Innovative Infrastructure Solutions (2024) 9:169
https://doi.org/10.1007/s41062-024-01489-3

CASE STUDY

Analyzing long-term parking preferences at Imam Khomeini International Airport: a stated preference approach

Ahmad Ghaffari[1] · Babak Mirbaha[1] · Hamid Mirzahossein[1] · Seyed Mohsen Hosseinian[1]

Received: 14 November 2023 / Accepted: 11 April 2024 / Published online: 29 April 2024

Abstract
This paper employed a stated preference approach to examine the long-term parking preferences of passengers at Imam Khomeini International Airport, with a particular focus on their propensity to use public and paratransit modes. A total of 377 passengers were investigated with 4 price scenarios and 6 mode choice options to access the airport, and discrete choice models, including binary, nested, and multinomial logit, were employed to evaluate the impact of parking price on passenger behavior. The likelihood ratio test was used to validate the models, and finally, using the sensitivity analysis, the effect of each variable on passenger choice for parking in the airport parking lot, as well as the sensitivity of each mode choice option to changes in parking prices, were examined. The binary logit model results indicated that married travelers with larger social networks and longer trip durations coming from their personal homes were less likely to park their vehicles at the airport. While the assumption of nesting behavior of options could not be confirmed, the multinomial logit model exhibited better performance than other models. Furthermore, the sensitivity analysis revealed that a 3.8% increase in parking fees, from 1.3 to $2, would reduce the probability of choosing an airport parking lot by 8.2%, while increasing the probability of selecting a drop-off personal vehicle, rental car, taxi, and Metro by 3.8, 4.9, 11.7, and 4.3%, respectively. These findings can inform policymakers in developing effective airport parking pricing strategies to encourage greater use of public and paratransit modes among passengers.

Keywords Parking price · Airport access mode · Binary logit · Nested logit · Multinomial logit

JEL Classification R41

Introduction

Today, the position of airports in the transportation system is very important. High speeds for passenger and freight transport have greatly increased the tendency to use this mode of transportation. Airports are an essential element of contemporary life and a vital source for moving people and transporting freight around the world [1–3]. Therefore, access to the airport and its parking lot is also an important problem in an aviation system, and it is vital to anticipate the decision of air travelers to choose a personal vehicle and use a parking lot. On the other hand, the increase in air travel demand will increase ground transportation around the airport because airports will transport air travelers to ground transportation mode, so air and ground travels will be interconnected and interacted [4–6]. Airport access at most airports around the world depends on the use of personal vehicles significantly, so a high percentage of airport access travels are performed using personal vehicles [7, 8]. These travels can generate significant revenue for airports through vehicle parking prices [9]. Sometimes crowded personal vehicles cause traffic at airport entrances, reducing air quality and increasing greenhouse gas emissions [10, 11]. However, public transportation stands as a cornerstone of

✉ Hamid Mirzahossein
mirzahossein@eng.ikiu.ac.ir

Ahmad Ghaffari
a.ghaffari.ie@edu.ikiu.ac.ir

Babak Mirbaha
mirbaha@eng.ikiu.ac.ir

Seyed Mohsen Hosseinian
s.m.hosseinian@edu.ikiu.ac.ir

[1] Department of Civil – Transportation Planning, Faculty of Technical and Engineering, Imam Khomeini International University (IKIU), Qazvin, Iran

urban development and sustainability [12]. It offers an efficient solution to reduce congestion, minimize environmental impact, and provide equitable mobility for all segments of society [13–15]. Tourists' interaction with airport facilities, particularly their parking choices, reflects a complex interplay of convenience, cost, and connectivity, making their behavior a critical consideration in the development of efficient airport transportation strategies [16].

Developing airport access policies that enable the effective use of airport access capacity is influenced by personal vehicle travel and is an important challenge for airport management [17, 18]. Ground traffic problems, such as traffic congestion can negatively affect air traffic management. Therefore, airport managers and officials are increasingly solving the problems related to ground traffic around airports [19]. Project management is a critical component in the field of airport operations, encompassing a wide range of activities from planning and design to construction and maintenance [20]. In the context of airport operations, dynamic pricing refers to the adjustment of prices for services such as parking based on current demand levels. This approach can be used to manage the demand for parking spaces, potentially encouraging passengers to use alternative modes of transportation during peak times or to park in less utilized areas of the airport [21]. The rapid growth of vehicle ownership and the use of personal vehicles has greatly increased the need for parking lots at airports. Therefore, it is necessary to evaluate the adopted strategies correctly. By applying highway safety concepts, such as traffic flow analysis, congestion management, and accident prevention, airport authorities can create safer and more efficient parking systems that accommodate the needs of travelers while minimizing the risk of accidents and improving overall airport operations [22]. Parking facilities located in the vicinity of airports play an important role in reducing congestion and travel delays due to a significant increase in traffic demand and lack of facilities. Low parking prices and easy access to the parking lot make more passengers park in the airport parking lots [23–25].

By increasing demand for air travel, the need to develop airports and create new facilities for access, parking space required, and other challenges posed by this growth in demand, require a review of existing plans. The effects of parking pricing at each airport are different and it is necessary to conduct special studies in an airport according to the cultural and economic conditions of the people of that country or city. Also, the price of parking at various airports is different in terms of congestion and air traffic load, and as traffic increases, the price can have an increment. In this regard, Imam Khomeini International Airport (IKIA), Tehran, Iran was studied in this research. IKIA due to the lack of bus rapid transit and also being located on the Qom-Tehran freeway has caused passengers to often come to the airport by personal vehicles. Therefore, in this study, the main focus was on public parking lots, which are for passengers and people who are not considered airport employees. For this purpose, in the first step, the stated preference (SP) method was used to collect the data. In this method, various scenarios were drawn for the desired situation for the respondent, and his/her choice and decision were asked. Also, in this study, discrete choice models, including binary, nested, and multinomial logit models, were used to evaluate the effectiveness of pricing for parking facilities. After analyzing the choice models, the most significant variables affecting the choice of the airport parking lot for vehicle parking, as well as the mode choice of air travelers to access the airport, were evaluated. In this regard, a questionnaire was considered consisting of the socio-economic parameters of passengers and also the features of the choice of each parking price scenario, including parking price and parking time in peak and non-peak traffic time. Additionally, the validity of the logit models was examined through the likelihood ratio test. Finally, the sensitivity analysis was conducted to assess the impact of independent variables on the decision of passengers to use the airport parking facilities and to evaluate how sensitive each parking choice option is to changes in parking prices.

Literature review

Various studies have been conducted to examine the important factors that have an influence on the choice of passenger parking. Ma et al. analyzed the parking choice behavior considering specific events and tourist areas using logit models. They showed that driving time, parking price, and walking time were three important and effective factors in the use of parking [26]. Some studies have focused on describing the behavior of passengers in the choice of on-site or off-site parking lots based on the nested logit model and have shown that the inclusion of heterogeneity and differences in preferences increased the ability to predict the parking choice model [27, 28]. Moreover, in a study aimed at analyzing the parking choice behavior using SP and nested logit model, Qin et al. examined parking outside the Beijing Capital International Airport as the second busiest airport in the world, and the choice behavior of passengers. The results of the study showed that parking price and distance were two important factors in the choice of long-term parking by passengers [29]. Also, in a research conducted by Roh on the choice of access mode to the airport and the factors affecting that, data were collected through a questionnaire in the airport, and the discrete choice models, including multinomial logit, nested logit, and mixed logit, were used for modeling. The results showed that travelers coming from longer distances were more likely to save travel time [30].

Pels et al. [31] in a study examining the access to the airport and competition between airports showed that in addition to travel time, parameters, such as travel purpose, number of companions, and place of origin, were also effective in the choice to access to the airport. Shaaban and Pande [32] developed binary logit models to understand parking choice behavior and found that parking intelligence was an important and influential factor in parking choice. Some studies have shown that in terms of passenger access to airports, personal vehicles have become the main mode of travel [33]. Zaidan and Abulibdeh [34] in their study identified the priorities of air travelers in using transportation modes to access Hamad International Airport using a multinomial logit model. Also, to analyze the priorities of passenger parking choice for off-campus parking activities, a study was conducted at Beijing Capital International Airport, in which the binary logit model was used to analyze the relationship between passenger parking behavior and their travel features. The results showed that passengers preferred to use off-site parking lots for long-term parking. In general, the main idea of governments is to introduce policies that aim to encourage changes in transportation modes from private to public transportation for airports. An interesting example in this regard is the Italian National Airport Plan [35].

Some studies have shown that passengers who had enough time had more flexibility for higher prices, and passengers with business purposes had more flexibility in terms of airport access or airport choice [31, 36]. Some studies have focused on the airport travel mode choice of employees and passenger access options from low-cost carriers (LCCs). In a study using the data resulting from SP, Tsamboulas et al. [37] found that employees were very sensitive to travel time and costs in the choice of access mode. In a similar study, Harvey investigated the mode choice of access to an airport in the San Francisco Bay Area. The results of the research showed that passengers were extremely sensitive to travel time (especially in cases where flight time increases) and travel costs [38]. Moreover, Sobieniak et al. investigated the mode choice of access to Ottawa International Airport using the multinomial logit model. The results indicated that passengers were sensitive to travel time, waiting time, walking time, number of baggage, gender, travel purpose, household income, and travel cost [39]. Studies also showed that passengers traveling for recreational purposes had more flexibility in paying higher prices for airport access, and business travelers had more flexibility in terms of airport access time [31, 36].

Some researchers have examined the most important factors influencing the choice of transportation mode for airport access. Akar [10], by the use of the binary logit model, showed that passengers traveling for business purposes were more likely to choose options than other passengers. Some studies have examined airport access options and the factors that affect them. Their research findings revealed that travelers to more distant destinations spent more to save travel time [4, 30]. Castillo-Manzano [40] used logit models to examine differences in the choice behavior of LCCs by passengers and showed that a passenger who chose a LCC was more inclined to use rental cars or public transportation. Various studies have also shown that travel time and cost at the airport are two factors that are the main concern of air travelers in the choice of ground access mode to access the airport, and the results have indicated that business travelers are more sensitive to travel time than other travelers [10, 11, 17, 36, 38, 41–44].

A variety of motivational access strategies, such as railroads, have also been proposed to reduce vehicle dependence on airport flights. Parking policies and regulations are important aspects in reducing the dependence of passengers on their personal vehicles and promoting a change in their mode of travel to public transportation systems. Parking pricing strategies at international airports have also been the focus of various studies. Parking demand may vary with parking rate changes [45, 46]. Birolini et al. examined the impact of transportation modes on passenger access to Milan Bergamo Airport. The results indicated that airports should consider transportation priorities for passenger transportation to better organize transportation access modes for passengers [47]. Also, studies in the field of airport parking show that the revenue from parking facilities is significant and in some small and medium airports, it includes 26% of the total airport revenue. However, in large airports, the share of parking revenue decreases due to the presence of other revenue-generating sectors in large airports, which reduces the revenue from parking [48].

In this research, to obtain information to create a model, the stated preference (SP) method was applied. The data was collected through 377 questionnaires with different price scenarios, each of which included 4 choices, in the form of interviews with travelers. Finally, the discrete choice models, including binary, nested, and multinomial logit models, were presented to evaluate the price effectiveness of parking facilities. Finally, the logit models were validated using the likelihood ratio test, and a sensitivity analysis was performed to determine the influence of variables on airport parking choice and price elasticity.

Methodology

Data collecting

In this study, an experimental design was employed to investigate the long-term parking preferences of passengers at Imam Khomeini International Airport (IKIA). This approach was chosen for its robustness in isolating the effects of parking pricing on passenger behavior.

In this regard, a questionnaire consisting of the socio-economic parameters of passengers and also the choice characteristics of each parking price scenario were considered. These characteristics included parking price, parking time in peak flight traffic time, and parking time in non-peak flight traffic time, and for this purpose, the recommendations of ACRP Report 26, which deals with the collection of information from air passengers at the airport, were used. Data collection was performed in April 2018 using 4 questionnaires at IKIA. Pricing scenarios were determined using experimental design, in which a total of 16 scenarios were prepared in the form of 4 types of questionnaires. In each questionnaire, a total of 15 questions were asked, which questions 1 to 14 were related to the personal characteristics of passengers, travel characteristics, and destination information, and in question 15, price scenarios were provided. Table 1 presents the scenarios related to questionnaires types A to D. Also, the method of determining the mentioned scenarios for parking prices and waiting time to find a parking space are presented in Tables 2 and 3, respectively. This methodology not only allowed for a controlled analysis of the stated preferences but also provided a comprehensive dataset that reflects the immediate behavioral responses to hypothetical yet realistic changes in parking prices and waiting times. The adoption of this particular approach over others, such as observational studies or historical data analysis, was driven by the need for a controlled environment to accurately assess the impact of pricing strategies on passenger choices. The detailed and systematic approach to data collection and scenario construction is expected to yield results that offer clear insights into the cause-and-effect relationships between parking pricing and passenger behavior, thereby informing effective policy recommendations for airport parking management.

After collecting data, the data were analyzed. The number of samples taken at IKIA was 377 passengers (before boarding). The number of samples was determined using the Cochran formula through Eq. 1.

$$n = \frac{1.96^2 p(1-p)}{(a/100)^2 + 1.96^2 p(1-p)/N} \tag{1}$$

in which n is the minimum number of samples required, N is the size of the study population, a is the confidence interval width, and p is the estimated proportion of the population [49, 50].

Statistical analysis

In this research, the SP method was used. Therefore, after collecting data by questionnaire, the number of levels of each characteristic related to each level was determined. In this method, the higher the number of characteristics and their levels, the greater the number of experimental design scenarios [51, 52].

Table 1 Questionnaire scenarios

Type A questionnaire	
Price of a 24-h stop: $2	Waiting time to find a parking space: 15 min
Price of a 24-h stop: $0.7	Waiting time to find a parking space: 10 min
Price of a 24-h stop: $1.3	Waiting time to find a parking space: 25 min
Price of a 24-h stop: $2.6	Waiting time to find a parking space: 20 min
Type B questionnaire	
Price of a 24-h stop: $1.3	Waiting time to find a parking space: 10 min
Price of a 24-h stop: $2.6	Waiting time to find a parking space: 15 min
Price of a 24-h stop: $2	Waiting time to find a parking space: 20 min
Price of a 24-h stop: $0.7	Waiting time to find a parking space: 25 min
Type C questionnaire	
Price of a 24-h stop: $1.3	Waiting time to find a parking space: 20 min
Price of a 24-h stop: $2.6	Waiting time to find a parking space: 25 min
Price of a 24-h stop: $2	Waiting time to find a parking space: 20 min
Price of a 24-h stop: $0.7	Waiting time to find a parking space: 15 min
Type D questionnaire	
Price of a 24-h stop: $0.7	Waiting time to find a parking space: 20 min
Price of a 24-h stop: $2	Waiting time to find a parking space: 25 min
Price of a 24-h stop: $2.6	Waiting time to find a parking space: 20 min
Price of a 24-h stop: $1.3	Waiting time to find a parking space: 15 min

Pearman and Kroes proposed that the number of characteristics in an experiment should be limited to 6 or 7 in each option [53]. In addition, changes in characteristic values from one level to another (differences between treatments of a characteristic) should be large enough for respondents to differentiate between them, otherwise, they may not be sensitive to it. At least one experimental completion is required in each SP experiment. At the experimental completion, the experimental design is reviewed. In the SP experiment, respondents were asked to express their preference for each scenario by choosing, scoring, or ranking. Considering that the response of respondents to the designed scenarios reflects their evaluation of the characteristics under study, information can be obtained from these responses. Answers based on scoring

Table 2 Method of determining scenarios for parking prices

Case	Price	Value
Current situation when collecting the questionnaires	Current parking price	$1.3
Determining the response of passengers to the policy of encouraging the use of the parking lot	Reducing parking price by 50%	$0.7*
Determining the response of passengers to the policy of encouraging the use of public transportation modes instead of the parking lot	Increasing parking price by 50%	$2*
Determining the response of passengers to the policy of encouraging the use of public transportation modes instead of the parking lot	Increasing parking price by 100%	$2.6

*Due to the fact that the price became more tangible when asking the passenger, the price was rounded off

Table 3 Method of determining scenarios for waiting time to find a parking space

Case	Value
Common waiting time (according to average timing in peak and non-peak hours with a stopwatch)	15 min
The scenario of reducing the waiting time by 5 min (the best situation), based on timing with a stopwatch when the parking lot is quiet and there is enough parking space at the beginning of the parking lot	10 min
The scenario of increasing the waiting time by 5 min, based on timing with a stopwatch when the parking lot is half full and there is parking space in the middle parts of the parking lot	20 min
The scenario of increasing the waiting time by 10 min (the worst situation), based on timing with a stopwatch during peak passenger traffic, the parking lot being full and passengers having to park at the end of the parking lot	25 min

scenarios provide the richest type of data. Questions about personal, economic, social, and travel characteristic information of passengers were provided in the data analysis of SP, and descriptions of behavioral responses were also used [54–56].

In discrete choice models, the utility function of option i for individual n is expressed as U_{ni}. This utility function has two parts, definite and random, and is shown in Eq. 2, which V_{ni} and ε_{ni} are the utility definite and random components of the choice of option i by individual n, respectively [57, 58].

$$U_{ni} = V_{ni} + \varepsilon_{ni} \tag{2}$$

According to Eq. 3, the decision-maker among the available options in the choice set (C_n) chooses an option that is most desirable compared to the other options. Discrete choice models usually result from the assumption that the utility is maximized by the decision-maker.

$$i \in C_n \quad if \quad U_{ni} > U_{nm} \quad \forall m \neq i \tag{3}$$

As a result, the probability that individual n chooses option i is determined by Eqs. 4 and 5.

$$P_{ni} = P\left(U_{ni} \geq U_{nm}\right) \forall m \neq i \in C_n \tag{4}$$

$$P_{ni} = P\left(\varepsilon_{nm} - \varepsilon_{ni} \leq V_{ni} - V_{nm}\right) \quad \forall m \neq i \in C_n \tag{5}$$

For modeling the data, binary, nested, and multinomial logit models were used in this research [57].

Modeling methods

Binary logit model

Many choice models are based on the economic theory of random utility. In these models, it is assumed that the choice of individuals is based on the utility of options. Therefore, the most desirable option is chosen. The utility of options is a function of their characteristics, the decision-maker characteristics, and other environmental conditions. This function has two parts, a random part and another part that is definite and measurable [59–61].

Nested logit model

In general, the multinomial logit model is based on the feature of independence of irrelevant options. This model presents incorrect results in the presence of dependencies between options. On the other hand, because the logit model is easier to use than other models, researchers have proposed a condition of this model that solves the problem of lack of independence of options. The model, called nested logit, is such that if the options are interdependent, they are placed on a different level from the other options, and other options are discussed on another level [62, 63].

Multinomial logit model

The multinomial logit model is one of the simplest and most used discrete choice models. The popularity of this method stems from the fact that it provides a closed form to express the possibility of the choice of options and is easy to interpret [64, 65]. The structure of the logit model was first used by Berkson in 1951. This model came to the attention of researchers in the 1970s after McFadden's research [66, 67]. The structure of this model was formed from the development of a binary logit structure in cases where there are several options [68].

In Eq. 2, different results will be obtained if different assumptions are made about the error term distribution. This is one of the most general and fundamental differences between discrete choice models. In obtaining the form of a multinomial logit model, it is assumed that the error terms for all options follow the Gamble distribution and are independently and identically distributed [69]. The form of the logit model will be as Eq. 6:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_{m\in C_n} V_{ni}} \tag{6}$$

The assumption of an independent and identical distribution of the error term in the logit model causes any change in the probability of the choice of an option and/or delete and add an option from/to the choice option set to have a similar effect on the probability of the choice of other options [70].

Maximum likelihood method

The maximum likelihood method involves finding the model variables in a way that maximizes the probability of observations. Therefore, if the desired probability function is of the logit type, the desired coefficients in the utility function of the various options are estimated in such a way that the probability obtained from the probability function is close to the probability obtained from the observations of the current situation [71]. Accordingly, for a sample with N observations, each of which can be chosen from k options, the likelihood function is defined as Eq. 7:

$$L(\beta) = \prod_{n\in N}\prod_{i\in C_n}\left(P_{ni}(\beta)\right)^{y_{ni}} \tag{7}$$

where y_{ni} is 1 if option i is chosen by individual n, otherwise, it is zero, P_{ni} is the probability of the choice of option i by individual n and $L(\beta)$ is the joint probability density function for the observed sample, called the likelihood function [72, 73].

A basic assumption in defining the likelihood function in this method is the assumption that the decisions of individuals are independent of each other, in which case their joint probability is equal to the product of the probabilities. By setting the first derivative of the likelihood function to zero, the values of the variables that maximize the likelihood function are obtained. Since the maximum logarithm value of a function occurs where the maximum value of the function itself occurs, and because it is easier to derive from the logarithm function, the log-likelihood function is maximized instead of the likelihood function. The first log-likelihood function and the first derivative are presented in Eqs. 8 and 9, respectively [74].

$$LL(\beta) = Log(L(\beta)) = \sum_{n\in N}\sum_{i\in C_n}\left(y_{ni} \times Ln\left(P_{ni}(\beta)\right)\right) \tag{8}$$

$$\frac{\partial(LL)}{\partial\beta_k} = \sum_{n\in N}\sum_{i\in C_N}\left(y_{ni} \times \frac{1}{P_{ni}} \times \frac{\partial P_{ni}(\beta)}{\partial\beta_k}\right) \quad \forall k \in K \tag{9}$$

where K is equal to the number of variables used in the model. By substituting the standard logit probability function (Eq. 10) into Eq. 9, this relation is obtained as Eq. 11 after the simplification.

$$P_{ni} = \frac{e^{\beta X_{ni}}}{\sum_{j\in C_n} \beta' X_{nj}} \tag{10}$$

$$\frac{\partial(LL)}{\partial\beta_k} = \sum_{n\in N}\sum_{i\in C_N}\left(y_{ni} - P_{ni}\right)X_{nik} \quad \forall k \in K \tag{11}$$

By setting Eq. 11 to zero, the best values for the parameters are obtained to maximize the likelihood function [75].

In these relations, the symbol LL is used to indicate the logarithm value of the likelihood function, for which four cases are defined:

- $LL(0)$: A state in which all coefficients in the model are zero and the share of all options (the possibility to choose any of the options) is considered equal.
- $LL(C)$: The state in which the utility function of each travel mode equals its share of the status quo (market share), or in other words, the utility function of each of the options is defined as a constant value.
- $LL(\beta)$: The state in which the coefficients in the utility functions are estimated based on the maximum likelihood method.
- $LL(*)$: The state in which the proposed model has made the future prediction very appropriate, which is assumed to be the marginal limit and cannot be achieved.

Indeed, case 4 shows the maximum amount of likelihood, in which the model is fully consistent with the observations. For comparison, it can be considered equal to $R^2 = 1$ fitting in regression models. There must be a condition in the form of Eq. 12 between the logarithm values of the likelihood function in the above-mentioned cases [76]:

$$LL(0) \leq LL(C) \leq LL(\beta) \leq LL(*) \tag{12}$$

Methods of evaluating models

Different criteria are used to evaluate logit models, some of which are mentioned below.

Likelihood ratio test To validate the binary and multinomial models, the likelihood ratio test was used. To examine the statistical significance of a model in general, a statistical comparison should be made between *LL* of the estimated model and the model without considering its behavioral variables. If *LL* of the estimated model is statistically better than that of the base model, it can be said that the model is statistically significant in general. For this purpose, the following hypothesis test (Eqs. 13 and 14) is proposed [77]:

$$H_0 : LL_{\text{base model}} = LL_{\text{estimated model}} \tag{13}$$

$$H_1 : LL_{\text{base model}} \neq LL_{\text{estimated model}}. \tag{14}$$

The likelihood ratio test statistics are presented in Eq. 15 or in another way in Eq. 16.

$$2\left(LL_{\text{base model}} - LL_{\text{estimated model}}\right) \sim X^2(\text{number of new parameters in the estimated model}) \tag{15}$$

$$2(LL(0) - LL(\beta)) > X^2_{N,1-\alpha} \tag{16}$$

where α is the significance level and N is equal to the number of parameters estimated in the model by applying constraints. If the calculated statistic value is greater than the critical chi-square statistic value at the significance level α (if Eq. 16 is established), the null hypothesis is rejected and the model is statistically significant in general [78].

Another importance of the chi-square test is the comparison between the two models. If it is assumed that in a statistical sample, two models with one type of structure (e.g., logit) are constructed and one model has more variables than the other model, the chi-square test can be used to compare the two models and determine the significance of additional variables. If the model with the higher number of variables is represented by α_b and the model with the lower number of variables is presented by α_a, Eq. 17 can be used to determine the significance of the additional variables.

$$-2\left(LL\left(\alpha_b\right) - LL\left(\alpha_a\right)\right) \sim X^2_K \tag{17}$$

in which K is the degree of freedom of the model (difference in the number of explanatory variables of the two models, i.e., $K = b - a$). The X^2_K value is compared with the critical value of X^2 distribution table and the statistical significance of the set of variables is examined [79].

Goodness of fit When estimating the initial model, the best evaluation is to check the sign of the estimated coefficients, their values, and the significance level of each variable. However, to compare the estimated models in the next steps, a goodness of fit parameter is used, which indicates the improvement or non-improvement of the subsequent models [80].

The ρ^2 statistic indicates the overall fit of the model and its types are defined based on the measurement criteria used. ρ_0^2 is equal to the difference between the logarithm of the likelihood function in the case of zero coefficients and the coefficients obtained from the method of estimating the maximum likelihood divided by the difference between the logarithm of the likelihood function in the case of zero coefficients and the coefficients obtained in the best possible case, as shown in Eq. 18 [81].

$$\rho_0^2 = \frac{LL(\beta) - LL(0)}{LL(*) - LL(0)} \tag{18}$$

The best state mentioned presents and estimates the probability of the consequence of each option in such a way that the probability of occurrence is equal to 1 in general. Accordingly, the value of $LL(*)$, which is actually $LL(1)$, will be equal to zero, and the relationship will be converted to Eq. 19 [82].

$$\rho_0^2 = 1 - \frac{LL(\beta)}{LL(0)} \tag{19}$$

Similarly, if the logarithm of the likelihood function in the case that the utility function of each option is defined constant (case 2) be considered as a reference, ρ^2 is represented as Eq. 20 [82].

$$\rho_C^2 = 1 - \frac{LL(\beta)}{LL(C)} \tag{20}$$

ρ_C^2 and ρ_0^2 are in the range between 0 and 1, where $\rho^2 = 0$ indicates that the obtained model is not better than the reference model and it is better to present the reference model, and $\rho^2 = 1$ shows that the obtained model is a perfect model [82].

Results

Statistical analysis

The number of samples taken at IKIA is 377 passengers (before boarding). Table 4 shows passenger information. The average age of passengers was 36 years, most of which were male (61%). In total, 66% of the people were traveling for recreational purposes, and 14, 10, 4, and 3% of passengers had the travel purpose of doing personal affairs, work, and education, respectively, and the rest had other purposes. Also, a large percentage of passengers (92%) traveled from their personal home to the airport and the rest traveled from acquaintances' homes (7%) and hotels (1%). In addition, based on the information obtained from the questionnaires, the average travel time of passengers was 17 days. 34% of passengers came to the airport by personal vehicle and parked their vehicle in the parking lot, and 16, 15, 9, and 7% of passengers came to the airport by rental car, taxi, bus, and Metro, respectively. Moreover, 19% of passengers were taken to the airport by acquaintances. The desire of passengers to reach the airport was to use a personal vehicle that had either parked the vehicle in the parking lot or the vehicle had been returned to a personal home by friends and acquaintances. Also, the average number of family members in the collected statistical data was equal to 4 people.

The dependent variable for modeling was whether airport parking pricing is effective in changing the way of ground access of passengers from personal vehicles to public transit and paratransit. Moreover, the independent variables used in modeling the effect of airport parking pricing were divided into three general categories of individual characteristics, parking conditions, and transportation mode, according to Table 4. In addition, 22 independent variables were examined to investigate the effect of price on changing the way of ground access of passengers, as shown in Table 4, in which the description of the variables was specified.

Binary logit model results

In this section, the results of the model of the effectiveness of airport parking pricing using a binary logit structure are presented. By developing multiple models and logically combining the effects of various variables, the model with the greatest improvement in the logarithm value of the likelihood function with 11 variables was finally selected as the superior model. The results of the binary logit model are presented in Table 5, indicating that the variables had significant signs, which shows that the model had the ability to analyze the response variable properly.

Analysis of the model results showed that the number of travel days (NoDay) negatively affected the choice of passengers to use a personal vehicle and park in the parking lot. The reason for this could be because of the increase in parking prices due to the rise in the number of days that the vehicle is in the airport parking lot. For travelers, particularly those on extended trips, the financial burden of long-term parking can be substantial. As the parking fees add up, the cost-effectiveness of alternative transportation options becomes more apparent. Moreover, the variable of the number of well-wishers (NoWell) in the model was significant and its coefficient had a negative sign, which indicates that passengers with more well-wishers had less tendency to choose the airport parking lot for vehicle parking. The reason for this may be that passengers who come to the airport with more well-wishers prefer that the vehicle be returned to the origin by its companions than to be parked in the airport parking lot. Thus, the number of well-wishers present not only reflects the social support of the traveler but also serves as a predictor of their parking choices, highlighting the interplay between social factors and practical considerations in travel behavior. Another variable with a positive effect on the model was the travel purpose of drivers (Purpose), which showed that people who traveled for recreational purposes or to meet acquaintances were more likely to park their vehicles in the airport parking lot.

Table 4 Variables studied in the research

No	Variable	Description	No	Variable	Description
1	NoDay	Number of travel days	12	Gen	Gender
2	NoWell	Number of well-wishers	13	Job	Job
3	Destination	Travel destination	14	Edu	Education
4	Purpose	Travel purpose	15	Age	Age
5	Origin	Travel origin	16	Mar	Marital status
6	Home	Passenger's place of residence	17	NoFam	Number of family members
7	Mode	Mode choice to reach the airport	18	VehType	Vehicle type
8	TT	Duration of arrival at the airport	19	NoVeh	Number of vehicles
9	NoOcc	Number of vehicle occupants	20	Price	Parking price
10	NOTrip	Number of travels in the last 6 months	21	WaTime	Waiting time
11	NoBag	Number of baggage	22	Choice	Choice of travel mode

Table 5 Results of binary logit model of the effectiveness of airport parking pricing

Variable	Coefficient (β_i)	Standard error	Sig. level
Constant	7.4091	0.8201	0.0000
NoDay	– 0.2154	0.0365	0.0000
NoWell	– 1.4129	0.2017	0.0000
Purpose	0.2547	0.1039	0.0131
Origin	– 1.2865	0.3122	0.0022
Home	– 1.1693	0.1824	0.0000
Mode	– 1.1172	0.0744	0.0000
NoOcc	– 0.4357	0.1042	0.0000
Edu	0.3839	0.1132	0.0008
NoFam	0.2815	0.0922	0.0019
Mar	– 0.5843	0.2569	0.0234
Price	– 0.2482	0.0169	0.0000

Parameter	Description	Result
$LL(0)$	Likelihood logarithm (equal share of coefficients)	– 1045.2641
$LL(C)$	Likelihood logarithm (market share)	– 937.9724
$LL(\beta)$	Likelihood logarithm (model coefficients)	– 423.1073
ρ_0^2	Fit criteria of the estimated model compared to the model with zero coefficients	0.5952
ρ_C^2	Fit criteria of the estimated model compared to the model with a constant parameter	0.5483
$-2 \times [LL(0) - LL(\beta)]$	Likelihood ratio test of equal share	1244.3141
$-2 \times [LL(C) - LL(\beta)]$	Likelihood ratio test of market share	1029.7435
AIC		3.017

The results of the binary logit model also showed that the variable of origin of travel to the airport (Origin) had a significant negative sign, which means that if the passenger travels from a personal home, the probability of parking the vehicle in the parking lot increases. Also, the negative sign of the variable of the place of residence of passengers (Home) in the model indicates that if the passenger lives in Tehran, the probability of choosing a parking lot decreases. The reason for this can be that because of the proximity of the place of residence to the airport, the passenger tends to choose other modes of transportation to reach the airport. In examining the effect of choosing the mode of transportation to IKIA (mode), the negative sign of this variable shows that choosing a personal vehicle to go to the airport had a negative effect on the choice of parking in the airport parking lot with different scenarios. Also, the analysis of the results regarding the variable of the number of vehicle occupants (NoOcc) with a significant negative sign indicated that increasing the number of occupants and the presence of companions in the vehicle made the passenger more likely to choose the airport parking lot for vehicle parking.

The results also showed that the variable of education level (Edu) had a significant positive effect on the model, so by increasing the education level, passengers were more inclined to park in the airport parking lot. Another variable with a positive effect on the model was the number of family members (NoFam), so the higher the number of family members, the more likely it is that the passenger parks the personal vehicle in the airport parking lot. According to the model, it can also be seen that the variable of marital status (Mar) had a significant role with a negative sign in the model. Accordingly, married people were more inclined to park their personal vehicles in the airport parking lot. Finally, according to the results of the model in the investigation of the parking price (Price) in different scenarios, it was revealed that increasing the parking price reduced the choice of parking in the parking lot, which is due to increased passenger costs.

Validation and sensitivity analysis of binary logit model

One of the most basic validation tests to evaluate the logit model is to check the amount and sign of the calculated coefficients. As shown in Table 5, all coefficients of the models had acceptable signs and values. Also, according to the p-value statistic to determine the level of significance of each explanatory variable of the model with a certain confidence level, all explanatory variables of the model were significant at the 95% confidence level. Moreover, the likelihood ratio test to validate the whole model showed that the explanatory nature of the binary logit model with respect to the equal share of 1244.3141 and market share of 1029.7435 against the critical value of 24.7294 was significant at a 95% confidence level. In terms of the Akaike information criterion (AIC), the final model was in a much better condition than the original models, and these values were gradually decreased, indicating that the model was appropriate. It should be noted that AIC is presented according to the effect of the number of parameters and the likelihood function, which indicates the amount of information lost by the model, and therefore, the smaller the value of the AIC evaluation criterion, the better and more appropriate the model is compared to the other models [83]. Also, another validation method for the binary logit model is the ρ_C^2 index. Given that the value is expected to range from 0 to 1, the achieved value of 0.5483 for the ρ_C^2 index is regarded as satisfactory.

In order to indicate the effect of each independent variable on the dependent variable, sensitivity analysis was performed [42]. As can be seen in Table 6, the variables of Origin and Home had the greatest impact on passenger choice for parking in the airport parking lot because they had the highest amount of elasticity. The NoDay variable had the least impact.

Table 6 The elasticity of independent variables for the binary logit model

No	Variable	Elasticity amount
1	NoDay	−0.00309
2	NoWell	−0.00215
3	Purpose	0.00387
4	Origin	−0.01930
5	Home	−0.01911
6	Mode	−0.01656
7	NoOcc	−0.00647
8	Edu	0.00572
9	NoFam	0.00429
10	Mar	−0.00873
11	Price	−0.00361

In the last step, the sensitivity of changes in parking prices on the possibility of choosing a personal vehicle park was examined and analyzed. Regarding the relationship between the parking price and the condition of the vehicle park, it is expected that with the increase in price, the vehicle parking will decrease. According to Fig. 1, if the parking price is equal to $3 and the other parameters have their average value, vehicle parking will not take place in the parking lot and if the parking price is reduced to $0.1 in the same conditions, it is 100% likely that passengers will use the vehicle parking.

Nested logit model results

In this study, due to the greater complexity of passengers concerning individual characteristics, parking choices, and transportation modes, binary models can not completely meet the purpose. Therefore, in the next step, a more complex model was developed. Among the more accurate and complex models for identifying the choice framework of users and their desirability, the nested logit model can be mentioned [84, 85]. In this model, the existing relationships among the choice options of users should be examined and, as far as possible, the related options should be placed in a nest. In fact, this model, considering the dependence between the parameters, reveals more accuracy in the results and expresses the overlap of homogeneous options well. Therefore, in this study, three nests were created. The first nest was for travelers who choose the parking lot, the second nest was for those who choose a personal vehicle (disembarked by others), rental car, and taxi, and the third nest was for passengers who choose the bus and Metro. The structure

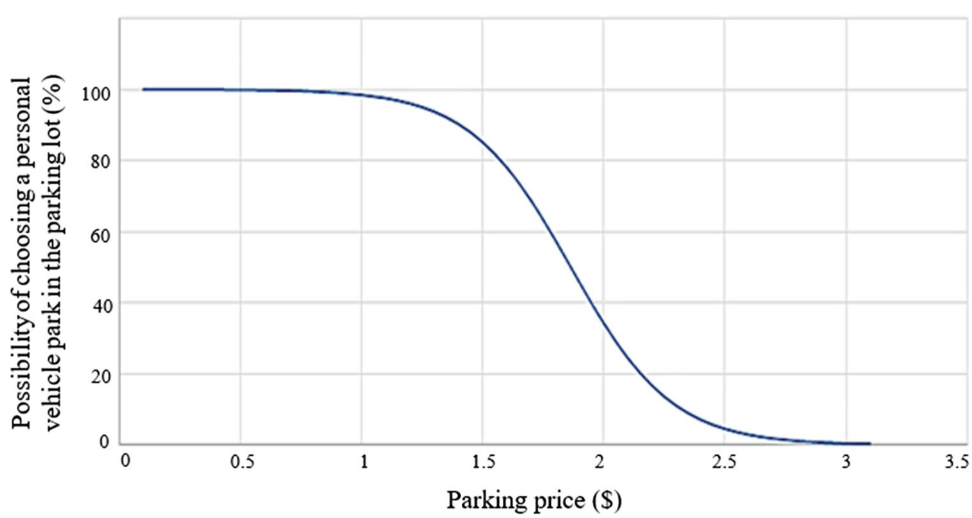

Fig. 1 The effect of increasing the parking price in personal vehicle parks

of the three nests is represented in Fig. 2, and described in more detail in the following:

- The first nest (parking choice):
  - Option 1: The passenger chooses the airport parking lot (first choice).
- The second nest (personal vehicle, rental car, and taxi choice):
  - Option 2: The passenger chooses a personal vehicle, who is disembarked from the vehicle of acquaintances and friends at the airport and the vehicle returns to the origin (second choice).
  - Option 3: Rental car, such as Snapp, Tapsi, etc. (third choice).
  - Option 4: Taxi (fourth choice).
- The third nest: Other modes of transportation (bus and Metro choice).
  - Option 5: Bus (fifth choice).
  - Option 6: Metro (sixth choice).

As shown in Fig. 2, the six options in each scenario were converted into 3 nests in order to develop this model, and the subsets of each option were structurally similar. After constructing the model with the mentioned conditions, the utility functions of the options were obtained, which can be seen in Table 7. Moreover, in Table 8, the coefficients and significance level of independent variables in the utility functions of the nested logit model are illustrated. Also, the fitness indices of the model are presented in this table, which are derived from the outputs of the model.

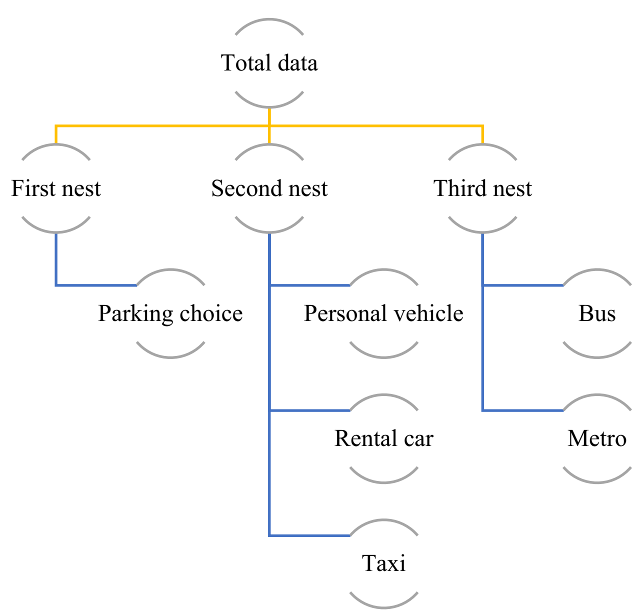

Fig. 2 Structure of the nested logit model in this study

Validation of nested logit model

A fundamental step in validating the nested model involves examining the coefficients' magnitudes and signs. Table 8 confirms that the model's coefficients had acceptable signs and values. Furthermore, the p-value statistic revealed that, at the 95% confidence level, all the variables of the nested logit model were statistically significant. Additionally, the validity of the overall model was examined by the likelihood ratio test, which indicates that the explanatory power of the nested logit model, with equal and market share values of 910.8727 and 783.5619, respectively, was significant against the critical value 22.9825 at the 95% confidence level. Also, for this model, other validation tests were examined, including the ρ_C^2 index value. Since this value should be between 0 and 1 and have an upward trend at each stage of model construction, the value obtained in this model (0.2194) can be considered appropriate. In terms of the logarithm of the likelihood function and the AIC index, the final model was illustrated to be appropriate. The next indicator, which is the most important indicator of the nested model, is the value of the inclusive value (IV) parameter of the model. This value should be less than 1. For more accuracy of the model, depending on the conditions of the problem, IV of one of the nests should be placed equal to 1, which was done in this model for the parking choice nest. After running the model, as shown in Table 8, the IV value in the nests was higher than 1, which did not change the output for other nests after repeating this operation, indicating that any increase in the utility related to the option in question (e.g., bus choice) increases the likelihood of choosing other options (e.g., Metro choice). This is contrary to the utility maximization assumption and is equivalent to creating a cross-elasticity with the wrong sign [69]. Therefore, the assumption of the nesting behavior of the options can not be confirmed, and finally, the processed nested model can not be used due to the rejection in the IV parameter test. Therefore, by removing the nests, the multinomial logit model can be used.

Table 7 Utility functions of the options in the nested logit model

Option	Utility function
Parking choice	$u(1) = \alpha + \beta_1 \times NoDay + \beta_2 \times NoWell$
Personal vehicle choice	$u(2) = \beta_3 \times NoFam + \beta_4 \times Price$
Rental car choice	$u(3) = \beta_5 \times Home + \beta_6 \times Age$
Taxi choice	$u(4) = \beta_7 \times Origin + \beta_8 \times NoOcc$
Bus choice	$u(5) = \beta_9 \times Purpose + \beta_{10} \times Edu$
Metro choice	$u(6) = \beta_{11} \times Job + \beta_{12} \times Mar + \beta_{13} \times Gen + \beta_{14} \times NoVeh$

Table 8 Coefficients and significance level of independent variables in the nested logit model

Variable	Coefficient (β_i)	Standard error	Sig. level
Constant	8.6842	1.1797	0.0000
NoDay	−0.2009	0.0352	0.0000
NoWell	−0.5858	0.1792	0.0011
NoFam	0.1012	0.0447	0.0237
Price	0.0437	0.0071	0.0000
Home	1.2220	0.2346	0.0000
Age	0.0089	0.0041	0.0325
Origin	0.3324	0.1566	0.0138
NoOcc	0.2173	0.0431	0.0000
Purpose	0.6616	0.1022	0.0000
Edu	−0.4608	0.1487	0.0021
Job	0.0572	0.0231	0.0133
Mar	0.5678	0.1671	0.0007
Gen	2.1229	0.4412	0.0000
NoVeh	0.3665	0.1905	0.0244

Parameter	Description	Result
$LL(0)$	Likelihood logarithm (equal share of coefficients)	−1852.6085
$LL(C)$	Likelihood logarithm (market share)	−1788.9521
$LL(\beta)$	Likelihood logarithm (model coefficients)	−1397.1723
ρ_0^2	Fit criteria of the estimated model compared to the model with zero coefficients	0.2458
ρ_C^2	Fit criteria of the estimated model compared to the model with a constant parameter	0.2194
$-2 \times [LL(0) - LL(\beta)]$	Likelihood ratio test of equal share	910.8727
$-2 \times [LL(C) - LL(\beta)]$	Likelihood ratio test of market share	783.5619
AIC		3.5295

IV Parameters

Parking choice	1	Fixed
Personal vehicle choice Rental car choice Taxi choice	3.5557	0.6786
Bus choice Metro choice	2.0619	0.4309

Multinomial logit model results

Since the nested logit model was rejected in the validation, the multinomial logit model was examined. In this model, each option had a separate utility function, which was ultimately obtained from the output of the model. These functions are briefly representative of their option; in other words, each represents the user choice framework for the choice of that particular option. Up to 22 variables were examined to construct the model, the variables of which could be effective in the choice options and have a positive or negative effect on the choice of users, depending on the nature of each option. In the process of developing the model, various independent variables were introduced, and according to the significance level of each variable, the final multinomial logit model consisting of the mentioned variables was constructed. Table 9 shows the utility functions obtained in relation to each option. Moreover, in Table 10, the coefficients and significance level of independent variables in the utility functions of the multinomial logit model are presented.

The results of the multinomial logit model indicated that the variable of the number of travel days (NoDay) was significant in the parking choice model ($u(1)$) and its coefficient had a negative sign, which indicates that the number of travel days had a negative effect on the parking choice. The observed negative impact is a reflection of the cost implications associated with prolonged parking. As travelers embark on longer trips, the cumulative cost of parking can become a significant financial consideration. With each passing day, the parking meter ticks, adding to the overall expense of the journey. This incremental increase in cost can act as a deterrent, prompting travelers to seek more economical alternatives. Also, according to the results of this model, it was found that increasing the number of well-wishers (NoWell) reduced the tendency of the choice of parking lots. This could be due to passengers accompanied by a larger group of well-wishers favoring the return of their vehicle to its starting point by friends or family, rather than leaving it in the airport parking lot. This behavior could be rooted in the desire for a more personal farewell or the practicality of avoiding parking fees, especially for brief trips. Moreover, the variable of parking price (Price) had a negative coefficient in $u(1)$ and had a positive sign in $u(2, 3, 4, 6)$. The negative sign of this variable indicates its negative impact on the choice of parking and its positive sign demonstrates the positive effect on the choice of other modes, such as taxi, rental car, and Metro, as well as personal vehicle choice. The negative coefficient of this variable in the parking choice model indicates that as parking prices increase, the likelihood of

Table 9 The utility functions of options in the multinomial logit model

Option	Utility function
Parking choice	$u(1) = \alpha + \beta_1 \times NoDay + \beta_2 \times NoWell + \beta_3 \times Price$
Personal vehicle choice	$\mathrm{u}(2) = \beta_4 \times NoFam + \beta_5 \times Price$
Rental car choice	$\mathrm{u}(3) = \beta_6 \times Home + \beta_7 \times Age + \beta_8 \times Job + \beta_5 \times Price$
Taxi choice	$u(4) = \beta_9 \times Origin + \beta_{10} \times NoOcc + \beta_5 \times Price$
Bus choice	$u(5) = \beta_{11} \times Purpose + \beta_{12} \times Edu + \beta_{13} \times NoVeh$
Metro choice	$u(6) = \beta_{14} \times Mar + \beta_{15} \times Gen + \beta_5 \times Price$

Table 10 Coefficients and significance level of independent variables in the multinomial logit model

Variable	Coefficient (β_i)	Standard error	Sig. level
Constant	6.1184	0.3468	0.0000
NoDay	−0.2415	0.0388	0.0000
NoWell	−0.8322	0.1860	0.0000
Price ($u(1)$)	−0.0766	0.0224	0.0006
NoFam	0.4931	0.0445	0.0000
Price ($u(2.3.4.6)$)	0.0748	0.0188	0.0001
Home	2.2204	0.3040	0.0000
Age	0.0154	0.0071	0.0315
Job	−0.0802	0.0242	0.0010
Origin	1.0133	0.1653	0.0000
NoOcc	0.1530	0.0641	0.0171
Purpose	1.0686	0.2841	0.0002
Edu	−0.5841	0.2476	0.0183
NoVeh	−2.4867	1.4535	0.0071
Mar	0.8489	0.2104	0.0001
Gen	1.3675	0.2292	0.0000

Parameter	Description	Result
$LL(0)$	Likelihood logarithm (equal share of coefficients)	−2701.9734
$LL(C)$	Likelihood logarithm (market share)	−2802.8657
$LL(\beta)$	Likelihood logarithm (model coefficients)	−1342.1962
ρ_0^2	Fit criteria of the estimated model compared to the model with zero coefficients	0.5035
ρ_C^2	Fit criteria of the estimated model compared to the model with a constant parameter	0.5278
$-2 \times [LL(0) - LL(\beta)]$	Likelihood ratio test of equal share	2719.5547
$-2 \times [LL(C) - LL(\beta)]$	Likelihood ratio test of market share	2921.3382
AIC		2.8824

travelers choosing to park at the airport diminishes. Conversely, its positive influence on choosing personal vehicles, rental cars, taxis, and the Metro suggests that as parking lots become pricier, travelers are more likely to opt for these alternatives. This shift is driven by the relative convenience, time savings, and cost-effectiveness of these options compared to expensive, long-term parking. Essentially, parking prices are a decisive factor in transport preferences, balancing on-site parking convenience against the savings from other modes of transport.

According to the model, it can be seen that the variable of the number of family members (NoFam) had a positive effect in $u(2)$, which indicates that the more family members, the more the passenger tends to choose a personal vehicle to access the airport. This pattern suggests that as families grow in size, the appeal of personal vehicles becomes more pronounced. Larger families may find that personal vehicles offer a level of convenience and cost savings that public transportation or other alternatives cannot match. Another variable with a positive effect on the model of the choice of a rental car to travel to the airport ($u(3)$) is the passenger's place of residence (Home), which increased the probability of using a rental car, such as Snapp, Tapsi, etc. if the passenger lived in Tehran. This trend may be influenced by several factors inherent to city living, such as traffic congestion, which can make driving one's own vehicle less desirable, or the availability of these services, which tend to be more abundant and reliable in larger cities. Also, the positive coefficient of the age variable (Age) in the rental car choice model indicates that the older the passenger, the more likely to use a rental car to access the airport. This could be due to several reasons. Older passengers may prioritize comfort and convenience, which rental cars provide, especially for navigating through traffic or managing luggage. Additionally, older travelers might value the reliability and predictability of a rental car service over public transportation, which can sometimes be less accommodating or more physically demanding. Also, in the case of the job variable (Job), the results of the model showed that if the passenger was a student, housewife, retired, and unemployed, he/she was more likely to use a rental car to travel to the airport. This preference could be influenced by several factors. For students, the flexibility and time-saving aspect of rental cars may align with their schedules and budget constraints. Housewives might prioritize convenience and safety, especially when managing family travel. Retirees may opt for the comfort and ease of access that rental cars provide, avoiding the physical strain of public transport. Similarly, those who are unemployed might find rental car services more accessible or cost-effective, particularly if they do not own a vehicle.

Results also indicated that in the choice of a taxi to travel to the airport ($u(4)$), the variable of travel origin (Origin) was significant with a positive effect, meaning that if the passenger left a personal home, the possibility of using a taxi by the passenger increased, maybe because the comfort and privacy of leaving the personal home could make a taxi ride more appealing. Additionally, the convenience of door-to-door service without the hassle of parking or navigating public transport can streamline the travel experience. Also, the significant positive sign of the variable of the number of vehicle occupants (NoOcc) in this utility function showed that increasing the number of occupants and the presence of companions in the vehicle made the passenger more likely to choose a taxi to travel to the airport. It represents that when passengers are not alone, the likelihood of opting for a taxi increases, which could be due to the shared cost among occupants making it a more economical option, or the social aspect of traveling together in a more private setting.

By examining the effect of travel purpose (Purpose) in $u(5)$, the results showed that passengers who had the purpose of recreation or meeting acquaintances were more likely to choose the bus as their mode of transport to the airport. This preference could be due to the cost-effectiveness of buses, which is particularly appealing for recreational travelers who may wish to allocate more of their budget to leisure activities. In addition, the bus offers a social environment that might resonate with those going to meet friends or family. Also, the variable of education level (Edu) with a significant negative sign in this utility function showed that people with a higher level of education were less likely to choose a bus mode to travel to the airport. This could be due to a variety of factors, such as higher expectations for comfort and convenience, a greater awareness of alternative transport options, or a higher likelihood of owning a personal vehicle. Additionally, those with higher education levels may have higher incomes, allowing them to opt for more private and direct modes of transport. Furthermore, the number of vehicles (NoVeh) was another significant variable that had a negative effect on increasing the probability of the choice of a bus to access the airport, which indicates that individuals with access to more vehicles were less inclined to opt for public transit options. This trend could be due to the convenience and flexibility that personal vehicles offer, particularly for those with multiple cars at their disposal.

The results of the choice of Metro mode to access the airport ($u(6)$) indicated that the marital status variable (Mar) was significant in the model with a positive sign, representing that people who were single were more likely to use the Metro to get to the airport. This finding could reflect the lifestyle and priorities of single individuals, who may favor the Metro's efficiency and cost-effectiveness over other modes of transport. Moreover, the Metro's appeal to singles could be enhanced by its alignment with their flexible schedules and possibly fewer family commitments, which allows for greater use of public transportation systems. Finally, the gender variable (Gen) with a significant positive sign in this utility function showed that men had a higher likelihood of choosing the Metro as their preferred mode of transportation to access the airport. This trend may be reflective of various socio-economic factors, such as work-related travel patterns or personal preferences for speed and convenience offered by the Metro. It also suggests that men might prioritize the efficiency and reliability of the Metro when making travel decisions.

Validation and sensitivity analysis of multinomial logit model

In examining the value and sign of the coefficients of the variables in the multinomial logit model, the results revealed that all the coefficients of the models had acceptable signs and values. The likelihood ratio test also showed that the explanatory nature of the multinomial logit model was significant against the critical value of 29.1473 in terms of the equal share of 2719.5547 and market share of 2921.3382, at a confidence level of 95%. The AIC parameter as a model fit index showed that to choose the model with the lowest AIC value, initially this index was equal to 1.3561, which decreased in the next steps and finally reached 2.8824. On the other hand, in the sensitivity analysis, the sensitivity of each significant option to changes in parking prices in the equation $y = 1$ was discussed. Regarding the relationship between parking choice and price, of course, it is expected that with the increase in price, the share of parking choice will decrease and the share of other options will increase. Figures 3, 4, 5, 6 and 7 shows the diagrams of probability changes of choosing access modes to the airport with increasing parking prices. According to Fig. 3, if the other variables have their average value, with increasing the parking price, the probability of the choice of a parking lot decreases with a relatively significant slope. At the price of \$6.5, the passenger will choose the parking lot with a probability of zero, and at the price of \$0.1, the possibility of the parking choice by the passenger will increase to 47%. Also, according to Figs. 4, 5, 6 and 7, if the parking price increases to \$2, the probability of choosing a parking lot at the airport will decrease by about 30% and the probability of choosing a personal vehicle (disembarked by friends and acquaintances), rental car, taxi, and Metro will increase by 12, 16, 22, and 8%, respectively.

Discussion

This study has provided a comprehensive analysis of the factors influencing passengers' choices of ground transportation to and from IKIA, with a particular focus on the impact of airport parking pricing. The findings from the logit models offer significant insights into the decision-making processes of travelers, highlighting the interplay between economic, social, and personal factors.

In the intricate landscape of transportation choices, the binary, nested, and multinomial logit models serve as pivotal tools for unraveling the complexities of decision-making processes. In this study, the results from these models provided a nuanced understanding of airport parking choices and their influencing factors. The binary logit model, with its focus on the dichotomy of choices, underscored the influence of travel duration and social accompaniment on parking preferences, revealing a tendency to eschew prolonged parking due to cumulative costs and favor the return of vehicles over parking. In other words, longer travel days discouraged the use of personal vehicles for airport parking, likely due to escalating parking costs. Interestingly, the presence of well-wishers also negatively influenced parking lot usage, suggesting that travelers prefer their companions to return the vehicle rather than incur parking fees. Conversely, recreational travel increased the likelihood of parking lot usage, indicating a preference for convenience. The origin of travel and residence location also played significant roles, with

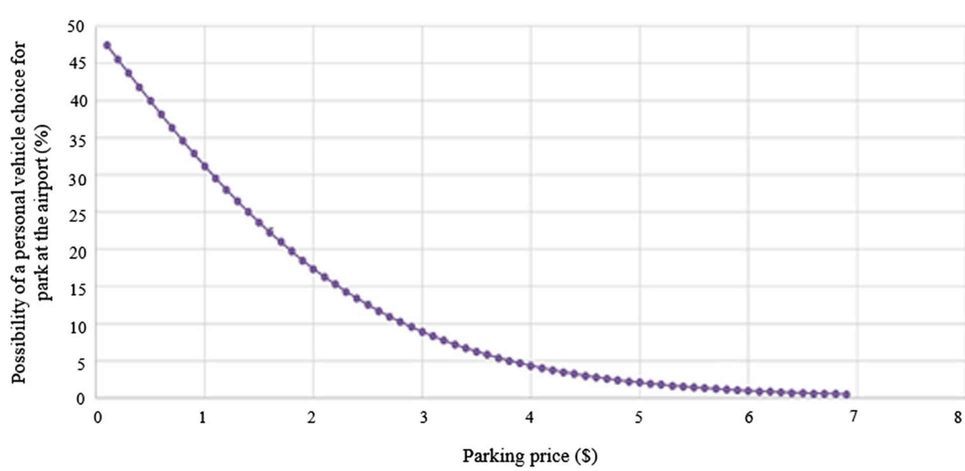

Fig. 3 The possibility of choosing a personal vehicle (park at the airport)

Fig. 4 The possibility of choosing a personal vehicle (disembarked by friends and acquaintances)

Fig. 5 The possibility of choosing a rental car mode

Fig. 6 The possibility of choosing a taxi mode

those traveling from personal homes more inclined to use the parking lot, while residents of Tehran showed a preference for alternative transportation due to proximity to the airport. On the other hand, the nested logit model, designed to capture the complexity of passenger choices, organized options into three nests: parking lot choice, personal vehicle/rental car/taxi choice, and bus/metro choice. This model accounts for the interdependencies between choices,

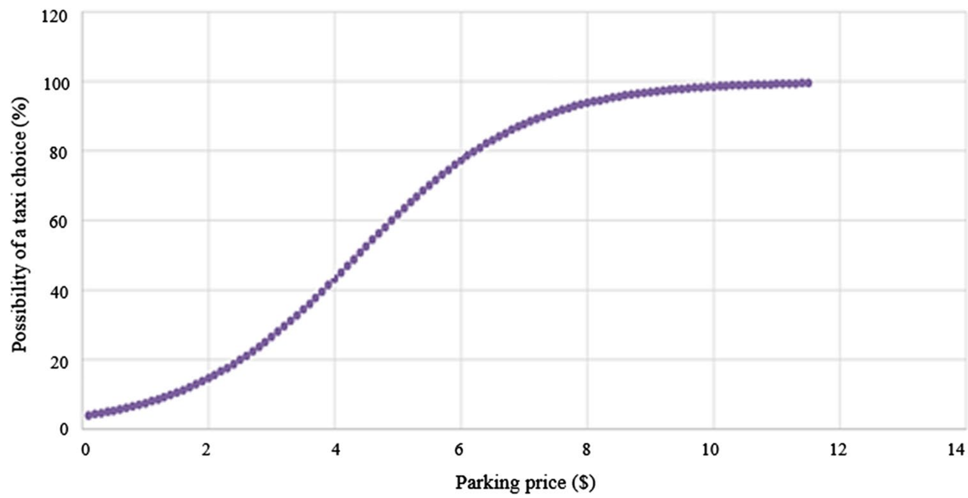

Fig. 7 The possibility of choosing Metro mode

providing a more accurate reflection of user preferences. However, the validation process revealed issues with the nesting structure, leading to its rejection in favor of the multinomial logit model, which with separate utility functions for each choice, delved deeper into the behavioral patterns of travelers. It confirmed the negative impact of travel days on parking lot selection. It also highlighted the influence of parking prices, which deterred parking lot usage while encouraging alternative modes of transport. Family size emerged as a factor increasing the likelihood of personal vehicle use, reflecting the convenience it offers larger families. The model also noted the propensity of Tehran residents to opt for rental cars and older passengers to prefer rental cars for comfort and convenience. The choice of taxis was linked to the number of vehicle occupants, suggesting a cost-sharing benefit, while the bus was favored for recreational trips due to its cost-effectiveness. Lastly, single individuals and men showed a higher likelihood of choosing the Metro mode to access the airport, emphasizing its efficiency and alignment with their travel needs.

In the realm of transportation research, the validation and sensitivity analysis of the models are pivotal for ensuring the robustness and reliability of predictive insights. In this study, the binary logit model's validation was affirmed through the logical consistency of coefficient signs and magnitudes, alongside the statistical significance of explanatory variables at a 95% confidence level, as evidenced by p-values. The model's overall validity was further corroborated by the likelihood ratio test, surpassing the critical value, and the AIC index, which demonstrated an improved fit over successive iterations. Sensitivity analysis underscored the elasticity of the Origin and Home variables, indicating their substantial influence on parking choice, while price sensitivity analysis depicted an expected inverse relationship between parking prices and the likelihood of vehicle park selection. The nested logit model, while initially showing promise through acceptable coefficient values and significant variables, encountered a stumbling block in the IV parameter test, where values exceeded unity, contravening the nesting behavior assumption and necessitating the adoption of the multinomial logit model. The multinomial logit model's validation was similarly robust, with the likelihood ratio test underscoring its explanatory power and the AIC suggesting a well-fitting model. Sensitivity analysis revealed the nuanced impact of parking price variations on the probability of selecting different airport access modes, providing a granular understanding of traveler behavior.

The comparison between the results of this study and previous literature revealed both corroborations and deviations in the factors influencing parking choice behavior. Consistent with findings by previous studies [26, 29, 35, 48], this research confirmed that parking price was a significant determinant in parking choice, with higher prices deterring the use of airport parking lots. This aligns with the consensus in the literature that pricing is a powerful tool for influencing passenger behavior. Therefore, the impact of parking pricing on the likelihood of choosing alternative modes of transport is in line with the principles of demand elasticity in transportation economics. The study's results suggest that passengers are sensitive to price changes, and this sensitivity can be leveraged to manage demand and encourage the use of more sustainable transportation options.

However, this study extended the understanding of parking choice by incorporating additional variables, such as the number of travel days and the presence of well-wishers, which were pivotal in determining whether passengers opt for airport parking or alternative modes of transportation. Longer trips and the presence of more well-wishers both decrease the likelihood of using airport parking, suggesting a cost-conscious and socially influenced approach to travel decisions. These results align with broader literature that emphasizes the importance of economic [4, 26, 29, 30, 35, 37–40] and social factors [31] in transportation choices. These findings offer a more comprehensive view of the decision-making process, highlighting the impact of social factors and trip duration on parking preferences. Furthermore, this study's emphasis on the negative impact of travel days on parking choice adds a new dimension to the literature, which has traditionally focused on the sensitivity of business and recreational travelers to travel time and costs [10, 11, 26, 29, 30, 33, 34, 39, 40, 42, 43]. It suggests that for longer trips, the cumulative cost of parking becomes a significant consideration, influencing travelers to seek alternatives.

The nested logit model's inability to capture the complexity of passenger choices in this study contrasted with the positive assessments of nested models in the literature, suggesting that the inclusion of heterogeneity and preference differences might not always enhance the predictive ability of the parking choice [27, 28]. Instead, the multinomial logit model's performance in this research underscored its utility in capturing a wide array of influential factors, resonating with the work of Ma et al. [26], Roh [30], Zaidan and Abulibdeh [34], Hess and Polak [36], Tsamboulas et al. [37], and Sobieniak et al. [39], who also utilized multinomial logit models to analyze access mode choices and found variables, such as travel purpose, parking price, number of companions, travel purpose, and passenger age, gender, vehicle ownership, and employment status, to be influential. Therefore, considering the influence of external factors on individual decision-making and behavior within a service-oriented context is important [86, 87].

In terms of policy implications, this study supported the notion that parking pricing strategies can effectively influence parking demand and mode choice, echoing the findings of Birolini et al. [47] and the Italian National Airport Plan [35], which advocated for policies encouraging the shift from private to public transportation for airport access. The significant revenue from parking facilities highlighted in this study also aligns with previous research [9, 11, 88, 89], indicating the economic importance of parking operations to airport revenue streams.

In summary, this study illuminated the multifaceted nature of airport parking choices and their sensitivity to various factors, particularly parking pricing. The insights obtained from the logit models underscore the complexity of passenger decision-making and the potential for strategic pricing policies to shape transportation behaviors. The findings advocate for a nuanced approach to parking management, one that considers the diverse needs and preferences of travelers. As airports continue to evolve and passenger volumes grow, the findings from this research will be invaluable in guiding the development of more efficient, equitable, and sustainable ground transportation systems.

Limitations and future research directions

While this study has made significant strides in understanding the determinants of long-term parking preferences at IKIA, it is important to acknowledge the limitations that may influence the interpretation of the findings and to consider the avenues for future research that can extend the knowledge in this domain. The following points outline the constraints encountered in this research and propose directions for subsequent inquiries to further elucidate the complexities of airport parking behavior and policy implications:

- *Sample size and diversity* The study's sample size of 377 passengers, while substantial, may not fully capture the diversity of the airport's user population. Future research could expand the sample to include a wider range of socio-economic backgrounds, travel purposes, and frequencies to enhance the generalizability of the findings.
- *Time constraints* The study was conducted over a limited period, which may not account for seasonal variations in travel behavior and parking preferences. Longitudinal studies could provide insights into how these preferences change over time and in response to external factors, such as economic shifts or policy changes.
- *Selection bias* The use of a stated preference approach assumes that respondents' stated intentions match their actual behavior, which may not always be the case. Future studies could incorporate observed behavior data to validate the stated preference findings.
- *Confounding variables* While the study controlled for many variables, there may be other unmeasured factors, such as marketing campaigns or changes in public transit services, that could affect parking preferences. Identifying and controlling for these variables could refine the model's accuracy.
- *Measurement error* The reliance on self-reported data introduces the potential for measurement error. Future research could use more objective data collection methods, such as tracking actual parking behavior through ticket sales or vehicle counts.
- *Using simulation in airport safety research* The current study did not employ simulation-based methodologies, which are essential in safety research. Simulations provide a controlled environment to analyze and predict the outcomes of various design and engineering decisions without real-world risks [90]. The absence of simulation in our research limits our ability to forecast the practical implications of our findings in a dynamic airport setting, which can be recommended to be applied in future research.

Ethical limitations:

- The study's methodology did not account for the potential ethical implications of increased parking fees, such as the disproportionate impact on lower-income travelers. Ethical considerations should be integrated into future pricing strategy evaluations.
- *Methodological constraints* The rejection of the nested logit model due to the IV parameter test suggests limitations in the chosen methodology. Exploring alternative modeling approaches, such as structural equation modeling (SEM) and hybrid logit models, as well as various types of statistical analyses and machine learning methods [91–94], could offer a more nuanced understanding of passenger choices.
- *Infrastructure and logistics* The study did not consider the limitations of the current infrastructure and logistics at IKIA, which could influence parking preferences and access mode choices.
- *Theoretical and empirical constraints* The theoretical framework may not fully account for the complex decision-making processes of travelers. Empirical studies that test the theoretical assumptions against real-world data could provide a more solid foundation for the study's conclusions.
- *Analytical limitations* The sensitivity analysis was based on the current pricing structure, which may not reflect future economic conditions or pricing strategies. A dynamic analytical approach that accounts for potential changes could offer more robust predictions.
- *Emerging transportation technologies* The influence of ride-sharing services on long-term parking demand and preferences can be assessed, considering their growing popularity as a convenient alternative to traditional parking. Also, the impact of autonomous vehicles on the parking demand change through drop-and-go scenarios can be investigated, potentially reducing the need for on-site parking. In addition, the potential of integrated mobility solutions that combine ride-sharing, autonomous travel, and public transportation to offer seamless door-to-door services can be explored, affecting airport parking requirements.

By addressing these limitations and pursuing the suggested future research directions, subsequent studies can build upon the current work to develop a more comprehensive understanding of airport parking behavior and its influencing factors.

Finally, it should be noted that providing specific, actionable policy recommendations based on the findings would greatly enhance the practical value of our research. To this end, some policy suggestions can be recommended, such as the introduction of a tiered pricing system, which adjusts rates during peak and off-peak hours to manage parking demand effectively. Additionally, the implementation of incentive programs can be proposed for passengers who choose public or paratransit modes, such as discounts or loyalty points. Furthermore, some successful parking management strategies can be applied to enrich the recommendations. For example, the use of license plate recognition (LPR) technology can streamline parking operations and improve user experience by allowing for frictionless access and exit. Another strategy includes camera-based parking guidance systems, which can reduce congestion and facilitate easier navigation to available parking spaces.

Conclusion

The present study investigated the parking preferences of IKIA passengers using a stated preference approach. In this regard, various price scenarios and mode choice options to access the airport were examined. The statistical analysis and modeling of the data collected were conducted using binary, nested, and multinomial logit models to evaluate the price effectiveness of parking lots. Then, the models were validated through the likelihood ratio test, and the sensitivity analysis was conducted to assess the impact of independent variables on the decision of passengers to use the airport parking facilities and to evaluate how sensitive each parking choice option is considering the changes in parking prices. The results showed that:

- According to statistical data, the desire of passengers to access the airport was to use a personal vehicle that either parked the vehicle in the parking lot or the vehicle was returned by friends and acquaintances. Also, 22 independent variables of social and individual characteristics and transportation mode were examined to investigate the effect of price on changing the way of ground access of passengers to IKIA.
- Analysis of the binary logit model results showed that passengers with more travel days and well-wishers and those who lived in Tehran had less tendency to choose the airport parking lot for vehicle parking. However, passengers with more family members who traveled for recreation or meeting acquaintances from a personal home by a personal vehicle to access the airport were more likely to park their vehicle in the airport parking lot. Moreover, although increasing the parking price reduced the choice of parking in the parking lot, by increasing the education level, passengers, especially the married ones were more inclined to park in the airport parking lot.
- The sensitivity analysis of the binary logit model was performed to indicate the effect of each independent variable on the dependent variable, so that traveling from a personal home and living in Tehran had the greatest impact on passenger choice for parking in the airport

parking lot. Furthermore, if the parking price is equal to \$3, vehicle parking will not take place in the parking lot and if the parking price is reduced to \$0.1, it is 100% likely that passengers will use the vehicle parking lot.

- The results of the nested logit model demonstrated that three nests were created in this study; the first nest was for travelers who choose the parking lot, the second nest was for those who choose a personal vehicle (disembarked by others), rental car and taxi, and the third nest was for passengers who choose the bus and Metro. The IV parameter value in the nests was higher than 1. Therefore, the assumption of the nesting behavior of the options can not be confirmed, and finally, the model can not be used due to the rejection in the IV test. So the multinomial logit model was used.
- The multinomial logit model results indicated that passengers with more travel days and well-wishers had less tendency to choose parking lots. Although the parking price negatively affected the choice of parking, it had a positive effect on the choice of other modes, such as taxi, rental car, and Metro, as well as personal vehicle choice. Moreover, the more family members, the more the passenger tends to choose a personal vehicle. On the other hand, older passengers who lived in Tehran and were students, housewives, retired, and unemployed had a higher tendency to use a rental car to access the airport.
- The results of the multinomial logit model regarding the choice of taxi mode showed that the passenger who left the personal home with more companions was more inclined to use a taxi to access the airport. Although passengers who had the purpose of recreation or meeting acquaintances were more inclined, people with a higher education level and more vehicles were less likely to choose the bus mode to access the airport. Finally, single and male passengers had more tendency to use the Metro mode to travel to the airport.
- The sensitivity analysis results of the multinomial logit model also revealed that with increasing the parking price, the probability of the choice of a parking lot decreases with a relatively significant slope. Moreover, if the parking price increases to \$2, the probability of choosing an airport parking lot will decrease by about 30% and the probability of choosing a personal vehicle (disembarked by others), rental car, taxi, and Metro will respectively increase by 12, 16, 22, and 8%.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were following the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent All subjects gave their informed consent for inclusion before they participated in the study.

References

1. Sedláčková AN, Švecová D (2018) The regional airports position within the Slovak Republic: the case study of Piešťany Airport and the proposal of measures for its revitalization. Transp Res Procedia 35:209–219
2. Sun X, Wandelt S, Zhang A (2021) Comparative accessibility of Chinese airports and high-speed railway stations: a high-resolution, yet scalable framework based on open data. J Air Transp Manag 92:102014
3. Graham A (2018) Managing airports: an international perspective. Routledge
4. Budd T, Ison S, Ryley T (2011) Airport surface access in the UK: a management perspective. Res Transp Bus Manag 1(1):109–117
5. Suárez-Alemán A, Jiménez JL (2016) Quality assessment of airport performance from the passengers' perspective. Res Transp Bus Manag 20:13–19
6. Gunay G, Gokasar I (2021) Market segmentation analysis for airport access mode choice modeling with mixed logit. J Air Transp Manag 91:102001
7. Gokasar I, Gunay G (2021) Modeling and implications of airport ground egress mode choice. KSCE J Civ Eng 25(2):669–679
8. Edrisi A et al (2020) Modelling of ground access mode choice: empirical evidence from Mehrabad International Airport, Tehran, Iran. Civ Environ Eng Rep 16(2):299–307
9. Maigha M, Crow M (2018) A transactive operating model for smart airport parking lots. IEEE Power Energy Technol Syst J 5(4):157–166
10. Akar G (2013) Ground access to airports, case study: Port Columbus International Airport. J Air Transp Manag 30:25–31
11. Tam M-L, Lam WH, Lo H-P (2011) The impact of travel time reliability and perceived service quality on airport ground access mode choice. J Choice Model 4(2):49–69
12. Lukina AV et al (2023) A new combined model for assessing the perceived accessibility of public transport by consumers in the megapolis. Emerg Sci J 7(6):2239–2259
13. Dehghani A, Alidadi M, Sharifi A (2022) Compact development policy and urban resilience: a critical review. Sustainability 14(19):11798
14. Saeidi S et al (2023) Factors affecting public transportation use during pandemic: an integrated approach of technology acceptance model and theory of planned behavior. Teh Glas 18(3):1–12
15. Dehghani A, Alidadi M, Soltani A (2023) Density and urban resilience, cross-section analysis in an Iranian metropolis context. Urban Sci 7(1):23
16. Wang T (2023) Study of optimization of tourists' travel paths by several algorithms. HighTech Innov J 4(2):402–411
17. Gokasar I, Gunay G (2017) Mode choice behavior modeling of ground access to airports: a case study in Istanbul, Turkey. J Air Transp Manag 59:1–7
18. Pasha MM, Hickman M (2016) Airport ground accessibility: review and assessment. In: 38th Australasian transport research forum (ATRF 2016)

19. Kristoffersson I, Berglund S (2020) Modelling connection trips to long-distance travel: state-of-the-art and directions for future research. VTI
20. Do Q et al (2023) Cost-weighted TF-IDF: a novel approach for measuring highway project similarity based on pay items' cost composition and term frequency. J Constr Eng Manag 149(8):04023069
21. Fadavi N (2022) Subgame perfect Nash equilibrium for dynamic pricing competition with finite planning horizon. Preprint http://arxiv.org/abs/2208.02842
22. Sun C et al (2020) Highway safety manual training. Missouri Department of Transportation. Construction and Materials Division
23. Jiang H, Zhang Y (2016) An assessment of passenger experience at Melbourne Airport. J Air Transp Manag 54:88–92
24. Evangelinos C et al (2021) The impact of airport parking fees on the tourist's airport/airline choice behavior. J Air Transp Manag 90:101961
25. Cheng C, Qi P (2019) Impact analysis of parking price adjustment on the quality of service of airport parking lots for light vehicles. J Adv Transp 2019:1–9
26. Ma X et al (2013) Parking choice behavior investigation: a case study at Beijing Lama Temple. Procedia Soc Behav Sci 96:2635–2642
27. Chaniotakis E, Pel AJ (2015) Drivers' parking location choice under uncertain parking availability and search times: a stated preference experiment. Transp Res Part A Policy Pract 82:228–239
28. Hunt JD, Teply S (1993) A nested logit model of parking location choice. Transp Res Part B Methodol 27(4):253–265
29. Qin H et al (2017) Nested logit model formation to analyze airport parking behavior based on stated preference survey studies. J Air Transp Manag 58:164–175
30. Roh H-J (2013) Mode choice behavior of various airport user groups for ground airport access. Open Transp J 7(1):43–55
31. Pels E, Nijkamp P, Rietveld P (2003) Access to and competition between airports: a case study for the San Francisco Bay area. Transp Res Part A Policy Pract 37(1):71–83
32. Shaaban K, Pande A (2015) Where did you park?: Revealed preference analysis of factors affecting parking choices in Qatar
33. Psaraki V, Abacoumkin C (2002) Access mode choice for relocated airports: the new Athens International Airport. J Air Transp Manag 8(2):89–98
34. Zaidan E, Abulibdeh A (2018) Modeling ground access mode choice behavior for Hamad International Airport in the 2022 FIFA World Cup city, Doha, Qatar. J Air Transp Manag 73:32–45
35. Cassetta E, Lo Re M, Pozzi C (2015) Efficiency performance and policies for the development of Italian airport system: a data envelopment analysis. L'industria (4):639–670
36. Hess S, Polak JW (2005) Mixed logit modelling of airport choice in multi-airport regions. J Air Transp Manag 11(2):59–68
37. Tsamboulas D, Evmorfopoulos AP, Moraiti P (2012) Modeling airport employees commuting mode choice. J Air Transp Manag 18(1):74–77
38. Harvey G (1986) Study of airport access mode choice. J Transp Eng 112(5):525–545
39. Sobieniak J et al (1979) Choice of access mode to intercity terminals. Transp Res Rec (728)
40. Castillo-Manzano JI (2010) The city-airport connection in the low-cost carrier era: Implications for urban transport planning. J Air Transp Manag 16(6):295–298
41. Foote PJ, LaBelle SJ, Stuart DG (1997) Increasing rail transit access to airports in Chicago. Transp Res Rec 1600(1):1–9
42. Cirillo C, Xu R (2010) Forecasting cybercar use for airport ground access: case study at Baltimore Washington International Airport. J Urban Plan Dev 136(3):186–194
43. Alhussein SN (2011) Analysis of ground access modes choice King Khaled International Airport, Riyadh, Saudi Arabia. J Transp Geogr 19(6):1361–1367
44. Yazdanpanah M, Hosseinlou MH (2016) The influence of personality traits on airport public transport access mode choice: a hybrid latent class choice modeling approach. J Air Transp Manag 55:147–163
45. Kanafani A, Lan LH (1988) Development of pricing strategies for airport parking—a case study at San Francisco Airport. Int J Transp Econ/Riv int di econ trasp 55–76
46. Ison S, Humphreys I, Rye T (2007) UK airport employee car parking: The role of a charge? J Air Transp Manag 13(3):163–165
47. Birolini S et al (2019) Access mode choice to low-cost airports: evaluation of new direct rail services at Milan-Bergamo airport. Transp Policy 73:113–124
48. Program, A.C.R., U.S.F.A. Administration, J. Consultancy (2009) Guidebook for evaluating airport parking strategies and supporting technologies, Transportation Research Board, 24
49. Woolson RF, Bean JA, Rojas PB (1986) Sample size for case-control studies using Cochran's statistic. Biometrics 927–932
50. Kasiulevičius V, Šapoka V, Filipavičiūtė R (2006) Sample size calculation in epidemiological studies. Gerontologija 7(4):225–231
51. Johnston RJ et al (2017) Contemporary guidance for stated preference studies. J Assoc Environ Resour Econ 4(2):319–405
52. Yan X, Levine J, Zhao X (2019) Integrating ridesourcing services with public transit: an evaluation of traveler responses combining revealed and stated preference data. Transp Res Part C Emerg Technol 105:683–696
53. Pearmain D, Kroes EP (1990) Stated preference techniques: a guide to practice
54. Jiang Y et al (2019) Capturing ownership behavior of autonomous vehicles in Japan based on a stated preference survey and a mixed logit model with repeated choices. Int J Sustain Transp 13(10):788–801
55. Rossetti T, Hurtubia R (2020) An assessment of the ecological validity of immersive videos in stated preference surveys. J Choice Model 34:100198
56. Mirbaha B, Saffarzadeh M, Mohajeri F (2018) PW 1283 investigating the willingness to pay of pedestrians to choose appropriate policies for improving the safety of pedestrian facilities. BMJ Publishing Group Ltd
57. Ng'ombe JN (2019) Economics of the Greenseeder hand planter, discrete choice modeling, and on-farm field experimentation
58. Li Y et al (2021) The real-time pricing optimization model of smart grid based on the utility function of the logistic function. Energy 224:120172
59. Fedorczak-Cisak M et al (2019) A multi-criteria approach for selecting the utility function of the historical building "Stara Polana" located in Zakopane. In: MATEC web of conferences. EDP Sciences
60. Afghari AP et al (2020) A home-based approach to understanding seatbelt use in single-occupant vehicles in Tennessee: application of a latent class binary logit model. Accid Anal Prev 146:105743
61. Regenwetter M, Davis-Stober CP (2018) The role of independence and stationarity in probabilistic models of binary choice. J Behav Decis Mak 31(1):100–114
62. Lu X-S, Liu T-L, Huang H-J (2015) Pricing and mode choice based on nested logit model with trip-chain costs. Transp Policy 44:76–88
63. Razi-Ardakani H, Mahmoudzadeh A, Kermanshah M (2018) A nested logit analysis of the influence of distraction on types of vehicle crashes. Eur Transp Res Rev 10(2):1–14

64. Matějka F, McKay A (2015) Rational inattention to discrete choices: a new foundation for the multinomial logit model. Am Econ Rev 105(1):272–298
65. Lee D, Derrible S, Pereira FC (2018) Comparison of four types of artificial neural network and a multinomial logit model for travel mode choice modeling. Transp Res Rec 2672(49):101–112
66. Lee HL, Cohen MA (1985) A multinomial logit model for the spatial distribution of hospital utilization. J Bus Econ Stat 3(2):159–168
67. McFadden D (1973) Conditional logit analysis of qualitative choice behavior
68. Kamboozia N, Ameri M, Hosseinian SM (2020) Statistical analysis and accident prediction models leading to pedestrian injuries and deaths on rural roads in Iran. Int J Inj Contr Saf Promot 27(4):493–509
69. Hensher DA et al (2005) Applied choice analysis: a primer. Cambridge University Press
70. Goranitis I et al (2021) Preferences and values for rapid genomic testing in critically ill infants and children: a discrete choice experiment. Eur J Hum Genet 1–9
71. Orth D et al (2017) A maximum likelihood method for driver-specific critical-gap estimation. In: 2017 IEEE intelligent vehicles symposium (iv). IEEE
72. Carta JA, Ramirez P, Bueno C (2008) A joint probability density function of wind speed and direction for wind energy analysis. Energy Convers Manage 49(6):1309–1320
73. Garrett D, Savransky D (2016) Analytical formulation of the single-visit completeness joint probability density function. Astrophys J 828(1):20
74. Czajkowski M, Budziński W (2019) Simulation error in maximum likelihood estimation of discrete choice models. J Choice Model 31:73–85
75. Dombry C, Ferreira A (2019) Maximum likelihood estimators based on the block maxima method. Bernoulli 25(3):1690–1723
76. Artyushenko V, Volovach V (2019) Nakagami distribution parameters comparatively estimated by the moment and maximum likelihood methods. Optoelectron Instrumen Data Process 55(3):237–242
77. Sur P, Chen Y, Candès EJ (2019) The likelihood ratio test in high-dimensional logistic regression is asymptotically a rescaled chi-square. Probab Theory Relat Fields 175(1):487–558
78. Arif F, Noor-Ul-Amin M, Hanif M (2021) Joint monitoring of mean and variance using likelihood ratio test statistic with measurement error. Qual Technol Quant Manag 18(2):202–224
79. Dou J, Aliaosha Y (2018) Optimization method of suspected electricity theft topic model based on chi-square test and logistic regression. In: International conference of pioneering computer scientists, engineers and educators. Springer
80. Eling M, Loperfido N (2017) Data breaches: goodness of fit, pricing, and risk measurement. Insur Math Econ 75:126–136
81. Kazemi A, Mirbaha B, Kordani AA (2019) Effect of on-street parking pricing on motorists' mode choice. In: Proceedings of the institution of civil engineers-municipal engineer. Thomas Telford Ltd
82. Mirbaha B et al (2014) Evaluating the Willingness to pay for urban congestion priced zones (case study of Tehran). Int J Transp Eng 1(3):199–210
83. Dennis B et al (2019) Errors in statistical inference under model misspecification: evidence, hypothesis testing, and AIC. Front Ecol Evol 7:372
84. Montgomery M (2002) A nested logit model of the choice of a graduate business school. Econ Educ Rev 21(5):471–480
85. Koppelman FS, Bhat C (2006) A self instructing course in mode choice modeling: multinomial and nested logit models
86. Edeh FO et al (2023) Impression management and employee contextual performance in service organizations (enterprises). Emerg Sci J 7(2):366–384
87. Rezaee MJ, Yousefi S (2018) An intelligent decision making approach for identifying and analyzing airport risks. J Air Transp Manag 68:14–27
88. Economics O (2011) Explaining Dubai's aviation model. A Report for Emirates and Dubai Airport
89. Consultancy J (2010) Guidebook for evaluating airport parking strategies and supporting technologies. ACRP (Airpt Coop Res Programme) Rep 22:24
90. Qi W et al. E-scooter simulator study of rider behavior and facility choice. Available at SSRN 4156403
91. Khodayari M, Razmi J, Babazadeh R (2019) An integrated fuzzy analytical network process for prioritisation of new technology-based firms in Iran. Int J Ind Syst Eng 32(4):424–442
92. Rezashoar S, Kashi E, Saeidi S (2023) Comparison of machine learning algorithms for predicting traffic accident severity (case study: United Kingdom from 2010 to 2014)
93. MacKenzie D, Malarkey D, Oshanreh MM (2023) Evaluating the effectiveness of computer vision systems mounted on shared electric kick scooters to reduce sidewalk riding
94. Khameneh RT et al (2023) A non-clustered approach to platelet collection routing problem. Comput Oper Res 160:106366