

# Influence of Land Use, Socio-demographic and Travel Attributes on Travel Behaviour in City of Lahore

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**Abstract** – Travel behaviour exists in both culture and the surrounding environment. It is crucial to understand it because it helps the policymakers to effectively develop the urban and transportation planning policies. Large scale mobility of people by motorized transport is making our cities polluted and more congested that ultimately affects urban assets. A single paradigm, e.g. land use or socio-demographics, might not clearly demonstrate people's preferences, it is necessary to take several paradigms in isolation. This study examined the joint influence of multiple attributes that includes land use, socio-demographic and travel information on travel behaviour and particularly preferred travel mode. A structured questionnaire was designed and interviews were conducted to obtain the data. Multinomial logit model (MNL) was applied to estimate the relationships among variables. Furthermore, spatial maps were prepared to highlight the classification of land uses. It was estimated that with the increase in income level people switched from walking to riding a vehicle and most of them prefer to ride a vehicle for longer trips. It was further investigated that people prefer to walk or ride a vehicle in residential and commercial areas. Based on the results, several planning related policies were recommended.

**Keywords** – Land use; Travel behaviour; Multinomial logit model; Travel mode

## INTRODUCTION

The issue of land use affecting travel behaviour has been widely studied. The land use can be defined in numerous ways but the simplest one is that land use is the arrangement of different activities, which people perform on a certain piece of land. In the same way, travel behaviour defines people's behaviour and how they travel. Which travel mode people prefer more? Do the surroundings directly influence people's choices. Moving elements of a city are its people, they are essential as the permanent part of land [1]. According to one estimate, there are more than two hundred studies found in the research area until 2010 [2]. Past studies estimated that cities are inherently complicated and continually changing over time. Rapid urbanization has become the reason of fast urban growing and growth in built environment and infrastructure. Most of the suggested strategies and plans to tackle such expansions include reducing the street distance, mix land use and adopting alternative modes of transportation, such as bicycle, walk and transit [3]–[5].

From the last few decades, the urban and transportation planners of Pakistan are potentially looking for evidence to link the land use with travel behaviour to manage and prepare the planning policies accordingly. However, the link between these is still inconclusive. The cities are becoming more car-dependent than walking or cycling. The increase in motorized trips is severely affecting the urban environment, and people's travel preferences are one of the significant concerns of policymakers. Because of these issues, it is essential to understand people's travel preferences

that ultimately helps to set the various planning policies to control mobility and to achieve a sustainable growth of cities.

This research applied MNL to study how land use, socio-demographic and travel information influence the travel mode. The land uses considered in this study are residential, commercial, residential-cum-commercial, industrial and other land uses, e.g. vacant areas. This study also integrates population density of the studied areas with travel behaviour of people to get to know the dependency of travel behaviour on population density. We also incorporated socio-demographic variables, including gender, age, occupation, income, and vehicle ownership. Additionally, we incorporated the travel information variables including trip purpose, trip length, and preferred travel mode for daily traveling. The preferred travel mode for daily traveling was considered as a dependent variable and remaining variables as independent variables, including land uses, population density, socio-demographic variables, and travel information variables.

Lahore, the second-most populous city of Pakistan, was selected for a case study. To our knowledge, no such study addressing the influence of land use along with population density, socio-demographic, and travel attributes on travel behaviour in the city of Lahore has been carried out before. The city of Lahore comprises ten towns four of which were selected to conduct the study based on the nature of their land use and contribution to the city transport. A structured questionnaire was designed in order to get the data. Further, ArcGIS software was used for mapping and study of land uses of the selected areas. More details on data collection and area selection are explained in Section 3 of this paper.

The paper is structured as follows: Section I presents a literature review of the previous studies. Section II presents the methodology and data collection. Section III discusses the analysis, results and findings. Section IV recommends a several policies based on the results, and Section V summarizes the whole work.

## I. LITERATURE REVIEW

Modern transportation planning necessarily focuses on land use patterns and characteristics to facilitate people's activities. Certainly, land use and traveling behaviour of people are strongly linked with one another but there is still little understanding in the context of developing countries. Extensive studies found a linkage between land use and built-environment and travel behaviour in developed countries. The most used techniques to relate these are simulations (i.e. hypothesis based on assumed travel behaviour or more complex land use and travel behaviour models rely on the forecast) descriptive (i.e. observing travel

behaviour by city size) and statistical analysis (i.e. correlation analysis, model estimations using behaviour theories) [6]. These techniques are very useful to travel studies, especially the multivariate, one of the statistical analysis methods as it takes a couple of factors at play. The studies described in [7] and [8] used regress commute length approach to study the residential density and demographic characteristics of commuters and estimated the significance of multiple factors on density. These studies found that behaviour reflects people's selection of travel mode for traveling from the group of feasible choices. It is suggested to identify and characterize the different sub-areas within a region, which is important in the development of land-use and transport policies, in effective evaluation of policies, and in facilitation of understanding concepts such as urban sprawl, suburban areas and mixed land-use [9], [10]. Some studies, e.g. [11] and [12] identified different area types within a region by applying qualitative method, such as maps, site visits, images, etc., and there is a growing body of researches, which seek to construct qualitative approaches to classify the distant areas within a region. Most of the variables taken under consideration by many researchers include socio-demographic variables, which are conventionally treated as control variables. These variables include variables like age, gender, employment, car ownership, income, and education level. Among these, car ownership is the most important considered endogenous variable in the travel behaviour studies [13].

Developing the relationship between land use and travel behaviour is one of the study areas which is paid a lot of attention to by researchers and is reflected in the literature related to the behaviour of commuters, to land use pattern and built environment characteristics [14]–[16]. Land use pattern defines the choices commuter make in the daily travel routine based on their living and work location in order to fulfill their travel behaviour desires. Many studies, e.g. [17] and [18], included transport considerations in order to model the characterization of different areas within the region using the concept of traffic calming, such as the supply of bike lanes, sidewalks, etc. within the different area of a region [19]–[22]. discovered that the built environment factors might have less influence on travel behaviour relative to other factors, such as living and work location choices and individual attitudes of commuters. Mostly the individuals choose the living locations, which allow them to travel in a certain way, e.g. walkability. In these situations, built environment factors might have secondary importance to study the influence on travel behaviour. With time researchers' interests changed from trip generation [20], [23] to the distance traveled by commuters, either by walking [24], by cycling [25], [26], or by motorized vehicle [27].

Most of the studies found in the literature have used the data collected through surveys conducted during research and data collection through household surveys by government organizations. Several studies have used the census data. A number of researchers used travel diaries records compiled by municipalities and relevant planning department of state, which are commonly used to construct the linkage among different land-use and travel behaviour factors. Study [30] used multinomial logistic regression to study the choice modeling including mode choices or desti-

nation choices. Correlation analysis and ANOVA analysis was used by researchers to estimate the association of different variables. Studies [29] and [30] utilized a structural equation modeling approach to study the land use influence on travel behaviour. Study [31] used a geographical information system to visualize activity patterns. Meanwhile, quantitative ways to analyse the data is dominating in the literature. This study takes advantage of creating the linkage of land use, socio-demographic and travel information with travel behaviour. To our knowledge, no such study has been carried out before for any city of Pakistan.

## II. METHODOLOGY

### A. Introduction to Case Study

The city of Lahore is the cultural capital of Province Punjab, Pakistan. Lahore has a population of 11.13 million people [32], it is the second-most populous city in Pakistan after Karachi. The total area of Lahore is 1772 sq.km with density of 6300 people per sq.km. Lahore is the largest city of Pakistan and is the historic cultural centre of the province, Punjab region and one of the most socially progressive cosmopolitan cities. The city of Lahore is administratively divided into ten towns (regions) and four out of these ten regions were chosen for study based on their land uses, population density and contributions to city transport. The four regions are Data Gunj Bakhsh, Ravi, Shalimar, and Gulberg, with population densities of 31132, 26724, 21879, and 19501 people per sq.km, respectively. The majority of the land uses of Data Gunj Bakhsh region is commercial shops and residential cum commercial. The Gulberg region is one of the planned areas of cities with low population density with the majority of land uses as residential. On the other hand, the Ravi and Shalimar region is intermediate to both Data Gunj Bakhsh and the Gulberg region. Majority of the land uses of Ravi region is commercial and part of Ravi is residential and residential cum commercial with a population density higher than in Shalimar and Gulberg region but lower than in Data Gunj Bakhsh region. Figure 1 shows land uses of the Data Ganj Bukhsh region, Fig. 2 shows land uses of Gulberg region, Fig. 3 shows land uses of the Ravi region, and Fig. 4 shows land uses of the Shalimar region.

### B. Sampling Size

The socio-demographic, and travel information data was collected through field surveys and interviews with the local people, which were considered very important as it helped to make better understandings of on-ground realities. The interviews provide in-depth evidence of contributors' practices and viewpoints of a particular topic [33]. The sample was found to be representing the overall travel pattern of Lahore residents. The land use data were collected in two different ways. First, the geo-referred images of study areas were collected from Google maps, digitization procedures were followed, after that the data collected from the field surveys were added. The land use data were classified into five major groups, i.e. residential, commercial, residential cum commercial, industrial, and others. The land use details of study

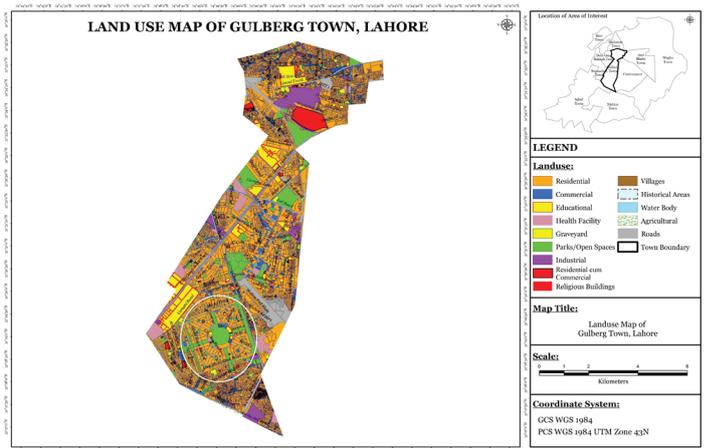
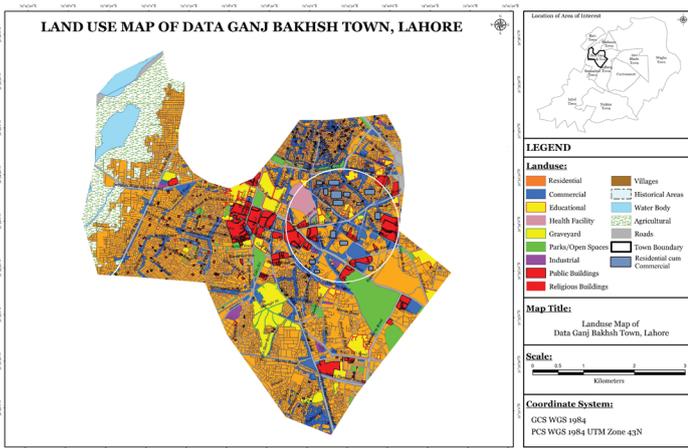


Fig. 1. Land use map of Data Ganj Bakhsh town [Authors of the article].

Fig. 2. Land use map of Gulberg town [Authors of the article].

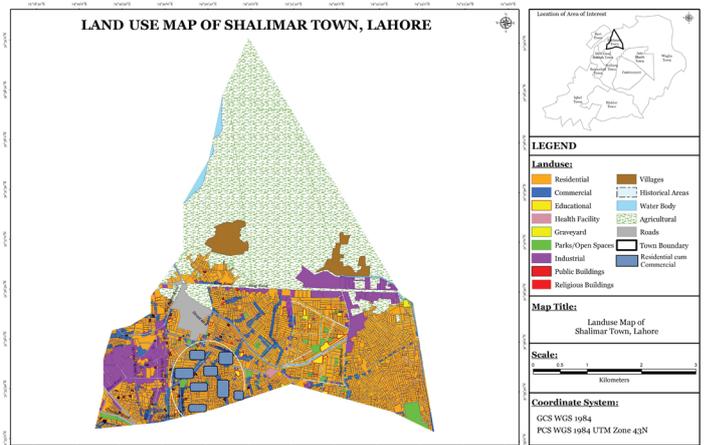
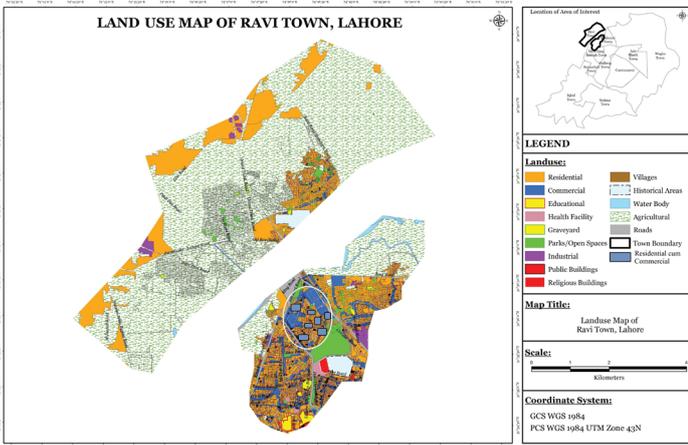


Fig. 3. Land use map of Ravi town [Authors of the article].

Fig. 4. Land use map of Shalimar town [Authors of the article].

regions are digitized in ArcGIS 10.2 software. Educational and health facilities, graveyards, parks/open spaces, religious buildings, public buildings and historical areas were classified as other land-use. The survey was conducted through a design questionnaire from the four regions of the Lahore city. In total, questionnaires were collected from 400 households, 100 from each region in Lahore city.

C. The MNL Model

Logit models are among the widely used statistical techniques to study the association between variables. The critical usefulness of using these techniques is that (a) it indicates whether independent variables have a significant relation with a dependent variable or not, (b) it indicates the influence of different independent variables on dependent variables, and (c) it helps to make predictions. MNL is a method for finding the relationship among variables when there are more than two choices of an indepen-

dent variable. MNL estimated the probabilities of each choice using Equation 1:

$$P_j = \frac{\exp(V_j)}{\sum_{j=1}^K \exp(V_j)}$$

where  $V_j$  is the utility vector of choice j from K choices. It further estimated the K-1 multiple regressions using Equation 2:

$$\ln\left(\frac{P(Y_i = r)}{1 - P(Y_i = r)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_N X_N$$

where  $\beta_0$  is constant and  $\beta_1, \beta_2, \dots, \beta_N$  are the coefficients related with the variables  $X_1, X_2, \dots, X_N$

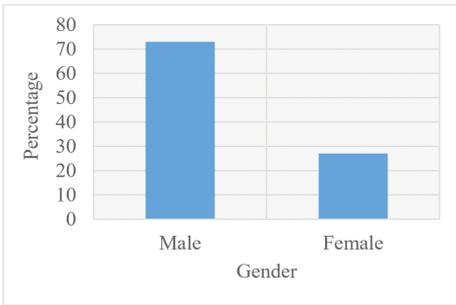


Fig. 5. Gender of the respondents [Authors of the article].

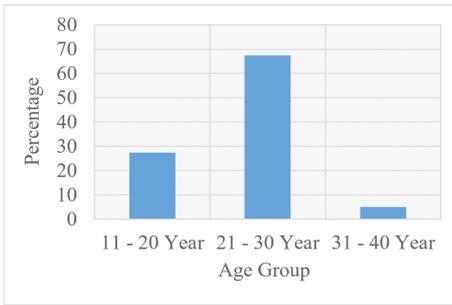


Fig. 6. Age groups of respondents [Authors of the article].

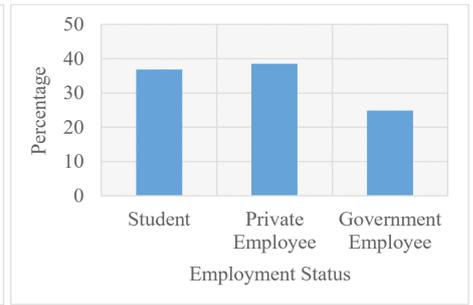


Fig. 7. Employment status of the respondents [Authors of the article].

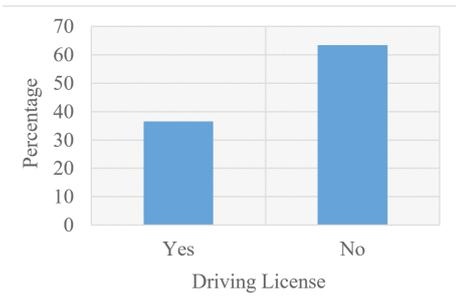


Fig. 8. Driving license status [Authors of the article].

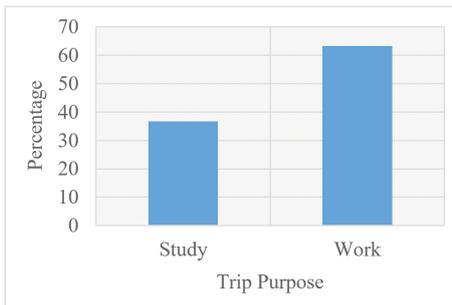


Fig. 9. Purpose of trips for daily commute [Authors of the article].

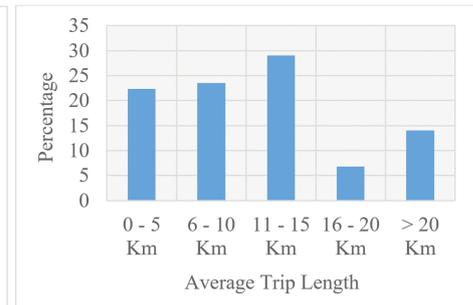


Fig. 10. The average trip length [Authors of the article].

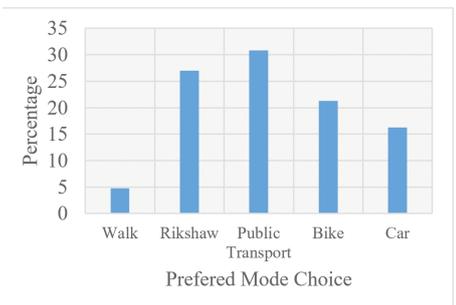


Fig. 11. People preferred travel mode for daily commute [Authors of the article].

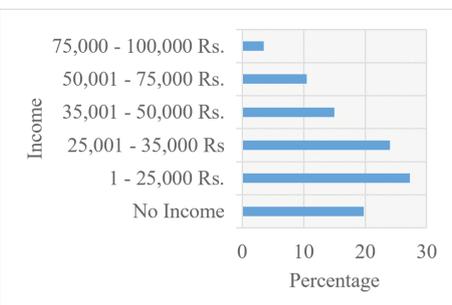


Fig. 12. Income status of respondents [Authors of the article].

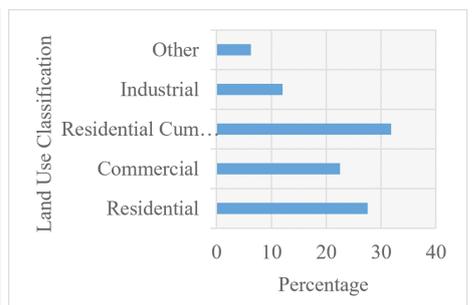


Fig. 13. The land use status [Authors of the article].

### III. ANALYSIS AND RESULTS

#### D. Exploratory Data Analysis

The exploratory analysis is a technique to summarize the characteristics and visualize the data for easy understanding. The exploration of the data helps to visualize, it informs what the data can bring out beyond the formal modeling. The data was arranged to pass through an exploratory analysis paradigm for visualization. The following are the results of the exploratory analysis of all the variables, which gives us an in-depth understanding of the current trend in the case study. It was observed that the majority of the respondents were male as shown in Fig. 5.

The majority of the respondents were belonging to the age group of 21–30. The majority of the respondents were engaged in private sector, followed by students and government employees, as shown in Fig. 7. The majority of people hold no driving license and drive the vehicle without having a driving license because people can own a vehicle without driving license as shown in Fig. 8. This is one of the reasons for more people preferring to drive a vehicle. The majority of the trips made were work trips followed by study-related trips, as shown in Fig. 9. The majority of the trips were made within the buffer of 11–15 kilometers followed by 6–10 kilometers, as shown in Fig. 10. People prefer walk less compared to the other available mode of transports, as shown in Fig. 11. The majority of the people belong to the lower

class income group followed by the upper lower and middle-class income group, as shown in Fig. 12. Looking into the land use classification status, the majority of the land use was found to be the mixture of both commercial and residential, i.e. residential cum commercial followed by residential, commercial, industrial and other land uses, as shown in Fig. 13.

### E. Model Results

In this study, we applied the MNL model because this is one of the promising techniques to deal with the dependent variable in the case when people have more than two choices. The results of detailed analysis are shown in Table 1. We checked each available choice of land use, socio-demographic and travel information variables to analyse the preferred travel mode. As the data sample was small the only way to study choice preference was when no other potential data source is available. Because, transport sector in Pakistan is still emerging and unfortunately there is not any stable data management system available. We declare that the performance of the model is not perfect, but this study is generalized so that the researchers from the developing countries like Pakistan can consider it as a baseline study to carry more studies that ultimately will help to improve urban and transportation planning and practices for the cities of Pakistan.

The results are expressed by the mean of the regression coefficient (B), and the odds that are further converted to a percentage, to have a clear idea of how one factor is influencing the target variable. Furthermore, we choose the car as a baseline travel mode to compare the other available choices that is one of the assumptions of the MNL. The results show that the chances of choosing walk over car as the preferred mode is higher for the age group of 11–20 followed by the age group of 21–30, compared to the age group of 31–40. In the same way, the chances of choosing both pick & drop and public transport over the car are higher for the age group of 11–20 years followed by the age group of 21–30, compared to the age group of 31–40. While the chances of choosing a bike over the car are higher for the age group of 21–30. It is because, with the increase in age, people preferences always shift from walk to their own vehicle, and the young generation prefers to drive more in the cities of Pakistan. The survey data contained no information on the age group of 41–50 years. Within the age group of 11–20 years, the majority of people are associated with being students preferring to walk while with the increase in their age, the trend changes to other available preferences. The chances of choosing walk over the car for the males are higher than for females, while the chances of choosing pick & drop and public transport are less. On the other hand, the chances of choosing a bike over the car are higher for males compared to females. It is because females are more dependent on their other family members to pick & drop, while males are less dependent and prefer to either walk or ride a bike instead of choosing pick & drop or public transport. The chances of choosing a walk or ride a bike over the car are higher for the students compared to the government employees, while there are fewer chances of choosing public transport over the car for the group having private jobs compared to government employees. As survey records have insufficient information on

business owners' choices and home-based work (mostly the older women working at home), it is open for further studies to analyse the mode preference of the higher class people. The chances of choosing a walk over the car are higher for the people who own a bike compared to the people who own no vehicle. The chances of choosing public transport and pick & drop over the car are higher, followed by walk and bike for people having a driving license. The chances of choosing public transport are higher (larger B value) for the group having no income, while those with an increase in income level preferred choices is to ride a bike over car compared to the group of reference choice. It was analysed that the trip purpose has no potential influence on the preferred mode in the city of Lahore, as both study-related or work-related mode preferences have an equal effect. The preferred mode for shorter trips is a walk (higher B value), while with the increase in the distance, people preferred to use either public transport or ride a bike over car compared to the distance of more than 20 kilometers. It was estimated that population density (number of people per kilometer area) have no potential influence on preferred mode because the preferred mode is least affected by the population density. More importantly, number of people preferring to choose a walk and bike over the car is higher in the residential and commercial areas because of small streets right-of-ways and traffic congestion, respectively. While the preference of choosing a walk and ride a bike over the car is also higher to other land uses.

### III. POLICY RECOMMENDATIONS

Travel behaviour, especially travel choices made by the people for daily commutes, is essential to understand because it helps urban and transportation planning related decisions and policies formulations. It is also crucial to investigate before introducing any urban development-related policies or plans, e.g. parking space provisions, roads-right-of-ways, etc. As it was investigated that the walk is more preferable for the age group of 11–20, that is the majority of the students, so walkability provisions should be a part of planning policies and regulations, particularly in the school zones. This ultimately helps to prevent accidents and keep the neighbourhood environment clean and more sustainable. In the same way, with the increase in the age and income level, people switched from a walk to driving a vehicle that demands better and planned infrastructure. It was also noticed that several people own and drive the car without the driving license. The increase in such riders shows the failures of the regulations and relevant departments. For the longer trips, it was noticed that people switched from a walk to riding a vehicle and prefer to ride but not to share. In other words, the promotion of the shared mobility concept in legislation can be a better alternative to reduce the vehicles on roads.

### CONCLUSIONS

This study was carried out to investigate the joint influence of land use, socio-demographic and travel information on preferred

travel mode by applying the MNL model to study how the land use, socio-demographic and travel attributes influence the travel mode. The land uses considered in this study are residential, commercial, residential cum commercial, industrial, and other land uses, e.g. vacant areas. This study also integrated the population density of the studied areas with travel behaviour of people to get to know the dependency of travel behaviour on population density. We also incorporated socio-demographic variables, including gender, age, occupation, income, and vehicle ownership. Additionally, we incorporated the travel information variables including trip purpose, trip length, and preferred travel mode for daily traveling.

It was found that the majority of people are engaged with the private sector followed by students that belonged to the lower class and upper lower class income groups. It was investigated that with the increase in income level, people switched from a walk to riding a vehicle and most of them prefer to ride a vehicle for longer trips. Looking into the land use classifications, it was investigated that people prefer to either walk or ride a bike in the residential and commercial area because more residential and commercial areas have lesser right-of-ways as compared to highways. This shows that planning related policies for residential and commercial areas should be developed in a way to promote walkability and secure the sustainable development of neighbourhoods. Urban and transportation-related policy formulation needs to be in accordance with people's preferences to secure successful implementations.

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APPENDIX  
TABLE I. THE RESULTS [AUTHORS OF THE ARTICLE]

Variables	Choices	Walk			Pick & drop			Public transport			Public transport		
		B	Odds	P	B	Odds	P	B	Odds	P	B	Odds	P
Age	Intercept	-74.7			25.1			-2.1			-32.0		
	1-10 years												
	11-20 years	64.6	1.13612E+28	100.00 %	54.0	2.83075E+23	100.00 %	22.3	4839126180	100.00 %	-1.7	0.182683524	15.45 %
	21-30 years	1.7	5	84.55 %	0.3	1.349858808	57.44 %	4.1	60.3402876	98.37 %	-0.9	0.40656966	28.91 %
	31-40 years (reference choice)												
	41-50 years												
	More than 50 years												
Gender	Male	31.0	2.99335E+13	100.00 %	-13.6	1.2405E-06	0.00 %	-11.8	7.50456E-06	0.00 %	3.3	27.11263892	96.44 %
	Female (reference choice)												
Occupation	Student	-1.0	0.353454682	26.11 %	-15.2	2.50452E-07	0.00 %	-12.1	5.55951E-06	0.00 %	26.0	1.9573E+11	100.00 %
	Private employee	0.2	1.221402758	54.98 %	0.1	1.105170918	52.50 %	-5.1	0.006096747	0.61 %	-0.8	0.449328964	31.00 %
	Government employee (reference choice)												
	Own Business												
	Home Based												
	Other												
Vehicle ownership	Cycle	-2.5	0.082084999	7.59 %	3.5	33.11545196	97.07 %	8.2	3640.950307	99.97 %	6.6	735.0951892	99.86 %
	Bike	0.4	1.491824698	59.87 %	2.0	7.389056099	88.08 %	8.1	3294.468075	99.97 %	4.3	73.6997937	98.66 %
	Car	-28.1	6.25641E-13	0.00 %	-25.3	1.02884E-11	0.00 %	-19.5	3.39827E-09	0.00 %	-23.0	1.02619E-10	0.00 %
	Other (reference choice)												
	No vehicle												
Driving License	Yes	0.3	1.349858808	57.44 %	-1.3	0.272531793	21.42 %	0.9	2.459603111	71.09 %	-2.7	0.067205513	6.30 %
	No (reference choice)												
Income	No income	18.0	65659969.14	100.00 %	21.3	1780215035	100.00 %	25.3	97196447559	100.00 %	10.8	49020.80114	100.00 %
	1-25 000 Rs.	18.2	80197267.41	100.00 %	23.3	13154108760	100.00 %	27.4	7.93723E+11	100.00 %	13.8	984609.1112	100.00 %
	25 001-35 000 Rs.	14.6	2191287.876	100.00 %	8.4	4447.066748	99.98 %	19.1	197253448.4	100.00 %	29.6	7.16336E+12	100.00 %
	35 001-50 000 Rs.	62.6	1.56863E+27	100.00 %	34.6	1.06314E+15	100.00 %	1.5	4.48168907	81.76 %	71.4	1.02006E+31	100.00 %
	50 001-75 000 Rs.	2.5	12.18249396	92.41 %	-18.8	6.84327E-09	0.00 %	-1.7	0.182683524	15.45 %	-6.9	0.001007785	0.10 %
	75 000-100 000 Rs. (reference choice)												
	More than 100 000 Rs.												
Trip purpose	Study	0.0	1	50.00 %	0.0	1	50.00 %	0.0	1	50.00 %	0.0	1	50.00 %
	Work	0.0	1	50.00 %	0.0	1	50.00 %	0.0	1	50.00 %	0.0	1	50.00 %
	Shopping												
	Recreational												
	Other												
Trip length	0-5 km	94.0	6.66318E+40	100.00 %	76.9	2.49601E+33	100.00 %	19.6	325215956.1	100.00 %	61.8	6.90874E+26	100.00 %
	6-10 km	61.3	4.19036E+26	100.00 %	31.9	7.14486E+13	100.00 %	45.9	8.59244E+19	100.00 %	46.9	2.33567E+20	100.00 %
	11-15 km	36.1	4.76465E+15	100.00 %	-19.6	3.07488E-09	0.00 %	31.6	5.29305E+13	100.00 %	30.9	2.62845E+13	100.00 %
	16-20 km	4.3	73.6997937	98.66 %	-18.7	7.56298E-09	0.00 %	6.7	812.4058252	99.88 %	-2.8	0.060810063	5.73 %
	More than 20 km (reference choice)												
Population density	31 131 people/sq.km	-116.2	3.42753E-51	0.00 %	-126.2	1.5561E-55	0.00 %	-37.4	5.71987E-17	0.00 %	-82.4	1.63732E-36	0.00 %
	26 724 people/sq.km	-28.8	3.10684E-13	0.00 %	-50.4	1.29288E-22	0.00 %	-15.3	2.26618E-07	0.00 %	-32.1	1.1459E-14	0.00 %
	21 879 people/sq.km	-49.5	3.17997E-22	0.00 %	-77.0	3.62514E-34	0.00 %	-21.2	6.20808E-10	0.00 %	-65.1	5.33862E-29	0.00 %
	19 501 people/sq.km (reference choice)												
Land use	Residential	14.2	1468864.19	100.00 %	-13.7	1.12245E-06	0.00 %	-18.4	1.06256E-08	0.00 %	7.9	2697.282328	99.96 %
	Commercial	16.0	8886110.521	100.00 %	-17.4	2.77508E-08	0.00 %	-18.3	1.12826E-08	0.00 %	14.7	2421747.633	100.00 %
	Residential cum commercial	15.9	8040485.3	100.00 %	-16.4	7.54346E-08	0.00 %	-15.1	2.76792E-07	0.00 %	15.4	4876800.853	100.00 %
	Industrial	15.8	7275331.958	100.00 %	-16.5	6.8256E-08	0.00 %	-16.6	6.17606E-08	0.00 %	14.5	1982759.264	100.00 %
	Others (reference choice)												