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Quantification of Land Use diversity in the context of mixed land use

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Abstract

Mixed land use is one of the major factors affecting the non-motorized and public transport based trips, specifically for work purpose. Same is evident from various past studies on the interaction between land use mix and the travel behavior. Mixed Land use patterns are commonly observed in urban areas of developing countries like India. In the context of land use mix observed in Indian cities there were no studies on how the change in land use mix influences the travel pattern. The existing indices, used for quantifying the land use mix, were found to have limitations in capturing the characteristics of land use mix observed in the smaller Indian cities. The present study analyzed the drawbacks and limitations of the existing indices. An attempt has also been made to use dissimilarity and entropy indices in a more relevant manner as well as to formulate new indices, suitable to measure the mixed land use. Effect of land use mix and socioeconomic characteristics on the travel related parameters has been analyzed to know their respective relevance. Non-motorized and public transport mode choices as well as the trip length have been analyzed. It was observed that a slightly modified approach for calculating dissimilarity and entropy indices characterize the mix land use in a better way. The newly proposed parameters, such as the Area Index, calculated separately for different trip purposes, and Mix type Index were found to be significantly influencing the trip length, transit choice, and the non-motorized mode choice. From the elasticity analysis it has been observed that a slight change in the land use mix significantly affects the above trip related parameters.

1. Introduction

Land-use mix is one of the important measures of land use development pattern and it refers to the diversity of land uses within an area. When diverse land uses exist in a given area it is expected that the many trips originating from that area may have trip ends in the same area. The relationship between land use mix and travel

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behavior has been widely studied. Cervero (1991) found that the transit share was more in mixed land use environments. According to Frank and Pivo (1994), mixed land use and the density influence the usage of single occupancy vehicles, public transport, and the active mode of transport (walking). Cervero and Radisch (1996) have concluded that the land use mix was a good predictor for mode choice for local shopping trips. They have observed that the mixed land use affects the non-motorized access trips. Cervero and kockelman (1997) have used two indices, entropy and dissimilarity index, to measure the land use mix, and found that both the indices were significant in explaining the vehicle-miles travelled (VMT) and the non-motorized work trips. Ewing and Cervero (2010), from their extensive literature review, have observed that the mode choice depends primarily on the socio economic characteristics and the trip lengths depend on the built environment characteristics. According to Tracy et al. (2011) land use mix is more significant in explaining non-motorized and transit mode choice. Tsai et al (2012) have observed that the impact of mixed land use, quantified using entropy, is not uniform across the traffic analysis zones. From these studies as well as from most of the other studies it can be observed that the land use development pattern, specifically the land use mix, has significant effect on trip length, non-motorized mode choice, and public transport choice. There have been varied results on the effect of mixed land use on mode choice, in general.

In majority of the small sized Indian cities, with population between 100,000 and 500,000, it can be said that the land use is mixed. The land use mix in these cities can be scaled at building level (such as the multi-functional buildings), street level (different buildings, located on a street, with different functionalities), and ward's level (coexistence of residences, shops, schools, offices, recreational areas, and industries). Also, there exists the heterogeneity within a particular land use such as the residential locality where people with various socio-economic backgrounds live together. One other peculiarity is that the extent of land utilized by different land uses varies from very small areas, say an isolated shop of five square meters to bigger areas such a shopping complex of 30,000 square meter. One major difficulty in handling such a kind of land use mix lies in developing the GIS based land use data base. But, it can be hypothesized that this kind of land use mix has significant impact on many of the travel parameters. Due to the above mentioned difficulty, there were no past studies that analyze the land use based travel determinants.

Agartala, capital of Tripura, with about 400,000 residents, has been taken as the study area to quantify the land use mix and to analyze the effect of mixed land use on travel parameters. Entropy and dissimilarity index have been considered to quantify the land use mix. An attempt was also made to analyze the effect of land use mix on travel parameters such as the trip length, non-motorized mode choice for work trips, public transport choice for all the trips. In this process, as pointed out by Hess et al. (2001), it was found that the dissimilarity index has certain limitations such as, the size of cell used, the insensitiveness to capture the land use interaction within the cells, and the inability to consider the composition of the land uses when allotting the points to a particular cell. Keeping this in view, an attempt has been made to understand the dissimilarity index with small sized cells. From the analysis of interaction between the travel and land use parameters, it has been observed that both the entropy (when measured in conventional way) and dissimilarity indices are not significant. When the cell size is reduced to 20 m x 20 m dissimilarity index is found to be significant in explaining the variability of the travel parameters. Entropy was also found to be significant when measured for the buffer zones created around the sampled household instead of measuring for the census tracts or municipal wards. To overcome the other drawbacks two more land use indices have been proposed in this study. To consider the land use composition when allotting the points to a particular cell (which will be used in calculating the dissimilarity index of a particular tract of land) a new index called Mix type Index is proposed. To consider the land use complementarity, another index termed as Area Index was proposed. Area Index values have been calculated for each of the sampled households by considering a buffer area with different radii. Area Index was measured separately for each trip purpose. It has been observed that the Dissimilarity Index for a 500 m x 500 m tract of land, calculated using 20 m x 20 m cell, Mix type Index for a 500 m x 500 m tract of land, calculated using 20 m x 20 m cell, and the Area Index are significant in explaining the variability of travel parameters, independently. Compared to the Dissimilarity Index and the Mix type Index, Area Index was found to be contributing significantly in explaining the variability of the travel parameters.

2. Study area description and preparation of land use data base

In this study, Agartala City, the capital of the state of Tripura, located in North Eastern Part of India, has been chosen as the study area. Agartala municipality consists of 35 municipal wards, divided mostly for administrative purposes. This city is second largest city in the north-east India, after Guwahati, in terms of municipal area. According to census data 2011, the population of Agartala city is 399688. The region falls under the subtropical and the temperate climatic zones. The average annual rain fall of Agartala city is 220 cm.

In this study, ArcGis10 software was used for storing and analyzing the land use and travel data. Land uses have been categorized into five different types, viz. residential, commercial, educational, service, and others. Data were collected at microscopic level using GPS technology and digitized in ArcGis10. Any dwelling, irrespective of its size and location, has been considered and digitized as residential land use. All the retail shops, including shopping complexes, and the buildings with retail shops and offices, have been considered as commercial land use. And the buildings meant only for office use have been considered as service area. All the schools, colleges are taken as educational land use. Social welfare centers, temples, recreation centers, cinema halls, and community halls are classified as other land use.

Travel data have been collected through a household survey conducted in the study area during March-September, 2012. Sample size, in terms of households, is about 1% of the total number of households of the study area. Information related to the trips and the travel modes like origin, destination, purpose of the trip, mode of travel, length of the trip have been taken. Also, the socio-economic characteristics like Age, Gender, and years of education, household size, household income, vehicle ownership, and the license status of the trip makers have been extracted. The sample data consists of 72.73% male and about 37.8% of the people was having driving license. Car ownership in the sample was reported to be 11.80% and two-wheeler ownership to be 32.45%. The sample was found to be representing the overall travel pattern of Agartala residents. In the collected sample, 37.2% of the trips are non-motorized and the more or less a similar figure was reported in a report of Ministry of Urban Development, Government of India.

3. Land Use Mix Indices

In Agartala, residential land use is predominant and the remaining land uses are negligible in comparison to the residential area (Fig 1). Detailed analysis of land use mix quantification using various existing parameters and the proposed new parameters is given in the following sections.

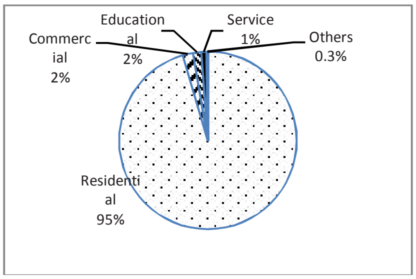

Fig. 1. Land use distribution observed in Agartala

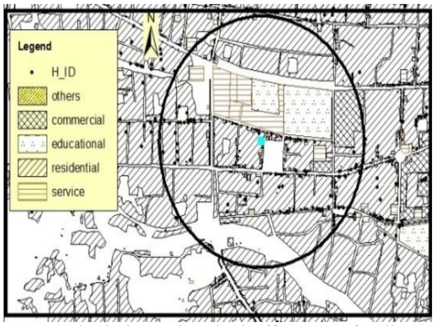

Fig. 2. Entropy calculation using the buffer area of radius 500 meter around the sampled household

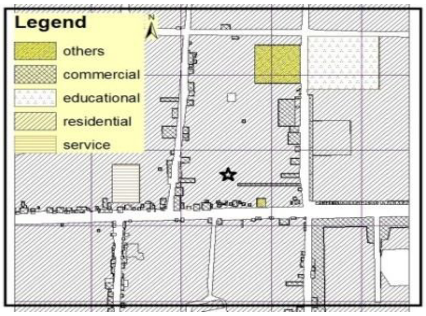

Fig. 3. Part of Study Area divided using 100 m x 100 m grid

3.1. Entropy Index

Entropy index is the most widely accepted and commonly used index for representing the land-use mix. Entropy generally quantifies homogeneity of land use in a given area. Entropy is expressed as

$$\text{Entropy} = \sum_{j} P_j \times \frac{\ln(p_j)}{\ln(J)} \quad (1)$$

Where,

P_j = the proportion of total land area of j^{th} land-use category found in the tract being analyzed

J = total land uses considered in the study area

Since, the entropy is normalized using natural logarithm of the number land uses, its value lies between 0 and 1 where 0 represents homogenous land use, and one indicates the tract of land is equally distributed across all land use types.

From figure 1, though it can be seen that the proportion of other land uses (other than residential) is very low, these areas are distributed across the study area. When the conventional approach was used (calculating the entropy for census tract/municipal ward) in computing the entropy index, many households with varying travel behavior were given single entropy value. This is resulting due to the fact that people with varying socioeconomic background co-exist in the same census tract/municipal ward. To overcome this problem to some extent, entropy index was measured for each sampled household. For this purpose, buffer areas of different radii (Fig 2) were created around each of the sampled household. Entropy Index values were computed for all the buffer areas created around the sampled households.

3.2. Dissimilarity Index (DI)

The dissimilarity index was used to compute the dissimilarity among the grid cells, within a tract (Kockelman (1997)). According to them, dissimilarity index is based on points awarded to each actively developed hectare cell on the basis of the dissimilarity of its land use from those of eight adjacent hectare cells. The average of these point accumulations across all active hectares in a tract is the dissimilarity index for that tract. It is calculated using the following equation:

$$\text{Dissimilarity Index} = \sum_{k} \frac{1}{K} \sum_{i}^{8} \frac{X_{ik}}{8} \quad (2)$$

Where,

K = number of actively developed grid-cells in a census tract or municipal ward

X_{ik} = number of different land-use categories from neighboring cells.

X_i =1 if land-use category of neighboring grid-cell differs from the central grid-cell. Otherwise, Xi = 0.

Land use of a particular cell was decided based on the dominant land use observed in that cell. With reference to Figure 3, the cell of 100m x 100m, marked with star symbol, will be considered as residential land use. The first step in calculating the DI (dissimilarity index) is to find the points awarded to each cell based on the comparisons of the subject cell with the eight neighbouring cells. With reference to Fig 4 the central cell will be awarded 6/8 points. Similar to the entropy index, higher value of dissimilarity index represents higher variability of land uses. When compared to entropy index, where a tract of land was considered in quantification of land use mix, in calculating the DI, tract of land is divided into finer actively developed land parcels known as cells of uniform size. Thus, the dissimilarity index presents more information about the type or intensity of mixing.

3.2.1. Limitations of dissimilarity index

As explained earlier, the points awarded to each actively developed cell play a major role in calculating the DI of a given tract of land. Points were awarded based on the comparisons of the land uses of the eight neighbouring cells with that of the subject cell. As shown in Fig 5 both the combinations of land uses shown in figure (a) and (b) results in 6/8 points being awarded to the central cell.

C	R	C
C	R	S
S	S	R

Fig. 4. Calculation of X_i

C	R	C
C	R	S
S	S	R

C	R	C
C	R	C
C	C	R

Fig. 5. (a) left ; (b) right Hypothetical land uses for awarding points to the central cell

From this, it can be seen that DI does not consider the type of land use of the adjacent cell, thus neglecting one of the important determinants of travel behavior, namely, land use interaction in between the adjacent cells. Also dissimilarity index does not consider the mix of the land uses. Thus, the dissimilarity index represents the unlikeness of the adjoining cells but doesn't incorporate the information about number of land use types around the central cell. Thus, there is a need to develop indices to incorporate the information of number of land use types around the cell as well as the interaction between the adjacent cells. In this study, to overcome this drawback of DI, a new measure, termed as 'mix type index' is proposed.

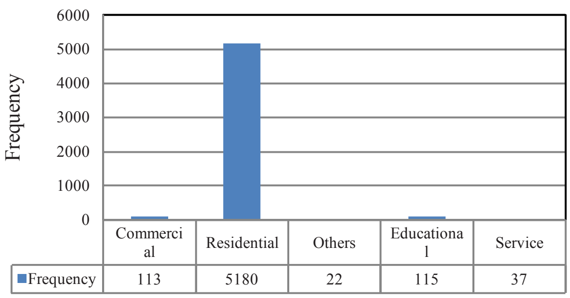

Fig. 6. Frequency of different land uses with 100m x 100m cell

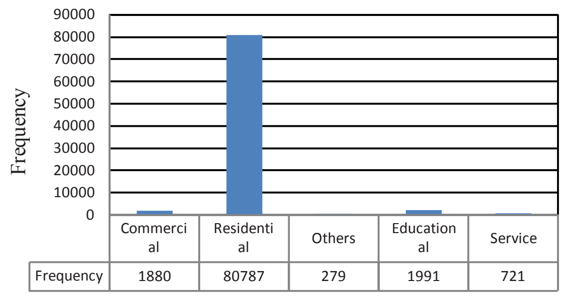

Fig. 7. Frequency of different land uses with 20m x 20m cell

Another drawback is that the conventional approach in calculating the DI uses hectare size cell i.e. 100 m x 100 m, and each cell is allotted a land use type based on the dominant land use type falling in that cell. In developing countries like India, the residential spaces in mixed land use patterns are in close proximity to the small commercial and education spaces. Hence, there is a possibility that the information related to such commercial spaces be neglected when compared to the other type of dominant land use (for e.g. residential). Thus, it is required that the cell size should be reduced so that small area features can also be given due importance. This study experimented with different cell sizes. 100 m x 100 m, 50 m x 50 m, and 20 m x 20 m cell sizes were used and the frequency of cells, attributed with different land uses, has been computed. It was found that when grid cell size of 20 m x 20 m was used the commercial area or any other minor land use area are given due importance. Same thing can be observed from Fig 6 and 7. Hence, for calculating the DI, cell size of 20 m x 20 m has been used, in tract of land of 250000 square meters (500 m x 500 m).

3.3. Mix type index

As discussed earlier, DI has limitations in quantifying the land use mix of a tract of land. To overcome this, a new measure called "Mix type Index" was proposed in this study. This measure allots points to each of the actively developed cells based on the mix of the land uses in the surrounding cells.

$$\text{Mix type Index} = \sum_k \frac{1}{K} \sum_i^k \frac{X_{ik}}{(No.of\ distinct\ land\ uses\ in\ study\ area)} \quad (3)$$

Where,
X_{ik} is the no. of distinct land uses observed in the adjacent eight cells
K = number of actively developed grid-cells in tract.

With reference to Fig 5, intensity of mixing is more in case of Fig (a) as there are three types of land uses present in the eight adjoining cells. On the other hand, in case (b), only two distinct land uses can be seen in the eight adjoining cells. Using the proposed index for case (a) the points allotted to the central cell is 3/5 (3 numbers of land uses present and five number of land use types considered for this study) and the points allotted in case (b) is 2/5.

4. Area index

Hess et al. (2001) have explained the need to develop an index based on land use functional and spatial complementarity. Land use functional complementarity ensures the consideration of origins and destinations that are likely to be linked by travel. Land use spatial complementarity ensures that the land uses linked with travel are within adequate proximity. It was assumed that the mode choice would be different for different work purposes inside the buffer zone of 500 meter radius, created around the trip origin (household in this case), and outside the buffer zone, thereby incorporating land use spatial complementarity as well as functional complementarity. An attempt has been made to develop an index called Area Index based on the land use types linked with travel.

Area index for work trip is the ratio of the work areas in the buffer zone to the work areas in the whole study area. The work areas included in this study were commercial area, service area, and industrial area. It was considered that the residential land uses are linked by travel to the work areas, thereby incorporating the land use functional complementarity. The ratio, when close to 1 indicates that most of the work places lies in the buffer zone, thus more non-motorized trips would be realized. The ratio when close to 0 indicates that much of the work places are outside the buffer zone and more motorized trips may be realized. Thus, these ratios gave the understanding between mode choice behavior and the amount of particular land use area available in the vicinity of the household. When Area Index was used for the analysis of shopping trips, the index value was computed based on the shopping space available in the buffer zone and the total shopping space in the study area. Area Index values for the destination of the trips have also been computed based on the hypothesis that the work and shopping space available in the vicinity of the destination influences the individual to make the non home based trips.

5. Results

To know the significance of all the land use mix parameters discussed in the previous section, various travel parameters have been analyzed using linear regression models. Travel parameters have been analyzed for their dependency on the socio economic and the land use mix related parameters. In this study, work trip indicates the travel from home to work, and the shopping trip indicates the travel from home to shop. Return trips were not considered in the present analysis. The models were estimated between the travel parameters as the dependent variables and the proposed indices and socioeconomic characteristics as the independent variables. The main purpose of regression modelling is to examine how the land use mix is useful in explaining the travel parameters, in general, and the individual land use parameters, in particular. Motorized vehicle ownership, household size, household aggregated income, gender, age, married status, and license status have been considered as the socioeconomic variables. Mode choice related parameters are entering into the model as binary variables. For example, in non-motorized mode choice modelling, the dependent variable takes 1 for trips made by non-motorized modes, and 0 for the motorized modes. First, a base model was prepared by considering the socioeconomic characteristics that are having strong influence on the travel parameters. In the subsequent models, only one land use parameter was entered the model, at a time. Entropy measured using the conventional approach, and using the buffer zone of 500 m radius, Dissimilarity Index measured for the municipal ward using 100 m x100 m cell, and measured using 20 m x 20 m cell size, Mix type Index, Area Index measured at origin and destination of the trip, were considered in this analysis. As shown in Table 1, though for the base model the correlation was poor, several land use parameters were found to have significant effect on trip length for shopping. All the land use mix parameters were found to be significant, when entered the model separately. When the Area Index for both the origin and destination were considered there was almost 120% increase in the model's ability in explaining the variability of trip length compared to the base model. In case of the trip length modelling for work purpose, the Entropy and Dissimilarity

Table 1. Model on Trip length per individual, for shopping trips

Socioeconomic parameters	**Base model**	**Base model with land use parameters**						
		Area Index at origin	Area Index (at origin and destination)	Entropy	Dissimilarity index	Mix type index	Dissimilarity index (cell size of 100m in census tract)	Entropy (census tract)
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
Constant	2.121 (7.641)	2.521 (11.225)	2.020 (7.888)	2.721 (11.348)	2.638 (11.473)	4.519 (7.977)	2.570 (10.896)	2.589 (10.714)
Age	-0.021 (-4.594)	-0.020 (-4.493)	-0.015 (-3.472)	-0.021 (-4.878)	-0.020 (-4.561)	-0.020 (-4.167)	-0.022 (-4.891)	-0.022 (-4.853)
		-4.754 (-4.499)	-6.387 (-5.697) 3.614 (3.840)	-1.609 (-3.973)	-6.782 (-4.465)	-9.394 (-4.114)	-2.726 (-2.843)	-1.071 (-2.512)
R^2	0.0658	0.1084	0.1429	0.0980	0.1077	0.1007	0.0795	0.0751
% increase in R^2 from base model		64.74	117.17	48.94	63.68	53.03	20.82	14.18

Table 2. Model on Trip length per individual, for work trips

Socioeconomic parameters	**Base model**	**Base model with land use parameters**						
		Area Index at origin	Area Index (at origin and destination)	Entropy	Dissimilarity index	Mix type index	Dissimilarity index (cell size of 100m in census tract)	Entropy (census tract)
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
Constant	4.148 (5.351)	4.126 (5.449)	4.179 (10.221)	4.496 (5.718)	4.409 (5.681)	7.762 (5.055)	4.313 (5.476)	4.294 (5.365)
Household size	0.2578 (3.002)	0.255 (2.984)	0.003 (0.060)	0.253 (2.967)	0.263 (3.085)	0.261 (3.057)	0.257 (3.003)	0.257 (3.000)
Age	-0.0309 (-2.133)	-0.025 (-1.745)	-0.019 (-2.295)	-0.026 (-1.794)	-0.025 (-1.723)	-0.025 (-1.723)	-0.030 (-2.077)	-0.030 (-2.102)
		-8.730 (-2.121)	-12.859 (-5.381) -4.816 (-4.003)	-2.652 (-2.364)	-11.467 (-2.867)	-16.690 (-2.722)	-3.116 (-1.176)	-0.866 (-0.739)
R^2	0.0221	0.0292	0.1041	0.0309	0.0349	0.0337	0.0243	0.0230
% increase in R^2 from base model		32.12	371.04	39.82	57.92	52.48	9.95	4.07

indices measured using the conventional approach were found to be not significant, at even 10% significance level. All the other land use mix parameters were found to be significant. When the Area Index for both the origin and destination were considered there was almost 370% increase in the model's ability in explaining the variability of trip length compared to the base model.

Table 3. Model on Non-motorized mode choice, for work trips

socioeconomic parameters	**Base model**	**Base model with land use parameters**						
		Area Index at origin	Area Index (at origin and destination)	Entropy	Dissimilarity index	Mix type index	Dissimilarity index (cell size of 100m in census tract)	Entropy (census tract)
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
Constant	0.367 (15.760)	0.306 (11.681)	0.358 (9.013)	0.292 (9.266)	0.303 (10.384)	-0.079 (-0.618)	-0.327 (-11.706)	-0.320 (-10.419)
Distance	-0.025 (-7.335)	-0.024 (-6.924)	-0.053 (-7.814)	-0.024 (-6.980)	-0.024 (-6.903)	-0.024 (-6.926)	-0.025 (-7.229)	-0.025 (-7.283
License status	-0.161 (-5.270)	-0.168 (-5.610)	-0.172 (-5.410)	-0.162 (-5.352)	-0.164 (-5.441)	-0.164 (-5.422)	-0.160 (-5.292)	-0.160 (-5.267)
		1.706 (4.816)	1.191 (3.047) 0.498 (2.522)	0.345 (3.525)	1.249 (3.564)	1.901 (3.545)	0.596 (2.565)	0.242 (2.353)
R^2	0.125	0.1570	0.2100	0.1426	0.1430	0.1428	0.1346	0.1332
% increase in R^2 from base model		25.6	68	13.6	14.4	13.6	7.68	6.56

Table 4. Model on Transit Mode Choice, for all the trips

socioeconomic parameters	Base model	Base model with land use parameters					
		Area Index	Entropy	Dissimilarity index	Mix type index	Dissimilarity index (cell size of 100m in census tract	Entropy (census tract)
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
Constant	-0.028 (-5.685)	-0.039 (-6.751)	-0.032 (-3.973)	-0.038 (-6.052)	-0.095 (-3.287)	-0.033 (-5.476)	-0.037 (-5.537)
Licensed holder	-0.042 (-5.796)	-0.044 (-6.031)	-0.042 (-5.795)	-0.043 (-5.903)	-0.043 (-5.899)	-0.042 (-5.751)	-0.042 (-5.759)
Trip length	0.027 (36.610)	0.027 (36.849)	0.027 (36.599)	0.027 (36.728)	0.027 (36.711)	0.027 (36.202)	0.027 (36.236)
		0.296 (3.639)	0.057 (2.544)	0.203 (2.532)	0.288 (2.341)	0.087 (1.622)	0.050 (2.117)
R^2	0.3026	0.3055	0.3040	0.3040	0.3038	0.2990	0.2994
% increase in R^2 from base model		0.95	0.46	0.46	0.39	-1.18	-1.18

In case of non-motorized mode choice for work trips, as shown in Table 3, the land use mix parameters were significant and also, there is a significant change in R^2 value when Area Index was considered at origin and at destination. From Table 4 it can be seen that all the mixed land use variables, except the Dissimilarity Index measured using the conventional approach, were showing significant impact on transit mode choice.

Table 5. Elasticity analysis between the travel parameters and land use variables

Land use parameters	Trip length		Non- motorized mode choice for Work	Transit mode
	Shopping	Work		
Area Index	-0.1767	-0.0762	0.2879	0.179
Entropy	-0.2648	-0.0140	0.0353	0.206
Dissimilarity Index	-0.2547	-0.1410	0.2968	0.169
Mix type Index	-1.6621	-1.0028	2.2086	1.174

5.1. Elasticity analysis between the land use and travel parameters

From Table 5 it can be seen that the elasticity between the trip lengths for shopping and work trips, non-motorized mode choice for work trips, and transit mode choice are strongly associated with Mix type Index. This implies that a one per cent increase of the mix type index decreases the trip length for shopping and work trips, increases the demand of non-motorized mode choice for work trips and transit use for all the trips by more than one per cent. In the remaining cases, the relationships were fairly inelastic. Area Index which was used to measure the land use complementarity is found to be influencing travel parameters but the elasticity with the travel parameters seems to be negligible. This may be due to the basic differences in the fundamental nature of the land use mix parameters. For e.g. a one percent change in the mix type index means a significant change in the land use mix and a similar change in the other indices mean less change in the land use mix.

6. Conclusions

In this study, an attempt has been made to find the relationship between travel behaviour and variables of land use mix, for the city of Agartala. Travel behaviour was quantified using three travel parameters, namely, trip length, non-motorized mode choice, and transit mode choice. Analysis was done for both shopping and work trips. The land use mix was measured using entropy, area index, dissimilarity index, and mix type index. Approach used in calculating the Entropy and Dissimilarity Index was slightly different from that of the conventional approach. Area Index has been calculated for the origin and destination of the trip and this index takes different values based on the trip purpose. The following conclusions are drawn from the present study:

- When a slightly a different approach was used in calculating the Entropy and Dissimilarity Index, both were found to be able to quantify the land use mix and were consistently having significant affect on the land use parameters.
- Area Index, proposed to capture both the land use mix and the land use complementarity, was found to be significant in explaining the travel parameters.
- The trip length of individuals for both the shopping and work trips was strongly correlated to the land use mix variables, even when controlling the socioeconomic characteristics.
- From the elasticity analysis, it can be concluded that the Mix type Index is strongly influencing the trip length for shopping and work purpose, non-motorized mode choice for work trips, and choosing the transit for any trip purpose. This implies that unit change in mix, characterized by the mix type index, will bring more than 1% change in above mentioned travel parameters.

Overall, it can be said that the proposed variables to measure the land use mix and the area index for land use complementarity have significant impact on the travel parameters, analysed in this study. Strong elasticity between the land use parameters and the travel parameters imply any change in the existing land use mix may significantly influence the trip length and the modal shares of non-motorized and public transport modes.

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