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Dynamics of Campus Travel Behavior under the COVID-19 Pandemic

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Abstract: The COVID-19 pandemic has shown to be a global challenge that, in addition to other effects, has influenced travel behavior. This study examines factors affecting academic travelers' mode choice before and during the pandemic and factors contributing to sustainable transportation on campus. By examining their travel patterns and behaviors, we contribute to understanding transportation preferences and identifying opportunities for sustainable transportation on university campuses. Studying academic travelers is crucial as they are significant daily travelers with a substantial impact on transportation systems and the environment. Understanding their mode choices helps transportation planners and policymakers promote sustainable transportation options. The literature has identified influential factors in making trips to university campuses, including age, gender, accommodation, cost, and travel time. However, cross-sectional studies involving comprehensive variables are lacking and the influence of the COVID-19 pandemic on transportation has not been thoroughly evaluated. To address this gap, the current study aims to evaluate novel variables, including intra-transport modes, entry permits, accessibility, parking availability, occupations, level of study, travel purpose, and visit frequency. The University of Isfahan, accessible by all modes of transport, was selected as the study area. After analyzing the questionnaire and variables using SPSS software (IBM SPSS Statistics for Windows, Version 22.0 Released 2013), travel behavior was studied by discrete choice models and the models' coefficients were estimated using NLOGIT. The finding demonstrated that using private modes (taxi, private vehicle, and active modes) increased in response to the pandemic, while using public modes (bus or subway) represented a decline. Before and during the pandemic, most people who had the same trip purpose shifted from taking the bus to using private vehicles and active transportation. Generally, people became more inclined to walk on campus during the pandemic. This study aimed to examine the travel behavior of academic travelers, who possess diverse travel choices compared with typical commuters, thus providing valuable insights into how the broader population might respond to different transportation options. The findings offer a novel perspective for university and city planners, enabling more informed decisions regarding sustainable development in campus areas.

Keywords: COVID-19; travel behavior; multi-nomial logistic; mode choice; university campuses

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1. Introduction

Reducing private vehicle travel among students and the general public can have significant environmental benefits. However, most research has focused on employees, overlooking the unique characteristics of college students [1]. Therefore, more in-depth studies are needed to understand students' travel patterns and to promote sustainable modes of transportation, particularly in reducing single-driver trips. Additionally, studying

the travel patterns of teachers, staff, and students is crucial for targeted transportation policies, pandemic response strategies, and sustainable transportation planning [2]. This study aims to fill the research gap and provide valuable insights for transportation planning and policymaking by investigating these patterns. Students represent a significant portion of the population, with distinct travel needs; understanding their travel patterns is essential for tailored transportation services and for promoting sustainable travel options. Furthermore, the share of travel to universities by students can be substantial in urban areas with large educational institutions, emphasizing the need to study this segment of travel. Students' and workers' travel behaviors differ due to schedules, distances, and trip purposes. Studying these differences enables the development of transportation solutions that meet the specific needs of each group [3]. Studying academic travelers is crucial because they represent a significant proportion of daily travelers and their travel behaviors can substantially impact transportation systems and the environment. Understanding their mode choices can help inform transportation planners and policy developers to promote sustainable transportation options and reduce single-occupancy vehicle use, which can lead to environmental benefits.

The COVID-19 pandemic, spreading rapidly across the globe, is an example of a critical situation that significantly impacts many countries. The COVID-19 pandemic was first reported in Wuhan, China in late 2019; it has since spread to numerous countries worldwide [4,5]. Many cities have implemented measures to reduce unnecessary social interactions in response to the pandemic, including banning or severely reducing intra-city and inter-city travel [6,7]. This has led to the banning of and partially restricting the use of private vehicles and public transportation (considered the riskiest areas for spreading the virus). While these measures are crucial to preventing the spread of COVID-19, they have also had adverse effects on vulnerable populations and essential workers who need to leave their homes.

Numerous studies have explored the determinants of academic travelers' mode choice for intra-campus travel under normal circumstances, identifying influential factors such as age, gender, accommodation, cost, travel time, and activity schedules. However, the traditional factors previously examined in mode choice studies may not capture the full range of influences on travel behavior, especially during the COVID-19 pandemic. Additionally, comprehensive cross-sectional studies encompassing teachers, employees, and students examining their travel patterns both on and off-campus, especially during the global pandemic and its impact on travel behavior, are lacking. Therefore, examining the factors influencing travel mode choice and developing a resilient transportation infrastructure to mitigate virus transmission is crucial. This study fills a research gap by analyzing and contrasting the factors affecting travel mode preferences, considering the diverse limitations imposed by COVID-19, such as quarantine measures, public transportation shutdowns, job closures, and traffic restrictions. These variables influence individuals' mode choice decisions during the pandemic. This research makes a distinctive and significant contribution to the existing body of the literature by offering valuable insights into travel behavior patterns during the pandemic among academic travelers. It enhances the understanding of transportation decision making and provides valuable data for formulating focused strategies to reduce driving among this specific group. The study's investigation of the diverse travel choices of academic travelers also offers the potential to gain a valuable understanding of how the broader population might respond to different transportation options, making it relevant for policymakers and transportation planners seeking to promote sustainable transportation choices in campus and urban settings.

The current research project was conducted at the University of Isfahan, Iran. The first cases of COVID-19 in Iran were reported on 19 February 2020, followed by a rapid increase in the number of cases throughout the country, affecting all provinces. One thousand one hundred and seventy-six questionnaires were distributed in six months from 2021 to 2022. The structured questionnaire included demographics and travel information before and during the COVID-19 pandemic. To reduce the answering error and the required time, the

answering algorithm was designed to delete or change the following questions based on the previous questions' answers. The data were analyzed using multi-nomial logit models.

This study fills a research gap by examining the travel behavior of academic travelers, particularly during the COVID-19 pandemic, and identifying factors influencing their mode choice. It provides insights into academic travelers' characteristics and travel patterns on and off campus. The findings emphasize the need for targeted strategies to reduce single-driver trips and promote sustainable transportation. The study informs transportation planning and policymaking, highlighting the importance of resilient infrastructure and sustainable travel options. It contributes to understanding travel behavior and suggests policies to reduce private vehicle travel and mitigate virus transmission.

The research aims to answer several questions, including:

- How inter- and intra-university passengers behave in different unexpected situations;
- How we should plan and develop policies and be prepared for these conditions;
- What are the critical factors that influence travel mode choice before and during the pandemic;
- What policies are appropriate to improve transportation during critical situations.

The subsequent sections of the study include a literature review, research methodology, results, discussion, and conclusions.

2. Review of the Relevant Literature

Only a few studies have been conducted in the field of university campus travelers about the factors affecting the choice of students' travel methods. The existing studies have only examined individual aspects separately. They primarily have focused on specific aspects or subgroups of the overall travel behavior of university populations. For example, some studies may have examined travel behavior solely among students, while others may have focused exclusively on off-campus travel or students residing on campus. While these studies may have considered multiple factors within their specific scope, they may not have comprehensively analyzed all factors influencing travel behavior across different groups and contexts. In contrast, environmental cognition analysis has been performed by several universities, including Holm Lacy College [8], University of Wales, Swansea [9], Newcastle University [10], Redland University [9], and two other campuses, including East Anglia, UK and Oxford Brooks, UK [11]. Most studies have measured energy consumption concerning university transportation and the use of its buildings, food consumption, water consumption, and waste generation [8]. Some results have reported about the area of the university space [10] and other studies have used measures based on the number of staff [8] or students [12]. While examining the travel behavior of university users, including professors, staff, and students, is of great importance when designing and prioritizing policies, this issue becomes even more critical when we face unknown and complex conditions that can drastically change travel behaviors. This knowledge is essential for developing responsive policies, designing resilient transportation systems, and mitigating the potential negative impacts of unforeseen events on travel behavior. For this purpose, it is necessary to study the impact of factors that we have not examined in the past, analyze the travel behavior in the conditions that have arisen, and compare it with the normal conditions in the past. According to another research, expanding the existing areas for development is better than creating new ones because it will reduce new pressures on transportation systems as the distance between destinations becomes shorter and the need for driving reduces [13]. Most campuses are designed to be pedestrian friendly, but a culture encouraging the desire to drive puts more pressure on university officials to expand parking lots and increase capacities and neglects the non-motorized transport infrastructure [14]. Universities have paid close attention to sustainability issues, but most of them ignore transportation and land-use issues [15–17]. However, they can influence people's travel behavior [18] and often generate much traffic in their communities [19].

Travel demand management involves multiple solutions (such as traffic calming schemes), not just traffic engineering. The most comprehensive management solutions in-

clude parking management, shared travel, combined park-and-ride schemes, high-capacity transportation, vehicle-based technologies, alternative fuels, the use of the Internet and media for online training classes, and transportation information [20]. As mentioned earlier, the fundamental goal of travel demand management is to change individual travel behavior that is affected by many factors such as structural (e.g., distance, time, cost, urban density, road characteristics, and public transport services) and individual (e.g., travel purpose and schedule) variables. Further, work, time constraints, environmental concerns, number of people, age, income, gender, attitudes, and lifestyles will affect this behavior [21–26].

Minimizing travel time can be achieved by considering destination and residential location choices. However, when focusing specifically on mode choice, using faster modes of transportation and establishing a consistent daily travel time can effectively reduce travel time [27]. Consequently, personal car travel, characterized by its expeditious nature and reliability, plays a more prominent role in university travel. Health and environmental issues do not yet seem well understood [28]. The university community's understanding of the benefits of the other modes of transportation can be enhanced by information and education campaigns that promote active transportation modes such as cycling and walking [29]. According to one study, the rate of car use for students and staff traveling to university is similar to the average car use per working day for the entire Barcelona region of Spain [30]. Universities frequently decide on land use, infrastructure, and location in a way that promotes walking or cycling [31,32]. The built environment has been highlighted as an essential factor in pedestrian and bicycle activity [33,34].

There are previous studies on academics' travel behavior; each of them focused on some variables. According to our knowledge, some researchers have compared the travel behavior of staff and students [35–37] (specifically graduate vs. undergraduate [19]) on campuses. They revealed that each group has different behaviors. In this case, there might be a lack of knowledge in analyzing the behavior of professors and different levels of students. Furthermore, the field of study of each group can also be considered. Studies were carried out on driving behavior on and off campus [35–37] and, depending on accommodation, in urban areas compared with rural areas [38]. However, they missed the chance to work on the behavioral differences in other modes such as public transportation and active modes. Some studies focused on one or two travel modes into campus each time; they worked on active modes [1,28,29,38–40], public transportation [28,38,40–42], and private modes [19,43–45]. Furthermore, studies have focused explicitly on the anticipated use of public transport in the post-pandemic era [46] and the travel behavior of university students who live on campus [47]. Many studies have focused on travel behavior in cities in the face of the COVID-19 pandemic [6,46–62]. Car use might be dominant in academic communities due to similarities with urban transportation patterns. However, the unique characteristics of drivers within these communities offer the possibility of altering this trend [29].

The literature has identified influential factors in making trips to university campuses, including age, gender, accommodation, cost, and travel time. However, cross-sectional studies involving comprehensive variables are lacking and the influence of the COVID-19 pandemic on transportation has not been thoroughly evaluated. This current study aims to evaluate novel variables to address this gap. These include on- and off-campus transportation modes, permission to use cars on campus, accessibility to on-campus modes, parking availability, occupation, educational degree, the purpose of visit, type of destinations within the university, length of attendance (history), the field of activity, and frequency of visit before and during the COVID-19 pandemic. These variables have not been evaluated in previous studies and their evaluation will provide insights into the factors influencing university students' travel mode choice in such a complex situation.

3. Methodology

This present study investigated factors affecting university travelers' choice of travel modes before and during the COVID-19 pandemic using surveys, questionnaires, analyses, and multi-nomial logit models.

The diagram of the conceptual model of the study is shown in Figure 1.

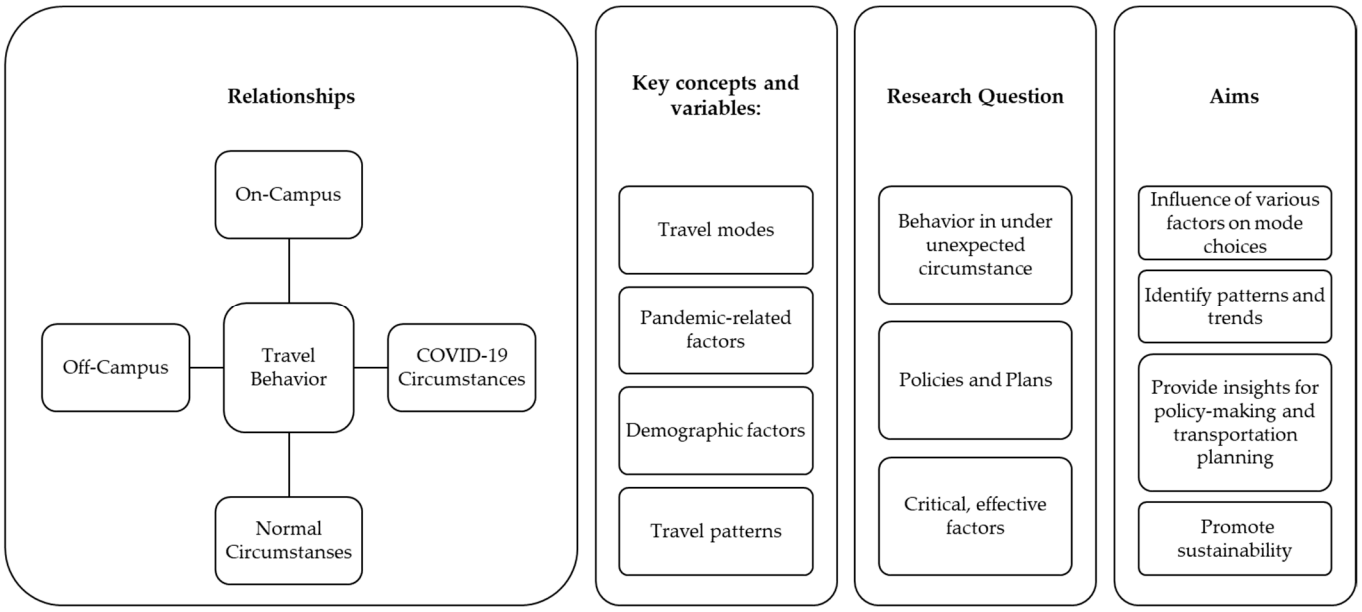


Figure 1. The diagram of the conceptual model of the study.

3.1. Questionnaire and Variable Description

The survey method used in the study involved sample selection, recruitment, and administration. The sample selection process aimed to include a diverse representation of the statistical community, including professors, students, and staff. Participants were recruited using various methods such as email invitations, online announcements, and campus-wide communications. The study relied on participants' recall of their pre-COVID travel behavior. The structured questionnaire included demographics and travel information before and during the pandemic. Including descriptive questions in the questionnaire was intended to gather more comprehensive data. By formulating the questionnaire so that subsequent questions varied based on the responses received, we aimed to elicit more specific information from participants. This approach allowed for a flexible and adaptive questionnaire design, enhancing the data collection process. Then, based on the collected answers, these answers were divided into several options after analysis and used in data evaluations. Due to limited access to the respondents and the diverse statistical community, including professors, students, and staff, data collection lasted over a semester. Table 1 presents the independent variables extracted from the questionnaire for modeling.

Before the COVID-19 pandemic refers to the period before the outbreak of the pandemic, explicitly referring to the years leading up to 2019. This timeframe represents the period when the restrictions and impact of the pandemic did not influence travel behaviors and patterns.

During the COVID-19 pandemic refers to the period when the global health crisis caused by the coronavirus disease (COVID-19) was ongoing. During this period, various measures and restrictions were implemented at both the city and university levels to control the spread of the virus and ensure public safety.

Table 1. Variables extracted from the questionnaire for modeling.

Personal Characteristics		**Before the COVID-19 Pandemic (2019 and Earlier)**		**During the COVID-19 Pandemic**	
Definition	**Variable**	**Definition**	**Variable**	**Definition**	**Variable**
Occupation	Professor	Inter mode choice (Independent)	Private vehicle	Inter mode choice (Independent)	Private vehicle
	Student studying		Taxi		Taxi
	Graduate student		Bus		Bus
	Staff		Subway		Subway
Study/work length	No. year		Active		Active
Trip distance	No. Km	Intra mode choice	Personal car	Intra mode choice	Personal car
Living	Urban/suburb		Taxi		Taxi
Age	No. year		Bus		Bus
Field of activity	Engineering		Bike		Bike
	Science		On foot		On foot
	Humanities		Motorcycle		Motorcycle
	Office work	Second destination	Shopping centers	Visit	Similar to before pandemic
Degree	PhD		Restaurant		Yes, once a week
	Master's		Library		Yes, more than once a month
	Bachelor		Religious centers		Yes, once a month
Gender	Male/female		Other		Rarely, less than once a month
Car permit	Entrance permit				No, I meet my needs virtually
	Parking permit				No, I did not need it
	None			Changing destination	Yes, it has changed
Parking	Inside the university, near the destination				No, it is the same as before the pandemic
	Parking (near the door)			Second destination	Cultural department
	Outside the university				Library
Mode change time	Less than 5 min				Educational department
	5–10 min				Official department
	10–15 min				Student department
	More than 15 min				

Here are the definitions of the variables:

Intra-mode choice: refers to the regular choice of transportation mode for trips between different locations inside the campus.

Inter-mode choice: refers to the regular choice of transportation mode for travel to the campus.

Trip distance: represents the distance traveled to the campus in kilometers (Km).

Living: describes the types of residential areas where the individual resides, categorized as urban or suburban.

Age: represents the age of the participant in years.

Field of activity: indicates the area and the geographical zone within the campus where the participant is involved, such as engineering, science, humanities, or office work.

Visit: indicates changes in the frequency of visits to specific destinations intra-campus, such as shopping centers, libraries, religious centers, etc.

Gender: represents the gender of the participant.

Car permit: Refers to the availability of an entrance permit or parking permit for the participant's vehicle. Options include "Entrance permit", "Parking permit", or "None".

Changing destination: indicates whether the participant's destination inside the campus changed during the pandemic.

Parking: describes the parking location for the participant's vehicle, such as inside the university near the destination or parking near the doors.

Second destination: represents the type of additional destination visited by the participant, such as a cultural department, library, educational department, official department, or student department inside the campus.

Mode change time: indicates the time the participant takes to change transportation modes to travel to the campus with the modes to travel within the campus during a trip.

These definitions provide an overview of the variables mentioned in the table and their respective categories or measurement scales.

The respondents of this cross-sectional study included teachers, staff, and students. Based on Cochran's formula, the required sample size for the case study is estimated by Equation (1). Further, the same number of responses is required according to the Morgan table [63].

$$n = \frac{\frac{z^2 pq}{d^2}}{1 + \frac{1}{N}\left(\frac{z^2 pq}{d^2} - 1\right)} \quad (1)$$

where n is the sample size, N is total population, Z is the selected alpha level (e.g., 1.96 for a 95% confidence level), p is the estimated proportion of an attribute that is present in the population, q is $1 - p$, d is the acceptable margin of error for the proportion being estimated [63].

In this study, N is 16741, Z is 1.96, p and q are 0.5, and d is 0.05. According to Equation (1), the case study's required sample size was 375 individuals.

The initial results and questionnaire analysis were examined with SPSS software, version 22.

3.2. Mode Choice Model

The main idea of the mode choice model is to understand any relationship between the choice made by travelers and the factors affecting that choice. According to previous evidence, mode choice has been studied by behavioral models such as discrete choice models and random maximum utility functions [64]. Utility functions present a quantitative measure for travelers. The economy-based notion of random utility forms the basis of many mode choice models. These models have assumed that transport mode, personal characteristics, and environmental conditions affect an individual's travel choice. This, together with the behavioral nature of such models, makes the discrete choice models stand better among the other models. Discrete choice models are usually used for selecting the travel mode.

Additionally, given that the dependent variable includes private vehicles, buses, taxis, the subway, and active modes, the multi-nomial logit model was selected in this study. A considerable number of research, e.g., [65,66], have asserted the credibility of the logit

model as the most popular type of the random utility model derived from the consumer economics theory initially developed by McFadden. Functionally speaking, in utility maximization behavior, an individual q selects one choice among discrete alternatives (C_q) by evaluating their associated attributes X. Moreover, the individual q selects the j that provides the maximum utility.

$$j \subset C_q \text{ if } U_{jq} \geq U_{mq}; \forall m \neq j \tag{2}$$

Practically, researchers do not see the complete utility of the individual. Hence, the utility is classified into observed (V_{jq}) and unobserved (ε_{jq}) utility sections. The observed utility typically contains two sets of attributes: covariates associated with the individual and the alternative (X_{jq}) and decision-maker characteristics (S_j). The observed or stated utility (V) is a value derived from a linear combination of the applied attributes, capturing the attractiveness of an alternative bounded to the given model specification. This is shown below:

$$V_{jq} = V(X_{jq}, S_j) \tag{3}$$

The utility function is then expressed as Equation (3):

$$U_{jq} = V_{jq} + \varepsilon_{jq} \tag{4}$$

When compared with the observed one, the unobserved utility (ε_{jq}) cannot be seen by researchers. This unobserved section mainly results from the characteristics of the observed utility (V_{jq}). Practically, statistical methods are not able to account for all possible attributes. Hence, researchers see the unobserved terms as a stochastic element. In particular conditions, the logit model is derived by assuming that each unobserved term (ε_{mq}) is independent and identically distributed extreme values, i.e., Gumbel and type 1 extreme values. A combination of the two utilities provides us with the probability of individual q choosing alternative j by solving these mathematical formulations, as shown below:

$$P_{jq} = P(U_{jq} > U_{mq}); \forall m \neq j \in C_q \tag{5}$$

$$P_{jq} = P(\varepsilon_{jq} - \varepsilon_{mq} \leq U_{jq} - U_{mq}); \forall m \neq j \in C_q \tag{6}$$

$$P_{jq} = \frac{\exp(V_{jq})}{\Sigma_{m \in C_q} \exp(V_{mq})}, V_{jq} = \beta_j X_{jq} \tag{7}$$

In the above-stated equations, X_{jq} and β_j are, in turn, the vector of observed explanatory variables for selecting a given alternative and the parameter for the observed utility. The model coefficients were then estimated using version 6 of NLOGIT software, inspired by researchers in [65,66]. The process was then continued by comparing and analyzing factors that affect the travel mode choice before and during the pandemic.

This study stands unique in terms of the survey approach, which was conducted using a complex algorithm depending on previous questions. Moreover, the methodology considers new respondents at the same time, travel behavior analysis, comparisons in different aspects, and working on new variables, marginal effects, and intrinsic values. Consequently, it made a new bright vision for policymakers and planners since the results revealed how university passengers behave in different unexpected situations for the first time.

3.3. The Study Area

The validity of the hypothesis was examined using data collected from the University of Isfahan, located in the historic city of Isfahan, Iran. This is a government-subsidized university affiliated with the Ministry of Science, Research, and Technology in Iran (Figure 2). The following results made the University of Isfahan a comprehensive and scalable case to study in terms of its potential to serve as a model or example for other academic institutes

facing similar challenges. The findings, strategies, and interventions developed based on the study of the University of Isfahan can be generalized and adapted to other institutions that share similar characteristics or face comparable circumstances. This scalability stems from the transferability of knowledge and best practices from the case study, allowing other academic institutes to learn from and replicate successful approaches to managing campus transportation.

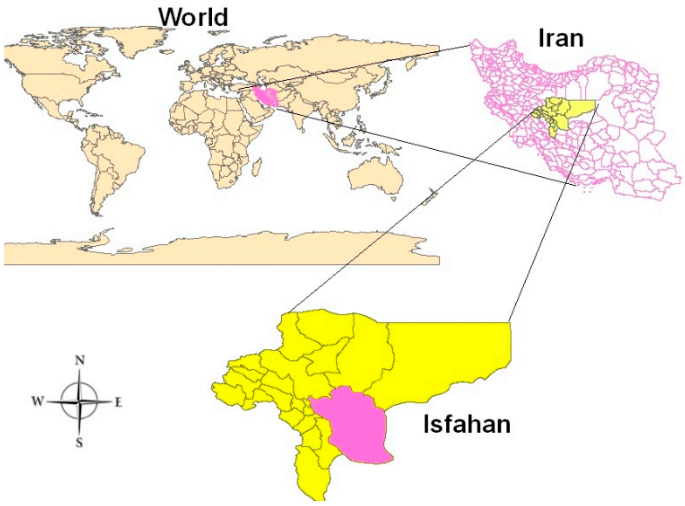


Figure 2. Isfahan's location in the world and Iran.

1. Access to different modes of transportation because it is located in the downtown area.
2. Diverse, comprehensive, and desirable statistical community.
3. Existence of a platform for the development of active modes because of the logistics of its area.
4. Extensive access to different streets due to a large number of entrances (Figure 3).

Figure 3. University's location in Isfahan.

The University of Isfahan, one of the oldest scientific and cultural centers in the center of Iran, is one of the national universities active in various fields of education and research.

Since its establishment (nearly 75 years ago), over 100,000 graduates have gained education in various fields. Currently, 670 staff, 900 professors, and 15,171 students in different bachelor's, master's, and doctorate levels are working in 14 faculties, 55 departments in engineering, humanities, sciences, and foreign language works, and 381 fields of study in this university.

Currently, the University of Isfahan has 54 scientific societies, 7 scientific poles, 10 research institutes, and 32 active research groups, as well as a central laboratory, about 190 educational and research laboratories of scientific groups, a central library, 5 faculty libraries, and 4 study halls for better use. Considering that Isfahan is located in the center of the country and the university's geographical location is in the best climatic point of Isfahan, the access of this university to different parts of the country is easily possible by various air, land, and rail transportation. Similarly, students can easily access different parts of the city through all transportation modes, such as the subway, bus rapid transit (BRT), buses, etc. Figures 4 and 5 illustrate the university's scheme, including entrances, building locations, passageways, and different zones.

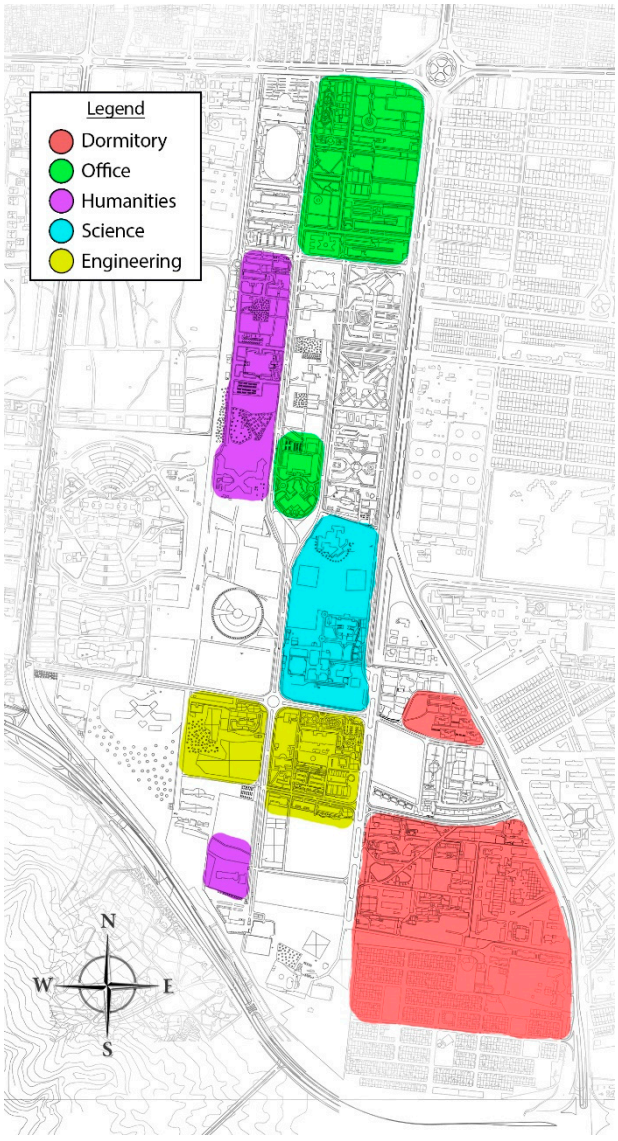


Figure 4. University's different zones.

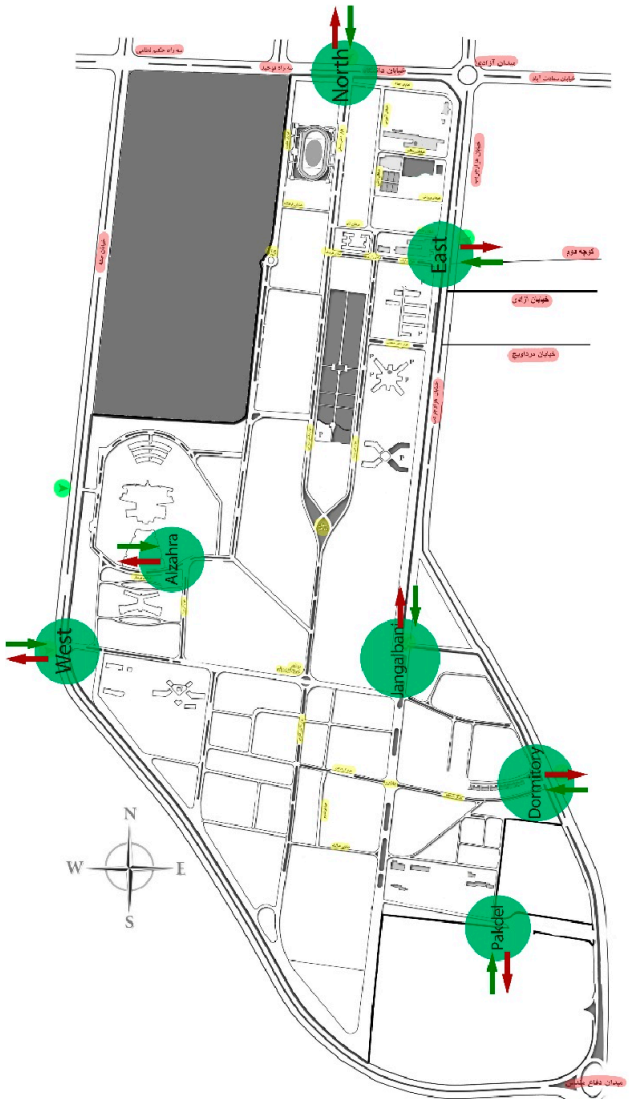


Figure 5. University's entrance, buildings, and passageways.

The sample used in this study aimed to be representative of the university population. In total, 1176 questionnaires were distributed in six months from 2021 to 2022, from which 661 were answered and delivered to the researcher. In a more accurate refinement, 647 questionnaires were complete and error-free. Notably, the sample size surpassed the required size of 375 individuals, as determined by the Cochran formula for this case study. Regarding the comparability of samples collected before and during the pandemic, data were collected simultaneously, ensuring that the respondents were similar regarding their characteristics and circumstances.

4. Results

Table 2 describes the socio-demographic characteristics of the respondents. The majority of participants are students (84.1%), followed by professors (7.4%), staff (7.6%), and others (0.9%). The sample represents a small percentage of the total student population (3.59%), professors (5.33%), and staff (7.31%). Key findings include the distribution of permits, education levels, gender, age groups, and accommodation preferences.

Table 2. Socio-demographic characteristics of samples.

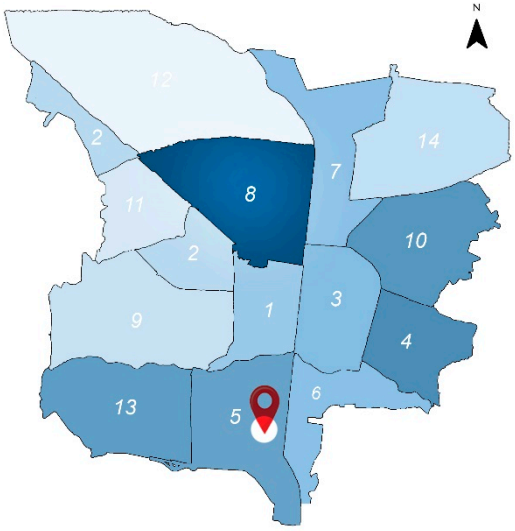
Variable			%	Number
Occupation	Professor		7.4	48
	Student		84.1	544
	Staff		7.6	49
	Other		0.9	6
Education	Students	PhD	6.2	40
		Master	15.9	103
		Bachelor	61.7	399
	Professor/Staff		15.0	97
	Other		1.2	8
Gender	Female		58.0	375
	Male		41.3	267
	Other		0.8	5
Age	18–24		64.8	419
	24–30		13.0	84
	30–36		5.3	34
	36–42		4.3	28
	42–48		5.3	34
	>48		3.4	22
	Other		4.0	26
Accommodation	On campus		27.0	175
	Urban		53.9	349
	Suburb		15.8	102
	Other		3.2	21
Study/work zone	Engineering		33.69	218
	Science		18.24	118
	Humanities		41.42	268
	Office		4.02	26
	Other		2.63	17

4.1. Travel Behavior

The percentages of different travel origins (in the urban area) are depicted in Figure 6.

Figures 7 and 8 display the percentages of using different modes to travel to the campus before and during the pandemic and the different modes used to travel within the campus between various destinations, respectively.

Figure 7 shows that before the COVID-19 pandemic, 25% of people used private vehicles, while 12% used taxis, 38% used buses, 18% used subways, and 6% used active modes. During the COVID-19 pandemic, there has been a significant shift in the mode of transportation used. The percentage of people using private vehicles has increased to 45%, while the percentage of people using taxis has increased slightly to 15%. On the other hand, the percentage of people using buses has decreased to 20% and the percentage of people using subways has reduced to 13%. The rate of people using active modes has remained the same at 6%. Using a private vehicle for commuting to university has significantly increased during the pandemic, while using bus and subway modes has shown a decrease, which is in line with [67].



Origin	% No. Trips
Region 1	5.2%
Region 2	3.4%
Region 3	6.3%
Region 4	8.3%
Region 5	7.4%
Region 6	6.1%
Region 7	6.1%
Region 8	11.0%
Region 9	2.7%
Region 10	7.9%
Region 11	1.8%
Region 12	0.4%
Region 13	7.6%
Region 14	2.8%

Figure 6. Origins of travel to university (the area of residence within the city).

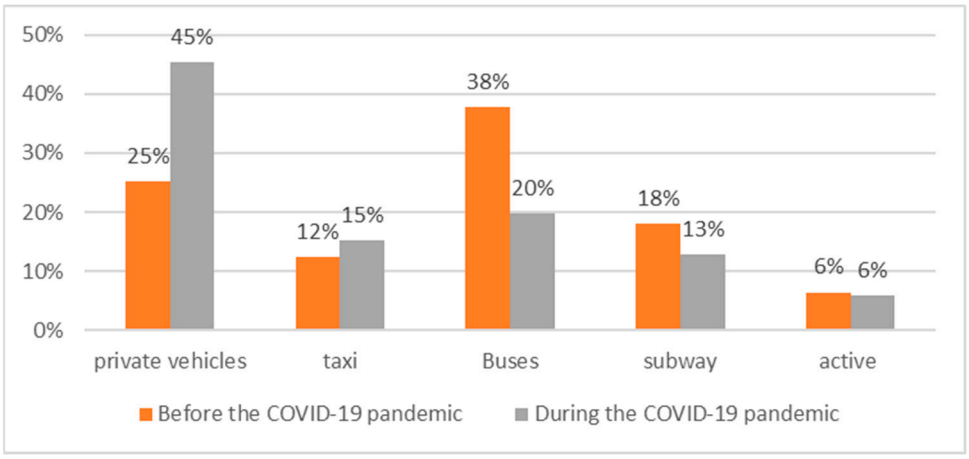


Figure 7. Intertravel mode usage.

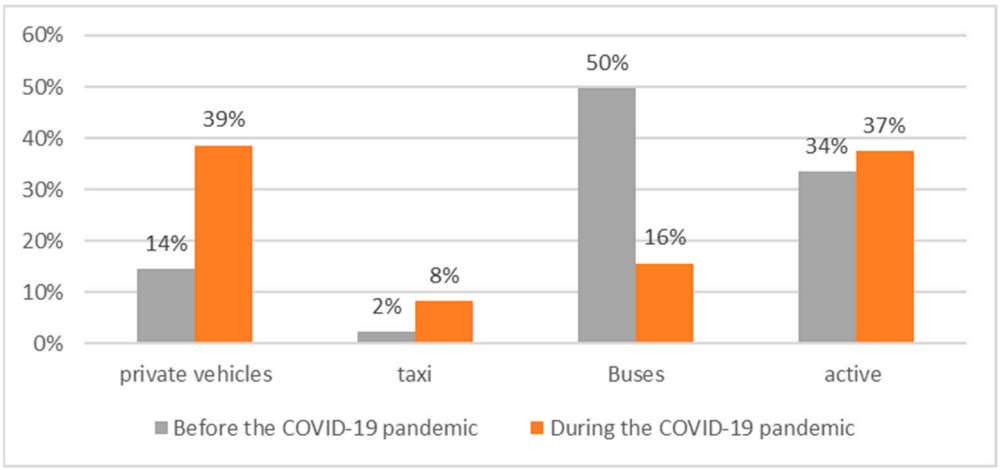


Figure 8. Intra-travel mode usage.

Figure 8 illustrates that, before the pandemic, 14% of people used private vehicles for transportation, while 50% used buses. Only 2% of people used taxis for transportation. The remaining 34% of people used active transportation, such as walking or cycling. During the COVID-19 pandemic, there has been a significant shift in the mode of transportation

used. The percentage of people using private vehicles for transportation has increased to 39%, while the percentage of people using buses has decreased to 16%. The rate of people using taxis has also expanded to 8%. The percentage of people using active transportation has increased slightly to 37%, 3% more than before.

Tables 3 and 4 provide the percentage of mode usage, which is clustered based on different variable groups. Professors and staff used private vehicles more than students in both periods for inter- and intra-campus. However, these two groups tended to employ active modes less. The study's findings indicate that PhD students used private vehicles more frequently than other transportation modes before the pandemic. However, after the onset of the COVID-19 pandemic, bachelor's and master's students had a significantly higher number of inter-campus travels.

Table 3. Mode choice share for different groups of variables before the pandemic.

	Inter					Intra			
	Before the Pandemic					Before the Pandemic			
	Bus (%)	**Private Vehicle (%)**	**Taxi (%)**	**Subway (%)**	**Active (%)**	**Bus (%)**	**Private Vehicle (%)**	**Taxi (%)**	**Active (%)**
Professor	10	68	11	5	6	42	39	2	17
Student	44	16	13	20	7	62	5	2	30
Staff	11	69	8	11	2	48	34	3	16
PhD	38	30	13	18	3	61	11	5	24
Master's	42	21	16	18	4	62	7	2	29
Bachelor	45	14	12	21	8	62	5	2	31
Female	42	20	13	20	5	61	8	3	28
Male	33	31	11	16	9	55	16	1	28
Shopping	31	28	13	16	12	50	16	2	32
Restaurant	41	20	13	20	7	56	9	2	32
Library	41	17	13	21	7	55	9	2	34
Religious	43	21	13	21	3	54	10	2	34
Official	8	52	16	16	8	47	35	3	15
Fun and sports	35	27	12	12	15	53	15	3	30
Same as before pandemic	33	32	14	16	5	55	17	2	25
Cultural department	20	25	20	25	10	55	9	0	36
Library	58	8	0	33	0	74	0	0	26
Educational Department	43	17	17	12	12	57	10	2	31

Additionally, among these students, bachelor's students had a higher number of intra-campus travels. Moreover, compared with men, women used less active modes for their trips before the pandemic, but the results were different during the pandemic. Based on data in Table 3, access to limited facilities to fulfill academic travelers within the campus, most shopping (50%), religious (54%), restaurant (56%), library (55%), official (47%), and fun and sport (53%) travel purposes were made by bus before the pandemic; however, during the pandemic, they were mainly executed by private vehicles. Generally, people having the same trip purpose before and during the pandemic mostly changed their mode choice from a bus to a private vehicle and active modes.

Table 4. Mode choice share for different groups of variables during the pandemic.

	Inter					Intra			
	During the Pandemic					During the Pandemic			
	Bus (%)	Private Vehicle (%)	Taxi (%)	Subway (%)	Active (%)	Bus (%)	Private Vehicle (%)	Taxi (%)	Active (%)
Professor	9	80	0	2	9	3	65	6	26
Student	17	38	24	15	6	19	30	9	42
Staff	11	66	11	8	5	8	62	5	25
PhD	21	37	21	16	5	21	29	16	34
Master's	22	38	18	15	6	20	27	13	41
Bachelor	14	38	27	15	5	19	31	7	43
Female	18	37	23	17	5	18	30	11	41
Male	12	57	16	8	7	13	48	5	33
Shopping	11	56	14	10	9	9	48	8	35
Restaurant	15	43	21	14	6	17	35	8	39
Library	17	42	20	14	7	16	34	10	40
Religious	13	42	23	16	5	17	36	7	41
Official	20	65	5	5	5	10	62	19	10
Fun and sports	0	69	15	8	8	0	50	0	50
Same as before pandemic	16	47	20	12	5	16	40	8	36
Cultural department	13	47	7	20	13	0	44	13	44
Library	4	13	46	25	13	26	16	0	58
Educational Department	19	47	23	7	5	21	33	8	38

After the pandemic, people tended to use private vehicles (an increase of 44%), taxis (an increase of 9%), and active modes (an increase of 3%) more than before. However, the use of the subway (a decrease of 5%) and bus (a decrease of 52%) decreased compared with before the pandemic situation (as shown in Figure 9).

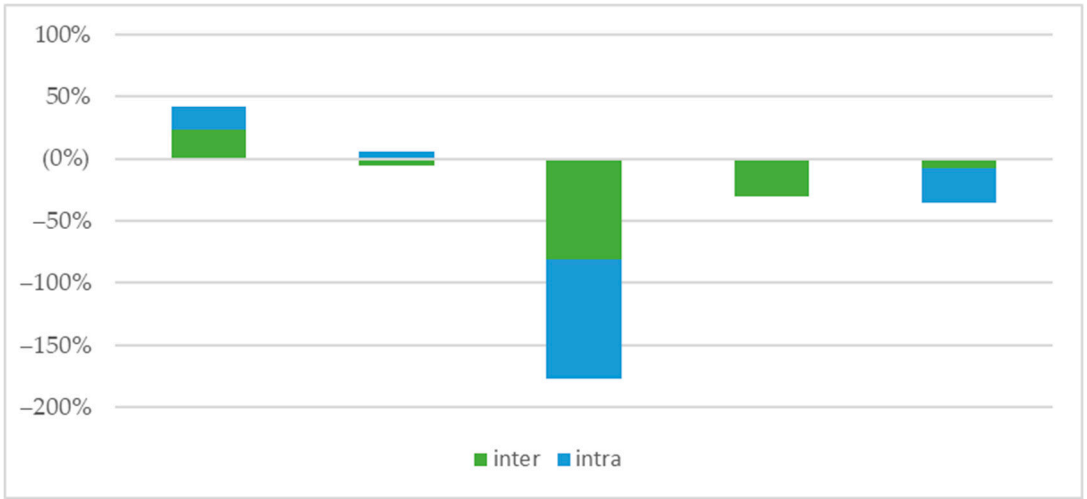


Figure 9. Comparison between before and during pandemic mode shares.

4.2. Mode Choice Models

Subsequently, mode choice modeling was performed before and during the COVID-19 pandemic. The following sections present the results of each model and their comparison. Regarding the suitability of travel modes before the pandemic, factors such as intra-mode, travel distance, accommodation relative to the urban area, entry and parking permit, walking time to shift modes, parking location, age, and travel purposes were generally effective. The model analysis demonstrated that the average estimation accuracy of the model was 97% and the model's goodness of fit ($\varrho_0{}^2$) equaled 0.595. Regarding the suitability of travel modes during the pandemic, generally, factors such as the first destination, intra-mode, travel distance, accommodation relative to the urban area, occupation, entry and parking permit, walking time to shift modes, gender, length of attendance (history), and educational degree were influential. According to the analysis, the model's average estimation accuracy and the model's goodness of fit were 89% and 0.674, respectively. Table 5 illustrates the result of mode choice models before and during the pandemic.

Table 5. Mode choice models before and during the pandemic.

Duration		**Before the Pandemic ***					**During the Pandemic ****				
Mode Choice		**Private Vehicle**	**Taxi**	**Bus**	**Subway**	**Active**	**Private Vehicle**	**Taxi**	**Bus**	**Subway**	**Active**
Variable	**Symbol**	-	-	-	-	-	-	-	-	-	-
Constant	-		−0.66					−1.8			
Gender	A									1.3133	
Age	B	0.532									
Being Staff	C	1.001						2.3266			
Destination: Engineering	D									−1.9907	
Destination: Humanities	E									−1.884	
Studying Master	F								0.4695		
Attendance history (year)	G								0.1986		
Destination: Official	H						1.5963				
Intra mode (walk)	I					1.6328	0.6067				
Intra mode (bike)	J					3.8006					
Distance from origin	K				0.0381	−0.1601					−0.0574
Origin within urban	L				0.6875		0.8484-	−1.0093		−1.7996	
Car permit (none)	M			1.2706				2.8278			
Walking time (mode change)	N		0.4989	0.3607						−0.7001	−0.5312
Intra mode (taxi)	O		1.6267					−2.2161	−2.0268		
Intra mode (motorcycle)	P	1.5846									
Parking (inside)	Q	1.9416									
Intra mode (car)	R	0.9329									−1.3307

* Model accuracy LL(B) = −487.98, $\varrho_0{}^2$ = 0.595; ** Model accuracy LL(B) = −334.88, $\varrho_0{}^2$ = 0.6741.

Based on the provided table, following is a utility function for the mode choice models before the pandemic:

$$\text{Utility(Private Vehicle)} = 0.532\text{B} + 1.001\text{C} + 1.5846\text{P} + 1.9416\text{Q} + 0.9329\text{R} \quad (8)$$

$$\text{Utility(Taxi)} = -0.66 + 0.4989\text{N} + 1.6267\text{O} \quad (9)$$

$$\text{Utility(Bus)} = 1.2706\text{M} + 0.3607\text{N} \quad (10)$$

$$\text{Utility(Subway)} = 0.0381\text{K} + 0.6875\text{L} \quad (11)$$

$$\text{Utility(Active)} = 1.6328\text{I} + 3.8006\text{J} - 0.1601\text{K} \quad (12)$$

Based on the provided table, following is a utility function for the mode choice models during the pandemic:

$$\text{Utility(Private Vehicle)} = 1.5963\text{H} + 0.6067\text{I} + 0.8484\text{L} \quad (13)$$

$$\text{Utility(Taxi)} = -1.8 + 2.3266\text{C} - 1.0093\text{L} + 2.8278\text{M} - 2.2161\text{O} \quad (14)$$

$$\text{Utility(Bus)} = 0.4695\text{F} + 0.1986\text{G} - 2.0268\text{O} \quad (15)$$

$$\text{Utility(Subway)} = 1.3133\text{A} - 1.9907\text{D} - 1.884\text{E} - 1.7996 - 0.7001\text{N} \quad (16)$$

$$\text{Utility(Active)} = -0.0574\text{K} - 0.5312\text{N} - 1.3307\text{R} \quad (17)$$

4.2.1. Private Vehicles

The study found that, before the pandemic, PhD students used private vehicles more frequently than other modes of transportation. This could be due to factors such as age limit requirements for driver's licenses, easier access to a car, and car entry permits to the campus. The study also found that using a car or motorcycle and having parking permission had a positive relationship with the utility of private vehicles.

During the pandemic, people were more likely to walk on campus due to practicing caution against congested areas such as public transport stations. People living in the suburbs also preferred to use private vehicles during the pandemic, likely due to their caution about using public transport and the reduced frequency of their trips. Official travel purposes also positively affected the use of private vehicles, as passengers occupied different occupations and had different numbers and frequencies of travel.

4.2.2. Taxi

Before the pandemic, people preferred taxi services if they had to wait longer for mode shifting and they continued their trips within the campus using the same mode.

During the pandemic, being a staff member could be among the factors influencing the desirability of the taxi mode. Not having a car entry or parking permit was another positive factor affecting the desirability of this mode. Moreover, living outside the city seems to be one of the positive factors contributing to this mode.

The convenience of traveling within the campus with the taxi mode has decreased during the pandemic due to caution against intra-public transport, the tendency to use the active mode on campus, and cost reduction.

Compared with before the pandemic, the use of taxi services decreased during the pandemic. This is likely due to the overall reduction in travel and the public's avoidance of public transportation.

4.2.3. Bus

The results suggest that the desirability of the bus mode before the pandemic was negatively affected by poor accessibility during the mode shift from outside to inside the campus. Additionally, not having a car entry and parking permit was also found to negatively affect this mode's desirability.

During the pandemic, the desirability of the bus mode was negatively correlated with using taxis within the campus. Moreover, the number of undergraduate students and length of attendance positively affected the utility of this mode, which may also represent the age variable. These findings suggest that younger students attending the university for longer are more likely to choose the bus mode during the pandemic.

Comparing the results from before and during the pandemic, it is clear that the desirability of the bus mode was affected by similar factors at both times. However, the negative relationship between using taxis within the campus and the desirability of the bus mode during the pandemic highlights the impact of COVID-19 on mode choice behavior. Additionally, the positive association between the number of undergraduate students and length of attendance and the utility of the bus mode during the pandemic may suggest a shift towards more sustainable transportation modes among younger students attending the university for longer.

4.2.4. Subway

Subway use before the pandemic was positively correlated with two variables; the accommodation within the urban area and the travel distance.

Travel to engineering and humanities zones was estimated as a negative factor during the pandemic. These destinations have poor access to the subway stations around the campus and are relatively far from them. Notably, this mode's desirability was unfavorable for people whose origin is in the city. People having good access to the campus's public transportation while using public transportation outside the campus also avoided choosing this type for the given reasons. It seems that men were more inclined to choose this mode, which may be related to the riskiness of this group.

4.2.5. Active Mode

The study found that before the pandemic, choosing to walk or cycle on-campus positively affected off-campus transportation mode choice, while using a car had a negative effect. The distance of the travel origin had a negative relationship with the desirability of walking and cycling before and during the pandemic.

During the pandemic, the desirability of using the car mode for on-campus travel had a negative effect. Additionally, the study found that people with better access to campus transportation modes negatively perceived walking and biking during the pandemic.

Overall, the pandemic has impacted transportation mode choices and people have become more cautious about using public transportation. Private vehicles were preferred during the pandemic, especially for those living in the suburbs. The use of taxi services decreased during the pandemic, while the desirability of the bus mode increased among students attending the university for longer. Subway use was influenced by travel distance and urban accommodation before the pandemic. In contrast, the desirability of using active modes, such as walking or cycling, was negatively affected by using a car and better access to campus transportation modes during the pandemic. The study implicitly acknowledges the presence of the infection variable as a hidden factor that manifested its effects by altering mode choice compared with the pre-pandemic period.

5. Discussion

Overall, the spread of COVID-19 has affected the travel behavior of thousands of students globally [68]. The results confirmed a general mobility loss in the form of reduced travel frequency in all modes of transport. However, the results also indicated that changes across modes of transportation were not uniform, which agrees with Jamal and Paez [69], and the shift in travel behavior varied across different socio-demographic groups [48]. Some main factors affected the travelers' decisions, including hygiene, the destination's health system reliability, and dissatisfaction [49]. Also, available travel alternatives and specific risk mitigation measures were significant [37]. In particular, the loss of mobility was more pronounced for public transport, which agrees with Jenelius and Cebecauer [70].

As reported by Jamal and Paez [69], there was an increase in walking and a return to the before the pandemic option of bike sharing, however subway usage remained low [67].

Moreover, the results suggested that shared bicycles are a resilient transportation option for cities [67]. Therefore, promoting bicycle use and sharing, carpooling, and micromobility among students can effectively promote sustainable mobility habits [37]. The results indicated a high tendency to switch to virtual (e.g., teleworking and online classes) and private modes (e.g., car and motorcycle) from public ones (e.g., bus transit and subway), which agrees with the findings of Bhaduri et al. [50]. Furthermore, the extent of inertia varied according to the purpose of travel (commuting and discretionary travel) [50,71]. The study found that age, staff status, and living location significantly influenced private vehicle use [19]. The study also suggested that policymakers could limit the number of car entry and parking permits to reduce the utility of private vehicles [19]. Other measures, such as providing an inter-campus shuttle, allocating public transportation subsidies [43,44], developing biking facilities [38,39], and promoting teleworking and online classes, could also be helpful. The influence of these variables indicated that people living in the suburb preferred to use a private vehicle during the pandemic, possibly due to their caution about using public transport [49,68] and the reduced frequency of their trips [69]. The official travel purposes also positively affected the use of the vehicle, which seems reasonable due to the occupation of passengers and the number and frequency of travels [68,69]. It is, therefore, necessary to develop policies that will reduce the utility of private vehicles. In doing so, planners can increase the accessibility and quality of public transportation on campus [40,70]. In addition, providing dormitories for people who live far from the university (suburb) [38], motivating teleworking and offering online classes [71], and providing an inter-campus shuttle can be helpful.

Furthermore, developing cycling and walking facilities is an efficient travel demand management strategy [38,39]. The study also found that people were more likely to walk within the university campus during the pandemic, possibly due to caution against congested areas such as public transport stations. The study recommends developing policies that reduce the utility of private vehicles and increase the accessibility and quality of public transportation on campus. Providing dormitories for people living far from the university, providing an inter-campus shuttle, and developing cycling and walking facilities are also efficient travel demand management strategies.

In addition, the study found that people preferred taxi services if they had to wait longer for mode shifting before the pandemic. The study recommends developing an on-campus public transportation system with good accessibility to promote public transportation modes [40,70]. Limitation policies for taxi entry might also be another option [19].

Regarding subway use, the study found that the accommodation within the urban area and travel distance positively affected the utility of this mode before the pandemic. The study recommends that policymakers consider developing policies that address these factors to promote subway use.

In conclusion, the study recommends implementing a comprehensive travel demand management strategy considering various factors influencing travel mode choices. Such measures should include limiting car entry and parking permits, providing an inter-campus shuttle, developing biking and walking facilities, promoting teleworking and online classes, and improving accessibility and quality of public transportation on campus. Consequently, the results confirmed dynamic relationships between policymaking, factors, and consequences [71]. The findings of this study could be helpful to policymakers and transportation planners for designing effective and efficient transportation policies and strategies.

6. Conclusions

The COVID-19 pandemic has affected university passengers' travel behavior worldwide in countless ways and the utility and sharing of all transportation modes has changed in response to the pandemic. The literature has identified influential factors in making trips to university campuses, including age, gender, accommodation, cost, and travel time.

However, cross-sectional studies involving comprehensive variables are lacking and the influence of the COVID-19 pandemic on transportation has not been thoroughly evaluated. The study aimed to fill a knowledge gap by examining travel behavior in diverse socio-demographic groups through various analytical methods. New variables were introduced and marginal effects and intrinsic values were measured to provide a more comprehensive understanding of the differences between these groups. This study investigated the travel behavior of teachers, staff, and students on- and off-campus before and during the pandemic. It was followed by studying the impact of the pandemic and some novel variables such as intra-mode choice, destination zone, sustainable policies, attendance history, mode change's walking time, trip frequency, car permits, and parking locations. Surveys, questionnaires, analyses, and multi-nomial logit models were employed, separately analyzing before and during pandemic situations and comparing the results. It was found that the use of private modes (taxi, private vehicle, and active modes) increased in response to the COVID-19 pandemic, while the use of public modes (bus and subway) demonstrated a decline.

The results revealed a remarkable increase in the use of private vehicles, while bus usage, as a public transportation mode, decreased significantly. Furthermore, most travel destinations reached by bus before the pandemic, including shopping centers, religious centers, restaurants, libraries, and recreational (centers), were reached by private vehicles during the pandemic. Generally, people with the same trip purpose before and during the pandemic mostly changed their mode from bus to private vehicle and active modes. Meanwhile, other transportation modes did not represent a significant change. During the pandemic, people became more inclined to walk on campus, which may be due to caution against intra-public transport, lack of car permits, and a desire to use the active mode in the campus green area. Taxi mode has been popular among staff during the pandemic, which can be explained based on the car usage for unplanned trips by other members of the family. Living outside the city was one of the positive factors affecting the utility of the taxi mode, which seems reasonable considering the general avoidance of using public transportation and a reduction in the number and frequency of visits and costs. Because of the unique ventilation conditions in subways and the long headway, people living in urban areas detested using this mode due to the caution and avoidance of public areas. People having easy access to the university's public transportation while using the city's public transportation also avoided choosing this mode for the same reasons. Men were more likely to choose the subway mode, which may be related to their greater willingness to take risks. Choosing active modes was negatively affected by the travel distance. The desirability of using this mode was also negative for people who had better access and spent less time on shifting modes inside and outside the university.

In conclusion, the study proposes a comprehensive approach to managing travel demand that accounts for various factors that affect the choice of transportation modes. This approach should include measures such as restricting car entry and parking permits, offering an inter-campus shuttle, creating facilities for cycling and walking, promoting teleworking and online classes, and enhancing accessibility and quality of public transportation on campus.

This study is subject to limitations due to the use of self-reported data, which may introduce response bias and recall errors. Future research could encompass a broader sample by including multiple universities or diverse geographical locations to improve the generalizability of the findings. Incorporating objective measures of fear of infection and other psychological factors would enhance understanding of their impact on mode choice during the pandemic. Furthermore, investigating the influence of social and cultural factors on travel behavior would contribute to a more nuanced comprehension of mode choice dynamics. Additionally, examining travel behavior changes after the pandemic would be valuable for assessing the long-term effects and adaptations in mode choice preferences. Furthermore, it is essential to study individual-level analysis, the implications

of findings for long-term changes in travel behavior, and the need for ongoing monitoring and analysis.

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