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Impact of Land Use Parameters on Household Travel Behavior

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Abstract Influence of socio-economic and land use factors on households travel behavior are important to develop a travel demand forecasting model. This paper examines the relative importance of these factors on household daily trips generation rate and household kilometers travelled. Linear regression models have been developed in this regard. Data used to develop these models have been collected from household's survey among different zones of Sylhet City Corporation (SCC) area and other secondary sources. From the model output, it has been found that land use parameters (accessibility and entropy) have significant contribution on trip production, trip attraction and household kilometers travelled along with the socio-economic characteristics of the people living in SCC area. The model framework developed in this paper can help to formulate comprehensive transport and land use policy for the different cities of Bangladesh as well as for other developing countries, particularly those in Asia, which share similar socio-economic characteristics.

Keywords: *trip production, trip attraction, household kilometer travel, accessibility, entropy*

1. Introduction

In emerging countries like Bangladesh institutional, commercial, educational, health services, shopping and other indispensable living facilities very often are saturated in city center or major city location where percentage of uptown neighborhood is low and living cost is incredibly high [1]. Most of the people from low to average income class are living in suburbs or periphery of the city because of low living cost and as a result they have to commute to city center to meet the everyday requirements and responsibilities. Conversely, people living in city center very often do work far away from the residential location. They do not reside in the vicinity of job location for schooling of their kids, spouse job location, better shopping as well as medical facilities etc. [2,3]. All these activities lead to increase the number of trips on the road way and household kilometers travelled. However, taking these factors into consideration transportation facilities (road network, travel mode) are very insufficient in context to their requirements. This imbalance of transportation demand and supply results huge congestion with economical loss and environmental degradation.

In addition, with rapid socio-economic transformation and increase in population the major cities of the country are expanding vigorously without proper planning and control resulting in improper and imbalanced land-use pattern. This situation is severe in the capital city Dhaka and also is going to be severe in other moderate to large cities of Bangladesh like Sylhet. Sylhet is the fifth densely populated city in Bangladesh with a population around 0.9 million in an area of only 26.5km^2, whereas population growth rate is 2.1%, which is highest within Bangladesh [4].

Integrated land-use and transport planning can be regarded as an effective way to solve transport related problems in the city. Therefore, the main focus of this research is to identify the most influential land use parameters which may have significant contribution to travel behavior as well as to be a guideline to ensure efficient land-use transport policy for Sylhet city.

2. Literature Survey

Transportation affects land use conversely land use affects transportation. Decisions that affect one result in alteration of usage pattern of the other. Therefore, it is important to coordinate transportation and land use planning decisions so they turn into complementary ones rather than becoming contradictory. This ensures that transport planning decisions support land use planning objectives and land use planning decisions support transport planning goals hence requiring an understanding of how specifically land use patterns affect household travel behavior. The ways that transportation decisions affect land use patterns, and the resulting economic, social and environmental impacts was examined by Litman [5]. He describes the direct impacts on land used for transportation facilities, indirect impacts caused by changes to land use development patterns specific and methods for evaluating these impacts in transport planning.

First efforts were made in the USA in 1950s towards systematic study the interrelationship between transport and the spatial development of cities. Several researches were then conducted in this context for developed and developing countries focusing on land use pattern and transportation. Many investigations have concluded that urban form have significant contribution to household vehicle miles travelled (VMT) [6,7,8]. Kockelman [9] illustrates that accessibility is a far better predictor of vehicle kilometers travelled (VKT) and mode choice than density itself. Land use balance (entropy) and mix (dissimilarity) do matter, with both affecting VKT and with entropy influencing walking-biking probabilities—substantially. Automobile ownership appears to be more significantly influenced by local attributes of the built environment. Sun, Wilmot and Kasturi [10], estimated household's total number of trips and VMT as the functions of socioeconomic characteristics and land use condition. To explore the maximum explanatory power of the independent variables, three models were developed for each the travel indicators. Handy [11], account for demographic factors, find that virtually all groups that live in highly saturated areas reduce their average annual vehicle mileage. The study of Frank and Pivo [12] gave an idea about the ability of transportation and land use models to predict the effects of land use management strategies on travel behavior and VKT has been found to be a function of land use mix. Study on six neighborhoods in San Francisco bay area discovered that land use mix was partially responsible for reducing of vehicle miles travelled [13]. Researchers found population and employment density to be the aspects of land use that are highly correlated with travel behavior [14]. Rashidi, Mohammadian and Zhang [15] found household socio-demographic variables and land use parameters are highly correlated with the travel behavior. Zhang (16) and Frank (17) also showed that increase in residential density and mixed land use (entropy) significantly reduce the VMT whereas Ewing, Deanna and Li [18] established that socio demographic characteristics has strong influence on house hold trip rate as compared to land use parameters (residential density, mixed land use and accessibility).

The impact of land use parameters on travel behavior were summarized by Zhou and Kockelman [19]. They showed that increased density, land use mix, regional ease of access, network connectivity, parking supply and management tend to reduce per capita vehicle travel however roadway design and management, walking and cycling provisional features, transit quality and accessibility, site design results in increased alternative mode choice and reduced automobile trips.

Land use travel behavior researches are relatively new field of transportation study in the context of Bangladesh. Ayaz [3] developed a residential location choice model to capture the heterogeneity in VKT for commute trips which was conducted on faculty members of two representative universities of Bangladesh. Education facilities of children, job of spouse, house rent, health care facilities, shopping facilities, scope of professional work were considered as instructive variables to assess the impact on residential location choice. Most of the variables were found with expected sign and magnitude and superior goodness of fit. Faysal and Khan [1] conducted a study on Sylhet city area to identify the most influential land use parameters that have significant impact on travel behavior but no mathematical framework was established to quantify the impact.

3. Methodology

Influence of land use parameters on transportation has been assessed in this study by modeling performance. Effect of land use parameters on trip generation and household kilometers travelled has been modeled using SPSS (Statistical Package for the Social Science). For modeling performance, Sylhet city area has been divided into five specified zones in succession which are zone 1 (Madina Market), zone 2 (Ambarkhana), zone 3 (Zindabazar), zone 4 (Uposahar) and zone 5 (Kadamtoli) and shown in Figure 1. Afterwards aforementioned zones have been subdivided into 27 traffic analysis zone (TAZ) numbering as per ward numbers. House hold interview has been conducted to know household socio economic characteristics and travel behavior. Sample household has been selected randomly from TAZs to ensure unbiased information. Few secondary data has also been taken from literature. Primary data has been analyzed first using simple statistical tools and technique and then modeled increasingly to quantify the impact of land use parameters on household travel behavior.

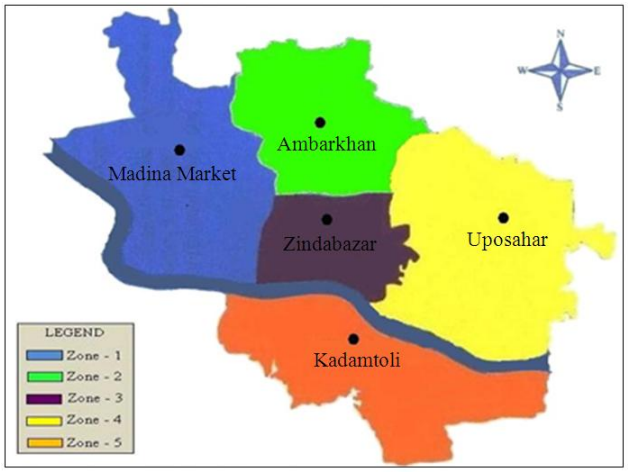

Figure 1. Zoning of Sylhet City Corporation Area (Source: SCC)

4. Existing Land Use and Travel Pattern

From the demographic analysis of all zones, it has been observed that the highest population density exists in the zone 3 followed by zone 2, zone 1, zone 4 and zone 5 respectively. Average house hold size in different zones of Sylhet city have been found in proximity (within the range of 3.5 to 4.2 person per household) however income level of household varies from zone to zone.

By analyzing and observing the existing land use scenario of Sylhet city it has been found that trip production rate from zone 1 and zone 4 is high (Figure 3) due to large proportion of residential spaces (Figure 2). On the other hand zone 3 (Figure 3) is attracting highest amount of trip due to having highest amount of commercial space availability (Figure 2). Scenario of balanced land use can be quantified by entropy analysis. Entropy has been found lowest in TAZ-02(0.44) (Figure 4)

which is located in zone 03 enclosed by huge commercial space and relatively lower amount of residential space as explained above. Conversely highest entropy has been observed in TAZ-04 (0.74) (Figure 4) which is located in zone-04 with good proportion of residential and commercial spaces. It reveals that the value of entropy varies between one, when the different land use occurs in equal proportion (the "perfect" balance), and zero, when the land use differs widely (the "worst" balance).

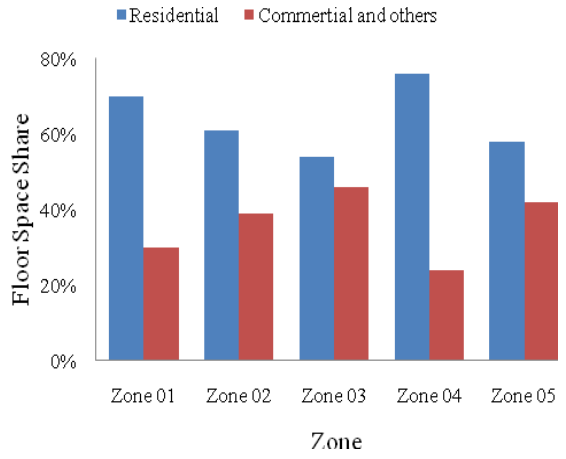

Figure 2. Floor space shared by the people living different zones of SCC

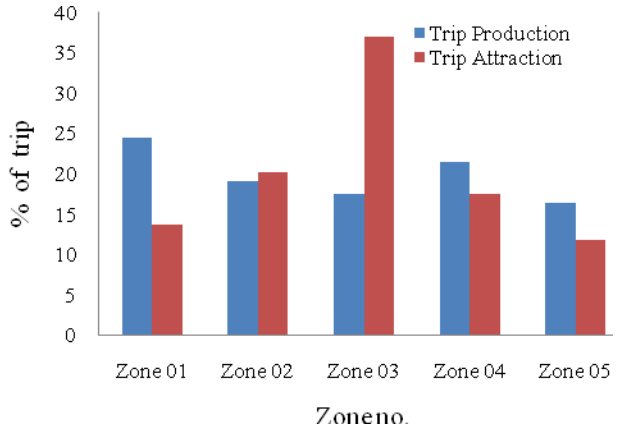

Figure 3. Trip production and attraction in different zones of SCC

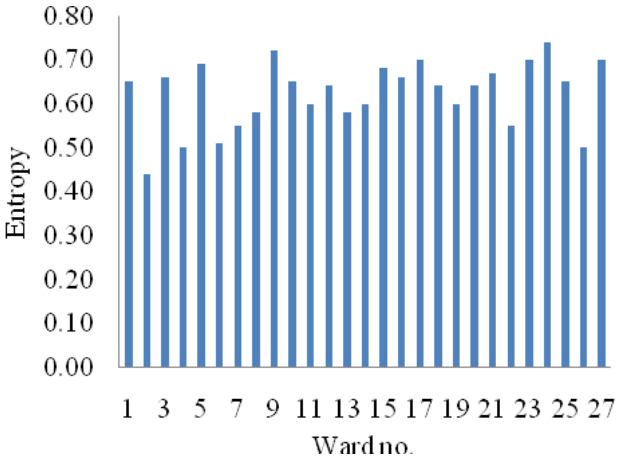

Figure 4. Entropy of different ward of SCC

Rickshaw and auto rickshaws have been found the most dominant travel mode in Sylhet city and these modes contribute to around 80% of total trips in Sylhet city because of their availability and easy accessibility. High occupancy public transport (town bus) is very limited in Sylhet though it may have significant contribution to reduce roadway vehicular population.

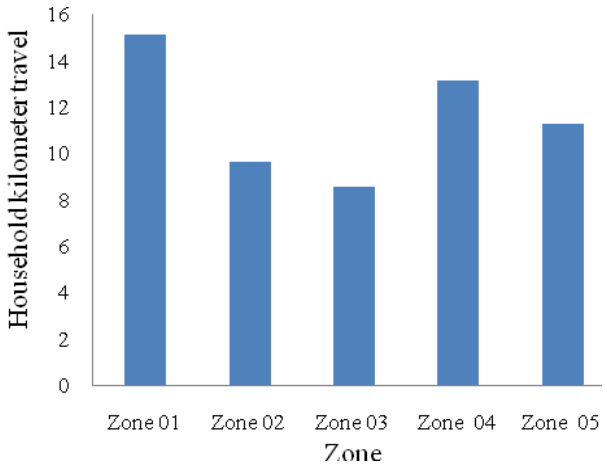

Figure 5. Average household kilometer travel at different zones of SCC

Household kilometers travelled are also an important determinant of the number of vehicles in the road way which induce traffic congestion. An individual living in zone 1 of Sylhet city area travel the highest among that of all zones averaging in 15 kilometers per day for office, educational, shopping or other purposes (Figure 5). This zone is situated far from the central zone where maximum trips is attracted as stated earlier and residents of this zone travel greater distance for educational, commercial and job purposes. Minimum daily travel distance has been found to the people living in zone-03 (9 Kilometers) because they have to travel less to carry out the same purposes.

5. Model Estimation

5.1. Trip Production Model

Trip generation model of the households lives in Sylhet City Corporation (SCC) area has been developed by linear regression analysis. In trip production model, the numbers of trips produced from each household have been considered as dependent variable and socioeconomic characteristics (household size, household income, and auto ownership), land use characteristics (entropy), accessibility have been considered as independent variable. Hypothesis of different variables that may have significant impact on trip production at SCC are illustrated in Table 1.

Table 1. Assumption of trip production variables of SCC

Variables	Assumption
Household size	There may have chance to produce more trip from large size household as compared to small one
Household's income	Members of high income households are more likely to extra expanse which may be induced by extra trips.
Household auto ownership	Household's having auto ownership very often generate additional trip for recreation, shopping or other purposes.
Accessibility	Higher accessibility of different zones may increase trip production rate.

General form of trip production model of SCC is given below:

$P_{trip\ production}$ = Constant + β_{hs} * household size + β_{hi} * household income + β_{ao}*auto ownership + β_{acc} * accessibility.

The betas (β) refer to the sensitivity associated with each variable. The subscripts of betas (β) refer to corresponding variables where hs, hi, ao and acc indicate household size, household income, auto ownership and accessibility respectively.

Coefficients of the trip production (β) have been estimated using software SPSS (Statistical Package for the Social Sciences). Model outputs with sign, magnitude and t-test in parenthesis are presented in Table 2.

Table 2. Estimated results of trip production model of SCC

Variable	Coefficient (t-test)	Coefficient (t-test)
	Base Model	Final Model
Constant	-0.177(-0.62)	-0.327(-1.076)
Household size	0.694(0.90)	0.690(9.039)
Household income	8.13E-07(0.174)	1.05E-07(0.225)
Auto ownership	0.0739(0.68)	0.095(0.855)
Accessibility	--	3.3E-05(1.35)
Adjusted R^2	0.453	0.498

A base model has been estimated first considering the socioeconomic variables. Having the best model, land use variables have been then added and increasingly been modeled to find the best fitted model. With the addition of land use parameter, goodness of fit of the model increases. From model output socioeconomic characteristics of respondents and land use parameter (accessibility) have been found significant on household trip production rate which is justified by literature [10,18]. Increased accessibility, household income, household size and auto ownership accelerate the household trip production rates which also agree with prior hypothesis.

5.2. Trip Attraction Model

In trip attraction model, accessibility, retail floor space and employment opportunity have been considered as independent variable. Hypothesis of the trip attraction variables are illustrated in Table 3.

Table 3. Assumption of trip attraction variables of SCC

Variables	Assumption
Accessibility	High accessibility of any area may decrease trip attraction rate.
Retail floor space	If the retail floor space of an area is increased, then the overall trip attraction of the area will increase.
Employment opportunity	Employment opportunity always attracts work trip.

A general form for trip attraction model of SCC is given below:

$A_{trip\ attraction}$ = Constant+ β_{acc} * accessibility + β_{rf} * retail floor space + β_{eo} * employment opportunity

Where acc, rf and eo indicate accessibility, retail floor space and employment opportunity respectively.

Table 4. Estimated results of trip attraction model of SCC

Variables	Coefficient (t-test)	Coefficient (t-test)
	Base model	Final model
Constant	2.201(2.58)	2.243(2.80)
Retail floor space	5.83E-06 (13.17)	6.17E-06(14.48)
Employment opportunity	0.00017(1.68)	0.000629(4.02)
Accessibility	---	-0.00085(-3.70)
Adjusted R^2	0.723	0.755

Coefficients of the trip attraction are estimated using Software SPSS. Model outputs with sign, magnitude and t-test in parenthesis are presented in Table 4.

In trip attraction model, all the variables have given expected sign and found statistically significant. From the model output, it has been found that accessibility decreases the trip attraction rate and retail floor space and employment opportunity accelerate it as expected. For addition of accessibility in the final model, adjusted R square has been increased which indicate the better goodness of fit the model compared to base model.

5.3. Household Kilometers Travelled Model

Literature strongly recommends that accessibility and land use balance (entropy) has strong influence on household vehicle kilometers travelled. Influence of these land use parameters are modeled here. For model development, household size, household income, auto ownership, entropy and accessibility have been considered as independent variable for final model whereas only influence of socioeconomic variables have been assessed in base model. Hypothesis of these influential variables are illustrated in Table 5.

Table 5. Assumption of variables on household kilometers travelled of SCC

Variables	Assumption
Household size	More trip may be produced from large household with increase total kilometer travel by household.
Household's income	High income household members are more likely to more expanses which may be induced by extra trips.
Household's auto ownership	Auto ownership may increase inclination towards more shopping, recreational trips and increase person kilometer travel.
Accessibility	Higher accessibility will decrease in trip length resulting decrease of household kilometer travel.
Entropy	Land use balance may also result in declination of trip length.

A general form of household kilometers travelled model of SCC is given below:

$V_{vehicle\ kilometers\ travelled}$ = Constant + β_{hs} * household size + β_{hi} * household income + β_{ao} * auto ownership + β_{acc} * accessibility + $\beta_{entropy}$ * entropy.

Coefficients of the household kilometers travelled model (β) have been estimated using Software SPSS. Model outputs with sign, magnitude and t-test in parenthesis are presented in Table 6.

Table 6. Estimated results of household kilometers travelled model

Variable	Coefficient (t-test)	Coefficient (t-test)
	Base Model	Final Model
Constant	-2.275(-1.282)	1.002 (0.278)
Household size	2.835(5.926)	2.835(5.981)
Household income	5.28E-05(1.820)	6.6E-05(2.181)
Auto ownership	1.485(2.150)	1.176(1.693)
Accessibility	---	-0.00036(-2.39)
Entropy	----	-2.529(0.510)
Adjusted R^2	0.451	0.489

Base model has been estimated primarily considering socioeconomic variables only then the model has been improved by considering land use parameters accessibility and entropy. Both land use parameters are found best fitted and influential parameter on household kilometers travelled. With the increase in accessibility and entropy, household kilometers travelled have been found in

decreasing trend which agrees with aforementioned literature [6,7,8,9,13]. It has also been found that household size, household income and auto ownership are more influential for kilometers travelled by household [9].

6. Discussion

From the research output, it was found that peoples of the Sylhet city corporation area have almost similar socioeconomic characteristics but travel demand is different in different zones due to the imbalance land use. By analyzing and observing the existing land use scenario of Sylhet city it has been found that people living in zone 1 and zone 4 produce large number of trip due to large proportion of residential spaces whereas tip attraction rate by zone 3 is high due to having highest amount of commercial spaces here. It is also found that entropy of TAZ-02(0.44) located in zone 03 is lowest indicating imbalance land use. Effect of the land use parameters on travel demand were then quantified by modeling performance. From the model output it was observed that land use parameter like accessibility and entropy has significant impact on trip generation rate and household kilometers travelled. Socioeconomic characteristics (household size, household income) also have strong influence on travel demand of the city.

7. Conclusion

The aim of this paper was to find the correlate between the land use parameters and travel behavior which can be an effective tool for the city planners to ensure optimum use of transportation system. From the research findings it can be concluded that urban planning ensuring the balance uses of spaces where an individual can meet their demand from closest distance can reduce the commuter trip length and the total number of person trips. It may be noted that the model framework developed in this paper might be useful for other cities in Bangladesh as well as other developing countries.

The study has few limitations. Due to the time and budge constrain, sample size has been considered very small (100) as compared to target population, so the model developed in this paper can be a guide line. For practical implementation detailed investigation with larger sample size is needed. Difficulties have been faced during data collection due to the non cooperative attitude of the respondents. In future study, more attractive data collection system can be evolved to ensure better response. For example data can be collected from interview of the respondents instead of giving questionnaire and respondents can also be motivated by declaring prizes among them. Model can also be improved considering more variables like land use mix, employment density, population density, network connectivity etc.

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