Activity Based Trip Generation Forecasting for a Suburban Area

Tissa U. Liyanage and Amal S. Kumarage

Abstract: Travel patterns in suburban areas are different from those of other areas as the characteristics of activities are specific to a particular area. The distribution of such activities in an area may be found in terms of the economic activities of the households and their social attributes such as age, sex, educational level etc, denoting the intensity of engagement in these activities. On the other hand the level of activity in an area is also determined by the supply of facilities for such activities, such as availability of transport, employment opportunities, commercial and service facilities and recreational facilities, found in the given area. It has been observed that most of these supply functions do not vary significantly in the short term, a concept which has been used since the very early stages of travel forecast modelling. Therefore it has been found, that travel behaviour in a given area can be forecasted using primarily, the activity characteristics, of its population, as the demand variable.

This research paper is an attempt to forecast the travel behaviour of a suburban community, based on their social and economic activity status. It is based on an empirical analysis of travel demand data and the corresponding socio-economic activity profile of 30 Gramaseva Niladhari Divisions (GNDs) in a suburban area of Colombo. The results based on a category analysis between these variables, indicate the possibility of estimating the aggregate trip rates of a GND, based on its population classified by groups engaged in different socio-economic activities. The paper concludes by determining trip generation rates for different socio-economic households, based on their aggregate activity profile. Furthermore, that this method could be used for estimating trip generation in any suburban area wherein such data are available. .

Keywords: Category Analysis, Urban Travel Demand Forecasting, Suburban Area

1. Introduction

The socio-economic activities of an area are different from that of other areas in a country due to the variation of the socio economic characteristics. These activities also indicate the economic characteristics of an area. The population of an area can be disaggregated by employment, education and economically inactive occupations [2]. These different categories have a different level of potential to make day to day trips. In other words trip rates by such categories depend on their respective economic activities. Also they become decisive factors for mode selection for such trips. All these indicate the possibility of explaining the trip generation behaviour of an area based on the economic activities of its population.

The different areas in a state or a province can be categorised as urban, suburban, and exurbs [1]. These can be categorised mainly, based on the population densities of such areas and generally, the socio economic distribution. It has been observed by early research that similar

levels of urban population densities are also likely to have similar socio economic characteristics among them. The similarity of the above factors among different areas is related to the concept called "spatial homogeneity" of urban activities [7]. The assumption of spatial homogeneity of urban areas helps to reduce the need to collect large numbers of data requirement for making traffic forecasting [5]. Hence this paper attempts to establish a simpler method of calibration for developing the relationship to explain trip generation behaviour by using socio economic attributes in identifying when spatially homogenous zones may be formulated.

The socio economic data in suburban areas in Sri Lanka are available with the Department of Census and Statistics. These data are collected

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every 5 years Island wide and have also been used to make forecasts for future years. The basic assumption in this trip generation forecasting method is that the spatial homogeneity of activities in suburban areas is assumed to be the same for all suburban areas concerned. Then the prediction models of traffic forecasting based on socioeconomic attributes can be applied in any other suburban areas other than the study area.

The category analysis method for calibration of trip generation rates by individuals on an activity basis pursued in this research is applied in this method of trip generation forecasting. The smallest traffic analysis zone (TAZs) is taken as Gramaseva Niladhari Divisions (GND) as it is the smallest disaggregate unit for socioeconomic data [2].

2. The Objectives

The following are the objectives of this research paper.

- To introduce an activity based trip forecasting method using economic engagement of the population in a suburban area.
- To develop a simple model with available socio-economic data as a cost effective traffic forecasting method.
- To compare and evaluate the trip behaviour between different activity groups in suburban areas.

3. Review of Activity Based Trip Generation Analysis

There have been many researches carried out in the past for category analysis, based on household size and car ownership [11]. Also the relationship between trip generation and income of household/population has been modelled for many urban areas in developed countries in the past. The accuracy of the traffic forecasting based on category analysis has been tested in comparison with regression analysis in Seoul metropolitan area [6] where car ownership has been analysed against household size to forecast work trip rate per household in both the City of Seoul and the Kyonggi Province. Also these rates have been compared with a foreign case. The above research has

revealed the importance of category analysis for an area with different activity behaviour from another for higher accuracy of the trip forecast model development. The number of workers and the number of persons in the household has been cross classified for trip rates by the Puget Regional Council recently [11]. The internal volume forecasting model (IVF) developed by Kristy and Rahi, has used employees and job positions per zone as the basis for trip generation [8]. Employment, income, education level and household size were among the variables that were generated in the micro simulation of urban travel demand forecasting by Goulias and Kitamura [4]. Population and employment estimates from state income tax roles, census data, electricity utility records and privately developed databases were geo-coded to TAZs for traffic forecasting in urban areas using GIS by Muglar and Quinn [10]. A Recent study of suburban travel forecasting based on a hybrid process of category analysis and regression modelling, has been carried out by Liyanage and Kumara [9]. The variables used here are the household type and domestic electricity consumption, as a surrogate variable, for the combined income of households in a suburban community. The urban density characteristics such as employment, household, retail business etc are thought of as a surrogate variable for accessibility in metropolitan travel model systems [3]. All the above literature and much more has shown the importance of having activity based category analysis, for accurate travel forecasting, in urban areas.

4. Methodology

This analysis is based on empirical data collected from a household survey in the Maharagama suburban area. The trip rate of residents and their trip purpose was surveyed and recorded with the economic activity (employment type, unemployment, housework etc.) involvements of individuals. Each trip was recorded with the mode of travel used for such trips. Therefore the trip rates for different categories of economic engagements could be analysed for each passenger vehicle type. The trip rates between one activity and another were analysed and found to be significantly different in most cases. Also the selection of mode for such trips was found to be significantly different for different categories of activity groups. The

categories of activities are as defined in the publications of the Department of Census and Statistics (DCS), Sri Lanka [2].

Basically the three major categories of activity involvement defined in this study are, employment, educational and economically non active group. The different employment types are further categorised into three groups based on the income and the social status of (a) Professionals and Senior Managers, (b) Associate Professionals and (c) Clerks and Supporting Staff. The category analysis applied in this instance considers the average trips in each category on a daily basis. Finally, these trip rates by activity types are cross classified by vehicle types, so that the output of the analysis can be given as mode based trip rates per person per day.

5. Data Collection

The suburban area of Maharagama includes a wide range of socio economic activities ranging from agriculture to commercial land use. Also, the reason to select this as the study area is its geographical location in terms of proximity to Colombo and it being considered as an important suburb. The Maharagama Divisional Secretariat (DS) area has 41 Gramaseva Niladari Divisions (GNDs) and a land area of 37.35 square kilometres. The population in the study area is 175,428. There are 78,106 economically active inhabitants and 81,061 economically inactive inhabitants in the study area. Of these, there are 73,131 employed persons and 4,975 unemployed persons. There are 26,262 students, 35,976 houseworkers, 6,140 retired persons, 4,514 persons unable to work, 8,169 persons defined as others and a further 2,135 persons whose activity status is not stated [2].

The primary data for the analysis was collected from a randomly selected sample of 2,210 households (7.2 per cent of total) in 30 Gramaseva Niladari (GN) divisions. Details of a total of 6,642 daily trips made by 9,304 occupants were recorded. The questionnaire included socio economic data such as employment, type of population, age, sex, and travel information of the occupants such as trips per day, mode of travel, travel destination and purpose.

The relationship developed between travel behaviour and socio-economic data could be used to forecast traffic volumes using data bases available in DCS [2]. In the future, the traffic forecasting is possible with projected data with population growth rates.

Table 1: Classification of activity involvement by type of economic engagement

No	Activity Group	Activity Category
1	Employment	Professionals and senior managers
		Associate professionals and clerks
		Supporting staff
		Own business
3	Educational	Pre-school
		School
		University and others
3	Economically Inactive	Housework
		Retired
		Unemployed
		Non active

6. Analysis

The method of category analysis has been used to derive the trip rates of individuals, in the study area by the different activities they are engaged in. Thereafter these rates are cross classified with the mode of travel they use. Trip rates by the different activity groups by the different modes are shown graphically.

6.1 Behaviour of Travel Pattern by Employment Group

6.1.1 Professionals and Senior Managers (Type 1)

The results of the category analysis between the activity group and their mode selection are shown in Table 2. The population category of professionals and senior managers (Type 1) indicate different mode selection behaviour in comparison with other employment categories (Figure 1).

This category has a high rate of trips by private transport modes as indicated in Figure 1. The 74% of trips made by private transport in this category includes 55% of car trips; which is the highest rate for car trips by any kind of activity category. The observed demand for public transport from Type 1 population is 25%. There are no non motorised trips by this category.

Figure 1: Trips by the Professionals and Senior Managers category

6.1.2 Associate Professionals and Clerks (Type 2)

This group of employment has the highest potential for using different modes for their day to day travel. A major percentage (64%) of this category uses public transport (Figure 2). It has a highest rate of motor bike users (12%) than any other category showing its middle income characteristics. The total share of private motorised transport trips is 29% with less than 10% making car trips. This indicates a lower affordability of four wheel vehicles by this group.

Figure 2: Trips by Associate Professionals and Clerks category

6.1.3 Supporting Staff (Type 3)

Almost 90% of persons in this category use public transport and non motorized transport. 17% of them walk. Four wheel owner users are not significant. However this category has a lower trip rate for buses than Type 2 employment. Also three wheelers have a significant share of the usage by people in this category. This category of employment has the lowest overall trip rate.

Figure 3: Trips by Supporting Staff category

6.1.4 Business Employment (Type 4)

Persons engaged in business employment have a well distributed mode selection as shown in Figure 4. All motorized private modes have almost equal shares. There are however no trips by trains. The trip length of this category is generally short as their business places are usually close to their place of residence. They use private motorised modes more than Type 2 category. Significant use of cars and vans are found which is second only to the Type 1 category of employment.

Figure 4: Trips by Business Employment category

6.2 Behaviour of Travel Pattern by Educational Group

Trip generation behaviour from those in educational activities is also very different from other activities with changes in terms of age of population also being observable.

6.2.1 Pre-School Education Group

Persons in the pre-school category have a very high trip rate for walking. This result indicates that they are attending schools close to their home when at an early age. However it is observed that even then, 35% of such trips are made by motorised private transport. This

indicates that they may be dropped/picked up by their parents who use private vehicles. Very few bus trips are recorded in this category of activity compared with other types of educational groups. The total trip rate by this category is comparatively low that they are not a common trip type for most households.

Figure 5: Trip Rate by Pre- School Education Group

6.2.2 School Education Group

As shown in Figure 6, public transport seems to play a major role in school educational trips as shown. Contributions from private motorised modes are very few. Van trips shown are those representing school transport services. Train trips are not popular for school/educational trips. The total trips per person indicates that their could be multiple trips. It is found that around 20% of such trips are made to private tuition classes after school.

Figure 6: Trip Rate by School Education Group

6.2.3 University and Other Education Group

The population engaged in the university and higher education group has the highest trip rate by public transport (80%). No non-motorised trips are observed while 10% of walking trips are observed. These trips are owing to the presence of a university in the study area.

Figure 7: Trip Rate by University and Other Education Group

6.3 Behaviour of Travel Pattern by Economically inactive Group

This category of people is not involved directly with the economic activities in society. It is also the lowest trip making category in society. Less than 30% of such people make trips daily. This is very different from the other two categories. However between 35 - 40% of the total population in suburban areas belongs to this category and therefore has a significant effect on the number of trips in a zone.

6.3.1 Housework Group

Around 60% of the economically inactive population belongs to the household work category. Almost 100% of them are females. A major parts of these trips are, characteristically, market and shopping trips. They are rarely seen to use private motorised modes. Long distance trips are made by bus while short distance trips are made walking by this group of people, (Figure 8).

Figure 8: Trip Rate by Housework Group

6.3.2 Retired Group

Retired persons are those who make the highest trips among the economically inactive group. The major parts of these trips are observed to be

social trips. They make good contributions to all types of modes. However, the public transport and walking modes have the major contribution to the share of the total trips.

Figure 9: Trip Rate by Retired Group

6.3.3 Unemployed Group

The trip rate of unemployed persons is very similar to the housework group as can be seen when comparing Figures 8 and 10. They also basically depend on bus transport with a significant proportion seen to walk. This indicates their poor economic situation.

Figure 10: Trip Rate by Unemployed Group

6.3.4 Non Active Group

This is the lowest rate of trip makers found among all the different activity groups. They seem to rarely make trips and thus their trip rate is as low as 14%. This means 86% of the population belonging to this category remains at home on a given day.

6.4 Summary of the Characteristic Behaviour of Different activity groups

The results of the above category analysis are given in Table 2. The trip rates of all categories discussed above is tabulated against the mode selection. These results can be used for

Figure 11: Trip Rate by Non Active Group

forecasting total trips by each mode based on the total population of each category given in DCS tables for suburban areas.

Table 2: Category Analysis of Trip Rates

Activity Type	Total Trips By Mode								Total		
	Walk	Bicycle	Bus	Train	MBike	3W	Car	Van			
Professionals and Senior Managers	6	0	115	10	8	10	303	95	548	4042	53
Associate Professionals and Clerks	53	10	537	36	107	31	82	79	936		
Supporting Staff	425	100	1090	26	128	464	28	98	2358		
Own Business	27	6	66	1	29	20	22	30	199		
Pre - School	85	1	32	1	13	18	11	25	185	2751	36
School	348	11	655	13	31	111	49	381	1599		
University and Other	87	5	730	10	34	24	34	44	967		
Housework	167	1	237	2	7	62	24	33	533		
Retired	27	7	42	0	6	9	17	9	117	821	11
Unemployed	23	3	42	1	4	6	4	6	89		
Non Active	17	1	31	1	2	13	9	9	82		
Total	1264	145	3578	100	369	767	583	808	7613	7613	100

7. Results

A trip generation by a given mode m for a given traffic analysis zone i can be expressed as a linear function :

$$T_{im} = a_m Ep1_i + b_m Ep2_i + c_m Ep3_i + d_m Bp_i + e_m Psp_i + f_m Sp_i + g_m Up_i + h_m Hwp_i + i_m Rp_i + j_m Uep_i + k_m Np_i \dots\dots\dots (1)$$

Where

$a_m, b_m, c_m, \dots$ are the trip rates by a given mode, based on each category of activity group as given in Table 2 and where the other abbreviations used in the formula are defined in Table 3.

Hence the Total trips generated in a given zone can be expressed as

$$T_i = \sum_{m=1}^n T_{im} \dots\dots\dots (2)$$

A work example and results for a different TAZ selected outside the base area is discussed in the

next section as a demonstration of the practical use of the model.

7.1 Case Study - Application of Trip Generation forecasting in a different GND (Katubedda)

Table 3 indicates the socio-economic data required for applying this model to another DSD (Moratuwa) for verification purpose. As a first step the paper illustrates the estimation of trip generation for a TAZ which is a GND in Moratuwa DSD.

Table 3: Population by different activity engagement of a different suburban area (Katubedda GND)

Activity Type	Lable	Zonal Population
Professionals and Senior Managers	Ep1	495
Associate Professionals and Clerks	Ep2	902
Supporting Staff	Ep3	2523
Own Business	Bp	194
Pre - School	Psp	199
School	Sp	1466
University and Other	Up	1020
Housework	Hwp	1780
Retired	Rp	268
Unemployed	Uep	261
Non Active	Np	592

The estimation of the total trip generation by different modes based on the model for the selected GND (Katubedda) are given in Table 4.

Table 4: Total Trip Generation by Mode in Selected TAZ (Katubedda).

Activity Type	Total Trips By Mode								Total	%
	Walk	Bicycle	Bus	Train	MBike	3W	Car	Van		
Professionals and Senior Managers	6	0	115	10	8	10	303	95	523	53
Associate Professionals and Clerks	53	10	537	36	107	31	82	79	936	
Supporting Staff	425	100	1090	26	128	464	28	98	2358	
Own Business	27	6	66	1	29	20	22	30	199	
Pre - School	85	1	32	1	13	18	11	25	185	36
School	348	11	655	13	31	111	49	381	1599	
University and Other	87	5	730	10	34	24	34	44	967	
Housework	167	1	237	2	7	62	24	33	533	
Retired	27	7	42	0	6	9	17	9	117	11
Unemployed	23	3	42	1	4	6	4	6	89	
Non Active	17	1	31	1	2	13	9	9	82	
Total	1264	145	3578	100	369	767	583	808	7613	100

It can be seen that Katubedda GND which has a population of 9,700 has a daily estimated total trip generation of 7,613 trips. The employed categories make 53% of these trips while educational and inactive categories make 36%

and 11% respectively. When this is estimated for other GNDs in the Moratuwa DSD area, it was observed that there was a significant variation of these estimated values for different GNDs.

7.2 Validation of the results

There are many methods for validation of this type of model output for accuracy. Usually the estimated total trips are cross checked with the actuals surveyed at site using a statistical measure. Also, such results maybe compared against the estimation done by another valid model if available. Since this paper is a part of an ongoing research, and the traffic counts have not been done so far, for validation, an existing trip generation model is used for comparison of results with this estimation model [6].

The estimated total trips by employees with the developed model and total work trip estimated using the Seoul Regression Model (SRM) [6] are tabulated in Table 5. These estimates are very much close to the estimates from the model for the employed population. The comparison of work trip estimates of the model against those from the SRM estimates is shown in Figure 12.

Table 5: Comparison of Results SRM.

Traffic Analysis Zone (GND)	SRM Model	Activity Model	
	Work Trips	Work Trips	Total Trips
547 - Angulana North	1177	1269	2522
548 - Kaldemulla	2028	2187	3636
548A - Soysapura North	1577	1701	3278
548B - Soysapura South	1104	1190	2342
548C - Dahampura	1446	1560	2474
549B - Thelawala North	2442	2633	4079
549A - Borupana	3145	3392	5277
549 - Thelawala South	1477	1592	2681
550A - Lakshapathiya North	2502	2698	4082
550B - Lakshapathiya Central	1046	1128	2252
547A - Angulana South	960	1035	2180
552A - Uyana South	1623	1750	3139
552B - Uyana North	1148	1238	2557
557B - Rawathawatta South	812	876	1597
557 - Rawathawatta East	1666	1797	3276
550 - Lakshapathiya South	2107	2272	4109
551B - Kuduwanmulla	1069	1152	2238
551 - Katubedda	3748	4042	7613
551A - Molpe	1718	1852	4160
551C - Moratumulla North	1072	1156	2359
558A - Kadalana	1224	1320	2544
557A - Rawathawatta West	1482	1598	2823
552 - Idama	1311	1414	2411
553C - Uswatta	816	880	1777
553 - Moratuwella South	1420	1531	3137
559 - Indibedda West	1241	1339	2790
558 - Moratumulla East	1277	1377	2908
558B - Moratumulla West	1151	1241	2438
560/6- Villorawatta East	1186	1279	2525
560/6- Villorawatta West	1331	1436	2858
559A - Indibedda East	1052	1135	2383
553A - Moratuwella North	1228	1325	2175
553B - Moratuwella West	727	784	1727
554 - Korawella North	1617	1744	3798
554B - Korawella East	755	815	1546
554C - Korawella West	1182	1275	2569
554A - Korawella South	1220	1315	2757
555 - Katukurunda North	1155	1246	2669
555A - Katukurunda South	1485	1602	3287
556 - Egoda Uyana North	1523	1642	3424
556A - Egoda Uyana Central	1066	1149	2323
556B - Egoda Uyana South	1596	1721	3982

Figure 12: Comparison of Estimates with the Foreign Model.

The above comparison is statistically tested with Chi-square distribution using SPSS software. SRM model estimates are assumed as observed values for the statistical test.

Large values for Chi-Square of the test statistic indicate large discrepancies. The test statistics table has shown a very good fit between model and observed data. Relatively large significance values ($>.10$) indicate a reasonably good fit of the model to the observed data. Therefore the statistical test has indicated an acceptable goodness of fit for the estimates.

	Test Statistic	
	SRM	Activity MODEL
Chi-Square ^a	.000	.000
df	41	41
Asymp.Sig.	1.000	1.000

a.42 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.0.

8. Conclusions

The activity based trip generation analysis could be used for forecasting traffic in suburban areas, cost effectively, with DCS data bases which are released from time to time. The trip rates estimated for each mode of transport in this analysis is assumed not to vary with time in the short term, unless there is a major variation of transport supply in suburban areas. The trip rates should be revised accordingly in such situations.

Validation has been done, comparing the estimated figures, with results obtained by running an already existing model, where a very high degree of fit has been observed.

Finally it is recommended that the model could be validated with field counts for better accuracy and the adjustments could be done accordingly, in the future.

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