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Understanding the choice for sustainable modes of transport in commuting trips with a comparative case study

Tuğçe Yanar^{a,b,*}^a Institute for Transport Studies, University of Leeds, Leeds, United Kingdom^b Department of City and Regional Planning, Faculty of Architecture, Middle East Technical University, Ankara, Turkey

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ABSTRACT

This study aims to understand the reasons behind people's modal preferences in commuting trips, which contribute to transportation-related problems and to develop and prioritize policies that increase the use of sustainable modes. For this reason, in this study, a comparative case study was conducted to evaluate the factors that lead to choosing or not choosing sustainable modes. Commuting trips in San Francisco, San Diego, Los Angeles, San Jose and Sacramento, which are large cities with high automobile dependency and many potential alternatives to driving, were examined using the National Household Transportation Survey (NHTS) and spatial data. The factor classifications suggested in the literature were shaped according to the scope of the study and examined on four main headings. Proximity analyses were completed in the GIS environment to evaluate the environmental effects. The effects of all factor parameters on modal preferences were calculated for each mode of transport in the study with Binary Logistic Regression analyses. As a result of the comparative analysis, the barriers to using sustainable transportation modes in cities and the reasons for driving are determined. As a result, long-term policies were determined and prioritized with literature to manage these causes and barriers. The results show that modal choices are affected by many different parameters, the reasons differ locationally, and accordingly, the policy measures in each region should be different.

1. Introduction

With rapid urbanization, sustainable mobility has gained importance in ensuring and promoting the sustainability of cities (Li et al., 2015). As Tolley (2003) mentioned, if sustainable urban transportation is to meet today's needs without endangering the opportunities of future generations, car-based trips are considered unsustainable in this context, and a need for more sustainable forms of transport such as walking, cycling, and public transport (PT) arises. As Newman and Kenworthy (1996) explained, automobile usage was increased with its elasticity created in time and space, but it turned into an undesirable situation as the requirements and adverse effects began to increase.

According to the EEA (2020) statements, the most powerful options for providing sustainable transportation on an urban scale are defined as walking, cycling, and PT. With the use of these modes, many positive contributions are made, such as reducing air and noise pollution, increasing public health with daily activities, and reducing urban costs. As defined in the EEA (2020), in order to reduce the adverse effects of transportation, 'avoid' to reduce energy use and the number and length

of trips, 'shift' to increase the use of non-motorized modes and 'improve' to make vehicles more harmless are required. Also, in order to realize these, planning, regulatory, economic, information, and technological tools are needed (Dalkmann and Brannigan, 2007). For this reason, all these problems created by motorized transport have led researchers to work on the use of sustainable modes for years (Tolley, 2003). Therefore, many studies have been carried out with many different statistical methods like descriptive statistics, spatial statistics, travel preference functions to understand the reasons for choosing or not choosing sustainable modes (Black et al., 2002). In these studies, the effects of many elements such as travel characteristics, socioeconomic characteristics, attitudinal characteristics, city structures were examined (Buehler, 2011). However, the effects of each element on modal preferences differ, and it is found beneficial in many transportation studies to evaluate them comparatively. For this reason, in this study, the factors that cause to choose or not to choose sustainable modes will be calculated and interpreted by performing a comparative case study.

This study will be carried out in the US, which is one of the countries with a considerable automobile dependency, as Burton et al. (2013)

* Address: Mustafa Kemal Mahallesi, 2151. Cad. No: 5/A, Kat:14 Çankaya, Ankara, Turkey.

E-mail address: tugce.yanar@uab.gov.tr.

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observed. It is also a suitable research area in terms of having the National Household Travel Survey (NHTS), which is carried out at the national level to understand people's travel patterns. The cities preferred in the study are selected from cities with noticeable walking, cycling, and PT opportunities for business trips. As [Khan et al. \(2016\)](#) explained, business trips constitute a large part of travel demand in urban areas. In addition, as [Heinen et al. \(2010\)](#) mentioned, the choice of modes in these journeys is meaningful because commuting journeys are fixed in terms of time and space and contribute to transportation-related problems to a large extent. This study is essential to show the possible different effects of the same factors in different cities, test the factors in the literature, and illustrate the change of policy priorities in cities. Accordingly, the integration of the necessary instruments, which are also defined by [Dalkmann and Brannigan \(2007\)](#) and the reasons for modal preferences can be examined comparatively. The primary purpose of this study to understand the reasons behind people's modal preferences in commuting journeys and to develop and prioritize policies that will increase the use of sustainable modes. Accordingly, the main objectives of the study are classifying the factors that affect people's preferences, comparing the effects of these factors in different cities, identifying the barriers and reasons for increased use of sustainable modes and specifying improvements for sustainable transport policies using reasons and barriers.

2. Literature review

In the last fifty years, the demand for private vehicle ownership has been increasing, and this situation has caused many problems such as increased emissions and traffic congestion ([Nerhagen, 2003](#)). For this reason, there is a need to understand and estimate people's demand in determining critical and significant measures to reduce vehicle use. Many factors (such as sociodemographic, environmental, attitudinal) affect the travel mode preferences of individuals regarding these multi modes ([De Vos et al., 2016](#)). Many classifications have been proposed in the literature examining the factors of preferences for active modes. In [Goldsmith \(1992\)](#)'s study, these variables are evaluated objectively (directly observed) or subjectively (personal evaluations or characteristics understanding with attitudinal or perceptual survey questions). In this evaluation, objective variables are socioeconomic and household characteristics, trip characteristics, built environment, natural environment and cycling facilities. Additionally, subjective variables consist of perceptual and psychological indicators. Alternatively, the classification can be structured as individual features, generalized cost of mode and generalized cost of the alternative modes, as in the study of [Rietveld and Daniel \(2004\)](#). [Heinen et al. \(2010\)](#), on the other hand, examine it under five headings: built and natural environment, socioeconomic features, psychological factors, and further aspects including cost, time, safety. Similarly, [Buehler \(2011\)](#) specifies that it would be sufficient to classify socioeconomic and demographic features, spatial growth models, policies changing travel behaviour, public cultures, or personal choices. In this study, the classification of factors will be carried out under four headings. A summary of studies and factors is given in [Table 1](#). In this direction, the details will be evaluated in sub-headings.

As stated in many studies, one of the most critical variables for mode choice is the trip characteristics ([Kim and Ulfarsson, 2004](#)), and the most important elements are trip distance, travel time and trip cost ([Bhat and Sardesai, 2006](#); [Frank et al., 2008](#)). Travel time, the trip feature that will be focused on in the study, consists of walking time, waiting time, access time, and vehicle time ([Walle and Steenberghen, 2006](#)). Although the access and walking times also show the reaching time to PT stops, they are examined separately as the reasons for preferring walking differ from the other modes ([Millonig et al., 2012](#)). As [Brezelius \(1979\)](#) mentioned, walking and waiting times can be seen to be nearly-three times more valuable than in-vehicle time (IVT) for PT. When travel distances are examined, it is seen that the distance between work and home locations is essential, especially in cycling and walking ([Ton et al.,](#)

Table 1
Summary of classifications and factors from literature review.

Classification	Main Factors	References
Trip characteristics	Trip distance, travel time, trip cost, transit features,	Bhat and Sardesai, 2006 ; Frank et al., 2008 ; Kim and Ulfarsson, 2004 ; Wardman, 2001 ; Millonig et al., 2012 ; Cervero, 1996 ; Keijer and Rietveld, 2000
Household characteristics	Income, number of children, number of cars, number of workers	Ton et al., 2019 ; Dargay and Gately, 1999 ; Dill and Voros, 2007 ; Pucher and Buehler, 2006 ; Parkin et al., 2008 ; Clark et al., 2016 ; Srinivasan and Ferreira, 2002 ; Bhat and Srinivasan, 2005
Personal characteristics	Gender, age, education level, habits, abilities	Goulias and Pendyala, 2014 ; Cervero and Kockelman, 1997 ; Ajzen, 1988 ; Heesch et al., 2012 ; Idris et al., 2015 ; Heinen et al. 2010 ; Van den Berg et al., 2011
Built and natural environment	Diversity in land use, local densities, employment densities at destination, population densities at origins, urban design, green spaces, slope	Cervero and Kockelman, 1997 ; Ewing and Cervero 2001 ; Giuliano and Dargay, 2006 ; Schwanen and Mokhtarian, 2005 ; Kenworthy, 2002 ; Cervero and Sullivan, 2011 ; Crane, 2000 ; Burton et al. 2013

[2019](#)). As [Keijer and Rietveld \(2000\)](#) stated, the effects of trip features differ according to the modes and affect the modal shifts to each other significantly.

Household characteristics, on the other hand, examine the effects of individual features of household members on each other and modal preferences ([Ton et al., 2019](#)). Although these features generally include vehicle ownership and the number of workers and children in the household, it is stated that the importance of income is high ([Dargay and Gately, 1999](#)). In general, it has been observed that the desire of the households to buy a car increases with the increase in income, and the level of avoiding car ownership increases as the income decreases ([Clark et al., 2016](#)). While some studies indicate a linear relationship between bicycle use during commuting journeys and household income ([Dill and Voros, 2007](#); [Pucher and Buehler, 2006](#)), some studies have calculated a negative relationship ([Witlox and Tindemans, 2004](#); [Shafizadeh and Niemeier, 1997](#)). When the relationship between vehicle ownership and walking preference is examined, although vehicle ownership reduces the desire to walk, if the household is already walking, vehicle ownership does not affect their willingness to walk even longer distances ([Ivan et al., 2019](#)). The effect of household features on commuting journeys includes the household's preferred location and neighbourhood structure ([Schwanen and Mokhtarian, 2005](#)). Households prefer commuting by PT choose their home location considering PT infrastructure rather than population and housing stock characteristics ([Schwanen and Mokhtarian, 2005](#)). Having children, the number of children, and household size in general increase the probability of buying a car for households that do not own one ([Clark et al., 2016](#)).

As [Ajzen \(1988\)](#) states, each individual's character, economic situation, habits, attitude, behaviour, perceiving the environment and travel demands differ. Individual characteristics include elements especially about socio-demographic characteristics and they have an important and comprehensive effect on modal preferences ([Ton et al., 2019](#)). For example, in a study conducted for Queensland, Australia, it was observed that men cycled and drove longer than women for commuting ([Heesch et al., 2012](#)). Mainly, bicycle journeys are highly influenced by individual abilities and capacities, and particular reasons such as excessive physical exertion, not knowing how to ride a bicycle, and feeling of fear directly affect preferences ([Heinen et al., 2010](#)). It has

been observed that the relationship between bicycle journeys and age is also directly proportional, and individuals prefer other modes because they do not have the ability to ride a bicycle as their age increases (Dill and Voros, 2007). Gender, another feature, causes differences in the maximum acceptable travel time and distance to individuals (Garrard et al., 2008). When the level of education is evaluated, it has been observed that educated people mostly travel by PT (Van den Berg et al., 2011). In addition, it has been mentioned that people with higher education have a higher tendency to walk (Ivan et al., 2019). As Ajzen (2005) states, there are also intangible reasons such as comfort, convenience, travel satisfaction, culture, responsibilities, values and affect mode choice (De Vos et al., 2016).

Many studies in the literature have examined the relationship between the built environment, spatial development patterns and travel behaviour (Cervero and Kockelman, 1997; Giuliano and Dargay, 2006; Schwanen and Mokhtarian, 2005). As Ewing and Cervero (2001) concluded, local land-use patterns affect mode choice considerably depending on land use mixing, local densities, employment densities at destination and population densities at origins. It has been observed that in areas with high density and mixed land-use, trip distances decrease, and walking and cycling becomes easier for individuals (Kenworthy, 2002). Therefore, sustainable urban city structures such as compact, polycentric and linear have been essential in increasing sustainable mode usage (Frey, 2003). In this respect, the differences in urban features and opportunities of urban and suburban areas are also elements that impact modal preferences (Cervero, 2018; Srinivasan and Ferreira, 2002). Also, urban forms and designs have effects on modal preferences (Saelens et al., 2003). As Cervero and Kockelman (1997) stated, not only density and diversity, but also pedestrian-friendly or cyclist-friendly designs of spaces or designs around PT stops are elements that significantly impact people’s orientation to these modes. In this category, another important element affecting sustainable mode choice is the physical environment (Rodriguez, 2004). Weather conditions, green areas, slopes and landscape affect individuals’ walking and cycling preferences (Crane, 2000). Also, green areas support the user preferences by creating shade and providing comfortable space for PT (Cervero and Sullivan, 2011).

In conclusion, characteristics of trips, household, individual and built and natural environment have been influential in many studies evaluating modal preferences. Nonetheless, the level of importance between the parameters shows some differences. For example, according to Goldsmith (1992), environmental and infrastructural characteristics significantly affect the total use of sustainable transportation modes, as there are very notable differences between cities. Ton et al. (2019) claim

that, on the other hand, sustainable mode preferences are more affected by trip and built environment features. As Buehler (2011) reached a similar conclusion, the effects of environmental characteristics, features of alternatives, and infrastructures are seen as most remarkable. Although there are groups of parameters, it has been understood that the comparative evaluation of these parameters is critical in this sense.

3. Methodology, data and case study design

Potential reasons affecting people’s modal preferences were grouped and examined and In this direction, literature review has been completed relatedly. In this direction, the general methodological flow of the research has been shaped. Thus, it is decided to conduct a comparative case study to examine and compare the factors of mode choices between the cities. After obtaining and examining the NHTS data for California and investigating the general characteristics of the cities, five case study areas are selected, parameter groups affecting modal preferences are created by literature review, these data are arranged for five cities. The reasons and barriers are defined according to the cities, and potential policies are defined. The general research design of the study is summarized in Fig. 1. Data, case study areas, comparative case study design and analysis methods will be detailed in this title.

3.1. Data and sources

One of the most significant limitations in making the choice evaluation is the insufficient data, including the spatial, temporal, cultural, attitudinal, built environment and social context reflecting the background of the decisions (Goulias and Pendyala, 2014). In this direction, NHTSs are among the important sources. Within the scope of this study, California data of 2017 NHTS, which is the eighth and most up-to-date study created by the Federal Highway Administration (FHWA), is used (Westat, 2018). The survey was applied to 55,819 people selected by random sampling in total. There are four main topics in the study: household, person, trip, and vehicle. In this study, data except vehicle characteristics will be used. While there are 19 modal choices in the data, car and SUV categories are combined under the car title, and seven titles, including PT services such as different bus and rail systems, are combined under the PT title. Also, spatial data provided by cities’ data systems are used to understand the infrastructure features. The data and sources used in the study are summarized in Table 2.

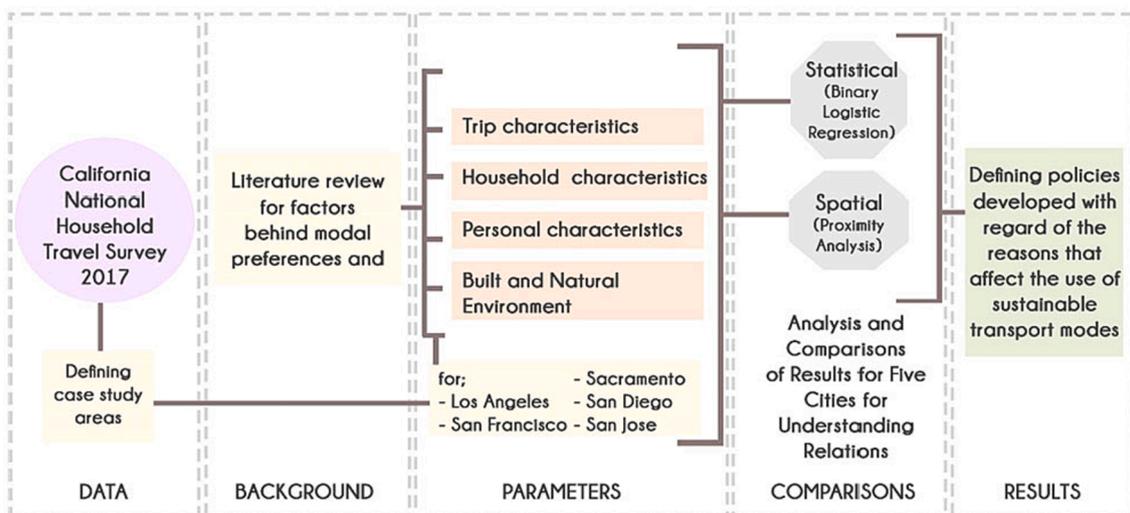


Fig. 1. The general research design of the research.

Table 2
Data and sources used in the study.

Data	Source
California NHTS 2017	https://nhts.dot.ca.gov/
• Neighbourhood boundaries,	Data for Los Angeles https://data.lacity.org/
Green Space,	Data for San Francisco https://datasf.org/opendata/
Bikeways,	Data for Sacramento https://data.cityofsacramento.org/
PT Stops,	Data for San Diego https://data.sandiego.gov/
	Data for San Jose https://gisdata-csj.opendata.arcgis.com/

3.2. Case study areas

When the trend towards walking and cycling modes is examined around the world, it is observed that only 1 % of daily trips are made by bicycle and walking is minor in the USA, while this rate can reach up to 18 % for European countries (Pucher et al., 2010). In this direction, it is crucial to examine the reasons why individuals make these choices and to produce tools and policies to support the shift to active modes in daily journeys in the USA. The evaluation of commuting journeys is appropriate for this study, as it is in the urban context and includes short-distance and daily repetitive journeys. Accordingly, Los Angeles, San Francisco, Sacramento, San Diego and San Jose (Fig. 2) are selected for comparative analysis, considering the cities with the highest concentration of trips, city characteristics and modal choices. When the data is filtered according to these cities, a total of 3398 HBW trips were obtained. Of the data, 463 belong to Los Angeles, 509 to San Francisco, 1028 to Sacramento, 1044 to San Diego and 354 to San Jose.

3.3. Comparative statistics

When the distribution of the journeys according to the modes is

examined (Fig. 3), it is seen that the most important difference takes place in San Francisco. Commuting trips in San Francisco is made on foot to a large extent. In other cities, the use of sustainable modes is relatively low, and the use of vehicles is quite high. Moreover, the rate of bicycle use is significantly low in every city. San Francisco is the main focus of comparisons because of this modal distribution. The motorcycle is eliminated in the rest of the study due to the low share. The Chi-Square test (X^2), which allows testing the relationships between categorical variables (IBM, n.d.), is used to test whether there was a significant difference between the modes and it is seen that there is a significant difference in modal preferences between cities.

Considering the distribution of travel distances and durations (Fig. 4), although the similarity is observed in all modes, PT journeys differ between cities. In San Jose, which has the highest trip distance for PT journeys, it is seen that the distances and trip times are comparatively high. Another remarkable issue is that PT journeys in Los Angeles are not very long, but their duration is considerably longer than in other cities. One-Way ANOVA analysis which enables the comparison of a numerical variable in at least three groups (IBM, n.d.) is performed and significant differences are observed between the cities in trip distance and trip duration data. When the result of the Games-Howell Post-hoc Test, which is applied for multiple comparisons in cases where the variances and the number of samples are not equal with each other (Games, 1971), is compared, it is seen that Los Angeles, San Francisco and San Jose differ in trip duration only with Sacramento and San Diego, while Sacramento and San Diego differ with all cities except each other. While Los Angeles and San Francisco significantly differ from San Diego and San Jose in the trip distance, Sacramento does not significantly differ from other cities.

When the education, age, driver status and gender of the individuals in the cities are compared in general; it is seen that the age is around 44, people who are able to drive is dominant over people who are not able to drive, the education level is generally bachelor's degree and men are more dominant. However, when the distribution of modal preferences



Fig. 2. Case study areas.

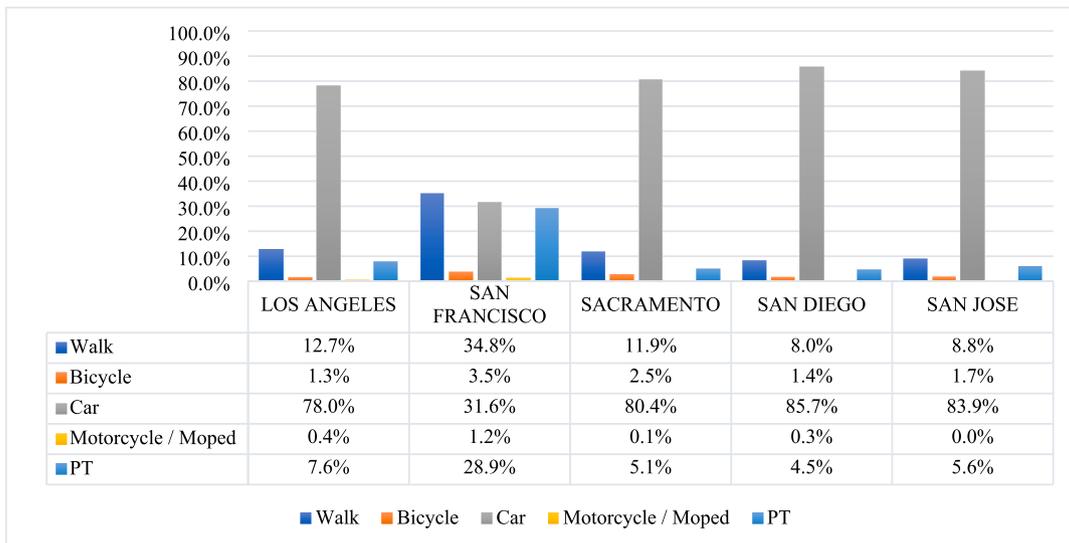


Fig. 3. Modal Shares across cities in commuting trips.

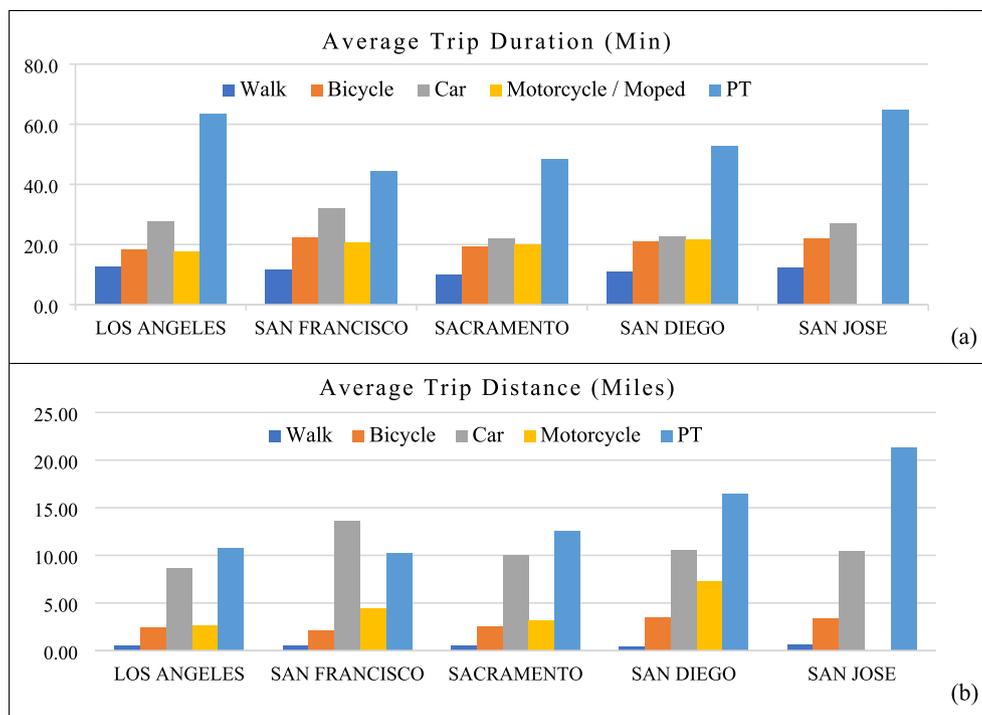


Fig. 4. Average trip durations (min) (a) and trip distances (miles) (b) of cities.

by age is examined, it is seen that young workers prefer walking more, the rate of using PT decreases as age increases, and the use of bicycles does not change much with age (Fig. 5).

The most noted variation in education level is observed in the use of PT in all cities (Fig. 6). San Francisco has a higher percentage of people with the highest levels of education overall. In general, highly educated people with bachelor or professional degrees use bicycles. The increase in vehicle usage rates generally starts with college-level education.

As shown in Fig. 7, while there is no gender variation in the three cities in commuting on foot, males dominate in San Diego and San Jose. In particular, the predominance of men up to 84 % in some cities is seen in cycling. Gender variation is not observed in the use of individual cars and PT; however, it is seen that men are dominant in all cities. The lowest differences in the distribution of modal preferences by gender are

encountered in Sacramento, and the highest differences are encountered in San Jose. Since the distribution of labour force participation by gender is not known, definite judgments cannot be made based on this comparison. While significant differences are observed in age and education, no significant difference is observed in gender with One-Way ANOVA analysis.

When the average annual income of households is evaluated, this value is generally higher than \$75,000, but it ranges from \$125,000 to \$149,999 in San Francisco (Fig. 8). Also, the average number of vehicle is closer to one in San Francisco, two in other cities. In this case, household income and vehicle ownership are inversely proportional in San Francisco. Also, 90 % of San Francisco households marked “convenient to work” and “close to PT” options out of twelve (Fig. 9). While proximity to PT is not considered very important in other cities, it

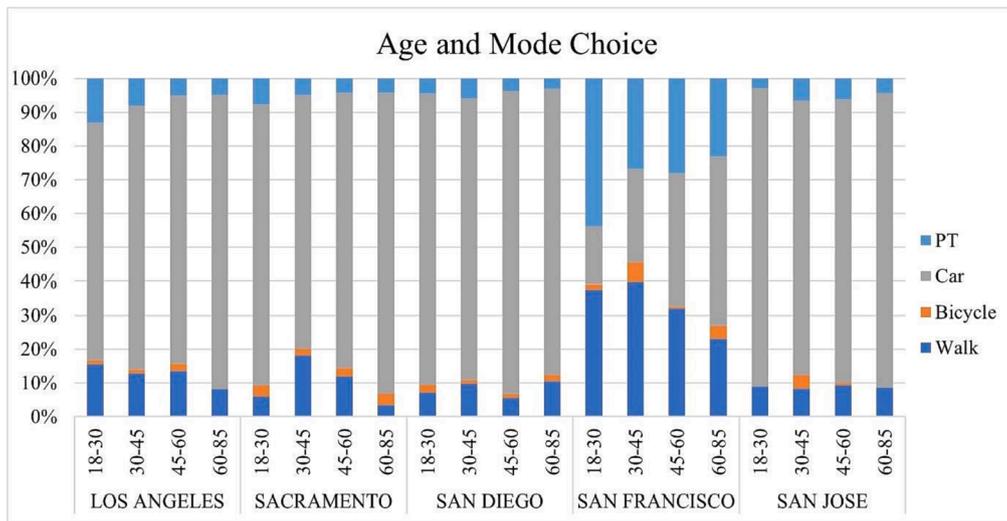


Fig. 5. Age ranges and mode shares in cities.

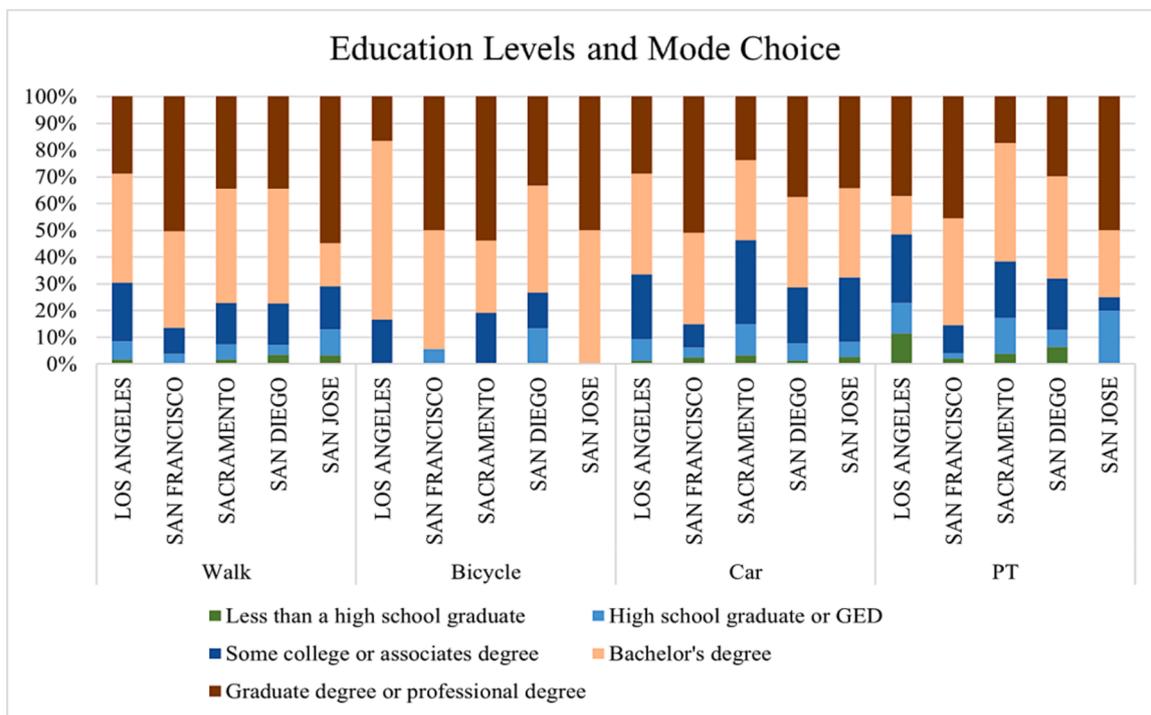


Fig. 6. Education levels and mode shares in cities.

has been seen that individuals care highly in San Francisco. When the difference of income, household size, number of workers and number of vehicles are tested with the One-Way ANOVA, a significant difference is observed between cities and all modes except number of workers.

When the origin–destination distributions of one-day business trips are examined, it is seen that the journeys generally take place between suburban neighbourhoods. In general, it is observed that 69.2 % of the origins are in the suburban neighbourhood, and 14.75 % are in the urban neighbourhood, while 58.10 % of the destinations are in the suburban neighbourhood, 15.58 % are in the urban core, and 14.84 % are in the urban neighbourhood. The population density is relatively low compared to the population in Los Angeles (Fig. 10). In San Francisco, which has a low population, population density is relatively high. It is seen as a sign for compact and dense urban form development in San Francisco.

When the spatial analysis results are examined, the distances to the nearest PT stops are shorter at home than at work, and it is very long in San Jose (Fig. 11a). Green areas around the nearest PT stop are higher in San Francisco and San Jose (Fig. 11b). Similar results are obtained in the distribution of green areas in residential neighbourhoods (Fig. 11c). For cycling infrastructure close to home and work, distances in Los Angeles are long, and lengths are relatively short (Fig. 11d and 11e). The higher infrastructural results are found in San Francisco, while the rates are similar in other cities. When the difference of spatial analysis outputs between cities is tested with One-Way ANOVA, it is observed that there is a significant difference in each of the parameters.

It has been proven by statistical tests that there are differences between cities in almost all factors within the title. In this direction, it is possible to evaluate the effects of factors in each city on modal preferences for commuting trips.

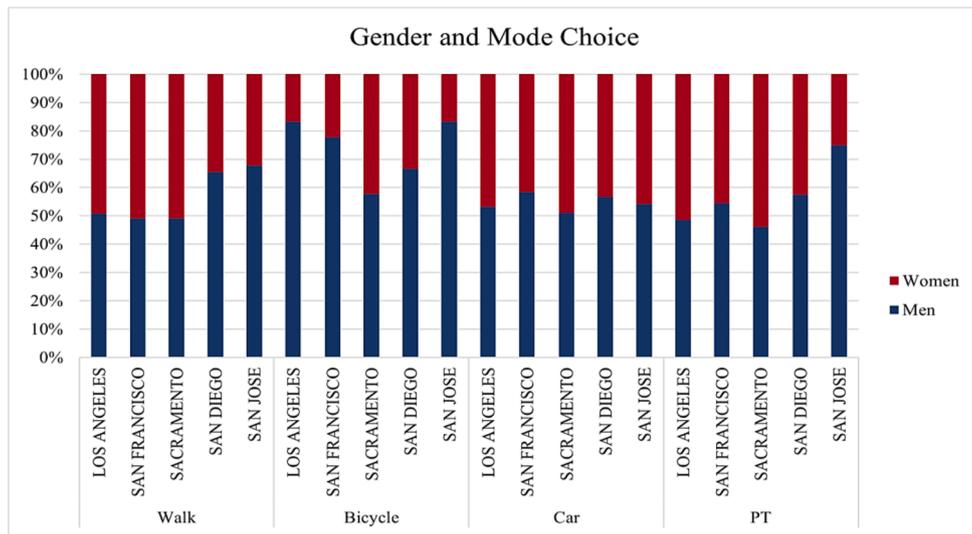


Fig. 7. Gender distribution in modal preferences in the cities.

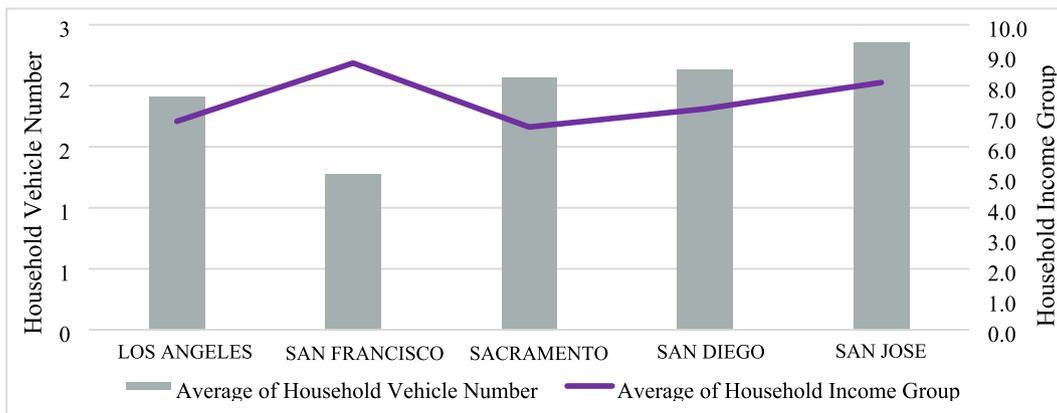


Fig. 8. Comparison of average household vehicle number and average household income group in cities.

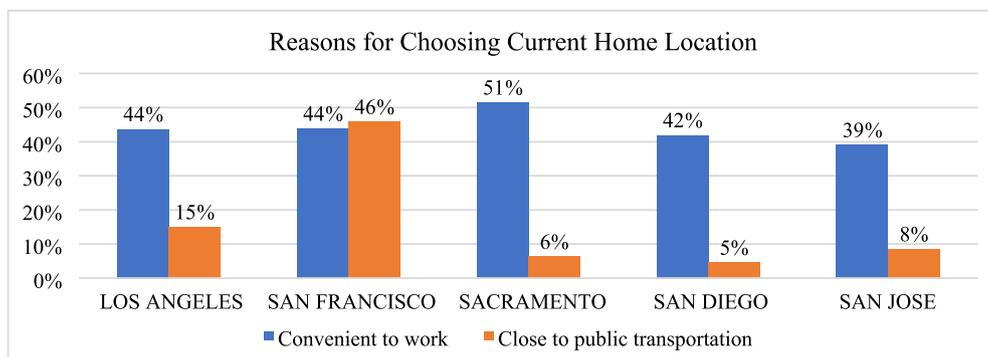


Fig. 9. Share of “convenient to work” and “close to PT” options in reasons for choosing a current home location.

3.4. Comparative case study design

Although the transport user profiles in the world generally change, transportation infrastructure and facilities are generally similar (Par-eekh et al., 2017). Many analysis methods such as descriptive, causal, predictive, comparative etc. are used in transport studies (Washington et al., 2020). Comparative analysis is preferred in this study. The effects of factors under four headings, namely trip, household and personal characteristics and built and natural environment, on modal preferences

for five cities will be calculated and compared. Proximity analysis will be carried out first to measure the effects of built and natural environment and the features of alternatives. In order to access the research question, binary logistic regression analysis will be performed. The study findings will be accessed by determining the factors with a correlation obtained from the significant regression results and the primary measures to be taken for them. The study’s comparative case study design is summarized in Fig. 12. The factors to be evaluated in the sub-headings are summarised in Table 3.

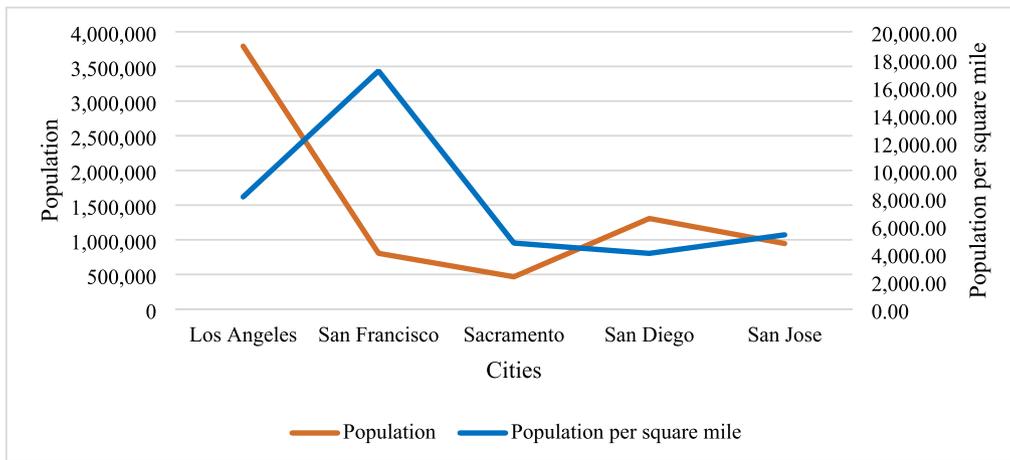


Fig. 10. Population and population density comparison.



Fig. 11. Summary results of spatial analysis.

3.4.1. Spatial analysis (Proximity Analysis)

The spatial analysis explains the spatial arrangement, patterns and relationships of the elements (Unwin, 1996). This study will perform proximity analyses using buffer, summarize within, near, and spatial join tools with using ArcGIS Pro software. While the ‘buffer’ is used to determine the area at a certain distance around the input, the ‘near’ and ‘spatial join’ tools are used to find the elements closest to the input. In first analysis, the input elements will be origin and destination points, while ‘near’ and ‘spatial join’ tools will be used to detect the nearest PT stops and bikeways and measuring distances. In the ‘buffer’ analysis, the 100 m effect area of the PT stops, which will be found to be closest to homes and workplaces, will be determined, and the green area density will be calculated with the ‘summarize within’. Another buffer analysis will be carried out to measure the total bikeway length in the 500 m impact area from origins and destinations. The general algorithms used to generate proximity analysis are summarized in Fig. 13.

3.4.2. Statistical analysis (Binary Logistic regression (BLR))

Logistic regression is a method used to examine the cause and effect relationship between dependent and independent variables (Bonney, 1987). There are three main logistic regression techniques: binary, ordinal, and multinomial (Harrell, 2015). As adopted by Al-Salih and Esztergár-Kiss (2021), Multinomial Logistic Regression (MNL) is a highly preferred alternative in evaluating modal preferences. However, as the researcher mentioned, MNL works based on the comparison of modal choices made by individuals and the characteristics of the alternatives. However, only the travel data and thoughts of the people are accessible in the NHTS data, but there is no information about the features of the alternatives (such as travel time, cost) at that time. Although these data can be produced from other data sources, as in the literature, it was not preferred to increase the rate of benefiting from the available data. Also, it requires a detailed study that could not be carried out within the scope of this study. Therefore, MNL is not considered suitable for the study. Binary Logistic Regression (BLR) to be used in this study is a regression model in which the dependent variable is binary (Harrell, 2017). In the study, it is decided to simply encode the people’s modal preferences as “1” while the other modes are coded as “0” and to perform separate calculations for each mode with this technique. Briefly, the relationship between the dependent variable and each independent variable in the model is examined with this method. The general formula used for BLR is as follows (1).

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 \tag{1}$$

Where;

Y_i describes the dependent variable,
 X_i describes the independent variables,

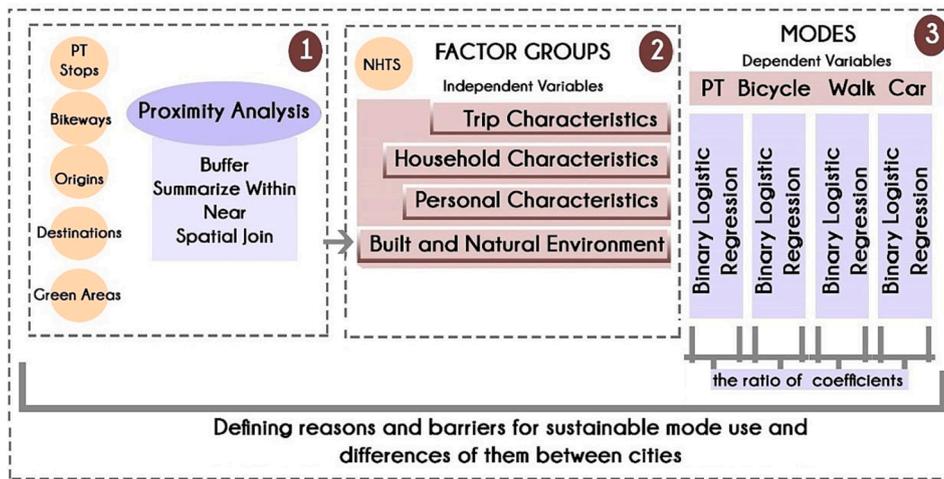


Fig. 12. Comparative case study design of study.

Table 3
Factor groups and factors to be evaluated in the sub-headings.

Trip Characteristics	Personal Characteristics	Household Characteristics	Built and Natural Environment
Trip Distance	Age	Income	Population Density
Trip Duration	Gender	Household Size	Green Area Size in Neighbourhood
Transit Waiting Time	Education	Vehicle Number	Home Location
Transit Origin Time		Number of Worker	Work Location
Transit Destination Time		Reasons For Choosing Home Location	Distance of Nearest PT Stops to the Origin and Destination
Transit Origin Mode			Green Area Size Near to Nearest PT Stops to the Origin and Destination
Transit Destination Mode			The total length of the bikeways in the 500 m buffer zone to Origin and Destination
			Distance of Nearest Bikeways to the Origin and Destination

β_0 is a constant,

β_i presents the regression coefficients (Harrell, 2017).

So, the Binary Logistic Regression (BLR) method is used to understand the relationship between modal preferences in parameters and factors in commuting trips. The dependent variable constitutes binary data as the modes preferred by individuals and others. For example, if an individual's preferred mode for commuting is PT, those who choose PT are evaluated as 1, and those who choose other modes are evaluated as 0. On the other hand, independent variables consist of other features whose contributions to this preference are desired to be examined (as briefly described above). According to the study results, the determinants with $P < 0.05$ are considered statistically significant factors.

4. Comparative findings across research question

SPSS 27.0 software is used to perform BLR analysis on parameters and preferences. As a result of the BLR analysis, the modal preferences of individuals in their commuting trips and the relationships between the factors defined in previous sections. The classification accuracy rates of

the analyses which shows the correct grouping rate of the data made with the coefficients estimated by the model (IBM, n.d.) are generally above 90 %, with some exceptions. The high level of this measure, which is generally used to understand the accuracy of estimation, is considered as an indicator of how accurate the outputs are. The ratio of coefficients of the factors (percentages in Table 4) is compared to remove the scale barrier to use the model to compare cities.

4.1. Public transport

In general, gender, preference of home located close to work, number of workers at household, a distance of nearest PT stop to the destination and category of home location are not the determining factors for any city for the individuals' PT use. Also, it has been observed that PT use is associated with high trip durations in all cities. Although trip distances negatively correlated with the PT preference in San Francisco and Sacramento with low ratio, no correlation is observed for the other three cities. Also, the rate of choosing PT decreases with the increase in the age (1 %), household size (9 %) and income (5 %) of the people significantly only in Los Angeles. In addition, the increase in education levels (11 %) positively affects this preference only in Los Angeles with a high rate. However, the increase in education level has a similar opposite effect in San Jose. In San Francisco (18 %) and Sacramento (13 %), the increase in household size significantly reduces PT use.

While the increase in the vehicle number has a high negative impact ratio in all cities, this situation is significant only in Sacramento (16 %) and San Jose (24 %). One of primary factor for PT use in San Diego is the preference for houses close to the PT (44 %). This effect is also significant in Sacramento, with a 22 % ratio. Another prominent factor is that the workplaces in urban areas in San Francisco contributed positively to this preference with 32 %. In San Francisco, contrary to other cities, the higher the population density in a census block and the larger size of the green area at the closest PT stop to the origin and destination positively affect PT use, although it is very slightly. An increase in the size of the green area at the closest PT stop to destination also has a slight effect on the PT use in San Jose. Although the increase in the distance of the nearest PT stop to the origin has significant slight adverse effects in Los Angeles, San Francisco and Sacramento, no effect is observed for the other two cities.

4.2. Bike

There is no significant relationship between cycling and age, vehicle number, choosing home location close to work and the distance of nearest bikeway to the origin and destination in all cities. Increasing

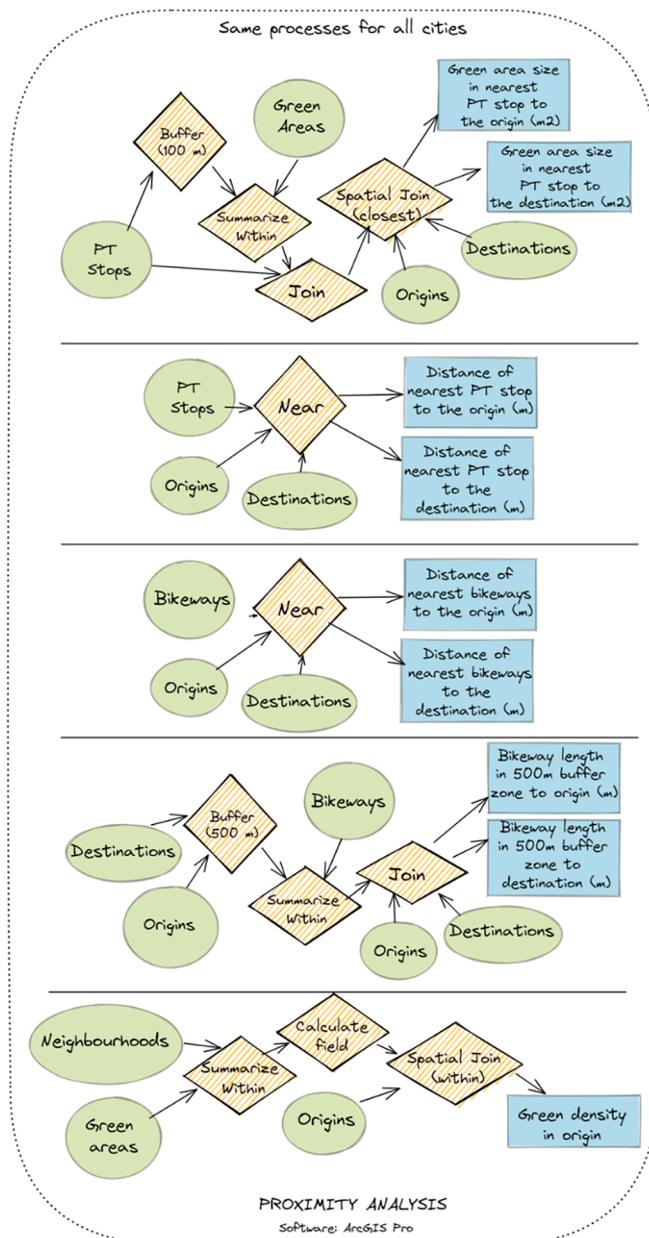


Fig. 13. Algorithms for proximity analysis.

travel distances has a significant negative effect (6 %) only in Sacramento. Also, an increase in the level of education in Sacramento strengthens the choice of cycling. Cycling in San Francisco is also seen to be predominantly done by men (29 %). Income groups effect is not much in the cities in general, but the increase in income in San Jose has a negative effect on commuting by bike (2 %). When the analysis of the bikeways is performed, it is seen that the increase in the bikeway length in the 500 m buffer zone to origin (km) in Los Angeles has a significant positive relation (3 %). Additionally, an increase in the bikeway length in the 500 m buffer zone to destination (km) has a significant positive effect (7 %) in San Diego, although it does not have an effect in other cities. In general, the factors with the highest ratio of coefficients for all cities are home and work locations. Especially in Sacramento (54 %) and San Diego (20 %), home location in more urban areas has a significant positive effect on cycling. Similarly, work locations in urban areas have a significant positive effect in San Diego (34 %).

4.3. Walk

No significant relationship is observed between age, gender, education, preference for a home location close to work, population density in census block and home location and preferences to go to work by walking. Otherwise, most notable adverse effect on walking preference is the trip distance in all cities. Trip duration increases slightly in all cities in walking trips. Although it does not have a high share, the increase in income in San Diego negatively affects walking preference. In Los Angeles and San Francisco, the factor that significantly and distinctively affects this preference is vehicle ownership. When the effect of the increase in the green area densities in the neighbourhoods where the homes are located is evaluated, it is seen that there is a slight significant positive correlation in Los Angeles and San Francisco. Additionally, workplaces are in a more urban area positively affects the walking preference in Sacramento (12 %).

4.4. Car

The household size, education level and home location do not have an effect on driving. In all cities, it is observed that the use of vehicles increased as the trip distance increased. Also, driving and trip duration have a negative relationship with low rate of coefficients. In Los Angeles, San Francisco, and Sacramento, it is seen that people drive more as they get older, but the percentage of its effect among the factors is relatively low. While no significant and important effect is observed in other cities, it is seen that women drive more in San Jose with a high ratio of coefficients (22 %). Another feature that distinguishes San Jose from other cities is the increase in vehicle usage rates with the increase in the number of workers in the household. A similar effect is found in Sacramento with the most notable impact for all cities are the vehicle number in the household, choosing a home located close to PT and work location. In general, these parameters cause the most considerable changes in the model. The increase in the number of vehicles in households pushes people to drive. In all cities except Sacramento, vehicle usage of people who consider living close to the PT is declining. On the other hand, the vehicle use rate of those who prefer to live close to work in San Francisco also decreases significantly. Also, in all cities except Los Angeles, the work location is in a more urban area has a negative relation with car usage.

4.5. Barriers for PT and bicycle use

In the NHTS, people are asked about the reasons behind not choosing sustainable modes. In the questions asked separately for PT, walking and cycling, a high rate of answers is obtained for PT and cycling, but not a sufficient number of answers for walking. Therefore, in this part of the study, only the reasons why people do not prefer to use PT and bicycle more will be evaluated.

In general, “prefer to drive” comes first among the reasons affecting the use of PT (Fig. 14). These reasons are followed by “no stop near destination” and “service does not frequent enough” options with close rates. In addition, although the most preferred options in San Francisco are more related to service quality (frequency, reliability, availability), the rate of people preferring to drive is very low compared to other cities. Another reason gaining importance in Sacramento and Los Angeles is safety concerns. It is also noteworthy that the issue of service hours and fees is relatively insignificant in Los Angeles.

The most rated option for why people do not cycle is safety concerns, with 22 % (Fig. 15). This is followed by too far to travel by bike (17 %), too much traffic (16 %), prefer to drive (15 %) and not enough bike lanes or wide curb lanes (13 %). While preferring to drive is the most significant reason for people not to use PT, the effect of this desire is relatively moderate on bicycle trips. When the results are examined for cities, San Francisco and Los Angeles have the highest rates for ‘safety concerns’.

Table 4

BLR results of the models performed for cities and modes (NSR: Negative Significant Correlation, PSR: Positive Significant Correlation, N: No Correlation (at 5% significance interval)).

Modes	Factors	Los Angeles	San Francisco	Sacramento	San Diego	San Jose	
Public Transport (1:PT, 0: others)	Trip Distance	N (1 %)	NSR (3 %)	NSR (2 %)	N (0 %)	N (1 %)	
	Trip Duration	PSR (1 %)	PSR (3 %)	PSR (1 %)	PSR (1 %)	PSR (1 %)	
	Age	NSR (1 %)	N (0 %)	N (0 %)	N (1 %)	N (0 %)	
	Gender (0: Male, 1: Female)	N (0 %)	N (2 %)	N (2 %)	N (11 %)	N (12 %)	
	Education (1: Less than a high school graduate, 5: Graduate degree or professional degree)	PSR (11 %)	N (0 %)	N (1 %)	N (2 %)	NSR (10 %)	
	Household Size	NSR (9 %)	NSR (18 %)	NSR (%13)	N (2 %)	N (8 %)	
	Income	NSR (5 %)	N (2 %)	N (0 %)	N (4 %)	N (4 %)	
	Vehicle Number	N (10 %)	N (1 %)	NSR (16 %)	N (%9)	NSR (%24)	
	Reasons for choosing home location: close to PT (0: No, 1:Yes)	N (18 %)	N (12 %)	PSR (22 %)	PSR (44 %)	N (21 %)	
	Reasons for choosing home location: close to work (0: No, 1:Yes)	N (10 %)	N (%8)	N (%9)	N (4 %)	N (3 %)	
	Population density in census block	N (0 %)	PSR (0 %)	N (0 %)	N (0 %)	N (0 %)	
	Number of Worker	N (7 %)	N (14 %)	N (12 %)	N (6 %)	N (5 %)	
	Distance of nearest PT stop to the origin (m)	NSR (0 %)	NSR (0 %)	NSR (0 %)	N (0 %)	N (0 %)	
	Distance of nearest PT stop to the destination (m)	N (0 %)	N (0 %)	N (0 %)	N (0 %)	N (0 %)	
	Green area size in nearest PT stop to the origin (m2)	N (0 %)	PSR (0 %)	N (0 %)	N (0 %)	N (0 %)	
	Green area size in nearest PT stop to the destination (m2)	N (14 %)	PSR (0 %)	N (0 %)	N (0 %)	PSR (0 %)	
	Home Location (0: Non-urban, 1: suburban, 2: urban)	N (12 %)	N (4 %)	N (18 %)	N (4 %)	N (4 %)	
	Work Location (0: Non-urban, 1: suburban, 2: urban)	N (0 %)	PSR (32 %)	N (4 %)	N (13 %)	N (7 %)	
	Accuracy		%96.8	%82.4	%96	%96.4	%96.7
	Bike	Trip Distance	N (1 %)	N (4 %)	NSR (6 %)	N (2 %)	N (5 %)
Trip Duration		N (0 %)	N (1 %)	N (1 %)	PSR (0 %)	N (1 %)	
Age		N (0 %)	N (0 %)	N (1 %)	N (0 %)	N (1 %)	
Gender (0: Male, 1: Female)		N (4 %)	NSR (29 %)	N (1 %)	N (6 %)	N (25 %)	
Education (1: Less than a high school graduate, 5: Graduate degree or professional degree)		N (0 %)	N (0 %)	PSR (12 %)	N (6 %)	N (19 %)	
Income		N (0 %)	N (3 %)	N (0 %)	N (2 %)	NSR (2 %)	
Vehicle Number		N (1 %)	N (9 %)	N (8 %)	N (6 %)	N (4 %)	
Reasons for choosing home location: close to work (0: No, 1:Yes)		N (1 %)	N (5 %)	N (1 %)	N (14 %)	N (4 %)	
Distance of nearest bikeway to the origin (m)		N (0 %)	N (0 %)	N (0 %)	N (0 %)	N (0 %)	
Distance of nearest bikeway to the destination (m)		N (0 %)	N (0 %)	N (0 %)	N (0 %)	N (0 %)	
Bikeway length in 500 m buffer zone to origin (km)		PSR (3 %)	N (2 %)	N (5 %)	N (2 %)	N (14 %)	
Bikeway length in 500 m buffer zone to destination (km)		N (0 %)	N (1 %)	N (2 %)	PSR (7 %)	N (0 %)	
Home Location (0: Non-urban, 1: suburban, 2: urban)		N (45 %)	N (18 %)	PSR (54 %)	PSR (20 %)	N (18 %)	
Work Location (0: Non-urban, 1: suburban, 2: urban)		N (44 %)	N (27 %)	N (11 %)	PSR (34 %)	N (3 %)	
Accuracy			%98.9	%95.9	%94.9	%99.2	%96.7
Walking		Trip Distance	NSR (61 %)	NSR (53 %)	NSR (56 %)	NSR (74 %)	NSR (45 %)
		Trip Duration	PSR (1 %)	PSR (2 %)	PSR (2 %)	PSR (2 %)	PSR (2 %)
		Age	N (0 %)	NSR (0 %)	N (0 %)	N (0 %)	N (0 %)
		Gender (0: Male, 1: Female)	N (2 %)	N (4 %)	N (2 %)	N (6 %)	N (14 %)
		Education (1: Less than a high school graduate, 5: Graduate degree or professional degree)	N (0 %)	N (3 %)	N (4 %)	N (5 %)	N (1 %)
	Income	N (0 %)	N (0 %)	N (1 %)	NSR (2 %)	N (3 %)	
	Vehicle Number	NSR (11 %)	NSR (7 %)	N (6 %)	N (0 %)	N (3 %)	
	Reasons for choosing home location: close to work (0: No, 1:Yes)	N (7 %)	N (5 %)	N (1 %)	N (4 %)	N (18 %)	
	Population density in census block	N (0 %)	N (0 %)	N (0 %)	N (0 %)	N (0 %)	
	Green density in origin	PSR (1 %)	PSR (%1)	N (6 %)	N (0 %)	N (1 %)	
	Home Location (0: Non-urban, 1: suburban, 2: urban)	N (16 %)	N (13 %)	N (9 %)	N (2 %)	N (9 %)	
	Work Location (0: Non-urban, 1: suburban, 2: urban)	N (1 %)	N (11 %)	PSR (12 %)	N (6 %)	N (4 %)	
	Accuracy		%93.7	%94.3	%96.3	%97.7	%97.2
	Car	Trip Distance	PSR (7 %)	PSR (3 %)	PSR (7 %)	PSR (4 %)	PSR (2 %)
		Trip Duration	NSR (1 %)	NSR (1 %)	NSR (2 %)	NSR (1 %)	NSR (1 %)
		Age	PSR (1 %)	PSR (1 %)	PSR (%0)	N (0 %)	N (0 %)
		Gender (0: Male, 1: Female)	N (1 %)	N (6 %)	N (2 %)	N (2 %)	PSR (22 %)
		Education (1: Less than a high school graduate, 5: Graduate degree or professional degree)	N (6 %)	N (4 %)	N (2 %)	N (0 %)	N (1 %)
		Household Size	N (7 %)	N (1 %)	N (2 %)	N (1 %)	N (1 %)
		Income	N (0 %)	N (1 %)	NSR (4 %)	N (1 %)	N (2 %)
Vehicle Number		PSR (20 %)	PSR (22 %)	PSR (20 %)	PSR (10 %)	PSR (12 %)	
Reasons for choosing home location: close to PT (0: No, 1:Yes)		NSR (20 %)	NSR (31 %)	N (11 %)	NSR (32 %)	NSR (28 %)	
Reasons for choosing home location: close to work (0: No, 1:Yes)		N (8 %)	NSR (18 %)	N (6 %)	N (4 %)	N (4 %)	
Number of Workers		N (2 %)	N (3 %)	N (5 %)	N (6 %)	PSR (6 %)	
Home Location (0: Non-urban, 1: suburban, 2: urban)		NSR (15 %)	N (3 %)	N (11 %)	N (4 %)	N (0 %)	
Work Location (0: Non-urban, 1: suburban, 2: urban)		N (13 %)	NSR (16 %)	NSR (28 %)	NSR (33 %)	NSR (20 %)	
Accuracy			%82.1	%79.3	%85.9	%86.6	%86.2

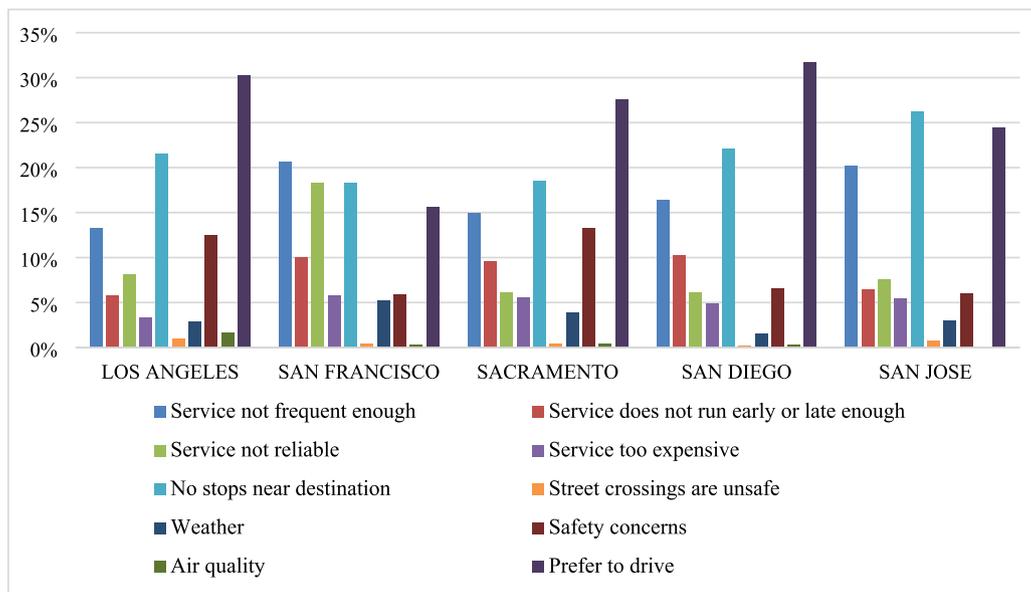


Fig. 14. Reasons for not taking transit more in cities.

The following causes in these cities are respectively the same and are related to the excess traffic and the lack of bikeway infrastructure. However, 'too far to travel by bike' option is important in the other three cities. In addition, 'prefer to drive' option is more preferred in these cities.

5. Summary of Findings, discussions and policy recommendations

This study is carried out to indicate that each city has its own dynamics and the reasons behind the modal preferences will vary, and incentives and disincentives should be differentiated in this direction. The barriers for using sustainable modes of transport for each city are summarised in Table 5.

5.1. Suburban areas

As can be seen, although the main reasons are similar in cities, there are also differences between barriers. The primary barrier for the four cities except Los Angeles is living and working in suburban areas. In San Francisco, those working in urban areas prefer PT, while people working in suburban areas travel by car. This modal shift, which Cervero and Landis (1992) detected with the dispersion of business areas to the city periphery in San Francisco since the 1980 s, supports the result obtained and shows the continuity of this problem for years. Also, in Sacramento, people living in suburban areas cycle less than people living in urban areas. Respondents working in suburban areas in Sacramento also prefer walking less than those working in urban areas and prefer driving instead. In San Diego, on the other hand, this effect is seen mainly in cycling. People living and working in suburban areas prefer to cycle less and tend to use a car. Although it does not affect other modes in San Jose, those working in suburban areas prefer to use cars. In short, it is seen that the priority policy for the four cities is about providing adequate services for PT, walk and bicycle in suburban areas. This problem, common in the USA (Cervero, 2018), has solutions such as providing financial support for mixed-use development in suburban areas, developing PT and bicycle networks in these areas, decreasing the proximity of these services to residences and workplaces or ensuring walking-oriented urban design (Stephenson et al., 2018).

5.2. Trip distances

Though not in large proportions, trip distances are also barriers that encourage car use in all cities. Especially in Los Angeles, although distances seem to reduce only walking preference and slightly increase car use in the test for modes, it is seen that the most important reasons for individuals to prefer driving are increased distances and reduced travel times. Although the effects are minor in Sacramento, it is also important because it is the only city where the use of all sustainable modes is negatively affected, and vehicle use and people's preference to drive are positively affected by trip distance. Although the increase in travel distances negatively affects walking preferences in all cities, the most considerable effect of this situation is seen in San Diego. In addition, people do not cycle because journeys are seen too long for the cycling in all cities. As Bannister (2008) mentioned, the most important measures to reduce travel distances are land-use measurements such as physical restrictions, compact, dense and mixed developments and high availability of services provided for modes.

5.3. Number of vehicles

One of the notable factors that increase car usage and decrease other modes' usage is the number of vehicles in the households. However, the effect of the excess number of vehicles on the modes differs in each city. It causes a significant shift of PT preferences in Sacramento and San Jose and walking preferences in Los Angeles and San Francisco to the vehicle. It does not affect cycling. In this direction, the most recommended measure in the literature is the implementation of economic disincentives and law regulations that reduce car ownership (Jakobsson et al., 2002). These can be road user charging (Berg et al., 1999), parking charges (Khordagui, 2019), permit and license plate regulatory restrictions (Falcocchio and Levinson, 2015), vehicle ownership taxes (May 2004).

5.4. Distance to the PT and bicycle infrastructure

Another important reason for a decrease in PT preferences is the distance to the PT stops. When the choice of houses close to PT in cities is examined, individuals in San Diego are more likely to use PT after this choice, while others choose to drive more. A similar relationship is not seen in other cities. Although it increases PT use in Sacramento, it is not

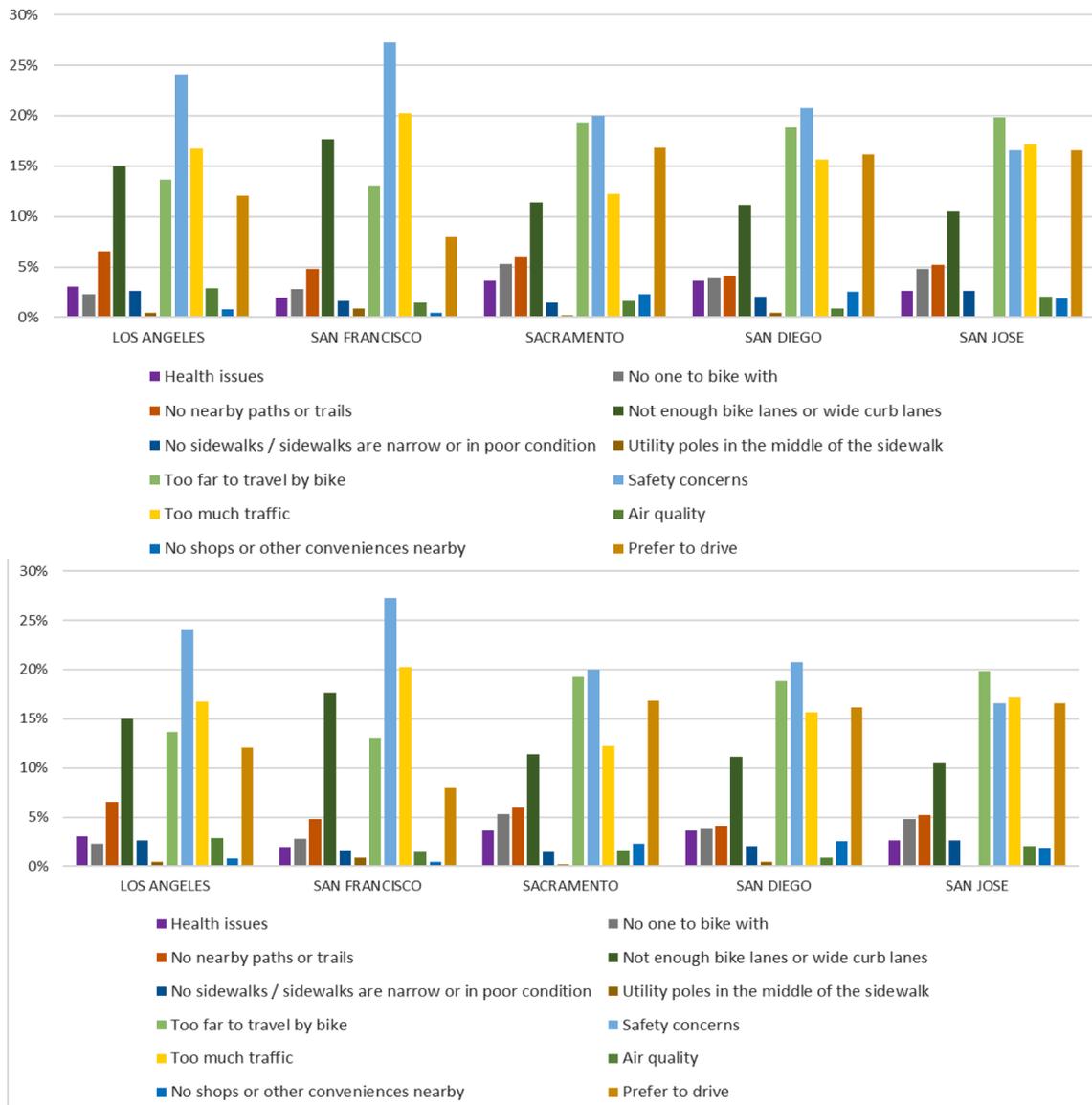


Fig. 15. Reasons for not cycling more in cities.

found to be associated with car usage. However, the increase in the distance from home and business locations to the nearest PT stops is one of the reasons for the perception of availability only in this city. In other cities, the fact that people prefer houses close to PT did not affect their use of PT, but it pushed those who did not prefer houses close to PT to use cars. Also, PT usage decreases slightly in Los Angeles, San Francisco, and Sacramento as distances to the nearest PT stop increase. Although it is not accurate to make a general assessment of PT with only the proximity measure, increasing the walking accessibility of PT in these cities is important as in the studies of Bannister (2008), Daniels and Mulley (2013), and Van Soest et al. (2020).

A similar situation is seen between proximity to bikeway infrastructure and cycling for Sacramento, San Diego, and San Jose. As the length of the bike path around people’s homes increases, the rate of people seeing cycling as an alternative increase. Therefore, it is necessary to invest in bicycle infrastructure and facilities (Biernat et al., 2020) and examine the effects of bikeway types and increase people’s proximity to their OD by bike with an effective bikeway type (Teschke et al., 2017). However, not only the distances but also the safety concerns of the people about cycling are significant for all cities. Therefore, it is necessary to carry out developments such as special bicycle streets and

traffic calming elements (Pucher and Dijkstra, 2000) instead of enhancements that increase bicycle use but also the likelihood of accidents, such as the replacement of one-way bicycle paths to two-way (Schepers et al., 2014).

5.5. Personal characteristics

Although the age factor had a small effect only in Los Angeles, the increase in age decreases the use of PT and pushes people to drive at the same rate. Although increasing age slightly increased vehicle use in San Francisco and Sacramento, there is no evidence of affecting individuals’ other modal preferences. In these cities, in addition to the policy arrangements recommended to reduce car ownership, environmental regulations for not choosing to cycle and walking due to the higher sensitivity of the elderly to environmental problems, and measures to facilitate PT comfort and access to PT can be taken (Van Cauwenberg et al., 2012). When comparing the impact of education, for example, while the increase in education level increases PT use in Los Angeles, it decreases by the same amount in San Jose and increases a large part of individuals’ willingness to drive. In Sacramento, on the other hand, the increase in the level of education has a positive contribution to the use of

Table 5
Summary of barriers for modal preferences in cities.

	Los Angeles	San Francisco	Sacramento	San Diego	San Jose
Barriers for PT usage	High age, high income, long distance to the PT stops from origin, low education level, not choosing home location close to PT	Long trip distance, high household size, long distance to the PT stops from origin, low population density, low green area size in nearest PT stop to the origin and destination, work location in suburban area	Long trip distance, high household size, high vehicle number, long distance to the PT stops from origin, perception of PT availability in origin, not choosing home location close to PT	Perception of PT availability in origin, not choosing home location close to PT	Long trip distance, high vehicle number, perception of PT availability in origin, low green area size in nearest PT stop to the destination
Barriers for Walking	Long trip distance, long trip duration, high vehicle number, high age, low percentage of green density in origin	Long trip distance, long trip duration, high vehicle number, gender, low percentage of green density in origin	Long trip distance, long trip duration, gender, work location in suburban area	Long trip distance, long trip duration, high income	Long trip distance, long trip duration,
Barriers for Cycling	Short bikeway length in 500 m buffer zone to origin	Gender, perception of bikeway availability in origin, not choosing home location close to work	Long trip distance, low education level, home location in suburban area,	Long trip duration, short bikeway length in 500 m buffer zone to destination, home and work location in suburban area	High income, perception of bikeway availability in destination
Reasons for Car usage	Long trip distance, short trip duration, high age, high vehicle number, not choosing home location near to the PT	Long trip distance, short trip duration, high age, high vehicle number, not choosing home location near to the PT and work, work location in suburban area,	Long trip distance, short trip duration, high age, low income, high vehicle number, work location in suburban area,	Long trip distance, short trip duration, high vehicle number, not choosing home location near to the PT, work location in suburban area, low education level	Long trip distance, short trip duration, gender, high vehicle number, not choosing home location near to the PT, work location in suburban area, low education level

bicycles. Additionally, while income growth negatively affects PT use in Los Angeles, the same effect is seen in cycling in San Jose and walking in San Diego. This is an example output that shows that the effects of similar factors may differ in different cities. In the study of [Javid et al. \(2016\)](#), it is observed that the middle-high income and high education group accept vehicle restrictions and incentives for sustainable modes more easily. Hence, incentives and disincentives about modes affected by income and education can change these preferences in these cities.

5.6. Household characteristics

In addition, as another example of contrast, the growth of the increase in household size encourages PT use in Los Angeles, while it negatively affects the use of PT in San Francisco and Sacramento. This shows that there may be high PT service quality for households in Los Angeles, contrary to complaints of people living in San Francisco. However, there is no significant relationship between the number of households and car use in San Francisco, and there is no evidence that they switched from PT to car. Understanding the cause of the situation in Los Angeles can set an example for San Francisco. It can also provide similar support in San Jose, where vehicle use increases with the increase in the number of employees in the household. Therefore, measures such as the family ticket in Berlin ([Jong, 2006](#)), mobility support for large families in the Emilia Romagna Region ([Pechin, 2021](#)) or improving the quality of PT for families ([Dell'Olio et al., 2011](#)) can be taken.

6. Additional discussion

As examined in the previous sections, the modal distribution of San Francisco differs from other cities. In this context, when the factors that reduce the use of vehicles in this city are examined, the main reason is that the households prefer homes close to their workplaces and PT. San Francisco is the only city where people prefer to live close to their workplace, although other cities also prefer to live close to PT. However, the reasons for driving the use of vehicles in this city are similar. The reason that prevents people from seeing PT as an alternative is not the distance, but the service quality features, unlike other cities. Although the amount of green space has little effect, the effect of this factor for PT use and walking in this city is a meaningful output. While the distribution of other modes is proportional in San Francisco, it has been mentioned before that the inadequacy of bicycle trips draws attention,

and it is seen from the model outputs that the barrier that has a significant effect on this situation is gender. When the reasons for not cycling are examined, it can be predicted that this may be due to safety. A similar situation exists as a result of women seeing walking as an alternative less than men. The results are consistent with the study of [Dill et al. \(2014\)](#), in which similar gender differences are defined for San Francisco. The study also shows that women's cycling rates notably increase with the protected bike lanes. Hence, urban design elements that increase women's sense of security ([Clifton and Dill, 2005](#)) or bicycle infrastructure that is highly differentiated from motorized traffic, which women find safer ([Garrard et al., 2008](#)), can be performed. In San Jose, where the rate of vehicle usage is very high, it is also seen that women prefer to drive more. However, in the barrier test, it is seen that men want to drive more than women. In this case, although women do not want to drive more than men, they prefer to drive. Similarly, PT, cycling and walking facilities should be made safer, more comfortable and preferable for women in this city. The policy prioritization table which obtained only with the factors tested in the study for the cities is presented in [Table 6](#).

As discussed above, similar and opposite conclusions have been reached in many studies in the literature. This shows that the scope, content and characteristics of the data used in the studies may produce different results in different contexts. While parameters were considered independently in the above studies, all effect groups were evaluated together in this study. The fact that this evaluation was made comparatively between cities provided new findings in explaining the causality that changes according to local characteristics. The fact that the output results for some cities differed from the accepted predictions showed that the scope of coverage that should be evaluated in understanding the modal preferences should be high.

7. Limitations and recommendations for future studies

The study's primary limitation is that there is no information on the attributes of alternative modes in the data for applying MNL analysis. In addition, the data coverage in the open-source portals of cities is not the same, which created an obstacle to the comparison of some infrastructural data. Other factors mentioned in the factor groups in the literature can be added to the analyses in future studies. Another issue is that the spatial analysis is only based on PT and bike. Also, only PT and cycling could be evaluated in the barrier analysis because data on walking has not enough response in NHTS in cities. This situation made

Table 6
Barrier and policy prioritization for cities.

B: Barrier PS: Potential Solution	Los Angeles	San Francisco	Sacramento	San Diego	San Jose
B1	Long trip distances	Driving preferences of people living and working in suburban areas			
PS1	Land use measures	Providing financial support, infrastructure, and arrangement on urban plan in suburban areas			
B2	Number of household vehicle				
PS2	Economic disincentives and law regulations				
B3	Distance to the PT stops	Lack of participation of women in active transport	Long distance trips	Lack of PT infrastructure on long trips	High rate of driving by women
PS3	Land use measures	Actions and decisions that support women's participation	Land use measures	Investments on PT routes	Actions and decisions that support women's participation to sustainable modes
B4	Less preference for PT as income increases	Lack of PT infrastructure on long journey and PT service quality	Inadequate PT and bike infrastructure around the home	Less preference for active modes as income increases	Inadequate PT and bike infrastructure around the home
PS4	Vehicle restrictions and incentives for sustainable modes	Investments on PT routes and services	Creating more connection with PT and bike infrastructure	Vehicle restrictions and incentives for sustainable modes	Creating more connection with PT and bike infrastructure
B5	Increase in driving with age	Increase in household size		Inadequate PT and bike infrastructure around the home	Increase in number of workers in household
PS5	Policy arrangements, environmental increasing comfort and access of sustainable modes	Incentives for family trips		Creating more connection with PT and bike infrastructure	Incentives for group trips
B6		Increase in driving with age			Less preference for active modes as income increases
PS6		Policy arrangements, environmental increasing comfort and access of sustainable modes			Vehicle restrictions and incentives for sustainable modes
Potential positive impacts for all cities	Increase in green areas in neighborhoods and near PT stops + close proximity between home and work				

it difficult to evaluate walking within the sustainable modes. In future studies, this scope can be expanded, and similar spatial analyses can be made on the basis of other modes. Also, only the proximity is calculated in the spatial analysis, and some other variables like the continuity of the networks, the PT system features, the width and safety information of the bike paths are not included. Incorporating these data into spatial analyses in future studies will increase the accuracy. In addition, although the spatial analysis was used only for the built environment features in this study, this approach can be developed with the same or different analysis types in other factor groups such as trip and personal. In addition, people's perceptions about alternatives and PT stop and bicycle path proximity were found uncorrelated in general in the study, but the factors causing these opinions could not be understood because there is no other data on alternatives. For this reason, examining the characteristics of all alternatives in people's commuting journeys can be used in future studies to understand these perceptions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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