Section 1, show that public transit should be the preferred mode of transportation for airport access and hence, support our following recommendations. Departing flight information can be provided at some of the stations among the public transit network for informing the passengers about the boarding times or delays. Furthermore, frequency of the M1A line between IST and Yenikapi district might be increased during off-peak hours if the number of flights departing from IST is higher at those hours. More importantly, a reimbursement can be made to the "IstanbulKart"s of the passengers who are arriving at IST as an incentive. Two types of reimbursements are proposed. First one is that if passengers have made connections along the public transit network on their trip to IST, the connection fee can be reimbursed. Secondly, there are 45 Park and Ride facilities in Istanbul (ISPARK, 2016) and those are integrated to "IstanbulKart" payment system. If passengers park their car at one of those facilities and take the public transit to IST, a significant proportion of their parking fee can be reimbursed to their "IstanbulKart" at the IST station of public transit. That proportion would be determined by the local authorities. This reimbursement strategy would help passengers whose trips to IST originate from outside of the transit areas of influence. Thus, this might attract these passengers to public transit ridership instead of automobile-dependent modes.

Transferability of the models to other airports with the same ground access mode types can be assessed in future work. Currently, the other airport in Istanbul, SAW, does not have any access on rail; hence, it is not possible to compare its mode choice mechanisms to those of IST. However, if a rail transit is introduced to SAW, the study can be repeated and the impact of the rail system to be introduced can be assessed and the IST-SAW comparison can be made. Furthermore, currently, a third airport for Istanbul is under construction at the northern side of the city. As a strong point, the findings from this study, especially about the transit areas of influence of the rail stations in Istanbul, can be useful for the planning and policies regarding ground transportation of the new airport in the future. On the other hand, a weakness of this study is that, if a new medium of transportation is introduced to IST in the future, such as public buses, this study might need repetition.

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