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Investigation of Factors Influencing the Transportation Mode Preferences of Academic Staff: Ege University Case

Akademik Personelin Ulaşım Türü Tercihlerini Etkileyen Etmenlerin Araştırılması: Ege Üniversitesi Örneği

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Abstract

University campus transportation plans should focus on reducing private vehicle trips, similar to strategies used in urban areas. This not only promotes an environmentally sustainable campus transportation system but also ensures safer transportation for non-motorized modes. In this context, it becomes crucial to identify the factors that influence mode choice. In this paper, by establishing a binary logit model, we estimate the factors influencing the choice of using car mode for commute trips among the academic staff of Ege University, Türkiye. The most significant variables found in this study are age, academic title, and trip durations for both car and public transportation. While sex is typically expected to play a significant role in mode choice models, it was found to be insignificant for academic staff in this study. A hypothetical scenario revealed that reducing the final walk durations from public transportation stops by half decreases the average public transportation trip duration from 38.08 minutes to 33.88 minutes, resulting in a 5% shift from private transportation to public transportation. These findings are informative and provide a basis for implementing measures to reduce car trips, thereby promoting a green university campus.

Keywords: university campus transportation plan, demand modeling, binary logit, green campus

Öz

Üniversite kampüs ulaşım planları, kentsel alanlarda kullanılan stratejilere benzer şekilde özel ulaşım yolculuklarını azaltmaya odaklanmalıdır. Böylece çevresel olarak sürdürülebilir bir kampüs ulaşım sistemi teşvik edilmekle birlikte motorsuz türler için daha güvenli bir ulaşım sistemi sağlanmış olur. Bu bağlamda, tür seçimini etkileyen faktörlerin belirlenmesi büyük önem kazanmaktadır. Bu çalışmada Ege Üniversitesi akademik personelinin iş yolculuklarında özel ulaşım türünü kullanma tercihini etkileyen faktörlerin belirlenmesi amacıyla ikili logit model kurulmuştur. Çalışma sonucunda en etkili etmenlerin yaş, akademik unvan, özel ve toplu taşıma için yolculuk süreleri olduğu görülmüştür. Türel seçim modellerinde cinsiyetin anlamlı bir parametre olması beklenirken, bu çalışmada akademik personel için anlamlı olmadığı görülmüştür. Duraklardan varış noktasına yürüme sürelerinin yarıya düştüğü, buna bağlı olarak ortalama toplu taşıma yolculuk süresinin 38,08 dakikadan 33,88 dakikaya düştüğü bir hipotetik bir senaryoda, logit model kullanılarak özel ulaşımdan toplu taşımaya %5'lik bir kayma gerçekleşeceği hesaplanmıştır. Bu bulgular, özel taşıt yolculuklarını azaltmaya yönelik tedbirlerin uygulanması ve böylece yeşil bir üniversite kampüsünün teşvik edilmesi için bir temel sağlayabilecektir.

Anahtar kelimeler: üniversite kampüsü ulaşım planı, talep modellemesi, ikili logit, yeşil kampüs

1 Introduction

An increase in the motor vehicle ownership rate, which occurs in parallel to population growth and economic condition improvements, causes an increase in transportation problems and environmental problems. This brings the necessity of proper transportation planning for cities to determine transportation-related needs to minimize environmental effects [1]. Due to their large populations and extensive areas, university campuses share transportation planning needs similar to those of cities. Even if the priorities may change, university campus transportation planning includes the main transportation planning principles, which are to determine goals, principles, recommendations, guidelines, and measures regarding the transportation system [2].

Similar to cities, university campuses should promote alternative transportation modes like public transportation or non-motorized modes rather than relying on private motorized vehicles. By reducing dependency on private vehicles, a sustainable transportation system can be implemented to create a 'green' university campus [3,4]. Therefore, it is essential to investigate the factors influencing mode preferences for commuting to university campuses.

The primary focus of plans that rely on private vehicle transportation is establishing adequate transportation infrastructure, including road networks and parking spaces. However, it is crucial to consider that private vehicle transportation is a high-cost mode of transport, impractical for short-distance trips, and a significant contributor to air pollution, noise pollution, and global warming [3].

Improving the public transportation system, implementing pedestrian-oriented transportation planning, and implementing bicycle-oriented transportation planning are the three main methods utilized in transportation planning studies to reduce traffic congestion and car dependency [5]. These three methods and other sustainable transportation planning methods applied in city plans should also be applied to

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transportation plans of university campuses that resemble cities with educational facilities, hospitals, business offices, and large populations comprising students, academic, and administrative staff [4]. For example, agreements between universities and local public transportation agencies offering students free access can reduce car dependency. This approach also helps in reducing the requirements for road networks and parking [6]. Every measure taken to reduce car dependency contributes to a sustainable transportation system, aligning with the main conventional planning goals, such as reducing trip costs, mitigating traffic congestion, and meeting parking requirements.

A mode choice model for the campus population needs to be established to conduct a planning study as mentioned above for a university campus. Therefore, analyzing the current condition of transportation infrastructure and forecasting future traffic under different scenarios regarding modifications to the transportation system is possible. Accordingly, a questionnaire data is required.

Examples of transportation planning, road network design, and parking lot planning studies based on mode choice and residence data of campus population can be seen on various university campuses around the world.

An example is a travel demand model developed for students at Arizona State University, which includes trip generation, trip distribution, and mode choice models based on questionnaire survey data [7]. This model translates campus enrollment into trips and uses a logit formulation to distribute generated trips to production zones, considering all traffic analysis zones as alternatives. The utility of choosing a zone is estimated as a linear combination of coefficients calculated in the model and the zone's spatial (i.e. distance from campus, distance from city center), demographic, economic, and accessibility measures .

A research study was conducted at Nigeria University using data from the Federal University of Agriculture [8]. A questionnaire survey was administered to 1,500 students. A multinomial logit model was used to examine the significant factors affecting modal preferences. The model identified location, waiting time at the bus stop, number of trips, cost of travel to school, and time to reach the bus stop as significant factors influencing mode choice.

Garikapati et al. [9] proposes a comprehensive framework to model travel demand associated with a large university. The travel data used in the study was collected through a survey administered to the university population at Arizona State University. The survey collected sociodemographic data, a 1-day travel diary, data on typical travel to and from the university and work, and attitudes and perceptions toward various transportation modes. Details about the survey and sample characteristics are not included in the paper. The location choice model used in this study is a multinomial logit model, while the mode choice model is a nested logit model. However, the study does not present model estimation parameters or coefficients for either the location or mode choice models limiting the ability to identify effective factors in mode choice from this study.

Hamad and Obaid [10] developed a travel demand forecasting model employing a tour-based approach rather than the traditional four-step modeling approach. This model was applied to Sharjah University City, UAE, to evaluate two scenarios aimed at reducing vehicular traffic volumes on campus. Travel data were collected using a survey designed to gather information regarding the travel patterns and characteristics of typical trips made by students, faculty, staff, and visitors. The study found that the likelihood of using private cars increases with trip distance and duration, while the likelihood of choosing active transport decreases. The model was applied to forecast demand over five years and to test two scenarios: introducing parking permits and pricing and establishing a park-and-ride facility. Among these, parking permits and pricing outperformed in terms of traffic operations and environmental performance. The study concluded that the model is effective for predicting travel demand and evaluating sustainable strategies to improve traffic operations and environmental outcomes on campus.

In a recent study [11] an integrated choice and latent variable model, composed of a latent variable model and a discrete choice model, was used to explain campus commute mode choice behavior. This model adequately addressed the role of attitudinal variables, such as pro-car, pro-bus, and pro-environmental attitudes. The campus commute data were collected from a questionnaire survey data of faculty and staff at the University of Illinois at Urbana-Champaign. Additionally, a traditional multinomial logit model without attitudinal variables was used to compare the results to the integrated choice and latent variable model.

As an example of studies on campus travel behavior, Altıntaşı and Yaman [12] developed a cost-effective alternative to the questionnaire data collection approach by using data from the RFID system installed at campus entrance gates to determine the basic characteristics of regular car users on campus. The study analyzed campus entry and exit hours and stay durations for different commuter types using RFID data, achieving a high sampling ratio of approximately 50% in a day. However, the lack of information on trip purposes and mode choice preferences limited their ability to fully identify all components of commute behaviors. While the RFID data provided valuable insights, such as distinct travel patterns among administrative staff, academic personnel, and students, this study underscores the need for a questionnaire-based approach to comprehensively capture commute behavior, as utilized in this study.

Countries with similar trip characteristics and passenger preferences offer valuable insights into understanding mode choice behavior and transportation trends. As an example, Tyrinopoulos and Antoniou [13] studied factors influencing habitual mode choices in Greece using binary probit models, with mode choice (private vs. public transport) as the dependent variable. They found a general preference for private cars, driven mainly by parking availability. Female respondents preferred cars less, while individuals aged 35–44 were more likely to use them. Work trips were the most common purpose for car use, followed by shopping and leisure. Public transport usage was most deterred by crowding and service unreliability, while high fares and poor network accessibility were found insignificant. In another study conducted in the Czech Republic [14], over 1,000 respondents were surveyed regarding their transport mode preferences. The study found that travel time is the most critical factor influencing mode choice. Among the sociodemographic and economic factors, perceptions and attitudes were strongly influenced by lifestyle, age, and health. Additionally, employed individuals were more likely to choose cars than the unemployed, while entrepreneurs predominantly used cars due to the independence they offer. A study utilizing a multinomial logit model based on survey data from five European countries, namely Hungary, Italy, Poland, Norway, and Spain, was conducted to analyze the choice between private, public, and active transportation modes [15]. In addition to identifying key factors such as travel time, cost, and sensitivity to externalities, the study emphasizes notable differences between countries. These findings suggest that transportation policies should be tailored to the specific context of each country, requiring public administrations to have a thorough understanding of citizens' behavior.

In this context, the present study seeks to contribute an analysis of transport mode choice by considering passenger and trip characteristics, specifically determining the factors influencing the transportation preferences of academic staff in Türkiye. While staff may represent a smaller proportion of the overall campus population compared to students, they are identified as the primary source of private vehicle trips to and from the university. The primary motivation of this research is to understand the reasons that discourage passengers from utilizing public transportation services, enabling decision-makers to implement sustainable transportation policy adjustments. Ultimately, this paper seeks to promote pollution-free, healthy urban college campuses by addressing the factors influencing mode choice and encouraging the use of sustainable transportation options.

Ege University is one of Turkey's oldest universities, and it has one of the largest campuses with an area of 1.7 km^2. The main campus, which is the subject of this study, has a population of about 45000, consisting of 42000 students and 3000 academic and administrative staff. The main purpose of this study is to establish a logit model by determining the factors that are effective in choosing a private vehicle as the primary transportation mode for Ege University academic staff's commute trips.

Logit models include binary logit, multinomial binary logit, and nested logit models, with the choice of model depending on the number of options available. While the binary logit model is applied when individuals face two options, multinomial and nested logit models are used for cases with more than two discrete choices. In this study, a binary logit model is developed, as only two options are considered. Binary logit models are widely used in literature due to their suitability for analyzing binary decision-making processes for various transportation preferences [16–19].

In addition to factors affecting mode choice, the ratio of staff shifting to public transportation with a change in trip duration is also investigated. The following sections include information regarding data and methods used to estimate a statistical model and analyses conducted.

2 Data and Methodology

Data used in this study was obtained from a previous study conducted by authors, in which an online survey was conducted with Ege University academic staff. The authors developed a web survey system using PHP language and MYSQL database, and a link to the survey was sent to email addresses of 1568 academic staff members who work in the main campus area. To achieve a high response and completion rate, the number of questions was limited to 14 to be answered in 2-3 minutes.

The survey questions were categorized into sociodemographic factors (gender, academic title, age, and driving license status), trip preferences (mode choice for campus trips, campus entrance gate used to determine the route, and departure time), vehicle availability (access to a private vehicle), trip details (trip duration for the campus trip, origin address), carpooling intentions (willingness to carpool for campus trips), and infrastructure evaluation (evaluation of in-campus infrastructure for both motorized and non-motorized modes and parking facilities).

Trip starting and ending locations were essential inputs in calculating commute duration in this study. Hence, survey data with insufficient residence street address details to determine trip starting location were eliminated, and 212 valid surveys were included in this study.

With a response rate of 26.1%, 410 completed survey data was collected. The adequacy of the survey data is determined using the sample size formula following previously published methods [20], as presented in Equation 1.

$$n_0 = \frac{z^2 \times p \times (1-p)}{e^2} \quad (1)$$

where z is the z-score corresponding to the desired confidence level, p is the estimated proportion, and e is the acceptable margin of error. In this study, $z = 95\%$ and $e = 0.1$ were chosen, while p was set to 0.5 to maximize the sample size. The calculated sample size using Equation 1 is 96. To account for the population size, the finite population correction factor was applied, and the sample size was recalculated as shown in Equation 2 where N is the population size [21].

$$n = \left\lceil \frac{n_0}{1+\frac{n_0}{N}} \right\rceil = \left\lceil \frac{96}{1+\frac{96}{1568}} \right\rceil = 91 \quad (2)$$

Based on these calculations, it can be concluded that the collected survey data meets the required sample size criteria, ensuring the reliability of the study results.

Survey data consists of various socio-demographic characteristics of academic staff, departure location, arrival time, transportation mode of commute trips, and ratings of several components of transportation on the campus. As per the objective of this study, the transportation mode variable (MODEPR) was coded binary: 1 for choosing a private motorized vehicle (i.e., automobile, motorcycle) and 0 otherwise (i.e., public transportation and non-motorized transportation). Socio-demographic data include sex, age, academic title, private vehicle availability (CARACCESS), and driving license holding variables (Table 1).

Table 1. Mode choice distributions for socio-demographic characteristics.

MODEPR		0		1		*Total*	
		N	*%*	*N*	*%*		
All		56	26.4	156	73.6	*N*	*%*
SEX	**Female**	31	31.6	67	68.4	98	46.2
	Male	25	21.9	89	78.1	114	53.8
TITLEGR	**1**	24	40	36	60	60	28
	2	14	25	42	75	56	26.4
	3	18	18.8	78	81.3	96	45.3
AGE	**20-29**	7	50	7	50	14	6.6
	30-39	20	28.2	51	71.8	71	33.5
	40-49	18	26.5	50	73.5	68	32.1
	50-59	11	22.9	37	77.1	48	22.6
	60+	0	0	11	100	11	5.2
CARACCESS	**No**	23	100	0	0	23	10.8

Yes	33	17,5	156	82,5	189	89.2

Age is expected to be a significant characteristic in mode choice. The age variable was categorized into 5 groups, starting from 20-29 to 60+. Other important socioeconomic characteristics, such as income and social status, must also be considered in a statistical model regarding modal split. Thus, the academic title variable (TITLEGR) was aggregated into three ordered groups representing similar income, academic rank, and perceived social status of job titles in Turkey. The title variable was coded 1 for research assistants, 2 for lecturers and assistant professors, and 3 for associate professors and full professors. The driving license holding ratio was 96%, thereby was not considered in statistical models.

Durations and costs of commute trips to the campus for private and public transportation modes were calculated using street address data. Origin and destination coordinates of trips were geolocated using various online map applications. Using trip origin-destination coordinates data, driving distance and trip durations in and out of the campus were calculated for each staff using Google Directions API [22]. In-vehicle and out-of-vehicle trip durations, number of transfers, and costs of public transportation trips for each staff were calculated manually by using the journey planner web application service that provides detailed public transportation information and trip alternatives, developed by ESHOT, the transportation agency of Izmir Metropolitan Municipality [23]. It should be noted that traffic congestion is not considered in the calculation of trip durations for both private and public transportation modes by both applications, which is a limitation of the study.

For commuters who use cars, the shortest public transport trips, and for commuters who use public transport, the shortest driving routes were chosen to calculate related data. Minimum, average, and maximum durations for private vehicle trips were 4.28 minutes, 16.10 minutes, and 58.40 minutes, respectively, and for public transportation, 10 minutes, 38.08 minutes, and 115 minutes, respectively.

At the time of the questionnaire survey, the public transportation fare was not distance-related, and one ticket fare was collected in 90 minutes independent of the number of transfers. Therefore, a variable substituting the public transportation monetary cost variable was used in statistical models, with a value of 0 for walking, 1 for trips shorter than 90 minutes, and 2 for trips with durations of 90 minutes to 180 minutes. The monetary cost of car trips could be calculated as fuel cost, using the average value of fuel consumption per kilometer. However, since this variable also reflects trip distance, in statistical models, the in-vehicle car trip cost is represented by the trip distance variable.

Factors that are effective in choosing a private vehicle as the primary transportation mode were investigated by establishing binary logit models using collected and calculated data. All variables that could be obtained from survey data and used in statistical analyses to estimate the most accurate model can be seen in Table 2.

Table 2. Variables used in statistical analyses to estimate the most accurate model.

Variable	**Description**	**min.**	**max.**	**avg.**
Socioeconomic variables				
SEX	Sex [female=0, male=1]	0	1	0.54
TITLEGR	Academic titles grouped by order [1, 2, 3]	1	3	2.17
MODEPR	Commuting by car [no=0, yes=1]	0	1	0.74
LICENCE	Holds license [no=0, yes=1]	0	1	0.96
AGE	Age groups by 10-age intervals (20-29 to 60+) [1, 2, 3, 4, 5]	1	5	2.86
Car commuting trip variables				
PR-OC-DS	In-vehicle trip distance out of the campus (meters)	572	72913	10036.09
PR-OC-TM	In-vehicle trip duration out of the campus (seconds)	173	3362	809.01
PR-IC-DS	In-vehicle trip distance on the campus (meters)	323	1950	943.01
PR-IC-TM	In-vehicle trip duration on the campus (seconds)	60	311	157.14
PR-TO-DS	In-vehicle total trip distance (meters)	1020	73731	10979.11
PRTOTMMN	In-vehicle total trip duration (minutes)	4.28	58.4	16.10
CEVPARK	Parking facilities are satisfactory (0=Strongly agree, 4=Strongly disagree)	0	4	1.10
Non-car commuting trip variables (PT: public transportation or walking)				
PTTOTMNW	In-vehicle time (minutes)	9	95	30.44
PTVEHCNT	Number of vehicles ridden	0	4	1.53
PTOUTVEH	Out-of-vehicle time (minutes)	9	35	20.31
PTINVEH	In-vehicle time (minutes)	0	86	17.78
PTTOTAL	Total trip duration (minutes)	10	115	38.08
PTPRDIFF	Car trip duration difference (minutes)	0	65	21.97
PTFARECO	Fare multiplier related to the trip duration	0	2	0.91
PTFINWLK	Walk duration from stop to the final destination (minutes)	0	23	8.41

To enhance the clarity of the methodology, the stepwise approach undertaken in this study is represented as follows:

1. Data collection and cleaning to address missing values and inconsistencies.
2. Calculation of variables representing trip durations based on trip end coordinates determined using the collected data.
3. Correlation analysis among variables for enabling the exclusion of highly correlated variables to prevent multicollinearity issues.
4. Binary logit model development through an iterative trial-and-error process, testing various combinations of variables to achieve a model that balanced accuracy with broader explanatory power.
5. Interpretation of the model to identify the significant factors affecting mode choice, with insights used to inform practical recommendations for campus transportation planning.

3 Statistical Analysis

Distinct choice models can analyze the relationship between the modal split and the characteristics of travelers and trips. In this study, the data obtained in a previous study were used to estimate the parameters of transportation mode choice of Ege University academic staff and to build a binary logit model.

The binary logit model approach was used to model whether travelers choose private motorized vehicles for commute trips or another travel mode. In other words, commuting trip mode is used as the dependent variable with a value of 1 if the traveler uses a car or motorcycle as the primary commuting mode and 0 otherwise. The collected, calculated, and organized data related to socioeconomic characteristics and trip characteristics were used as independent variables for binary logit models.

The logit value, that is, the log (to the base e) of the probability that the dependent variable is 1 [24], is calculated as presented in Equation 3.

$$Y = \text{logit}(P) = \ln\left(\frac{P}{1-P}\right) = B_0 + \sum_{i=1}^{n} B_i \times X_i \qquad (3)$$

where, B_0 is the model constant and B_i are the parameter estimates (i.e., coefficients) for the independent variables (i.e., predictors) denoted by X_i $(i = 1, \dots, n)$. The probability ranges from 0 to 1, while the logit value ranges from negative infinity to positive infinity. Solving Equation 1 for P, the equation transforms to the equation as given in Equation 4.

$$P = \frac{e^{(B_0 + \sum_{i=1}^{n} B_i \times X_i)}}{1 + e^{(B_0 + \sum_{i=1}^{n} B_i \times X_i)}} = \frac{1}{1 + e^{-(B_0 + \sum_{i=1}^{n} B_i \times X_i)}} \qquad (4)$$

where P is the probability of choosing the investigated alternative, in which the dependent variable takes the value 1. Using Equation 4 with estimated coefficients of predictors, it is possible to calculate the change of the probability with the change of parameter values. To exemplify, in this case, the change in probability of a traveler choosing the car as the commuting mode by the change of age can be calculated.

Numerous variables were used to estimate the most accurate statistical model to determine the significant predictors. In early analyses, it was seen that most of the variables were correlated with the dependent variable, they could not be used in the same model according to multicollinearity problems arising by intercorrelation between independent variables. Therefore, correlated variables, especially calculated variables regarding trip characteristics, were eliminated by removing them from models. For instance, as expected, the total driving distance and the total driving duration were correlated. Another example of correlated variables is the total driving distance and the out-of-campus driving distance, which were also correlated due to minor differences caused by short in-campus trips. Thus, more significant ones of such variables were used in models instead of using both.

While some correlations, such as those between trip characteristics, are evident as noted earlier, to provide a quantitative basis for the intercorrelations of categorical variables, a correlation analysis was conducted, and the results are presented in Figure 1. The figure demonstrates the degree of association between categorical variables obtained from questionnaire data using Cramér's V correlation coefficient. This analysis reveals a strong intercorrelation between age and academic title, which prevents them from being included in the same model, although they are two significant predictors of modal split.

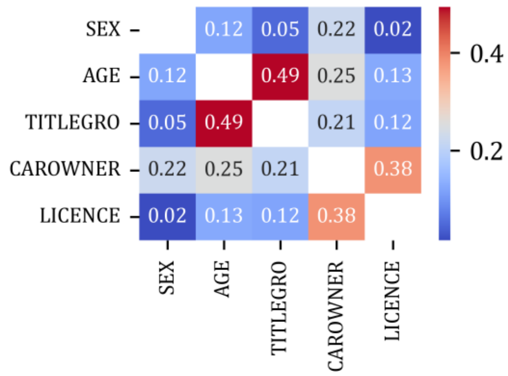

Figure 1. Cramér's V correlation matrix for categorical variables.

Due to their intercorrelation, the interaction of age and academic title variables was used to represent them both in the model. In practice, for statistical models, interaction is a new variable, with the value of multiplication of values of multiple variables. While academic title is a categorical variable, it is ordinal in nature, with higher values representing higher academic ranks. Similarly, age is grouped into ascending age categories. These ordinal properties allow both variables to be treated as numerical values for interaction purposes. Age and academic title are distinct characteristics, unlike correlated continuous variables such as total driving distance and out-of-campus driving distance or trip durations and distances that do not require interaction. While related, these two variables do not necessarily explain one another, allowing their combined effect on modal split to be meaningfully captured by an interaction variable. By contrast, combining age and academic title as an interaction variable ensures that the influence of these distinct yet interrelated predictors is effectively incorporated into the model without introducing multicollinearity.

Figure 2 shows the relationship between the age group and the academic title group, and Table 3 displays the commuter numbers and values of the interaction variable.

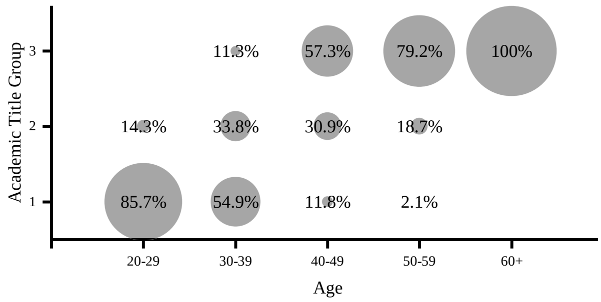

Figure 2. Age group and academic title group relationship.

Table 3. Age and title interaction variable values and commuter numbers per value.

	Title								
	1			**2**			**3**		
Age	**N**	**%**	**V**	**N**	**%**	**V**	**N**	**%**	**V**
1 (20-29)	12	85.7	1	2	14.3	2	0	0	3
2 (30-39)	39	54.9	2	24	33.8	4	8	11.3	6
3 (40-49)	8	11.8	3	21	30.9	6	39	57.3	9
4 (50-59)	1	2.1	4	9	18.7	8	38	79.2	12
5 (60+)	0	0	5	0	0	10	11	100	15

The columns labeled "V" represent the value of the variable used in statistical models.

The most accurate binary logit model was developed using collected and calculated data (Table 4) for commuting trip mode choices of Ege University academic staff. The model was estimated using STATA 13, a statistical software package.

Although the binary logit model presented in this study yields satisfactory results, it is important to note that alternative models may provide a broader understanding of the factors influencing mode choice. The model developed here primarily focuses on trip-related variables, particularly trip duration, due to the availability of data and the recognized impact of temporal cost on mode choice. These data are crucial as they directly reflect key aspects of the commuter experience, which are essential for transportation planning on campus. However, it is acknowledged that this emphasis on trip duration may not fully capture the complexity of transportation mode decisions, which are influenced by a variety of socioeconomic, psychological, and infrastructural factors.

A wider coverage model, incorporating additional socioeconomic variables, safety concerns, and environmental attitudes, could offer a more elaborate understanding of mode choice. Moreover, non-trip-related factors such as sustainability attitudes or preferences for comfort may also play an important role in shaping commuter behavior, but these variables were not captured in the current study. This limitation arises from the available data, which restricts the inclusion of such variables.

The model selection in this study was driven by the goal of achieving high accuracy while maintaining simplicity and was based on careful consideration of theoretical relevance and prior research. Additionally, potential collinearity issues were addressed by removing highly correlated variables to ensure the robustness of the model. Although alternative models with a broader range of variables might offer more comprehensive insights, the data limitations in this study constrained the ability to explore such models. Future research with more comprehensive datasets could explore these additional variables and potentially develop models that offer a more complete view of the factors influencing mode choice.

Table 4. Ege University academic staff mode choice binary logit model.

Number of observations = 212, Log likelihood = -108.83766, Pseudo R^2 = 0.1108				
MODEPR	**Coefficient**	**Std. Err.**	**z**	**P>|z|**
c.TITLEGR#c.AGE	0.0991657**	0.0420996	2.36	0.018
PRTOTMMN	-0.1450156***	0.0362857	-4.00	0.000
PTTOTAL	0.0559151***	0.0190217	2.94	0.003
_cons	0.6994656	0.4484771	1.56	0.119

***, **, * *Significance level of 1%, 5%, 10%, respectively.*

The statistical model shows that, as the value of the title and age interaction variable (c.TITLEGR#c.AGE) increases, the probability of choosing a car for commute trips increases. This outcome can be interpreted as an increase in income and an increase in the degree of social status yield to an increase in the tendency to use a car for commute trips of academic staff. Since public transportation, non-motorized vehicles, and walking are seen as low-prestigious modes of transportation in some communities, this result may be expected.

Another significant variable is the in-vehicle trip duration for car trips (PRTOTMMN). As the car trip duration increases, it can be seen that the probability of using a car for commuting trips decreases, as expected. Moreover, an increase in the car usage probability for commute trips is expected as the total trip duration for public transportation (PTTOTAL) increases.

Sex is a social role constraint that influences the responsibilities, activity requirements, and time availability of travelers [25]. In this study, sex was found to be not significant in contrast to the literature [26,27]. Thus, it can be said that sex does not affect the mode choice of academic staff. The subject group in this study not only shares similar education levels but also similar professions, which may entail similar activity requirements and time availability, affecting mode choice. Consequently, sex is not an effective variable.

Based on the statistical model built in this study, the probability of using a car for commute trips for academic staff can be calculated as given in Equation 3.

$$P = \frac{1}{1 + e^{-(0.0991657x_1 - 0.1450156x_2 + 0.0559151x_3 + 0.6994656)}} \quad (3)$$

Regarding statistical model variables found in this study for a university campus transportation planning study, it can be said that a planner who wants to shift commuters to public transportation mode cannot change the age or title of commuters (i.e., academic staff) to achieve his goal. In urban transportation plans, it is possible to increase private vehicle trip costs to shift transportation system users to public transportation. Especially in central business districts, this can be applied by limiting parking capacity to increase trip durations [28,29]. However, it is not an applicable method on the Ege University campus, which is a big area with no traffic enforcement to prevent roadside parking.

Therefore, based on the statistical model obtained in this study, the only variable in the statistical model that can be altered by the campus transportation planners seems to be the duration of the public transportation trip. With a rough estimation, in a hypothetical scenario, it is assumed that final walk durations from public transportation stops and the total time in walking trips are reduced to half. In this scenario, it is calculated that the average duration of public transportation trips decreases to 33.88 minutes from 38.08 minutes. Holding all other variables constant, using the logit model obtained (Equation 3), it can be estimated that the ratio of car users reduces from 76.2% to 71.7%, which corresponds to a shift of 71 people from private transportation to public transportation. It can be seen that with a simple improvement in the public transportation system, it may be possible to shift approximately 5% of staff to public transportation.

Figure 3 presents the results of a sensitivity analysis examining the impact of public transportation trip duration reductions on the share of private transportation mode usage. The x-axis represents the values of the title-age interaction variable, while the y-axis shows the corresponding reduction in the private transportation mode share ratio. The analysis includes eight scenarios, with trip duration reductions of 2, 4, 6, 8, 10, 12, and 14 minutes, in addition to a base case scenario. The base case is selected based on the statistically most prevalent trip duration in the collected data for private transportation (30 minutes), and the largest observed difference in trip durations between public and private transportation (14 minutes), resulting in a base case trip duration of 30 minutes for private transportation and 44 minutes for public transportation.

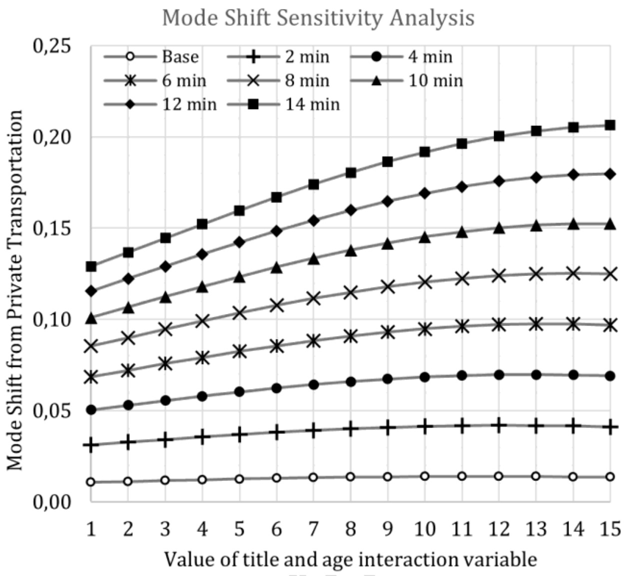

Figure 3. Sensitivity Analysis of Mode Shift Based on Public Transportation Trip Duration Reduction.

The results presented in Figure 3 reveal that the reduction in private transportation mode share is more distinctive as the value of the title-age interaction variable increases. This finding emphasizes the potential effectiveness of reducing public transportation trip durations in promoting mode shift, especially for individuals whose mode choices are more sensitive to these factors. Overall, the sensitivity analysis highlights the importance of targeting specific commuter groups and optimizing public transportation services to achieve a greater reduction in private vehicle use. Conducting similar sensitivity analyses based on the model will help optimize investments in transportation infrastructure by identifying the most effective reductions in trip durations, maximizing the mode shift to public transportation while minimizing unnecessary expenditures.

4 Conclusion

This paper aims to estimate the factors affecting academic staff's choice of a car as the primary transportation mode for commute trips. Thus, the outcomes of this study can be used to determine the necessary measures to achieve an environmentally friendly campus and assess transportation infrastructure efficiency in future studies.

Analyzing the survey data, it was found that the private transportation modal split is 74% for Ege University academic staff. A binary logit model is established using the socioeconomic data and the trip data that is calculated using the trip end coordinates. Significant variables that interact with mode choice are found to be age, title, and total trip durations for car and public transportation modes between trip ends, which is the duration of trips between the house and the destination on campus. According to the statistical model, the sex variable is not found to be significant in the mode choice of academic staff.

Statistical analyses show that the only variable that can be altered by planners for reducing car trips is to enhance public transportation facilities since age, title, car trip duration, and public transportation trip duration out of campus cannot be changed by campus plans. The developed model, capable of calculating mode shifts based on trip durations, can be utilized to optimize investments in alternative transportation modes, avoiding redundant expenditures that would result in only marginal increases in mode shifts. In a hypothetical scenario, implementing a shuttle service on campus, which reduces the average public transportation trip duration by approximately 4 minutes, may yield a mode shift to public transportation by 5%. In addition to enhancing in-campus public transportation facilities, staff and students can be encouraged not to use cars by providing cheap or free staff and student transportation services managed by the university administration. Also, obligatory measures such as restraining car entrances to campus or paid entrances can be applied. By taking essential measures and making more radical changes in transportation policies of university campuses, it can be possible to achieve more sustainable and safe transportation, complying with the green campus approach.

Achieving a mode shift from private car use to sustainable transportation modes requires carefully designed policies supported by effective implementation strategies. Policies such as introducing shuttle services, enhancing existing public transportation services, and offering subsidized or free transportation services for academic staff and students can promote the use of more sustainable modes. However, the implementation of these policies is expected to face several barriers. Financial constraints may limit the feasibility of providing free or subsidized transportation services or restricting car access or paid parking may face resistance from stakeholders due to concerns regarding convenience and affordability. To mitigate stakeholder resistance, a participatory planning process should be adopted, engaging campus users such as academic staff, administrative staff, and students in dialogue and decision-making. Demonstrating the long-term benefits of reduced car dependency can help build consensus. Campaigns emphasizing the environmental and communal benefits of sustainable transportation policies can further foster support and cooperation among stakeholders.

Future studies could benefit from collecting more comprehensive data representing the campus population, including staff, students, and visitors. This expanded dataset may include not only socioeconomic and trip-related variables but also additional factors such as monetary costs, safety concerns, environmental attitudes, and lifestyle preferences, which would allow for a deeper understanding of the multifaceted influences on mode choice behavior.

Instead of focusing solely on mode split, future research could develop integrated models that encompass all steps of travel demand modeling. Such a holistic modeling approach would better inform transportation planning and policy decisions.

The impact of real-time transportation data and dynamic feedback systems on commuter behavior can also be explored in future studies. This type of research could evaluate how access to real-time information impacts mode shift, providing findings for integrating smart technologies into campus transportation planning.

The potential of novel approaches for demand forecasting, such as machine learning techniques, agent-based modeling, and big data analytics to improve the accuracy and reliability can also be explored.

5 Author contribution statements

In this study, Authors 1 and 2 contributed to the study conception and study design, preparation of the questionnaire survey; Author 1 contributed to the literature review, data collection, analysis and interpretation of results, and manuscript preparation; Author 2 contributed to the examination of the results and critical revision of the article.

6 Ethics committee approval and conflict of interest statement

There is no need to obtain permission from the ethics committee for the article prepared. There is no conflict of interest with any person/institution in the article prepared.

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