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An Examination of the Land Use Determinants of Travel: A Case Study of Calicut City in India

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Abstract

Several travel studies focus mainly on mode shifting. Again, most travel studies have focused on mandatory trips. But the influence of land use on travel is rarely verified in all these studies. This paper examines the influence of land use measures on travel in a medium-sized city, India. The travel characteristics like number of trips, person-km and person-hr of travel by various modes and for various purposes are analysed separately. Land use is characterised by population density, employment density, land use intensity, land use mix and accessibility. During the modelling process, the explanatory variables are subjected to transformation to get over the nonlinearity issue. Statistical analysis reveals that a balanced mix of various land use activities causes people to travel less by any mode and for any purpose. Such studies can help the city planners formulate effective transport policies to improve the quality of transport within the city.

Keywords: Land use, Transport Network, Travel, Regression.

1. Introduction

The growing traffic and travel in most Indian cities cause reduced mobility, but increase travel-related issues such as energy insecurity and adverse effects on public health. Henceforth, how to reduce travel and thereby enhance mobility has emerged as an increasingly important question in Indian cities with rapid motorization. One of the several approaches to enhancing mobility is to promote the public mode of transport, while reducing the personal mode of transportation, in some way. The general statement that travel can be reduced by controlling personal trips can, of course, be ascertained by implementing various strategies. The interaction between land use and transport is one of the important themes that can finally help to develop suitable travel reduction strategies.

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A detailed analysis of the travel situation with attention to the different modes of travel and their comparison can be a source of improvement in this field. It is a general hypothesis that urban design has its greatest influence on work trips. Compared to work trips, non-work trips are more flexible in choosing the time and duration of a day for conducting an activity. This flexibility can again have implications for transportation planning.

There is a long-running debate about the effect of the built environment on travel demand and the degree to which travel demand preferences are reinforced by urban neighbourhood effects. Many studies have concluded the correlation between urban design and travel (Ewing and Cervero, 2001; Ewing and Cervero, 2010; Tae-Hyoung, 2018, Guzman et. al, 2020). Yet, surprisingly little harmony has been reached to date on how the built environment influences travel. Most of the land use-travel studies have incorporated easily available measures such as population density, employment density and land use type (Cervero and Kockelman, 1997; Tae-Hyoung, 2018), while some other studies have referred to any one of the intricate built environment conceptions such as land use mix (Cervero and Kockelman, 1997; Tae-Hyoung, 2018) or accessibility (Kockelman, 1997) to identify the effect of the built environment on travel. Because of this, the earlier studies exploring the effect of land use on travel have come out with mixed findings. Travel related to overall trips or mandatory trips is extensively analysed (Hatami and Thill, 2022; Hu et al., 2022), but the non-mandatory trips are rarely verified. Mode choice for automobile, transit and walking trips is intensively verified (Liu et al., 2021; Ding et al., 2018), but studies pertaining to the length of travel by different modes are limited. To the author's knowledge, very limited research has analysed the influence of land use on travel, categorising travel by various mode types and purpose types.

This paper attempts to address the research gap mentioned above based on a case study of a medium-sized city in India.

2. Brief Summary of Relevant Works

Studies linking the built environment to travel decisions have recently been the topic of interest to transportation planners. While understanding the travel pattern in terms of mode share, many studies have focused on land use measures such as accessibility, density and mix of land use (Ewing and Cervero, 2001; 2010; Cervero and Kockelman, 1997; Jerry and Koranis, 2017). Very few urban structure studies have examined their effect on travel distance and travel duration (Frank et al., 2000; Parthasarathi and Levinson, 2018). Many studies have confirmed the short duration and length of travel for highly dense, diverse and accessible land uses (Rajamani et al., 2003; Zhang et al., 2012). Travel distance for the purpose of commuting and shopping have strong influence from mixing of land use for the case of Agartala, a small-sized city of India (Bordoloi et al., 2013). Many authors have highlighted the effect of residential urban environment, explained in terms of residential density, city size and job-housing balance, on travel time and travel distance. (Levinson and Kumar, 1997; Ewing and Cervero, 2001; Bento et al., 2005; Fan and Khattak, 2008). Many foreign studies have reported that the commute time increases with city size and job-housing separation. A recent study from China has conveyed that commute duration is positively correlated with city size and job-housing separation, but negatively correlated with density and polycentrism (Sun et al., 2015).

Several authors have identified the influence of household and demographic variables such as employment status, income, personal vehicle ownership, family status, etc. on commuting (Levinson and Kumar, 1997; Shen, 2000). Kitamura et al. (1997) concluded the dominant effect of socio-demographic attributes on travel duration rather than the characteristics of urban structure. Hence, including socio-demographic factors and land use simultaneously, the effect of land use on travel cannot be properly identified (Schwanen et al., 2002). As to travel, options can be based on mode choice, travel distance, travel time, or even advanced travel options like trip chaining (Ewing and Cervero, 2010).

Literature on the relationship between land use and travel is abundant, but the inferences are varied. Numerous studies recommend the reduction of travel by mode shifting or by achieving reduced travel-km through the implementation of suggested land use policies. The urban land use measures and policy decisions to promote non-motorised transport modes are very well documented, but the policies so as to restrict motorised travel are missing. Likewise, almost all the urban travel studies concentrated on mandatory trips, which are conducted regularly as a matter of routine. This empirical evidence and related criteria cannot be applied to non-mandatory trips, which are more flexible in choosing the time, day and destination. Hence, it is very important to obtain the urban land use measures that control the travel decisions of non-mandatory trips as well. Addressing these problems can help the transport planners evaluate various urban land use developments so as to reduce the urban travel of developing cities.

Based on the review of literature, the research problem is identified and addressed through a study based on a city in a developing country, India. The main objective of this study is to identify how land use characteristics can explain travel by overall vehicles. The importance of land use characteristics in defining the travel undertaken by various modes and for various purposes is also studied separately. This study contributes to the existing literature in three ways. First of all, the study examines the determinants of travel in a developing city context. The heterogeneous mix of vehicles moving in the same lane, with the dominating feature of motor vehicles in the developing cities, differentiates the traffic of the developing cities from that of the developed cities. Second, while most existing studies are derived based on the assumption of linear correlation between the land use parameters and the travel attributes, this study uses transformed variables to arrive at the regression models. Third, while most studies included limited measures for assessing the urban land use characteristics, this study measures the urban environment in view of the land use attributes such as density, intensity, diversity and accessibility on a disaggregated scale, considering the census ward as the spatial unit of analysis.

3. Data Collection and Analysis

3.1 Study area

The analysis is based on a case study from Calicut, a medium-sized city in India. Calicut had initially been developed as a trading centre around the port region. The introduction of railroads and major roads attracted settlements close to the port area. The organic growth in the absence of proper control measures has resulted in heavy commercial development along the corridors.

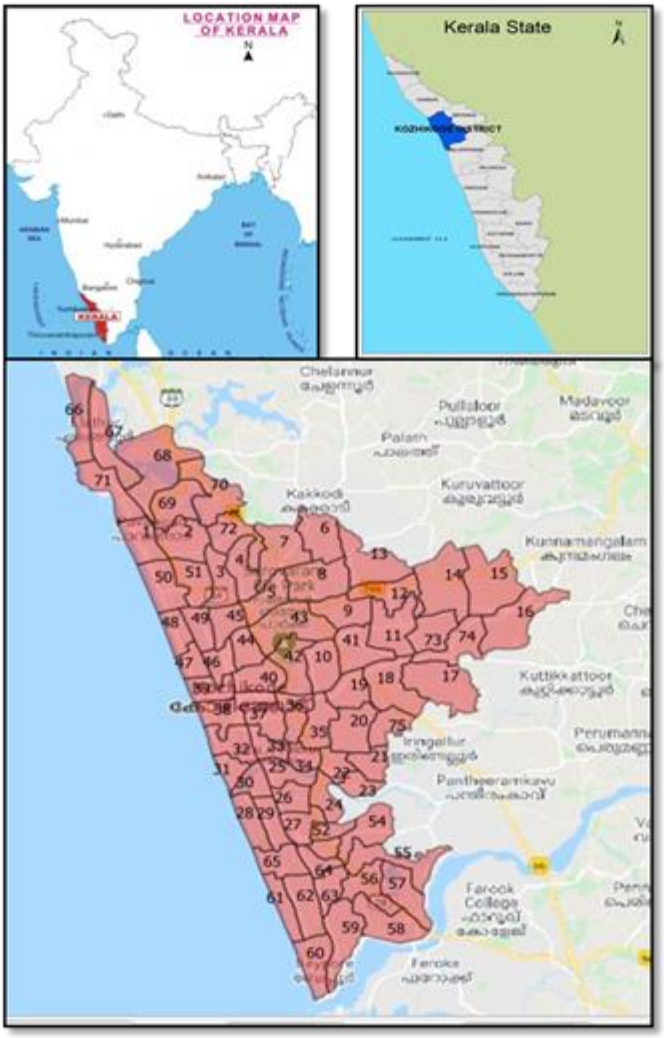

Figure 1. The zonal map of Calicut Corporation

Mananchira Square emerged as the central core of the city. The wholesale market at Valiyangadi and the retail market at S.M. Street were the commercial establishments in the city centre. Later, developments were along the corridors of Kallai road, Wayanad road, Kannur road and Mavoor road. In fact, Calicut is at present the most important commercial hub in the Northern region of Kerala. The city, placed among natural attractions such as beaches and cultural forms, is a hub of cultural and literary heritage. The structure of the city is expected to change with the addition of facilities such as flyovers, cyber parks and many private business establishments. It has excellent health facilities distributed all over, both in the public sector and the private sector. Calicut's urban area has many small-scale industries. But the recently established cyber parks can make the city one of the most important IT hubs in the state and can accelerate urban development.

As per the 2011 census, Calicut Corporation has a population of 6.13 lakhs and an area of 118 square kilometres. The gross population density of the area is 5,179 persons per square kilometre. The study area experienced population growth for many decades and had attained population stabilisation, but the growth rate decreased by 2011. The central zones indicate a retarding population, while the outer zones show increasing population growth (State Urbanisation Report, 2012). The negative population growth of the city core is due to the escalating land costs and the development constraints due to traffic congestion. The outer area's densification is due to the better connectivity to the nearby towns and the availability of a better environment and social amenities. Each electoral ward of Calicut Corporation is considered as the Traffic Analysis Zone (TAZ) in the present study. Figure 1 shows the map of the study area.

3.2 Data collection

The data required for the study includes details like TAZ zones, land use and travel. A CAD drawing giving the details of zonal boundaries was collected from the Town Planning Division of Calicut Corporation Office. A land use map, in jpg format, was collected from the Town Planning Office, Calicut. This map was later digitised in the GIS platform to obtain the land use details of each zone. The population and household details were collected from 2011 census data. Employment details of major shops and institutions in each zone were collected from the revenue division of the Calicut Corporation Office. The employment details of industries were collected from the District Industrial Office. These employment details were compiled to create the database of zone-wise employment. Travel data was retrieved from the activity and household survey conducted by NIT Calicut in 2011. Details from 9,900 households located in sixty-eight wards of Calicut Corporation were collected. This database included household, personal and travel details of 39,615 persons. The travel data indicates that about 47% of the trips are by bus and 10% of trips are by car. Interestingly, about 29% use two-wheelers and 8% use motorised three-wheelers. This infers that the majority of the trips depend on bus, two-wheeler and car for reaching the destination. Based on the purpose of travel, the majority of the trips are for work/business purposes (52%), followed by educational trips (32%). Trips for shopping, religious, medical or other purposes are much less, nearly 5%.

3.3 Characterisation of land use and travel

The land use parameters identified from the literature and included in the analysis are density, intensity, diversity and accessibility. Population density and employment density are used to measure the density aspect of land use. The intensity of a particular land use type indicates the cumulative area specific to that land use, expressed as a proportion of the total area of the zone. The predominant land uses identified from the land use data include residential, industrial, commercial, public, semi-public and religious. Thus, the intensity of residential use is defined as the ratio of residential use in a particular zone to the total area of the zone, and likewise for the other land uses. The diversity index, proposed by Shannon and Weaver (1949), is a measure of the proportional abundance of each land use type. The diversity ranges from 0 to 1, where 0 means a homogeneous location with a single land use type covering the whole area. On the contrary, 1 indicates a heterogeneous location, which has multiple land use types or mixed land uses. The diversity index is calculated using Equation (1).

$$H_{LD} = -\sum_{i=1}^{n} p_i \log p_i \quad (1)$$

Where,
H_{LD} indicates the land use diversity;
H_{LD} ranges between 0 and 1;
i indicates the land use type;
n is the number of land use types in the system;
p_i is the proportional area of land use of type i.

The accessibility index measures the capacity of a location to be reached and is an element in analysing the efficiency of land use. Of the different accessibility measures, the most commonly used one is the gravity-based measure (Simma and Axhausen, 2013). Again, job activities assume the presence of other service facilities nearby, and hence job accessibility can replace access to other land use activities (Merlin, 2014). Hence, the gravity-based measure of accessibility to job activity is calculated as in Equation (2) and is included in the analysis.

$$A_i = \sum_j O_j \, f(c_{ij}) \qquad (2)$$

Where,

A_i is the accessibility measured at point i to potential activity in zone j;
O_j is the size of the job opportunities in zone j;
$f(c_{ij})$ is the function to represent the deterrent effect of travel, here chosen negative exponential function.

Table 1. Summary statistics of land use variables

Index	Notation	Minimum	Maximum	Mean	Std. deviation
Population density (Thousand persons/sq. km)	PD	2.113	11.916	5.558	2.164
Employment density (Thousand jobs/sq. km)	ED	0.219	14.744	1.715	2.480
Intensity of residential use	IRES	0.356	2.360	1.071	0.463
Intensity of commercial use	ICOM	0.003	0.567	0.040	0.078
Intensity of industrial use	IND	0.000	0.341	0.036	0.062
Intensity of public & semi-public use	IPUB	0.001	0.320	0.069	0.073
Intensity of religious use	IREL	0.000	0.086	0.018	0.016
Land use diversity	LUM	0.042	0.784	0.304	0.169
Job accessibility	JOBACC	0.780	1.000	0.927	0.052

The travel measures included in the analysis are the number of trips, person-km of travel and person-hr of travel. The number of trips indicates the total number of person trips. Person-km and person-hr of travel indicate the total distance travelled and the duration of the person trips respectively. These travel parameters are analysed for the three cases like overall trips, trips by various modes, and trips for various purposes. Travel by various modes of transportation (car, bus and two-wheeler) is analysed separately. Subsequently, travel for various purposes such as work, education and shopping is examined. The parametric values of each of the land use variables and travel variables are synthesised from the database collected. Summary statistics of land use characteristics are summarised in Table 1, and travel characteristics are listed in Table 2.

Table 2. Summary statistics of travel variables

Index	Notation	Minimum	Maximum	Mean	Std. deviation
Number of trips (all)	NTRIPS	2374	16695	6649	2471
Number of bus trips	NBUS	808	7040	3025	1240
Number of car trips	NCAR	0	1726	532	408
Number of two-wheeler trips	NTW	263	2854	1603	647
Person-km by all vehicles	KMPER	11285	115388	36686	17777
Person-km by bus	KMBUS	4815	63156	19529	10187
Person-km by car	KMCAR	0	9981	3355	2578
Person-km by two-wheeler	KMTW	1003	18725	8717	4191
Person-hr by all vehicles	HRPER	1068	8588	2844	1185
Person-hr by bus	HRBUS	369	3457	1507	665
Person-hr by car	HRCAR	0	777	226	173
Person-hr by two-wheeler	HRTW	113	1258	606	261
Number of work trips	NWRK	810	6481	3414	1203
Number of education trips	NEDU	619	5229	2277	1051
Number of shopping trips	NSHP	89	2128	908	503
Person-km for work	KMWRK	4411	55179	19803	9110
Person-km for education	KMEDU	3272	30958	11411	6437
Person-km for shopping	KMSHP	634	14351	5087	3034
Person-hr for work	HRWRK	23231	202072	86721	34003
Person-hr for education	HREDU	14752	142228	59219	28651
Person-hr for shopping	HRSHP	1872	54267	23004	13729

Table 1 points out that residential land use is the most predominant type of land use in the city. Table 2 indicates that the bus is the predominant mode of transportation. Also, the majority of the trips are undertaken for work/educational purposes. Person-km of travel is the highest for work/educational purposes, while those for other purposes like shopping seem very low. Based on all these parameters, correlation analysis and regression modelling are performed.

3.4 Modelling technique

Regression analysis is the most widely used modelling technique in transportation planning. Hence, it is proposed to use the same technique in this study to understand the influence of land use on travel. The explanatory variables having nonlinear correlation are subjected to transformations. Thus, the model takes the form in Equation (3).

$$Y = \alpha_0 + \Sigma \alpha_i f(X_i) \quad (3)$$

Where Y is the dependent variable;
$f(X_i)$ is the transformed function of the predictor variable X_i;
α_i is the estimated coefficient;
α_0 is the constant term, assumed zero in the present study.

Transformations of independent variables are identified by recognizing the nonlinear function that has the highest correlation between dependent and explanatory variables. Hence, the necessary transformation is incorporated for each of the explanatory variables. In the next stage, the linear regression model is developed, incorporating these transformed variables. Regression models are prepared based on the explanatory variables having the highest correlation with the dependent variable, but not having a correlation with other explanatory variables.

4. Modelling the Influence of Land Use on Travel Demand

4.1 Influence of Land Use on Overall Trips

To obtain the predictive capability of land use characteristics on travel for all trips, models are prepared for the number of trips, person-km of travel and person-hr of travel, and the results are given in Table 3. As per the table, the models of land use variables on travel for all trips depict high R2-values, which indicate that all the models have very good explanatory power. Again, all the variables in the models are significant at the 95% confidence level, and the t-values are greater than the critical value of 1.96. Validation of the models is carried out based on Percentage Root Mean Square Error (PRMSE). The PRMSE values are coming in the range of 9% to 17%. The smaller the error, the better the model.

The result indicates that population density, commercial use, land use mix and accessibility emerged as significant variables for travel by all vehicles, including car, bus and two-wheeler. Population density has a positive association with the number of trips made by all vehicles. Where there are intense commercial establishments, a greater number of shorter trips will be generated. Mixed land use reduces the necessity of travel and hence shows a negative effect on person-km of travel, which is in line with many earlier studies (Parthasarathi et al., 2009; Frank et al., 2009). Accessibility to land use activities shows a negative influence on travel distance, which is in line with the literature (Frank et al., 2009; Bhat and Eluru, 2009).

Table 3. Models of land use on all trips

Dependent variable	Model	R^2 - value	F-value
Number of trips	NTRIPS = $229*(PD)^{1.02} + 54.71*\log(ICOM) + 2984*(LUM)^{0.84} + 2710*\exp^{(JOBACC)}$	0.87	233.06
Person-km	KMPER = $-1492*(PD)^{1.21} – 1060*(ICOM)^{-2.52} - 1890*(IPUB)^{-2.67} - 1.123*(LUM)^{-6.40} – 2160*\exp^{(JOBACC)}$	0.84	84.57
Person-hr	HRPER = $-164*(PD)^{0.92} – 0.98*(ICOM)^{-1.75} - 1.395*(LUM)^{-4.85} – 1616*\exp^{(JOBACC)}$	0.84	138.35

4.2 Influence of Land Use on Travel by Mode

The best regression models for travel demand by different modes, in terms of land use factors are given in Table 4. All the models have good R^2-values, and the variables are significant at a 95% confidence level based on the t-value. The PRMSE values are within the range of 11% to 24%, and hence the error is less.

Table 4. Influence of land use on travel by mode

Purpose type	Model	R^2-value	F-value
Dependent variable: Number of trips			
Bus	NBUS = 195*$(PD)^{0.92}$ +0.196*$(ICOM)^{-1.93}$ +0.133*$(IPUB)^{-2.03}$ + 0.823*$(LUM)^{-4.88}$ + 1999*$exp^{(JOBACC)}$	0.90	110.14
Car	NCAR = 320*log (PD) + 445*log (ED) - 8.31*log (ICOM)+ 858*(JOBACC)	0.65	65.38
Two-wheeler	NTW = 53.05*$(PD)^{1.02}$ -19.61*log(ICOM) + 570*$(LUM)^{0.84}$ +778*$exp^{(JOBACC)}$	0.87	136.29
Dependent variable: Person-km of travel			
Bus	KMBUS = -835*$(PD)^{1.14}$ -949*$(ED)^{1.38}$ -0.723*$(ICOM)^{-2.37}$ - 2.636*$(IPUB)^{-2.5}$ - 0.702 $(LUM)^{-6.01}$ -13453 $exp^{(JOBACC)}$	0.84	67.07
Car	KMCAR= -394*$(PD)^{0.77}$ -302*$(ED)^{0.94}$- 0.002*$(ICOM)^{-1.62}$ - 2326*(LUM)-5972*(JOBACC)	0.84	84.57
Two-wheeler	KMTW = -455*$(PD)^{1.04}$ -105*$(ED)^{1.28}$-0.763*$(ICOM)^{-2.16}$ - 0.042*$(LUM)^{-5.49}$ - 4292*$exp^{(JOBACC)}$	0.83	107.25
Dependent variable: Person-hr of travel			
Bus	HRBUS= -22.67*$(PD)^{0.84}$ - 0.005*$(ICOM)^{-.1.76}$ -0.432*$(LUM)^{-4.96}$- 1102*$exp^{(JOBACC)}$	0.87	97.21
Car	HRCAR=-157*log(PD)-142*log(ED)+0.353*log(ICOM) +149*(LUM) -393*(JOBACC)	0.66	64.24
Two-wheeler	HRTW= -145*$(PD)^{0.74}$ -64.29*$(ED)^{0.89}$ -0.009*$(ICOM)^{-.1.53}$ - 0.312*$(LUM)^{-3.87}$ - 240*$exp^{(JOBACC)}$	0.86	134.45

As given in the table, land use variables such as population density, employment density, intensity of commercial use, land use mix and job accessibility have a significant influence on travel demand by different modes. Population density and employment density indicate the presence of more opportunities. This tends to increase the number of trips by bus and two-wheeler, as evident from the literature (Lin and Yang, 2009; Zhang, 2004). A similar trend is seen for the number of car trips as well. Land use mix tends to increase the dependency on public modes, as evident from literature (Lin and Yang, 2009). A comparable effect is seen for personal modes such as car and two-wheeler, too.

Population density has a negative influence on person-km of travel by any of the modes, as reported by Zhang (2004). The intensity of commercial activities is likely to reduce travel. Land use mix varies negatively with person-km or person-hr of travel, irrespective of the travel mode. This indicates that a diverse land use pattern results in a reduced distance between the activities. This would result in a reduction in travel by any of the modes. Henceforth, it can be inferred that density, diversity and accessibility contribute to reducing travel.

4.3 *Influence of Land Use on Travel by Purpose*

Models relating land use and travel for different purposes are given in Table 5. All the variables are significant at a 95% confidence level and have a logical sign. The PRMSE values of the models range from 8% to 19%, and hence the models are good.

Table 5. Influence of land use on travel by purpose

Purpose type	Model	R^2-value	F-value
Dependent variable: Number of trips			
Work	$NWRK = 74.99*(PD)^{0.95} + 140*(ED)^{1.14} + 0.03*(IPUB)^{-2.06} + 1310*\exp^{(JOBACC)}$	0.90	101.90
Education	$NEDU = 46.64*(PD)^{0.89} + 52.92*(ED)^{1.14} + 0.014*(IPUB)^{-1.95} - 0.193*(LUM)^{4.68} + 1048*\exp^{(JOBACC)}$	0.82	150.65
Shopping	$NSHP = 53.23*(PD)^{0.77} + 34.40*(ED)^{0.94} + 0.012*(ICOM)^{-1.60} - 236*(LUM) + 1466*(JOBACC)$	0.80	87.57
Dependent variable: Person-km of travel			
Work	$KMWRK = -373*(PD)^{1.44} - 555*(ED)^{1.39} - 0.442*(LUM)^{-6.03} - 10102*\exp^{(JOBACC)}$	0.85	104.56
Education	$KMEDU = -184*(PD)^{1.07} - 285*(ED)^{1.3} + 103*\log(IPUB) - 1.352*(LUM)^{-5.66} - 5201*\exp^{(JOBACC)}$	0.78	57.97
Shopping	$KMSHP = -471*(PD)^{0.97} - 97.56*(ED)^{1.17} - 4.98*\log(ICOM)^{-2.02} - 1202*(LUM)^{-5.13} - 2961*\exp^{(JOBACC)}$	0.78	80.91
Dependent variable: Person-hr of travel			
Work	$HRWRK = -2235*(PD)^{1.32} - 2651*(ED)^{1.60} - 0.632*(IPUB)^{-2.89} - 17159*(LUM)^{0.84} - 42012*\exp^{(JOBACC)}$	0.89	109.76
Education	$HREDU = -1624*(PD)^{1.02} - 1202*(ED)^{1.54} - 25241*(LUM)^{-0.84} - 26263*\exp^{(JOBACC)}$	0.78	79.79
Shopping	$HRSHP = -2241*(PD)^{1.14} - 433*(ED)^{1.39} - 0.782*\log(ICOM) - 0.056*(LUM)^{-6.04} - 13514*\exp^{(JOBACC)}$	0.78	79.98

The number of trips has positive variation, and the person-km of travel have negative variation with density related variables, irrespective of the purpose of travel. Where there are more residents, naturally, the trips will be more for work or non-work purposes (Lin and Yang, 2009). Population density and employment density indicate the presence of denser locations, where the activities are nearby. This facilitates the reduction of travel for carrying out work or non-work-related activities (Cervero and Duncan, 2006). Due to the mix of various land uses in the surroundings, the residents tend to make a greater number of trips. Land use mix turned out to have a negative influence on person-km of travel irrespective of the purpose of travel, which is consistent with the literature (Parthasarathi et al., 2009). Similarly, job accessibility increases the number of trips for mandatory or non-mandatory purposes but reduces person-km or person-hr of travel (Cervero and Kochelman, 1997; Cervero and Duncan, 2006).

4.4 Elasticity estimates

The elasticity estimates demonstrating the influence of land use on travel by different modes are given in Table 6. From the analysis, it is clear that land use mix has the most influence on travel by different modes. The number of trips is not that sensitive to the land use variables, but the person-km of travel or person-hr of travel are very sensitive. Hence travel by personal modes can be kept to a minimum by suitable land use measures such as mixing of land uses or converting to dense and accessible locations.

Table 6. Elasticity of land use on travel by mode

Variable	Number of trips			Person-km			Person-hr		
	Bus	Car	Two-wheeler	Bus	Car	Two-wheeler	Bus	Car	Two-wheeler
Population density	**0.30**	**0.29**	**0.29**	**-0.80**	**-0.61**	**-0.88**	**-0.53**	**-0.64**	**-0.65**
Employment density	**-**	**0.29**	**-**	**-0.80**	**-0.91**	**-0.63**	**-0.89**	**-0.89**	**-0.58**
Intensity of commercial use	0.01	0.03	0.05	-0.01	-0.01	-	-	-0.01	-0.01
Intensity of public use	0.02	-	-	-0.04	-0.02	-0.09	-0.01	-0.01	-
Land use mix	**0.64**	**-**	**0.58**	**-1.36**	**-1.53**	**-1.76**	**-1.58**	**-1.39**	**-1.25**
Job accessibility	0.29	0.30	0.47	-0.78	-0.93	-0.76	-0.75	-0.52	-0.41

Table 7. Elasticity of land use on travel by purpose

Variable	Number of trips			Person-km			Person-hr		
	Work	Education	Shopping	Work	Education	Shopping	Work	Education	Shopping
Population density	**0.36**	**0.29**	**0.30**	**-0.29**	**-0.30**	**-0.93**	**-0.33**	**-0.37**	**-0.68**
Employment density	**0.62**	**0.49**	**0.34**	**-0.27**	**-0.59**	**-0.63**	**-0.29**	**-0.44**	**-0.53**
Intensity of commercial use	-	-	0.03	-0.01	-0.01	-0.03	-0.01	-0.01	-0.01
Intensity of public use	0.02	0.04	-	-0.01	-0.01	-0.03	-0.01	-0.01	-
Land use mix	**-**	**0.44**	**0.57**	**-1.29**	**-1.71**	**-1.76**	**-1.21**	**-1.31**	**-1.52**
Job accessibility	**1.26**	**1.10**	**0.97**	**-0.48**	**-0.53**	**-0.96**	**-0.75**	**-0.52**	**-0.41**

The sensitivity of land use measures on travel for different purposes is examined further, and the elasticity values are given in Table 7. Job accessibility has the most influence on the number of trips, while land use mix has the most influence on person-km and person-hr of travel. The results indicate that the urban land use is to be designed such that the developments are dense, diverse and accessible, so as to keep travel to a minimum.

5. Conclusion

The effect of land use on the number of trips, person-km and person-hr of travel has been included here. Separate models are prepared for different modes and for different purposes. The findings include:

- An increase in population density or employment density reduces the length of travel, but increases the number of trips, irrespective of the mode and purpose.
- A higher intensity of commercial activities and public places is likely to reduce the length of travel.
- Diverse land use or mixed land use with a balanced mix of various activities causes people to travel a lesser distance by any mode and for any purpose.
- Accessible locations reduce travel, irrespective of the mode and purpose.

The study confirms that the land use framework affects travel. The elasticity analysis reveals the relevance of including policy measures like mixing of land use, so that people travel less distance by any mode and for any purpose. Even though the number of trips is not reduced that much, the length of travel can be controlled by ensuring a balanced mix of various activity types. It is to be mentioned here that the results obtained refer to a specific reality, the city of Calicut, and may not be transferable. Transferability to other cities needs to be checked, after collecting sample data from the cities under consideration and then verifying the model.

The analysis presented here has policy implications for the transport planning field in Indian cities. Concerning Calicut city, the major activity centres are concentrated in and near the CBD. The planners can think of reducing the travel distance by finding residential locations near the CBD. So long as free space for further residential activity is limited within and near the CBD, particularly in the city area, the provision of mixed-use residential developments can be considered. Promoting non-residential activities in the suburban region so that travel can be minimised effectively for activity satisfaction is another suggestion for reducing city travel.

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