APPLICATION OF STATISTICAL REGRESSION IN THE DEVELOPMENT OF A TRIP GENERATION MODEL FOR RESIDENTIAL CONDOMINIUMS IN GREATER VITORIA: A CASE STUDY

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ABSTRACT

This article presents the development of statistical models for trip generation in middle-class multifamily residential condominiums in the Greater Vitoria Metropolitan Region – RMGV / State of Espírito Santo, Brazil, through observation of ventures characterized as Trip Generator Centers – PGT's. The lack of adequate parameters to suit the Brazilian realities, demands studies and analysis of such ventures from rates published by the U.S. Institute of Transportation Engineers. One can expect that the U.S. trip patterns, either motorized or non-motorized, are quite different from Brazilian ones, which highlights the need for studies aimed at the development of adequate models to the Brazilian reality, as the one presented in this paper.

The middle-class multifamily residential condominiums in RMGV to be surveyed have been preferably chosen among those whose establishment demands a Neighborhood Impact Study – EIV – where trip generation studies are needed. The sample selective counts were carried out during morning and afternoon peak hours by vehicle type as well as by pedestrians entering and leaving the site.
The choice of variables to be tested on statistical models considered literature review, availability to obtain and estimate the variable, and the extent to which they explained reality.

During modeling, we tested 31 different types of regression equations from 1 to 5 variable combinations among the following variable of each condominium: total area, constructed area, perimeter, number of house units, and population. We analyzed each variable explanatory coefficient, R^2 determination coefficient, number of generated trips, absolute error and percentage error from using each regression equation. The models that best explained trip generation were compared to the North American equations and results were perceived as satisfactory.

The significant housing deficit, especially in RMGV, has prompted public agencies to present actions towards mitigation. Many of these actions have resulted in incentives for constructing residential condominiums that require a Neighborhood Impact Study – EIV – and consequently, a trip generation analysis. Therefore, the proposed models are of great importance for the Urban Planning development in the RMGV and can be of use for future research in this area.

Keywords: Trip, Trip Generator Center, Greater Vitória Metropolitan Region, Condominium.

INTRODUCTION

Cities face problems resulting from lack of urban expansion planning and appropriate guidance for land use. The municipalities of medium-density cities, as the ones surveyed in this paper, in general, do not carry out analysis of the studies developed by specialists when implementing new ventures or expanding an existing one, neither of the suitability of land use and occupation, nor of interventions in the transportation system.

Another problem is the absence of efficient local legislation for implementing ventures that generate trips, the Trip Generator Centers (PGV) or Traffic Generator Centers (PGT), as published in legislations and norms. In regard to Trip Generator Rates, the authors show that in Brazil there are no further studies (SILVEIRA, 1991; PORTUGAL E GOLDNER, 2003) on the great diversity of PGV. Consequently, in many cases it is still necessary to use the trip rates developed in other countries, such as the ones elaborated by the U.S. Institute of Transportation Engineers - ITE.

The State of Sao Paulo Traffic Engineering Company (CET, 1983) in Brazil has helped with Generation Trips Models for certain types of use within the PGT concept. However, it has been a long time since then, and new studies are needed for the update of these rates and models. This paper intends to contribute to future studies on reliable rates for residential land use.

The major impacts resulting from PGV installation in urban sites vary according to its location, nature and intensity, dynamics of circulation areas and surrounds, and it may affect: road infrastructure; generate traffic jams and conflicts among different transportation modes; reduce mobility safety; increase noise and air pollution, and mainly increase traffic accident indices, a serious impact that contributes to the decrease of urban quality of life (ALVES et al., 2009).

The hypothesis of this paper is that middle-class residential condominiums in RMGV generate trips of the same pattern as in all municipalities, in such a way that one can establish a statistical model based on collected as well as on secondary data.

Rationale

Previous studies had been concentrating on a particular type of PGV – the Shopping Malls – due to their notable influence on circulation and urban structure. As a consequence, the other PGV developed model types were very limited (SILVEIRA, 1991). Since national reality values are missing, some studies and analysis focus on rates indicated by ITE publications. Obviously, the trip generation pattern per cars per household in the United States is higher than in Brazil. Therefore, one notes the need for studies in this area so that more appropriate models for the national reality can be elaborated and compared to the ones abroad.

Socio-economics

The social economic aspects are very important to the study object definition and secondary data application. Once the definition of which condominium is included as inhabited by middle-class dwellers, it is necessary to present income ranges (to be presented in the Condominium characteristics) as we get acquainted with the social habits of the PGV population that may influence trip generation.

The CadÚnico – A Social Registration Program– was established in July of 2001, as a tool to portray the socio-economic situation of all Brazilian municipalities, through mapping. It identifies low income families, including families living in poverty and extreme poverty. CadÚnico counts on information about people registered on federal assistance programs, including the "Bolsa Familia" (Welfare).

The RMGV has 105.700 families registered in CadÚnico, totalling 404.126 people, which represent 24% of the entire population of Greater Vitória in 2009 (IJSN, 2010a). Most registered families earn wages of up to 1 minimum salary per capita. Keeping in mind the number of people per household (approximately 3 - totalling 3 salaries per family, Middle Class - C1), these people make up the middle-class families who reside in the surveyed condominiums. One of the aspects that must be exposed to justify the choice of the study object, within the social factor, is the housing situation in RMGV. Once these data is put forward, one can see that the housing deficit is significant in the State, especially in the metropolitan area. The concerned public agencies have been presenting solutions to this matter.

As an example, the Federal Government housing program "Minha Casa, Minha Vida" (My House, My Life), has supported the financing of several state ventures as the ones to be analysed in this paper. Note, therefore, that the housing deficit is a motivation for trip generation studies in middle-class residential communities, not only in the metropolitan area of Greater Vitória, but all over Brazil, considering that the main mitigation action towards this deficit situation has been the government subsidy to the housing construction of the same nature as the trip generators surveyed in this paper, which will demand EIV and, consequently, trip generation analysis.

In regard to the civil construction enterprising in the surveyed area, the data from a conjuncture review published by the Institute Jones dos Santos Neves (2010b) - IJSN - in 2008, shows that the number of construction companies in Espírito Santo grew 12,9 % compared to 2007, rising in 6,8% the number of jobs in the sector. The payroll grew by 23,0% and the value of the constructions and services increased by 30,4%. In Greater Vitória, homebuilders / state venturers such as Rossi, Morar, MRV, among other smaller ones currently on the market, release several state ventures that can be characterized as Multifamily Condominiums projected for middle-class, encouraged by government subsidies causing the property market to rise.

Study purpose

The paper aims at proposing a statistical model of trip generation for the general middle-class residential condominiums in the RMGV. To do so, we have set goals along the article such as: select condominiums to be analysed, preferably the ones which fit match the definitions of middle-class trip generator centers; carry out the selective count of vehicles entering and exiting the condominiums; treat the collected data; formulate the model, by using different explanatory variables; validate the model by comparing it with the ones available.

LITERATURE REVIEW

Definitions

It must be said that the evolution of the term PGT to PGV has left the venture generated motorized traffic itself and started to consider the trips within a larger scope, such as socio-economic, taking into consideration the impacts, usage, occupation and land value. This conceptualization was brought up by Kneib (2004) when he defined Trip Generator Center. This is an important definition for the surveyed condominiums fit into such concepts. As stated previously, since the study objects match this concept, the research can be of use to further studies on trip generators for future implementation of condominiums in Greater Vitoria. Thus, for paper purposes, we have defined Trip Generator Center as: Any venture capable of causing considerable negative or positive, temporary or permanent, effects on people around them.

A similar study by MAGALHÃES et al. (2001) was carried out in Porto Alegre, Rio Grande do Sul State, Brazil, for residential allotments where he defined daily trip generation distribution.

In Brazil, studies on residence trip generation are underexplored, though mostly necessary to have more reality compatible rates and models. Inocêncio and Grado (2007) conducted studies for hotels in Florianópolis (Brazilian City) which showed that the ITE estimates tend to be overestimated, which was also confirmed by Andrade and Portugal (2010), in the case of shopping malls.

Table I below refers to trip generation rates and models based on the identification of land use parameters and other variables used in the United States for Residential ventures, presented by Portugal and Goldner (2003).

Table I – Generation Trips Parameters of Land Use in the United States

Residential land use type	Nº Of Studies	Average x	Explanatory variable (x)	Average of generated trip rate per unit time (interval)	Model (R^2)
Apartment	76	246	No Of households	0,67/afternoon peak hour (0,1-1,64) (61% entering)	0,599*x+1,6500 (0,80)
	27	419	No of inhabitants	0,40/afternoon peak hour (0,2-0,77)	0,392*x+3,845 (0,77)
Medium high Edifications (between 3 and 10 floors)	7	120	No of households	0,44/afternoon peak hour (0,19-0,60) (59% entering)	0,534*x-11,267 (0,90)

As it can be seen, there are a relatively large number of studies for each one of the land uses.

In this paper, a similar model is presented for the Middle-Class Multifamily Residential Condominiums in Greater Vitoria, where descriptive variables are home units, constructed area, total area, perimeter, number of people, or a combination of all.

Main statistical concepts

Regression is defined as a statistical technique that allows the evaluation of a dependent variable relationship with one or more independent variables, and it is very useful for research on several fields of knowledge (Tabachnick and Fidell, 1996).

When used on trip generation, it allows the formulation of models aimed at predicting the number of trips (dependent variable) because of the characteristics of land use, population, area, or another variable chosen to best represent reality (independent variable). Based on independent variables current data, it establishes an explanatory equation for the current trip generation to which future trips can be predicted, as it estimates the values of the independent variables for future circumstances.

In summary, regression is a research tool for empirical relations between two or more variables whose main purpose is to establish a relationship model, either linear, multilinear, polynomial, logarithmic or any other that fits best (GUERRA; DONAIRE, 1982).

The simple linear regression model is the specific case where it is assumed that the real relationship between "Y" (dependent variable) and "x" (independent variable) is a straight line. Being the average of "Y" a linear function of "x", the real value observed "Y", in most cases it is not exactly above the line. The real value of "Y" for a fixed value of "x" is determined by the average value of the function (linear model) plus a random error term, with the real value of "Y" given by Equation 1 – Simple Linear Regression:

$$Y = a_0 + a_1 x + E, \qquad \textbf{(1)}$$

where:
Y = dependent variable; a0 = intercepto-Y; a1 = the line coefficient; x = independent variable; E = random error (The random error "E" has a normal probability distribution with mean "0" and standard deviation "S" constant).

The Multiple Linear Regression is one of the statistical techniques used in prediction models aimed at analysing the influence of two or more independent variables acting simultaneously, in the specific case of this paper, on the trip generation. The dependent variable is the number of trips produced in a given traffic zone or venture, while the independent represent different factors, such as traffic data, land use and socio-economic data, contributing to the generation of trips. The relationship between a dependent variable and an independent variable representing the trips is the purpose of this article, according to Equation 2 – Multiple Linear Regression.

$$Y^a = \alpha + \sum_{b=1}^{m} \beta_b^a x_b^a \,, \qquad \textbf{(2)}$$

where:
a = identification of traffic zone or venture; b = number of independent variables; Y^a = dependent variable expressed as a number of trips of traffic zone or venture "a", where “a” varies from 1 to "n"; α = constant which explains Y^a value which was not explained by the independent variables; x_b^a = independent variable related to the chosen parameters of the traffic zone or venture analyzed "a" ranging from 1 to "n" and "b" varies from 1 to "m"; β_b^a = the coefficient of independent variables x_b^a, of the traffic zone or venture "a" ranging from 1 to "n" and "b" varies from 1 to "m".

The final result of a Multiple Regression is an equation of the line representing the best prediction of a dependent variable from several independent variables. This equation represents an additive model to which the predictor variables are added under the explanation of the dependent variable (Abbad and Torres, 2002). For the use of regression technique to be effective, one must examine and identify the consequences of certain assumptions: multicollinearity, singularity, homogeneity in variances, normality and linearity.

The statistic "F", or value of “F” is also used for the regressions’ validation to determine whether the observed relationship between the dependent and independent variables occurs by chance. It may happens that the coefficient of determination (R^2) indicates a strong relationship between the independent variables and the dependent variable (R^2 very close to 1), though the statistic “F” determines whether these results, with such a high value of R^2, happens by chance. The value of “F” must be compared to critical values on distribution tables of "F" for a given confidence interval (1 - alpha), in case it is greater than that, there is a high probability of random correlation. Another statistic used for validation of the regressions have been the values of "t" for each independent variable, according to Equation 3 – Value of Student t:

$$t_n = \frac{m_n}{se_n}, \tag{3}$$

where:

$n =$ number of independent variables; t_n = Student t value for each independent variable; m_n = coefficients calculated for each independent variable; se_n = standard error for each coefficient calculated;

If the absolute value of the value of "t" calculated for each independent variable value is greater than the critical two-tail tabulated "t", the variables used in the regression equation will be useful for predicting the dependent variable. Another analysis made is in regard to multicollinearity, defined as the presence of correlation between the regressive variables. The presence of multicollinearity in the model affects the estimated regression coefficients, yielding unreliable estimators, and the general applicability of the estimated model. One way to detect multicollinearity is through the construction of the correlation matrix between the regressive variables, and one of the two correlated variables is eliminated of the regressive model (Montgomery and Runger, 2003).

In this paper, we have used both, simple linear regression and multiple one, being chosen the model that best validated, or, that best explained the phenomenon of the trip generation on the surveyed PGV.

METHODOLOGY

The choice of middle class multifamiliy residential condominiums in Greater Vitoria was based on the municipal legislation criteria that define the Trip Generator Center, and we preferably picked the ones that demanded a Neighborhood Impact Study.

We carried out selective sampling of vehicles during morning and afternoon peaks, from 6 to 10 am and from 4 to 8 pm, by identifying the car type going in and out, as well as the number of pedestrians. The count was done on typical days, from Tuesday to Thursday, on a full work week, with no holidays or events that could alter results.

Sample counts

In strict terms, any sample can be dimensioned according to criteria defined by sampling theory. However, for practical reasons, based on road agencies' previous experiences, we present some considerations as follows.

Estimate counts, as the ones in this article, are normally preceded in such a way that less important intersections are included and carried out during the day, between 6 and 10 am or 4 and 8 pm. In certain areas, lunch time can present specific problems. In such cases, counts must be done during this time also. Results from auto selective counts during these times have been accepted by road agencies, as explained by DNIT (2006).

However, from stricter statistical criteria, to better estimate a minimum of necessary samples for this experiment, which a priori does not have the mean and standard deviation, we have defined a sample for this paper purposes, as the population dwelling in these residential condominiums in RMGV and used Equation 4 – minimum number for the sample, presented by Guerra and Donaire (1982):

$$n = \left(\frac{z_{\alpha/2}}{2e_0} \right)^2 , \qquad \textbf{(4)}$$

where:
n = number of samples; $z_{\alpha/2}$ = Critical standardized value retrieved from normal statistical distribution table as a function of the confidence interval; e_0 = Maximum estimate error, accuracy due to the amplitude.

For this paper purposes, we first took a 95% Confidence interval and a 1,5% of accuracy, in other words, we have 95% of chance that with the sample used there is a 1,5% of error probability, higher or lower. Hence, taking the above mentioned parameters, it was necessary to choose the RMGV Condominiums that added up to 3006 dwellers so that the sample were statistically acceptable. Note that by lowering confidence interval and accuracy the necessary population sample should also decrease.

APPLICATION

The Condominiums

The surveyed condominiums were selected among the ones that matched the following characteristics: Middle-class and Multifamily inhabitants. Another pre-requisite was that they represented a minimum of the needed sample, according to previously shown topics (sum of population > 3006 inhabitants, a 95% confidence interval to a ±1,5% error). We also tried to select a one-vehicle entrance condominiums or at least intervisible nearby accesses so as to facilitate larger selective counts by having one to four simultaneous teams working on the counts.

Summary of data from the Condominiums

The RMGV, according to the Supplementary Law no. 318 of 18/01/2005 covers the municipalities of Cariacica, Fundão, Guarapari, Serra, Viana, Vila Velha and Vitoria, and aims at integrating policies of common interest. However, in this article we have selected condominiums in Cariacica, Serra, Vila Velha and Vitoria, covering up to approximately 89%

of the RMGV population. From the area of interest of this paper, one can observe the following demographic indices:

Table II – Population and Area of Espírito Santo and RMGV

Regional Unit	Area (km²)	2000*	2007*	2009**
		Population	Population	Population
Espírito Santo	46.078	3.097.232	3.351.669	3.487.199
RMGV	2.318,9	1.438.596	1.624.837	1.686.045
Cariacica	280,0	324.285	356.536	365.859
Fundão	279,6	13.009	15.209	16.431
Guarapari	592,2	88.400	98.073	104.534
Serra	553,3	321.181	385.370	404.688
Viana	311,6	53.452	57.539	60.829
Vila Velha	208,8	345.965	398.068	413.548
Vitória	93,4	292.304	314.042	320.156

Source: IBGE (2000, 2007) / Census * / ** Population Estimates.

Summary of data from the Condominiums

The Multifamily Residential Condominiums surveyed are related to the share of the population belonging to social classes "C" and "B", so called middle-class. These economic classes have an average family income ranging from R$ 1.128,60 to R $ 5.553,60. It can be verified that most of the Espírito Santo population inhabiting the residential condominiums (IBGE, 2007) – approximately 50% - are on the income range belonging to middle class (between C2 and B1). We considered a unit of the surveyed Centers as inhabited by a family arrangement with a maximum of 2,8 people on average and a minimum of 2,3 people on average (IBGE, 2007). To be on the safe side, we will consider the upper limit in any calculation that uses the population of the condominiums.

Itaparica Mar Condominium

This condominium is located on C Street, CoqueiralItaparica District, City of Vila Velha/ES/Brazil. A former part of an old residential complex, this condominium is composed of other six (6) condominiums, totaling seven (7). It has 124 (one hundred and twenty four)-
4-storey-buildings of 2 apartments per floor, totaling 992 households. It is estimated that the population fluctuate around an average of 2.778 people (2,8 people per household, as previously described). The total area estimated by the Google^{TM} Earth Pro Software has approximately 89.600 m², a perimeter of 1.350 m and 99.600 m² of constructed area (all external areas to the buildings have been taken out and all floors have been considered). Upon count tabulation, we have:

Table III – Trips - Itaparica Mar Condominium

	Motorizedtrips			Non-motorizedtrips			Total trips		
	Morning	Afternoon	Total	Morning	Afternoon	Total	Morning	Afternoon	Total
Entrances	216	603	819	53	170	223	269	773	1042
Exits	828	239	1067	147	31	178	975	270	1245
Total	1044	843	1887	200	201	401	1244	1044	2287

We have confirmed a higher number of motorized exits rather than entrances during the surveyed period. By looking at the Table it is possible to note a higher total volume, entrances and exits, of morning trips. There is a balance between morning and afternoon periods of non-motorized trips. However, there are more entrances than exits, during the count period. The general peak aspects remain the same as the motorized ones (morning exits) because these are predominant transportation modes. By plotting a line graphic where abscissas are for period of trip allocated by every 15 minutes and the ordinates for number of trips, we have:

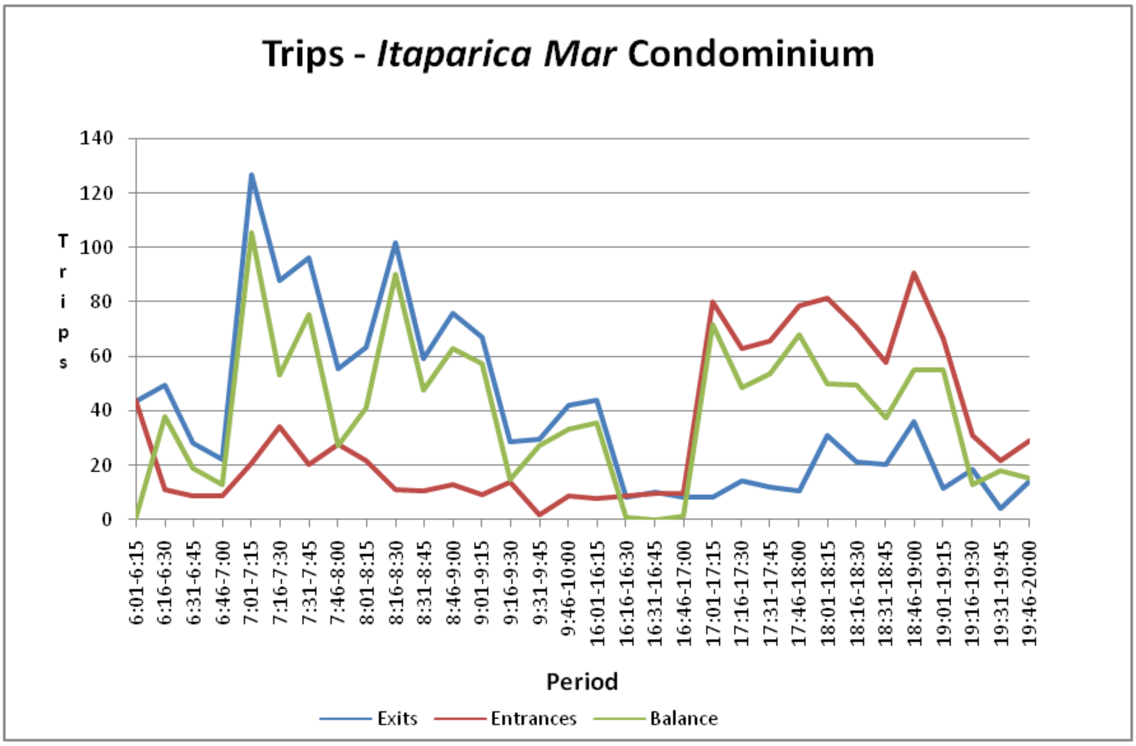

Figure 1 – Number of Trips by period - Itaparica Mar Condominium

The peak is observed at the period between 7:01 and 7:15 reaching a maximum of 127 trips on the exit movement. From these trips one can have the following allocation per auto type in the sample period:

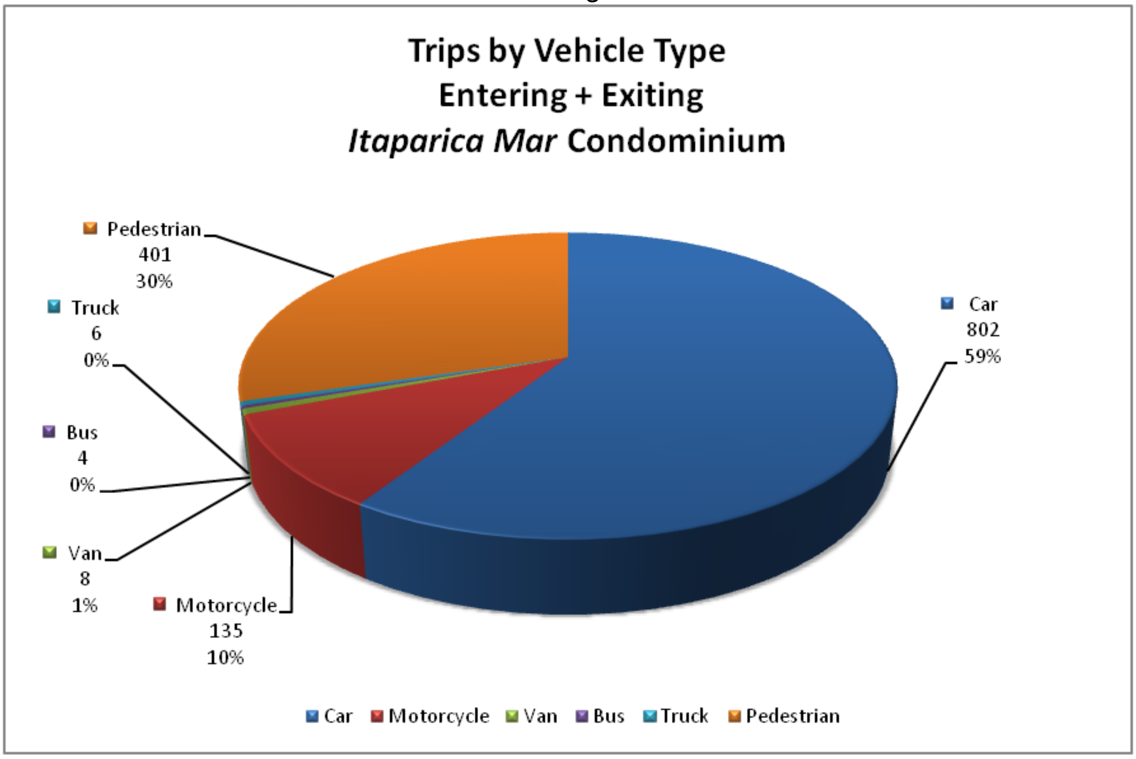

Figure 2 – Trips by vehicle type - Itaparica Mar Condominium

Valparaíso Condominium – Bloco Países

This condominium, located on Santos Dumont Street, Valparaiso District, City of Serra/ES/Brazil, integrates the old Valparaiso residential complex, composed of other three (3) blocks. The condominium has 34 (thirty four)- 4-storey buildings of 3 apartments per floor, totaling 408 households. It is estimated that the population fluctuates around the average of 1.142 people (2,8 people per household as explained in the previous section). The total area estimated by Google™ Earth Pro Software has approximately 28.100 m², a perimeter of 700 m and 42.800 m² of constructed area (all areas outside the buildings have been taken out). Upon count tabulation, we have:

Table IV – Trips - Valparaíso Condominium

	Motorizedtrips			Non-motorizedtrips			Total trips		
	Morning	Afternoon	Total	Morning	Afternoon	Total	Morning	Afternoon	Total
Entrances	188	493	681	37	114	151	225	607	832
Exits	762	172	934	131	20	151	893	192	1085
Total	950	665	1615	168	134	302	1118	799	1917

We have confirmed a higher number of motorized exits rather than entrances during the surveyed period. By looking at the Table it is possible to note a higher total volume, entrances and exits, of morning trips. There is a balance between morning and afternoon periods of non-motorized trips. However, entrances and exits are the same. The general peak aspects remain the same as the motorized ones (morning exits) because these are predominant transportation modes. By plotting a line graphic where abscissas are for period of trip allocated by every 15 minutes and ordinates for number of trips, we have:

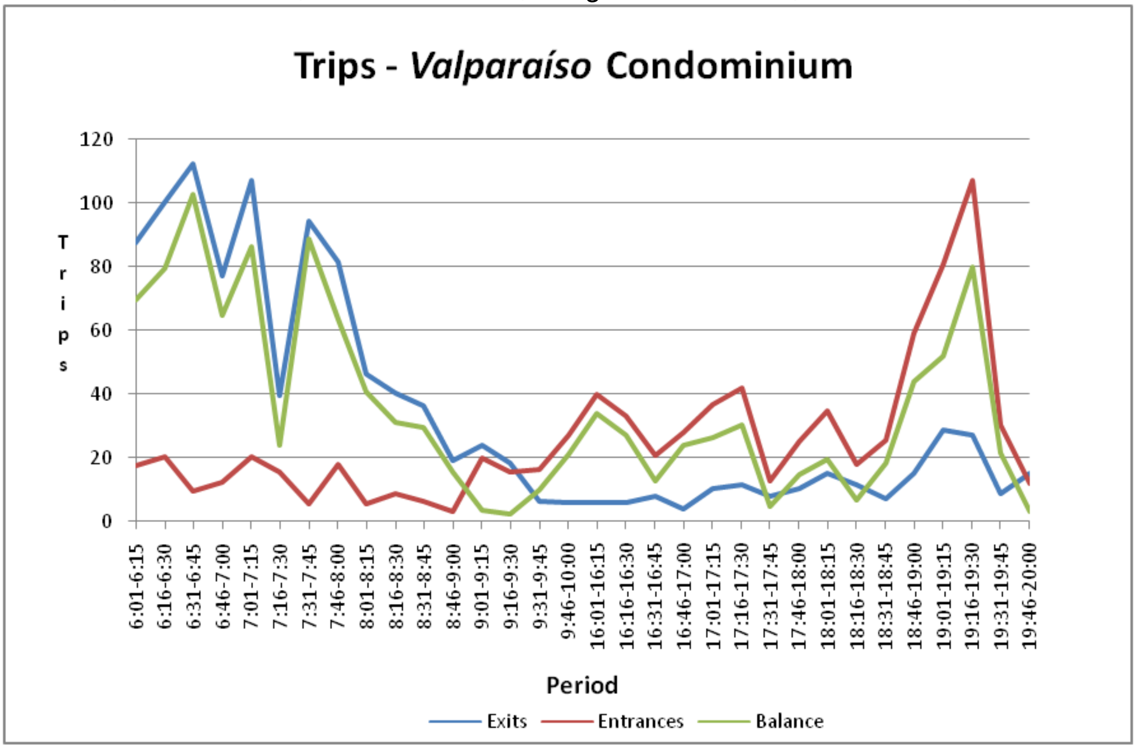

Figure 3 – Number of Trips by period - Valparaíso Condominium

The peak is observed at the periods between 6:31 and 6:45 on 112 trips in this condominium, as previously analyzed, it occurs on exit movements. From these trips one can have the following allocation per auto type in the sample period:

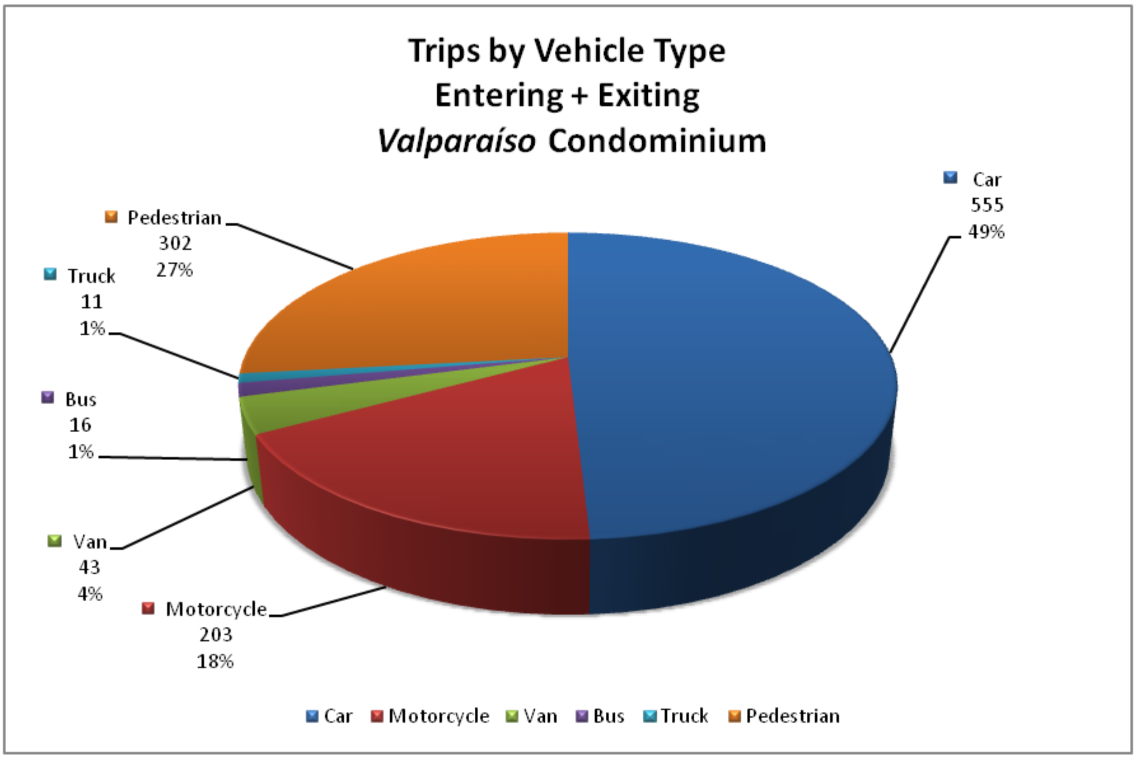

Figure 4 – Trips by vehicle type - Valparaíso Condominium

Vila do Mar Condominium

This condominium is located on Antônio Lima Darly Street, JardimCamburi, City of Vitória/ES/Brazil, across from a condominium of similar characteristics (Condominium Atalaia). The condominium has 4 (four)-4-storey buildings of 4 apartments per floor, totaling 48 households (only 3 floors are available to housing). It is estimated that the population fluctuate around an average of 134 inhabitants (2,8 people per household, as previously explained). The total area estimated by Google™ Earth Pro Software has approximately 1.900 m², a perimeter of 200 m and 5.700 m² of constructed area (all external areas to the building have been taken out. Upon count tabulation, we have:

Table V – Trips - Vila do Mar Condominium

	Motorizedtrips			Non-motorizedtrips			Total trips		
	Morning	Afternoon	Total		Morning	Afternoon	Total		Morning
Entrances	19	57	76	11	43	54	30	100	130
Exits	74	25	99	44	6	50	118	31	149
Total	94	82	175	55	49	104	149	131	279

We have confirmed a higher number of motorized exits rather than entrances during the surveyed period. By looking at the Table it is possible to note a higher total volume, entrances and exits, of morning trips. There is a balance between morning and afternoon periods of non-motorized trips. However, entrances are higher. The general peak aspects remain the same as the motorized ones (morning exits) because these are predominant transportation modes. By plotting a line graphic where abscissas are for period of trip allocated by every 15 minutes and the ordinates for number of trips, we have:

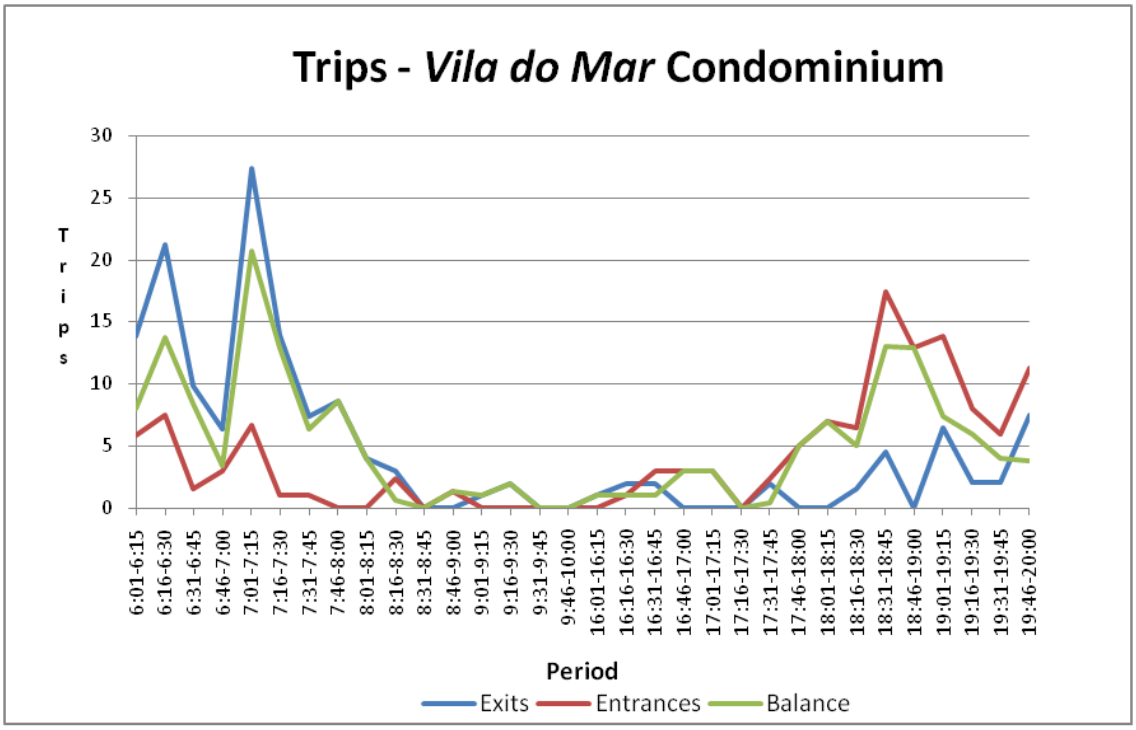

Figure 5 – Number of Trips by period - Vila do Mar Condominium

The peak is observed at the periods between 7:01 and 7:15 on 112 trips in this condominium, and, as previously analyzed, it occurs on exit movements. From these trips one can have the following allocation per auto type in the sample period:

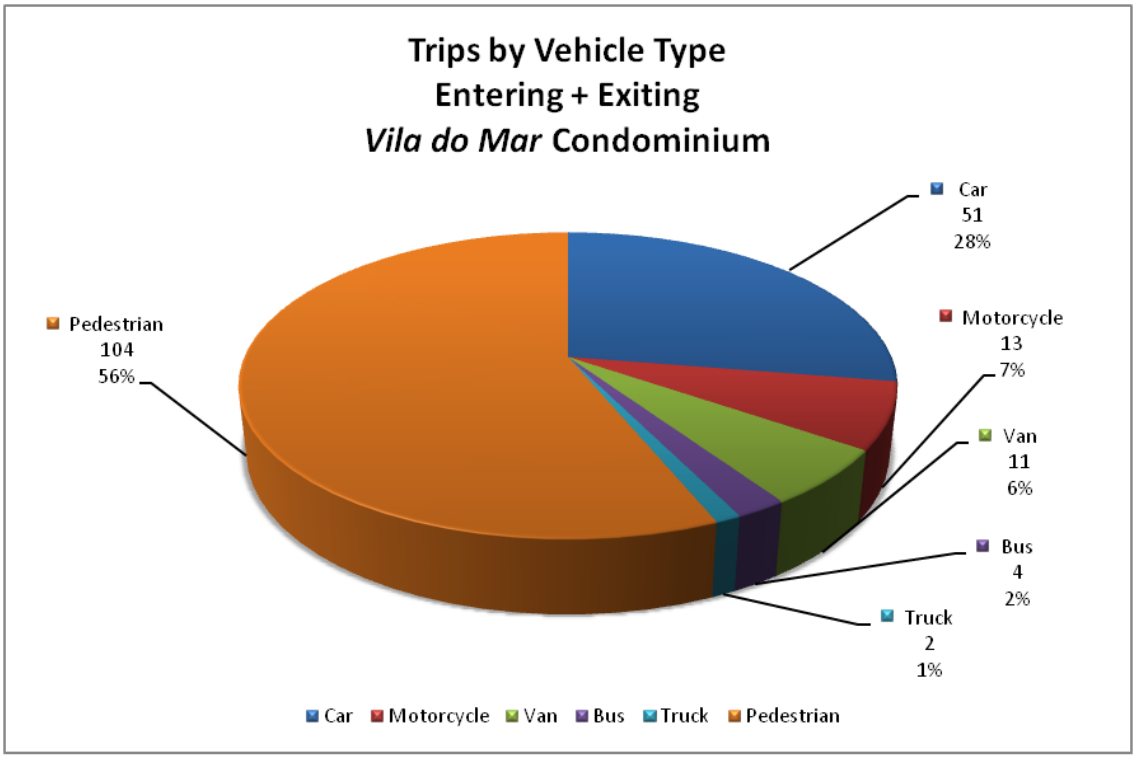

Figure 6 – Trips by vehicle type - Vila do Mar Condominium

São Francisco Condominium

This condominium is located on Agenor Vasconcelos Street, San Francisco District, City of Cariacica/ES/Brazil. It is one of the only multifamily residential condominiums in the city. Others, such as Mochuara and a few others in the neighborhood, are not yet fully inhabited, and their survey could result in deviation in the calculation of rates and pursued equations. There are 12 (twelve)-3-storey buildings of 4 apartments per floor, totaling 144 households. It is estimated that the population fluctuates around an average of 403 inhabitants (2,8 people per household as previously described) The total area estimated by GoogleTM Earth Pro Software has approximately 19.500 m², a perimeter of 900 m and 24.400 m² of constructed area (all areas external to the buildings were taken out). Upon count tabulation, we have:

Table VI – Trips - São Francisco Condominium

	Motorizedtrips			Non-motorizedtrips			Total trips		
	Morning	Afternoon	Total	Morning	Afternoon	Total	Morning	Afternoon	Total
Entrances	58	143	201	46	142	188	104	285	389
Exits	208	59	268	155	29	184	363	88	452
Total	267	203	469	201	171	372	468	374	841

We have confirmed a higher number of motorized exits rather than entrances during the surveyed period. By looking at the Table it is possible to note a higher total volume, entrances and exits, of morning trips. There is a balance between morning and afternoon periods of non-motorized trips. It is also noted that the number of entrances and exits are very close in magnitude. The general peak aspects remain the same as the motorized ones (morning exits) because these are predominant transportation modes. By plotting a line graphic where abscissas are for period of trip allocated by every 15 minutes and ordinates for number of trips, we have:

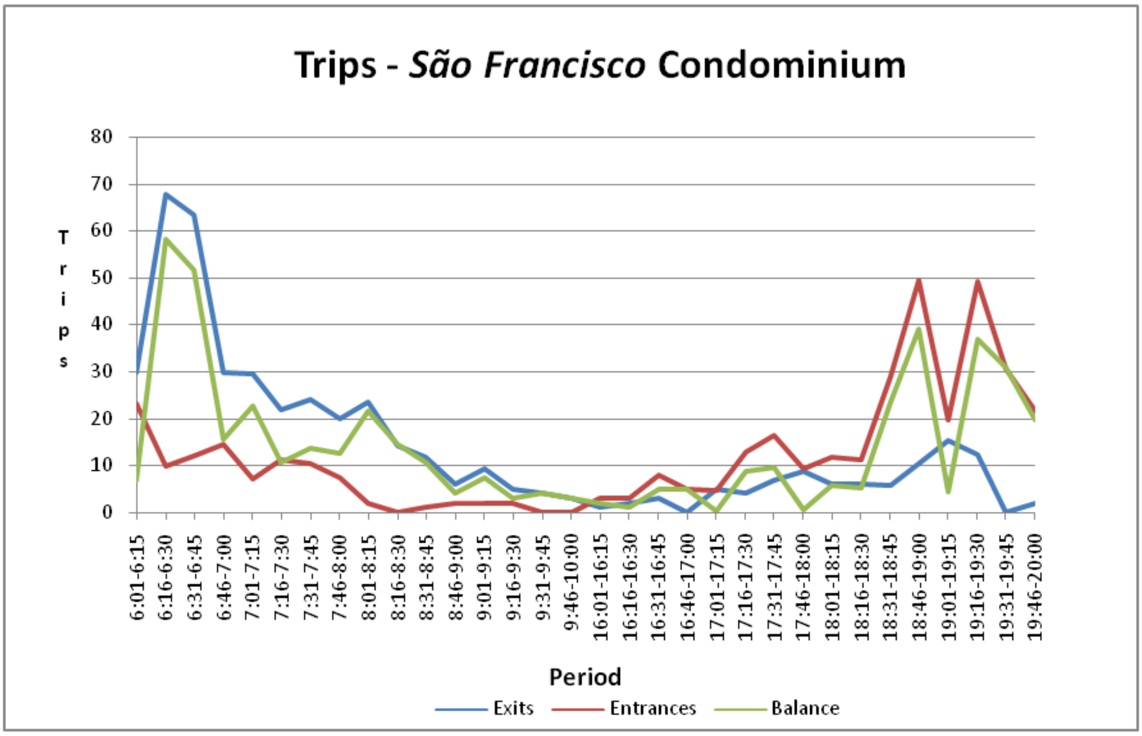

Figure 7 – Number of Trips by period - São Francisco Condominium

The peak is observed at the periods between 6:16 and 6:30 on 68 trips in this condominium, and, as previously analyzed, it occurs on exit movements. From these trips one can have the following allocation per auto type in the sample period:

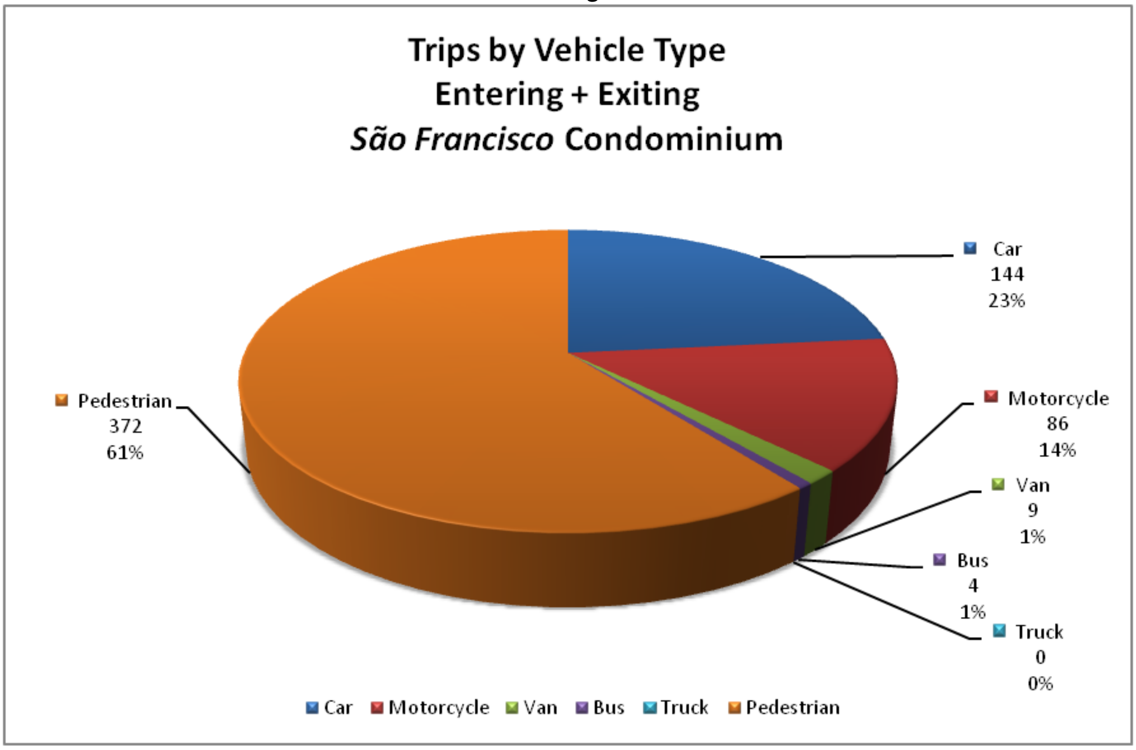

Figure 8 – Trips by vehicle type - São Francisco Condominium

Data analysis

The data were obtained on site and estimated when appropriate. On to analysis, and at last, on to equation that best explains trip generation in middle-class multifamily residential condominiums in Greater Vitoria.

Choice of Variables

The choice was made as a result of availability to obtain or estimate variables. This is a very important choice for, besides determining the experiment reproducibility, as well as the use of the proposed equation, it also determines the extent to which reality can be explained. The estimated variables, such as constructed area, total area, perimeter, and population, along with the unit variable obtained on site, were analyzed through multiple and simple linear regression. All 1 to 5 variables combinations were tested, among the variables: total area, constructed area, perimeter, units, and population.

Note that the independent variable chosen was Number of Trips (Entrances and Exits, Motorized and Non-motorized trips) at peak hour, in other words, the total Quantity of generated trips in the peak hour. This choice was a result of, as explained above, the relevance of this parameter for civil engineering infrastructure and traffic, besides being the independent variable found in the equations available in literature, thus allowing comparison among them as well as result.

Best adjusted regression models

All 1 to 5 variables combinations were tested, among the variables: total area, constructed area, perimeter, units, and population generating a total of 31 different types of equations. From these equations, each variable coefficient was analyzed, the coefficient of determination R^2, the number of trips generated by applying the equation found from the regression, the absolute error and percentage for each condominium, as well as the meeting requirements of the variables coefficient to "statistical t critical" two-tailed, based on "Value F" (minimum for the chosen alpha - see item concerned with the sample choice). However, not all adjusted models were statistically significant. We took it as valid the models that met the first "critical t statistic" two-tailed for the calculated coefficients. Then, even though there was a higher R^2, the equation that did not meet the above mentioned criteria was discarded.

This procedure was carried out for all possible combinations of variables, and analysis led to the best found adjustments:

Table VII – Statistical Analysis of Linear Regression

Units (UND)	Population (POP)	Coefficient - beta 0 (CF)	R²	Value F
0,3627	X	165,2988	0,68	4,2551
X	0,1295	165,2988	0,68	4,2551

Note that regression only became reliable when the explanatory variables, unity and population, were used. Note also that in this case simple linear regression is the best method, as opposed to multiple regression.

From analyzing the above table one can see a similarity between the two models obtained from regressions (Independent Variable R^2 and F Statistic of same value both), expected result, considering that the population variable has direct correlation with unit variable.

Comparing models

For validation, results were compared by applying the equations obtained from linear regression with the Trip Generation Handbook (ITE, 2004) and Trip Generation (ITE, 2003) equations. Below the comparison results are presented:

Table VIII – Comparison with other models

Condominium		Vila Velha	Serra	Vitória	Cariacica
Real Value		470	454	81	234
Equation ITE 1	0,534*UND-11.267	518	207	14	66
	Error	49	-247	-67	-168
	error %	10%	-54%	-82%	-72%
Equation ITE 2	0,599*UND+1,650	596	246	30	88
	Error	126	-208	-51	-146
	error %	27%	-46%	-62%	-62%
Equation ITE 3	0,392*POP-3,845	1085	444	49	154
	Error	615	-10	-32	-80
	error %	131%	-2%	-40%	-34%
Regression 1	0,3627*UND+165,2988	525	313	183	218
	Error	55	-140	102	-17
	error %	12%	-31%	126%	-7%
Regression 2	0,1295*POP+165,2988	525	313	183	218
	Error	55	-140	102	-17
	error %	12%	-31%	126%	-7%

From analyzing the comparative table presented above, note that for condominiums in Vila Velha and Cariacica, the result of regressions 1 and 2 shows a much smaller error than the ITE equations. For condominium in Serra, one of the ITE equations shows a better result, though with a relatively small (about 1%) average percentage difference between equations compared to regressions 1 and 2. For the Vitória condominium the ITE equations have had better results due to the size difference of the Vitória condominium when compared to others.

Among the equations obtained after having the data analyzed, we suggest the use of Equation 5 (Regression 1) and Equation 6 (Regression 2), for the study of Greater Vitoria Multifamily Residential Condominiums trip generations:

$$VM = 0,3627 * UND + 165,2988 \quad (5)$$

$$VM = 0,1295 * POP + 165,2988 \quad (6)$$

where:
VM = total trips at the peak hour; UND = total units on the condominium; POP = population of the condominium.

CONCLUSION

Once the set goals were met, we could confirm the hypothesis that the middle-class residential condominiums in the Greater Vitoria Metropolitan Region generate the same trip patterns as in all municipalities, in such a way that it has been possible to establish a model based on both, collected and secondary data.

When observing the Comparison Table of the American models with the ones obtained from linear regression, one notes that even from a relatively small sample (one condominium per municipality) the result was satisfactory as the presented models well explained reality.

Hence, the equations are valid for estimating the middle-class Multifamily condominium trips, in areas that basically have residential land use in Greater Vitoria with over 100 units. Nevertheless, they can be of use in further studies on other municipalities with similar characteristics as the ones surveyed for this paper.

In order to have an even better adjusted model, one that can explain reality more accurately, we advise larger samples, in other words, more condominiums surveyed in each municipality. After that, relate future studies in the region so as to obtain models that are more illustrative than the one presented in this article.

This paper is to work as a basis for other regions where future researchers can use the same methodology. The application of results can be of vital importance for the development of the RMGV Urban Planning as well as of similar regions, thus they can estimate through the obtained model the trip generation of the multifamily condominiums and prepare the necessary infrastructure for this demand.

Under the constraints of this study, ideally, concerning data collection, we should have had the 24 hour count and not only the peak hour. This collection would demand more time and financial resources.

Note that, still under the constraints, for smaller condominiums, such as the ones surveyed in Vitoria, the result from the equation application is not ideal. We recommend the use of equations presented to units above than 100 in this state-of-the-art stage.

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