Effects of Residential Land Use on Trip Generation in Urban Areas: Comparison between Estimated Trip Generation Rates and Planning Practices in Dar es Salaam, Tanzania.

Gordian Wilfred, Hannibal Bwire, Lars-Göran Mattsson, Daniel Jonsson

1.0 Introduction

Trip generation rates are useful components in urban transportation planning. In this study, models were developed to depict the difference between vehicle trip generation rates provided in Urban Land use and Transportation Planning Manual (ULTPM) and actual rates of vehicle trips generated in the study areas. The primary concern was determining the extent land use change affects trip generation rates, which are used in estimating travel in urban planned areas, and proposing the mechanisms of minimizing those effects. Land use is described in terms of physical plots, parcels, houses or dwellings and their associated social economic characteristics. Land use change is therefore presented in spatial dimensions regarding changes in location and size of living and working areas, and associated social economic characteristics. All urban land uses, including residential, commercial, institutions, industrial and open spaces, are important in trip generation, but due to time constraints, this study focused on residential land uses, specifically vehicle trips generated in detached, semi-detached, terraced and apartment dwelling categories.

A number of studies have described the causal relationships between the changes in land use and trip generation. Consequently, correlations between land use variables and trip generation have been established. However, it is still not clear to what extent the change of land use affects trip generation rates in planned urban areas. This knowledge gap has made it difficult for decision makers, planners and policy makers to effectively implement changes in land use policies without affecting transportation demand.

The objectives of this study are therefore :

(i) to examine the effects of changes in land use on trip generation rates used by local practitioners for different residential land uses;
(ii) to develop methodology for deriving trip generation rates for different residential land uses in the study area;
(iii) to compare trip generation rates provided in land use planning manuals and rates obtained in the study area;
(iv) identify factors planners and policy makers should consider in order to reduce the effects of land use changes upon transportation urban areas.

This study adopted a case study approach; 304 households within the study area were surveyed and regression models were used to determine number of vehicle trips generated per household per day. The model coefficients and values of independent variables were used to determine vehicle trips generated for work, school, shopping and recreation purposes. Then, trip generation rates for each purpose were aggregated in order to determine vehicle trips generated in detached, semi-detached, terraced and apartment dwelling categories.

The process of determining vehicle trips generated by household per day was accomplished in two main steps. The first step included determining the values of household characteristic variables (independent) applied in the model. The values were determined by summing up the total number of observations for each variable divided by the number of surveyed households in each respective dwelling category. In order to determine the number of vehicle trips generated by the household, each value was multiplied by its respective model coefficient. At this point in the process, sixteen categories of vehicle trip rates were determined. It included vehicle trips generated in each dwelling category (detached, semi-detached, terraced and apartment) for work, school, shopping and recreation purposes. The second step consisted of aggregating the trip generation rates across purposes within each dwelling category. The obtained trip rates are for vehicle trips generated in detached, semi-detached, terraced and apartment dwellings per household per day.

The comparison between vehicle trip rates obtained in the study area and rates provided in Urban Land Use and Transporta-

tion Planning Manual (ULTPM) were also divided into two parts. First, the values of household characteristics (independent) obtained in study area and values provided in ULTP manual were compared. The manual values were much lower than those within the study area. Next, the vehicle trip generation rates provided in the ULTP manual were compared to the rates obtained in the study area. Within the study area, additional vehicle trips (individual households per day) were noted in detached, terraced and apartment dwellings, while fewer trips were observed in semi-detached dwellings.

The rate of change in household characteristic variables and trip generation rates analyzed in this study prompt questions regarding the application of manual rates in estimating and forecasting transport demand. Therefore, this study suggests transport planners to carry out site or city specific travel analysis and determinations of vehicle trip rates. When an in-depth analysis is not possible, in order to determine if the transfer or borrowing of trip rates is appropriate, a comparative analysis of the household characteristics between the study area and sites or cities examined in developing manual standards is highly recommended.

2.0 Literature review

The process of estimating trip rates includes determination of the actual amount of travel in the region or specific zone, which is functionally related to land use distributions. The estimate of trip rates is described in terms of character, intensity and location of activities. Factors influencing the amount of travel in the planned area include automobile ownership, income, household size, density and type of developments, and availability of transportation infrastructures. The purpose of trip estimation is to determine the number of trips per person or trips per land parcel. Person trips estimates are based on population projection data from residential dwellings and household sizes whereby number of vehicle trips are estimated to every individual person per day, while trips per parcel are based on functions of land parcels and sizes in terms of ground areas or floor areas (Kitamura et al., 2006). Trip estimates are categorized into three major groups:

(i) Site-specific impact analysis for assessing the effects of new developments together with vehicle trips expected to be generated by the proposed development.
(ii) Short and long term development alternatives for evaluation of transportation needs in specific urban areas.
(iii) Long term development plans that consider vehicle trips generated by different types of developments in the country or entire region.

This review has concentrated on item number two, but specifically for vehicle trip rates generated in urban residential development areas which are most vulnerable to changes in land use.

Residential trip generation rates are a fundamental component of transportation planning. Miller et al., (2012) conducted household surveys in four residential neighbourhoods in order to determine trip generation rates of individual households in the neighbourhoods. Obtained rates were compared with the national trip generation rates provided in the manual by the Institute of Transportation Engineers (ITE). Generally, rates obtained in the study area were different from the manual rates. Single-family detached homes indicated slight differences between site-specific household surveys and ITE's trip generation rates. However, rates were significantly different for apartment dwellings. A summary of differences in vehicle trip rates between ITE and observed trip rates are not a source of frustration for transportation planners, rather, they illustrate the need for determining self-controlled, site-specific rates. Even when equivalent methods for determining rates are used for similar neighbourhoods, differences will occur because of the large and random variation inherent in trip generation. Borrowing rates from ITE or other sources may indeed be tolerable, but only if one provides the full range of possible rates, which is probabilistic rather than just the expected mean rate, which is a measurement prone to uncertainty and biases.

Ellys and Reid (2009) cautioned against the use of ITE trip generation rates in cit-

ies of developing countries. The study addressed changing land use patterns and the informal development of these cities. The authors suggested that the ITE trip rates, referred to as ''borrowed rates'', are best applied when analysts consider whether the rates can be modified in order to fit the proposed application. The growth and travel patterns of cities in developing countries are different than those in developed countries. As evidenced by the change of residential detached houses to multi-story business complexes or hotels in developing countries, equivalent changes is very rare in developed countries. Therefore, the practical application of borrowed rates in cities of developing countries requires precaution.

In the NCHRP-National Cooperation Highway Research Program, Williams et al., (2006) deliberates various techniques for determining parameters for trip generation, whether site-specific vehicle trip rates, or household vehicle trip production rates. According to Williams, determining site-specific vehicle trip rates requires identifying major land use categories and the number of trips produced or attracted at each category. Table 1 details the vehicle trip data that should be collected in order to ascribe to best practice.

On the other hand, Filitowish (2011) showed household trip production rates obtained by collecting data on the ground or floor area of a specific housing unit. Other data collected includes gender, age, number of household employee, number of vehicles owned in the household, number of school going children and children not going to school, number of licensed drivers in the household and annual household income.

Totems and Darks (2009) insisted on developing site-specific trip rates rather than adopting the rates developed at different locations for general applications. The study assessed the limitations for model and trip rates transferability, the major recommendations were to avoid unbranded assumptions that travel estimation factors are universal and therefore travel requirements are the same for all cities worldwide. Due to the unique characteristics of city travel patterns, the authors conclude that travel estimation and forecasting should make use of site or city specific trip rates.

The Institute of Traffic Engineers (ITE) (2012), provides the second set of trip generation rates. The rates were derived from

Land use	**Vehicle trips**	**Land use**	**Vehicle trips**	**Land use**	**Vehicle trips**
Residential: Vehicle trips per household/dwelling unit per day					
Detached	9.55	Semi-detached	9.55	Block flats and terraced	6.45
Other land uses: Vehicle trips per square meter per day					
Office	0.12	Park	0.14	Schools	0.11
Retail shop	0.7	Bus terminal	0.12	Collage/university	0.12
Bank	1.4	Religious	0.32	Health	0.23
Bank	0.96	Hall	0.11	Medical services	0.34
Shopping Centre/market	0.3	Open space/ recreation	0.013	Reserved/ conserved area	0
Service station	1.5	Sport ground	0.37	Bar & restaurant	0.08
Business park	0.14	Service/light industry	0.06	Manufacturing/heavy industry	0.03

Table 1: Vehicle Trip Rates in Different Land Use Categories
Source: Urban Land use and Transport Planning Manual 1982 revised on 2008

household survey data and traffic survey inventories. Generally, the ITE trip generation rates for various land use categories in Tanzania are also documented in the Urban Land Use and Transportation Planning Manual (ULTPM, 2008); these values are presented in Table 1. The manual trip rates are categorized into residential and non-residential land uses. The rates for residential land uses are the number of vehicle trips generated by individual households or dwelling units per day, whereas, rates for non-residential land uses include number of vehicle trips generated by the unit measures of the ground or floor area per day. Residential uses are categorized into detached, semi-detached, terraced and apartment, while non-residential include land use for commercial, institution, industrial, open spaces and recreational facilities.

Filitowish (2011) and TiIsdor (2012) described the shortcomings of applying manual trip rates in Tanzania and other developing cities for urban transportation planning as follows:

- Rapid increases of population in urban planned areas resulted from high rates of urbanization. Commonly, population is the most important aspect in calibrating trip generation rates. Therefore, increases in urban population ultimately affect trip rates.
- Emergence of formal and informal land use changes do not go in hand with the provision of transportation infrastructure.
- Accommodating multi-family units within the single family house. This situation is mainly caused by high rates of housing demand and lack of housing stocks in urban areas whereby two or more households can be accom-



Figure 1: Land Use in Year 1992

modated in one house or dwelling unit.

- Long travel distances to work that necessitate reliance upon automobile transportation to the urban centre. This is mainly caused by a high percentage of employment opportunities being located far away from residential neighbourhoods (Berry 2003).

3. 0 Selection of Study Area and Data Collection

The study was conducted in the city of Dar es Salaam, which is the largest city in Tanzania and is located in the eastern part of the country along the shore of the Indian Ocean. The study area was selected because it has been planned and developed for more than twenty years, it covers three or more neighbourhoods, and has undergone rapid land use change. Three categories of data were collected in the study area; the first category was land use change characteristics, the second was socioeconomic data and the third was travel attribute data. Land use change data was obtained by using land use plans, which were digitized in Arc GIS software and updated with satellite imagery from 2012 (Figures 1 and 2). The differences between planned and existing land uses were obtained through overlay functions, and verified physically by researchers moving throughout the study area using GPS receivers.

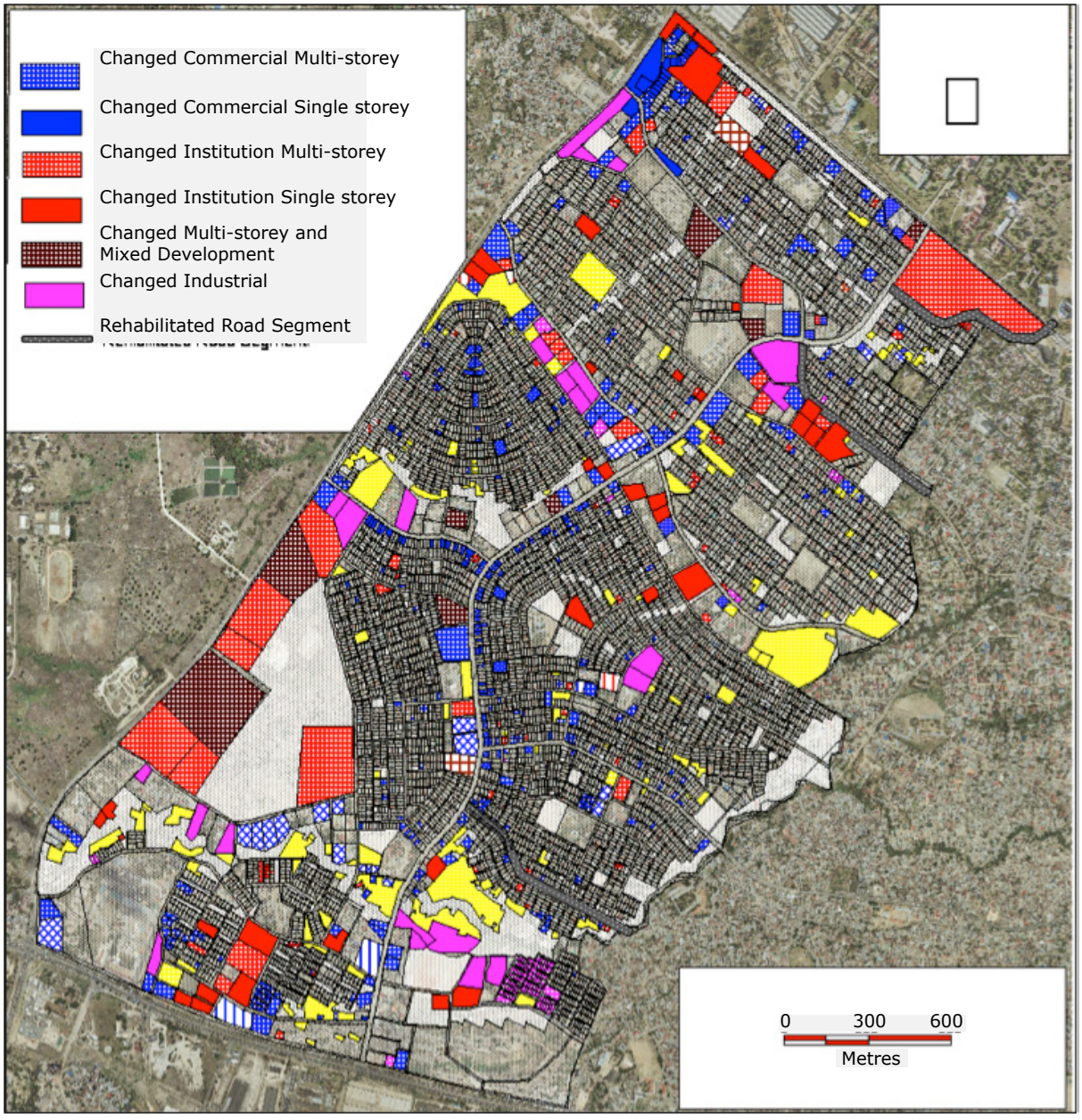


Figure 2: Land Use in Year 2012

Household surveys were used to collect social, economic, and travel attribute data in the study area. The survey process consisted of three steps. First, random sampling was used to determine the appropriate number of respondents in the study area. The responding population was the total number of houses or dwelling units (6743 houses). The sample size (377 houses) was determined using the formula n=N/(1+N(e)2), where n is the sample size, N is total number of houses (the population), and e is the level of precision (0.05 at 95% confidence level) (Glenn 1992). A uniform of 1 house out of 18 houses or dwelling units was selected as part of the sample population.

The second step was to select interview households. The interview was completed for one household in the sampled house or dwelling unit because most of sampled houses or dwelling units contained two or more households. The process includes interviewers physically visiting the sampled house and interviewing one member of the selected household. Interviews were conducted on weekend days in order to find adults at home, but questions were asked regarding the travels made on 'one' of the previous working days. 304 households, or 81% of the sample size, were interviewed. Primary reasons for achieving less than 100% of the sample size include inaccessibility of sampled houses and unavailability or unwillingness of interviewees.

The third and final step in the data collection process was carried out at the individual and household levels. At the individual level, the interviewee was required to state the trips chain[1] made for the previous working day. For each trip, the provided data included start and end times, origin and destination locations, purpose, mode of transportation used, and distance travelled. At the household level, the interviewees were required to provide data for household characteristics and travels made by each member of the household. Household characteristic data included household size, Number of employee, vehicle ownership, children of pre-school and school age, adults, and licensed annual income. Household travel data included the time each member started the first trip from home, the time back home, purposes of travels, and types of transportation used.

4.0 Land Use change in Tanzania

Land use Change is legally accepted and formally practiced in urban planning in Tanzania. The Urban Planning Act of 2007, Section 30-38 states that any person being a land holder of a granted right of occupancy who intends to change the use of land or building on that land shall take action in accordance with the provisions of the Act. Application of planning consent for change of use has to be submitted to the planning authority or to the director of the planning authority in the form and manner prescribed by regulations made under the Act. The planning authority is then required to make assessments on the proposed developments based on the planning space standards, building functions, heights, appearances, and arrangement of buildings. The director of the planning authority is required to accept the application and approve the proposed development subject to changes in the use of land or building and certify the proposal implementation.

In the study area, the changes were obtained by overlaying the planned 1992 land use map layers to the 2002 land use map layer. Current land uses were obtained from high-resolution satellite images for 2012. Through overlay operations the spatial differences for the ground area (GA) and floor area (FA) of each land use category were determined. GA was obtained by computing the area of land parcels for each land use category, and FA was obtained by measuring the sizes of the buildings and counting the number of stories. In order to avoid duplicating the computed areas, the GA was removed from the counted FAs in each multi-story building. The spatial differences between planned areas in 1992 and existing land uses in 2002 are presented in Table 2 below.

As indicated in Table 2, some residential land parcels changed to other land uses, and the addition of multi-story buildings

1 Trips were counted as going (for work, school, shopping and recreation) is one trip and coming back is another trip. For the intermediated destinations one trip was counted for each intermediate destination.

Land use category	Planned land use 1992	Land use on 2002	Change Difference	
	Area (m2)	Area (m2)	Area (m2)	Percentage
Residential				
Ground area	3,310,000	3,146,000	-164,000	-5.0%
Floor Area	223,000	263,140	40,140	18.0%
Commercial				
Ground area	236,180	724,478	488,298	206.8%
Floor Area	128,558	668,301	539,743	419.8%
Institution				
Ground area	567,377	894,991	327,614	57.7%
Floor Area	64,100	467,987	403,887	630%
Industrial				
Ground area	76,432	230,200	153,768	201.1%
Floor Area	0	0	0	0%
Open space				
Ground area	1,806,041	988,000	-818,041	-82.9%
Roads				
Ground area	1,161,100	1,173,360	12,360	0.17%

Table 2: Land Use Change Distribution

1. Residential, commercial and institution land uses include both ground and floor area with various multi-storey buildings; while industrial, open spaces and roads land uses are ground areas which do not include vertical or multi-storey developments.

2. Change difference (percentages) was computed and presented for each specific land use category.

for residential purposes is insignificant. Commercial and institutional land uses, however, increased considerably. Most notably, open spaces were converted to commercial and institutional multi-story buildings. Most of the altered parcels were used for hotels, shopping centres and retails, schools, churches, mosque, health and offices for public services. Changes in industrial land use are mostly to accommodate garages, parking yards and service industries.

The aforementioned land use changes obviously increase the travel demand within the planned area and necessitate the improvement of existing roads or the construction of new transportation infrastructures. However, the shortage of land for expansion, project costs, and government priorities limit transportation infrastructure improvement projects.

5.0 The Model Formulation

Models were formulated in bivariate structure and based on household survey data. The salient characteristic of this structure is that the determined or dependent variables are defined by independent variables in linear form. The number of vehicle trips generated by the household for a specific purpose was expressed by the linear function of independent variables. In addition, models also included variables that specify the dwelling categories where trips were originated. Therefore models were defined as follows:

$$Y_{im} = \alpha O_m + \alpha_{im} X_{i1} \ldots\ldots + \alpha 9_m X9 + \beta 1_m D_{i1} \ldots\ldots + \beta 4_m D_{i4} + \xi_{im}$$

Where:

Y_{im} = Number of vehicle trips made by individual household i for purpose m

αO_m = Constant coefficient for purpose m

αk_m = The associated coefficient of household characteristic variable k for purpose m

β_{jm} = The associated coefficient of

dummy variable j for purpose m
X*ik* = Value of characteristic variable k for household i
D*ij* = Dummy variable: 1 if household i is living in dwelling category j, 0 otherwise
ξ*im* = A random error term of household i for purpose m

Vehicle trips as applied in this model encompass trips made by individual household by using private cars, public buses (well-known Daladala), taxis, workplace or office vehicles and school buses. They exclude trip made by using regional or up-country buses, trucks and freight vehicles.

5.1 Variables

Both dependent and independent variables are shown in table 3. Dependent variables include vehicle trips made by individual households for the purposes of work, school, shopping and recreation. Vehicle trips for work were trips made by household employees to and from work or any work related journey performed from one workplace to another. Vehicle trips for school include vehicle trips to and from schools made by school children on their own, and all vehicle trips made by the parents when driving their children to and from the school. Shopping trips include vehicle trips made for all domestic purchases and non-work but related business trips, while recreation vehicle trips encompass vehicle trips made for visiting relatives, health, worship and other social activities.

Explanatory variables are variables that describe household characteristics. Such variables include household size, household employment (government, private and self employed), household annual income (low, medium and high income), age (pre-school, school age and adult going to school and college), household ve-

Variable	Definition
Dependent variables (Y*im*)	
WBT	Vehicle trips for work
SBT	Vehicle trips for school
ShBT	Vehicle trips for shopping
RBT	Vehicle trips for recreation
Independent variables - Household characteristics (X*ik*)	
NPHH	Number of people in the household (household size)
EmpHH	Number employees in the household
ANEmpHH	Number of adults in the household who are not employed
VOHH	Number of vehicles owned by the household
LDHH	Number of licensed drivers in the household
PSchHH	Number of pre-school children in the household (between 0-5 years)
SchHH	Number of children of school age in the household (between 6-18 years)
AHH	Number of adults in the household going to high school and college (19 years and above)
AIHH	Household annual income (in Tanzanian Shillings)
Independent variables - Dwelling categories (D*ij*)	
VTODH	1-if the household lives in a detached dwelling, 0 otherwise
VTOSDH	1-if the household lives in a semi-detached dwelling, 0 otherwise
VTOTH	1-if the household lives in a terraced dwelling, 0 otherwise
VTOAH	1-if the household lives in an apartment dwelling, 0 otherwise

Table 3: Specification of the Variables in the Vehicle Trip Generation Models

hicle ownerships and licensed drivers. In additional, there are also dummy variables characterising the dwelling category of the household such as detached, semi-detached, terraced or apartment dwelling.

5.2 Model Estimation Results

All models were estimated by using Ordinary Least Squares (OLS) regression procedures. Coefficients were determined for the work, school, shopping and recreation trips, and the dummy variable for detached, semi-detached, terraced and apartment dwelling categories. The R^2 (R-square) value determines the percentage of total variance that is explained by the predictor variables in the model. The higher the R^2 value the less error in the model and therefore the better the model prediction. The t-test is applied as a measure of Perceived Functional Ability (PFA) of the predictor variables. Each predictor variable is measured within a 95 percent confidence level at p-value ≤ .05.

5.2.1 Trip Generation Model for Work

The final model for daily vehicle trips generated by the household for work purposes is shown in Table 4. The independent variables can reliably explain and predict the dependent variable at 57.6% (R^2 = 0.576). All independent household characteristic variables included in the final model are positively associated with the dependent variable and the coefficients are significant at p-value ≤ 0.05. The estimated model coefficients imply that the number of vehicles for work purposes is positively correlated with the household size, number of employees, number of vehicles and number of licensed drivers in the household.

The model has also been tested for the dummy variables related to the dwelling category of the household. The results show that households living in detached dwellings have significantly lower work trip rates whereas households living in apartment dwellings have significantly higher work trip rates than those living in other dwelling categories.

5.2.2 Trip Generation Model for School

The final model for daily vehicle trips generated by the household for school purposes is shown in Table 5. The independent variables can reliably explain and predict the dependent variable at 28.7% (R^2 = 0.287). All independent household characteristic variables included in the final model are positively associated with the dependent variable and the coefficients are significant at p-value ≤ 0.05. The model coefficients imply that, the number of vehicle trips generated for school purposes are positively correlated with number of children of school age, number of adults going to school and collages and number of vehicles in the household. The model has also been tested for the dummy varia-

Variable	Alfa/beta	Std error	t-statistics	Significance
NPHH	0.226	0.048	4.790	0.000*
EmpHH	1.187	0.207	5.795	0.000*
VOHH	0.268	0.124	2.179	0.030*
LDHH	0.304	0.123	2.532	0.012*
VTODH (Dummy)	-0.848	0.324	-2.614	0.009*
VTOAH (Dummy)	1.315	0.184	3.425	0.001*
Constant	0.490	0.134	2.128	0.046*
R^2	0.576			
F	80.849			
N	304			

Table 4: Trip Generation Model –Vehicle Trips for Work
Alfa/beta: Estimated model coefficients;
* Significant at p-value ≤ 0.05

bles related to the dwelling category of the household. The results show that households living in apartments, semi-detached and terraced dwellings have significantly and increasingly higher school trip rates than those living in detached dwellings.

characteristic variables included in the final model are positively associated with dependent variables and the coefficients are significant at p-value ≤ 0.05. The model coefficients imply that, the number of vehicle trips generated for shopping

Variable	Alfa/beta	Std error	t-statistics	Significance
SchHH	0.462	0.062	7.483	0.000*
AHH	0.191	0.034	5.582	0.000*
VOHH	0.148	0.068	2.167	0.031*
VTOSDH (Dummy)	0.548	0.235	2.335	0.020*
VTOTH (Dummy)	1.215	0.386	3.146	0.002*
VTOAH (Dummy)	0.362	0.174	2.086	0.038*
Constant	-0.687	0.171	-4.026	0.000*
R^2	0.287			
F	20.142			
N	304			

Table 5: Trip Generation Model –Vehicle Trips for School
Alfa/beta: Estimated model coefficients;
* Significant at p-value ≤ 0.05

5.2.3 Trip Generation Model for Shopping

The final model for daily vehicle trips generated by the household for shopping purposes is shown in Table 6. The independent variables can reliably explain and predict the dependent variable at 41.0% (R^2 = 0.410). All independent household

purposes is positively correlated with the household size, employee, annual income and vehicle owned in the household.

The model has also been tested for the dummy variables related to the dwelling category of the household. The results show that households in detached and semi-detached dwellings have significant-

Variable	Alfa/beta	Std error	t-statistics	Significance
NPHH	0.108	0.040	2.698	0.007*
EmpHH	0.770	0.168	4.576	0.000*
AIHH	0.044	0.011	3.962	0.000*
VOHH	0.312	0.123	2.537	0.012*
VTODH (Dummy)	1.243	0.629	1.974	0.049*
VTOSDH (Dummy)	1.759	0.728	2.416	0.016*
VTOAH (Dummy)	-1.411	0.672	-2.100	0.037*
Constant	-1.415	0.709	-1.995	0.047*
R^2	0.410			
F	29.359			
N	304			

Table 6: Trip Generation Model –Vehicle Trips for Shopping
Alfa/beta: Estimated model coefficients;
* Significant at p-value ≤ 0.05

ly and increasingly higher shopping trip rates, whereas those living in apartments have significantly lower shopping trip rates than those living in terraced dwellings.

5.2.4 Trip Generation Model for Recreation

The final model for daily vehicle trips generated by the household for recreation purposes is shown in Table 7. The independent variables can reliably explain and predict the dependent variable at 33.2% (R^2 = 0.332). All independent household characteristic variables included in the final model are positively associated with the dependent variable and the coefficients are significant at p-value ≤ 0.05. The model coefficients imply that, the number of vehicle trips generated for recreation purposes is positively correlated with the household size, number of unemployed people, and number of vehicles in the household, whereas it is negatively correlated with the number of employees in the household. An interpretation of the latter result is that as more people within a household are employed, less free time is available to engage in leisure and social activities.

The model has also been tested for the dummy variables related to the dwelling category of the household. The results show that households living in detached, apartment and terraced dwellings have significantly and increasingly higher recreation trip rates than those living in semi-detached dwellings.

Variable	Alfa/beta	Std error	t-statistics	Significance
NPHH	0.424	0.089	4.783	0.000*
EmpHH	-0.269	0.136	-1.989	0.048*
ANEmpHH	0.407	0.154	2.641	0.009*
VOHH	0.639	0.171	3.745	0.000*
VTODH (Dummy)	1.741	0.692	2.514	0.012*
VTOTH (Dummy)	3.134	1.325	2.365	0.019*
VTOAH (Dummy)	1.909	0.816	2.339	0.020*
Constant	-1.970	0.785	-2.508	0.013*
R^2	0.332			
F	22.150			

Table 7: Trip Generation Model –Vehicle Trips for Recreation
Alfa/beta: Estimated model coefficients;
* Significant at p-value ≤ 0.05

6.0 Values of Independent Variables

After having estimated the model coefficients, we determined the average values of the independent variables to be applied for estimating trip generation rates. This requires aggregating the household characteristic data collected during the household surveys. Values for each variable were aggregated and averaged separately for each dwelling category. The values are presented in Table 8 (p43).

7.0 Estimation of Vehicle Trip Rates

The estimated model coefficients and the average values of the independent variables were used to determine household vehicle trip rates for each trip purpose across dwelling categories, sixteen categories in total. The detailed calculations are shown in Appendix 3-6.

Table 9 (p43) displays the rates of vehicle trips generated by the household per day according to the estimated models and average values of the independent variables. There are some variations between the dwelling categories. The work and school trip rates are highest among households living in apartments. The shopping and recreation trip rates are highest among households living in detached dwellings. The total trip rates across all trip purposes are highest for households living in detached dwellings, followed by apartment dwellings, next by terraced dwellings, and finally, by semi-detached dwellings.

Independent variable	Average Value			
	Dwelling category			
	Detached	Semi-detached	Terraced	Apartment
Household size	6.36	5.65	5.63	5.34
Pre-school age (between 1-5 years)	1.07	0.85	0.63	0.89
School age (between 5-18 years)	1.38	1.25	1.63	1.13
Adult age (19 years and above)	3.92	3.55	3.45	3.34
Household employees	1.67	1.50	1.53	1.82
Non employed adults	2.24	1.75	1.81	1.68
Annual household income (Millions Tanzania Shillings)	25.16	22.17	20.85	25.02
Household vehicle ownership	1.14	0.95	0.91	1.21
Household licensed drivers	1.44	0.75	1.54	1.61

Table 8: Values for Independent Household Characteristics Variables

Dwelling Category	Vehicle Trips - Purpose				Vehicle Trip Rate
	Work	School	Shopping	Recreation	
Detached	4.59	1.42	3.38	4.66	14.04
Semi-detached	4.02	1.02	3.27	2.45	10.76
Terraced	3.81	1.01	1.57	3.46	9.85
Apartment	5.99	2.08	1.63	3.25	12.94

Table 9: Estimated Vehicle Trips per Household per Day

8.0 Discussion of the Results

The trip generation rates obtained in this study are obviously a consequence of the impacts of land use changes that have occurred on the planned residential areas. In fact, the total vehicle trip rate is highest for households living in detached dwellings and slightly lower for those living in apartment dwellings. This is partially contrary to the pattern observed in cities in developed countries where vehicle trip generation rates usually are higher for households living in detached and semi-detached dwellings as compared to these rates for households living in terraced and apartment dwellings. This observation is also partially contrary to the standard values provided in the Urban Planning Guidelines (2007) in Tanzania. The Guidelines suggest high rates of vehicle trips for households in detached and semi-detached dwellings, and lower rates for households in terraced and apartment dwellings. The difference is mainly caused by the change of lifestyle in urban planned areas, whereby a great percentage of high and middle income households live in apartment dwellings and the majority low income households

and unemployed people live in detached and semi-detached houses. The study also found the number of employees and ve-

hicles were higher for households living in apartment dwellings. This contributes to higher vehicle trip rates for household living in apartments compared to those in semi-detached and terraced dwellings.

Another notable result is the relationship between household income and number of employed individuals, and vehicle trip rates for work and recreation. The results show that the households or dwelling units that have higher annual income and number of employees also have higher vehicle trips rates for work, but low vehicle trip rates for recreation. The households or dwelling units with lower annual income and numbers of employees also have low vehicle trip rates for work, but higher vehicle trip rates for recreation. This observation supports the notion that if individual households spend more time on work and other development activities, they use less time for social and leisure activities, and therefore will generate fewer trips for recreation. Although most recreation trips were generated by unemployed members of households, but this statement is still valid. However, further investigations are recommended in order to determine the relationship between social travels and household employment.

Variations were also observed in school trip rates generated in detached, semi-detached and apartment dwellings. Despite more school-age children present in detached and semi-detached dwellings, vehicle trip rates for school are higher in apartment dwelling. This situation is probably influenced by the location of schools in relation to dwelling categories. In most cases, schools are located near detached and semi-detached dwellings (at a maximum of 1 kilometre working distance) but a bit far from apartment dwellings. Location therefore greatly influences the use of private cars and public transportation for school related journeys for households located far away from schools. Also household vehicle ownership, number of employees and annual income impacts vehicle trip rates for school; as these categories rises school-related trip rates. As the number of employed individuals and income increases, households are able to afford school bus fees that contribute to vehicle trip rates for school.

Shopping vehicle trips rates are quite different from school and work. More trips for shopping purposes are generated in detached and semi-detached dwellings and minimized in apartment dwellings, while trips generated for work are maximized in apartments and minimized in detached and semi-detached dwellings. Fewer shopping trips originating from apartment dwellings is probably caused by the close proximity of local markets and shopping centres - most apartment dwellers tend to walk for shopping activities. In most cases detached and semi-detached dwellers use public transportation for shopping activities.

Recreation vehicle trip rates are greatly affected by the employment status. As discussed earlier, recreation vehicle trips are negatively associated with increasing number of household employees, but positively associated with unemployed adults. As presented in model results, household living in apartments have high rates of employment and low rates of unemployed adults that result to low vehicle trip rates for recreation purposes. On the other hand, households living in detached dwelling have low rates of employment and high rate of unemployed adults, therefore have high vehicle trip rates for recreation purpose.

9.0 Comparison

This section presents a comparison between values obtained in this study area and those provided in the Urban Land Use and Transportation Planning Manual (ULTPM). The comparison is divided into two parts: the first concerns the values of household characteristic variables applied in the model, and the second concerns the estimated vehicle trip generation rates. The household characteristic values used in the ULTP manual were obtained from datasets applied in ITE Trip Generation Manual 4th Edition (for details we refer to Filitowish, 2011), while the values applied in this study were obtained from the data collected in the study area.

Table 10 presents the differences between the values of household characteristics provided in the ULTP manual and the values observed in the study area. The differ-

Household Characteristics	Manual vs. Study Area	Values in Dwelling Categories			
		Detached	Semi-detached	Terraced	Apartment
Household size	ULTP manual	5.00	5.00	4.00	4.00
	Study area	6.36	5.65	5.63	5.34
Vehicle ownership	ULTP manual	0.75	0.75	0.50	0.50
	Study area	1.14	0.95	0.91	1.21
Licensed driver	ULTP manual	0.75	0.75	0.50	0.50
	Study area	1.44	0.75	1.54	1.61
Employment	ULTP manual	1.00	1.00	0.75	0.75
	Study area	1.67	1.50	1.53	1.82
Annual income (mil Tshs)	ULTP manual	12.50	12.50	7.50	7.50
	Study area	25.16	22.17	20.85	25.02
Households or families in the house	ULTP manual	1.00	1.00	1.00	1.00
	Study area	2.92	2.50	1.6	1.5

Table 10: Comparison of Household Characteristics Values

ences are of three kinds: Firstly, the manual has the same values for detached and semi-detached dwellings, and for terraced and apartment dwellings. It is not realistic to apply the same values in different dwelling categories in urban planning practice (Ellys and Reid 1982). In contrast, the estimated values are different for dwelling categories as observed in the study area. Secondly, in the manual all variables assume higher values in detached and semi-detached dwelling categories, and lower values in terraced and apartment dwellings. However, in the study area rates vary based on household characteristic values. In some cases rates in detached dwellings are higher, in other cases rates are higher in apartment dwellings. Lastly, the values in the manual are consistently lower compared to those estimated in the study area. The number of vehicles, number of licensed drivers, number of employees and annual income are almost consistently much higher in the study area. This is probably an effect of land use changes in the study area and general economic trends, which have resulted in a large change of household characteristics in the study area.

The comparisons between vehicle trip generation rates provided in the ULTP manual and rates found in the study are presented in Table 11. The rates in the study area are 100 percent higher for households living in apartment dwellings and about 50 percent higher for households in detached, semi detached and terraced dwellings. The dramatic difference in trip generation rates for apartment dwellings can be partially explained by changes in household characteristics which probably are caused by land use change.

Dwelling category	Vehicle trip generation rates		Difference in trip rates	Difference in percentages
	ULTP manual	Study area		
Detached	9.55	14.04	4.49	47.0
Semi-detached	9.55	10.76	1.21	10.2
Terraced	6.45	9.85	3.40	52.7
Apartment	6.45	12.94	6.49	100.62

Table 11: Comparison of Trip Generation Rates

10.0 Conclusion and Recommendations

10.1 Conclusion

Trip generation rates obtained in different residential dwelling categories have depicted the inconsistency of using manual trip rates in estimating and forecasting travel demand. The differences between the trip generation rates obtained within the study area and the rates provided in ULTPM are quite large, and therefore, the validity of the manual must be questioned. As indicated in the study area, the observed differences are perhaps caused by change of land uses, economy, lifestyles and other household characteristics that influence the number of vehicle trips generated by individual households per day.

10.2 Recommendations

In order to minimize effects of using disadvantaged manual rates in transportation planning, we recommend planners carry out an empirical study for the specific city or site with the goal of determining city or site specific vehicle trip rates. In the case of transferability or borrowing of trip generation rates, a comparative analysis between sites where trip rates were obtained and sites to be applied should be done before using the borrowed rates in transportation planning.

It is also important to consider how often trip generation rates need to be reviewed. The standards in the Urban Land Use and Transport Planning Manual developed in 1982 were reviewed in 2008. With such a large time gap between rate development and review, the rates were too old to be able to cope with the changes presented in fast-growing cities. Therefore, this study recommends a maximum of five years between reviews of trip generation rates.

Author details:
Corresponding author:
Gordian Wilfred,
Department of Transportation and Geotechnical Engineering,
College of Engineering and Technology,
University of Dar es Salaam,
P.O Box 35131,
Dar es Salaam,
Tanzania.
Email: wkazaura@yahoo.com

Hannibal Bwire,
Department of Transportation and Geotechnical Engineering,
College of Engineering and Technology,
University of Dar es Salaam,
P.O Box 35131,
Dar es Salaam,
Tanzania.
Email: bw_hann@yahoo.co.uk

Lars-Göran Mattsson,
Department of Transport Science,
KTH University,
SE-100 44
Stockholm,
Sweden.
Email: lars-goran.mattsson@abe.kth.se

Daniel Jonsson,
Department of Transport Science,
KTH University,
SE-100 44
Stockholm,
Sweden.
Email: daniel.jonsson@abe.kth.se

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Appendix 1: Values of Household Characteristics Variables

	HH Size	Pre-School Age	School Age	Adult Age	HH Em-ployee	Non Em-ployed	Income Millions	HH Vehicle Owner-ship	HH Li-censed Driver
Detached									
Surveyed house-hold	234	234	234	234	234	234	234	234	234
Total observation	1489	252	317	919	391	525	5889.6	267	339
Average	6.36	1.07	1.38	3.92	1.67	2.24	25.16	1.14	1.44
Semi-Detached									
Surveyed house-hold	20	20	20	20	20	20	20	20	20
Total observation	113	17	25	71	36	35	443.4	19	15
Average	5.65	0.85	1.25	3.55	1.5	1.75	22.17	0.95	0.75
Terraced									
Surveyed house-hold	7	7	7	7	7	7	7	7	7
Total observation	39	5	10	24	11	13	146.0	6	11
Average	5.63	0.63	1.63	3.45	1.53	1.81	20.85	0.91	1.54
Apartment									
Surveyed house-hold	43	43	43	43	43	43	43	43	43
Total observation	226	36	49	141	70	71	1034.2	50	67
Average	5.34	0.89	1.13	3.34	1.82	1.68	25.02	1.21	1.61

Appendix 2: Households or Families in the House

Items	Household/dwelling categories			
	Detached	Semi-detached	Terraced	Apartment
Surveyed houses	234	20	7	43
Total house-holds/ dwelling units/families	680	50	12	64
Average	2.91	2.50	1.71	1.49

Appendix 3: Vehicle Trips per Household per day for Work

Work vehicle trips originated in detached dwellings (Ywd)
Y_{wd}=0.490+0.226*Hsize*+1.187*Empl*+0.268*Vown*+0.304*License*− 0.848D*d*+ξ*im*
=0.49 + 0.226x6.36 + 1.187x1.67 + 0.268x1.14+ 0.304x1.44 – 0.848x1
= 4.585
Work vehicle trips originated in semi-detached dwellings (Yws)
Y_{ws}=0.49+0.226*Hsize*+1.187*Empl*+0.268*Vown*+0.304*License* +ξ*im*
=0.49 + 0.225x5.65 + 1.187x1.5 + 0.268x0.95 + 0.304x0.75
= 4.024
Work vehicle trips originated in terraced dwellings (Ywt)
Y_{wt}=0.49+0.226*Hsize*+1.187*Empl*+0.268*Vown*+0.304*License*+ξ*im*
=0.49 + 0.225x5.63 + 1.187x1.53 + 0.268x0.91 + 0.304x1.54
3.805
Work vehicle trips originated in apartment dwellings (Ywa)
Y_{wa}=0.49+0.226*Hsize*+1.187*Empl*+0.268*Vown*+0.304*License*+ 1.315D*a* +ξ*im*
=0.49 + 0.226x5.34 + 1.187x1.82 + 0.268x1.21 + 0.304x1.61 + 1.315x1
= 5.986

Appendix 4: Vehicle Trips per Household per day for School

School vehicle trips originated in detached dwellings (Ysd)
Y_{sd}=−0.687+0.462*Sch*+0.191*Adult*+0.148*Vown*+ 0.548D*d* +ξ*im*
=-0.687 + 0.462x1.38 + 0.191x3.92 + 0.148x1.14 + 0.548x1
= 1.416
School vehicle trips originated in semi-detached dwellings (Yss)
Y_{ss}=−0.687+0.462*Sch*+0.191*Adult*+0.148*Vown*+ξ*im*
=-0.687 + 0.462x1.25 + 0.191x3.55 + 0.148x0.95
= 0.709
School vehicle trips originated in terraced dwellings (Yst)
Y_{st}=−0.687+0.462*Sch*+0.191*Adult*+0.148*Vown*+ 0.362D*t* +ξ*im*
=-0.687 + 0.462x1.63 + 0.191x3.45 + 0.148x0.91+ 0.362x1
= 1.014
School vehicle trips originated in apartment dwellings (Ysa)
Y_{sa}=−0.687+0.462*Sch*+0.191*Adult*+0.148*Vown*+ 1.215D*a* +ξ*im*
=-0.687 + 0.462x1.13 + 0.191x3.34 + 0.148x1.21 + 1.215x1
= 2.075

Appendix 5: Vehicle Trips per Household per day for Shopping

Shopping vehicle trips originated in detached dwellings (Yhd)
$Yhd = -1.415 + 0.108Hsize + 0.770Empl + 0.044Inc + 0.312Vown + 1.243Dd + \xi im$
=-1.415+ 0.108x6.36 + 0.77x1.67 + 0.044x25.16 + 0.312x1.14 + 1.243x1
= 3.381
Shopping vehicle trips originated in semi-detached dwellings (Yhs)
$Yhs = -1.415 + 0.108Hsize + 0.770Empl + 0.044Inc + 0.312Vown + 1.759Ds + \xi im$
=-1.415+ 0.108x5.65 + 0.77x1.5 + 0.044x22.17 + 0.312x0.95 + 1.759x1
= 3. 268
Shopping vehicle trips originated in terraced dwellings (Yht)
$Yht = -1.415 + 0.108Hsize + 0.770Empl + 0.044Inc + 0.312Vown + \xi im$
=-1.415+ 0.108x5.63 + 0.77x1.53 + 0.044x20.85 + 0.312x0.91
=1.573
Shopping vehicle trips originated in apartment dwellings (Yha)
$Yha = -1.415 + 0.108Hsize + 0.770Empl + 0.044Inc + 0.312Vown - 1.411Da + \xi im$
=-1.415+ 0.108x5.34 + 0.77x1.82 + 0.044x25.02 + 0.312x1.21 - 1.411x1
= 1.631

Appendix 6: Vehicle Trips per Household per day for Recreation

Recreation vehicle trips originated in detached dwellings (Yrd)
$Yrd = -1.97 + 0.424Hsize - 0.269Empl + 0.407NEmp + 0.639Vown + 1.741Dd + \xi im$
=-1.97 + 0.424x6.36 – 0.269x1.67+ 0.407x2.24 + 0.639x1.14 + 1.741x1
= 4.659
Recreation vehicle trips originated in semi-detached dwellings (Yrs)
$Yrs = -1.97 + 0.424Hsize - 0.269Empl + 0.407NEmp + 0.639Vown + \xi im$
=-1.97 + 0.424x5.65 – 0.269x1.5 + 0.407x1.75 + 0.639x0.95
=1.341
Recreation vehicle trips originated in terraced dwellings (Yrt)
$Yrt = -1.97 + 0.424Hsize - 0.269Empl + 0.407NEmp + 0.639Vown + 3.134Dt + \xi im$
-1.97 + 0.424x5.63 – 0.269x1.53 + 0.407x1.81 + 0.639x0.91 + 3.134
=3.458
Recreation vehicle trips originated in apartment dwellings (Yra)
$Yra = -1.97 + 0.424Hsize - 0.269Empl + 0.407NEmp + 0.639Vown + 1.909Da + \xi im$
=-1.97 + 0.424x5.34 – 0.269x1.82 + 0.407x1.68 + 0.639x1.21 + 1.909x1
= 3.251