EXPLORATORY STUDY OF THE RELATIONSHIP BETWEEN SOCIO-ECONOMIC VARIABLES AND INTER-MUNICIPAL TRIP GENERATION IN GOIÁS, BRAZIL

Elaine Radel

Luiz Fernando Câmara Viana

Giovanna Megumi Ishida Tedesco

Gladston Luiz da Silva

Interdisciplinary Center for Transportation Studies – University of Brasília/Ceftru-UnB, Brasília, Federal District, Brazil, Telephone: (+55 61) 3307-2059

ABSTRACT

This article sets out to identify among the selected variables, the most "impactful" for trip generation in the Brazilian state of Goias, specifically those related to trip attraction. An analysis was made of socio-environmental data and demand data among the state's municipalities. The selected variables have been analyzed using regression models and the stepwise method, combined with the use of multiplicative and additive models. The simplicity of the latter model made it feasible to relate variables directly to one another and obtain a clearer explanation of inter-municipal trip attraction in Goias. The most influential variables were found to be the numbers of hospitals and of schools, highlighting the necessity of considering such variables in inter-municipal transport planning and demonstrating the dependence that smaller municipalities have on the infrastructure of metropolitan regions.

Keywords: transport demand, trip generation, inter-municipal transport.

INTRODUCTION

Road passenger transport is an essential public service and in Brazil it is the main mode of collective transportation in both intra-urban and inter-municipal translocations. Therefore estimating demand dynamics (behavior) by evaluating the characteristics that influence and interfere in trip generation is one of the most relevant aspects to be taken into account in the planning of transport services (Gonçalves, Bez and Novaes, 2007).

Although trip generation in the urban sphere has been extensively investigated, it presents a set of different characteristics when inter-municipal trips that go beyond the borders of a single municipality are examined. In that light, the present study seeks to identify among the selected variables, the most "impactful" for trip generation in the sphere of inter-municipal road transport in the state of Goias, focusing on the trips attracted to each municipality. Inter-municipal transport is defined as a service that involves crossing the territorial limits of municipalities and it has operational specificities that may vary from state to state but, nevertheless, it generally involves medium distance connections (Menezes, 2004).

The work is structured in seven parts. The first part addresses questions concerning characteristics of the demand for transport and the second and third concern the planning models and socio-economic variables involved in trip generation. The fourth part characterizes the study area and in the fifth and sixth, the methodology used to identify the determinant variables is presented along with the results obtained from the analyses. The paper finalizes with remarks on the results obtained.

1. THE DEMAND FOR TRANSPORT

The demand for transport stems from peoples need to move from place to place to carry out activities associated to production and consumption of goods and services; the greater the degree of a society's development the more intense its economic activity is and the more need there is for translocations (Ferronato, 2002). Thus transport of itself does not satisfy any need but instead it is more of a means to satisfy other needs associated the production and consumption of other goods and services (Ortúzar and Willumsen, 2008).

Manheim (1979) explains that an individual's decisions are motivated by the desire to achieve a certain standard/pattern of activities related to employment, residence, consumption and social activities. In that light it is the intended lifestyle that determines the pattern of activities undertaken and gives rise to decisions on location which in turn may lead to decisions involving trips. Ferronato (2002) complements that affirmation stating that in order to adopt a given standard or pattern of activities, an individual needs to be in a certain place at certain times and that leads to choices being made concerning trips or journeys.

Other singular characteristics, according to Ortúzar and Willumsen (2008), distinguish the demand for transport, among them: (i) it takes place in a certain space being determined by the distribution pattern of activities; (ii) it is differentiated according to the time of day, the day of the week, the reason for the trip, the frequency with which it is made and any offer of a transport service that does not have the features required to meet such differentiated demands may well prove to be useless; and (iii) it has the quality of temporal variation with a tendency to be concentrated in peak periods, especially in urban situations.

All those features conspire to make the elements that are vital for transport planning, namely analysis and forecasts of transport demands, highly complex. In short, it could be said that that the main objective of trying to foresee transport demands is to be able to adjust the supply to meet it and that includes the transport system infrastructure (Ferronato, 2002). It also plays an important role in determining the characteristics and type of the vehicles to be used, and the frequency, timetables and itineraries of services.

2. TRANSPORT PLANNING MODELS: TRIP GENERATION

Transport planning in the view of Vasconcellos (1996) is a form of intervention in a region designed to make the translocation of people and goods feasible. Its main objectives are: to guarantee accessibility, rationalize existing systems and assist the distribution of the benefits generated taking into account the different spatial, geographic, and socio-economic conditions. Thus planning embraces the definition of road transport infrastructure, the means to be used to offer transport services and the services to be offered in the region in question.

Barat (1971) proposes that planning seeks to adjust demands and capacity of the various modes of transport and determine investment priorities, taking into account changes in land use and settlement that affect the location and quantification of the demand. Similarly, Paiva (2010) declares that one of transport planning's main objectives is to estimate the patterns of vehicle and passenger flows within a given horizon, evaluating alternatives for investments in services and the road network and meeting future demands satisfactorily. In turn Ferronato (2002) points out that foreseeing the use of a new transport installation to be implanted is the first step to making a rational decision in regard to whether the investment should be made or not.

For all those reasons, for any transport planning to be feasible, the demand for transport must first be quantified and the way it is distributed in the area under study and the period of time in question must be known. To achieve that involves developing models and accordingly, modeling becomes an important tool at the service of decision making in the sphere of transport planning. In regard to the concept of a model in this context Ortúzar and Willumsen (2008) propose that a model is actually a simplified representation of reality; an abstraction that is used to obtain greater conceptual clarity regarding reality by reducing its variety and complexity to levels that make it possible to gain a proper understanding of it and to analyze it.

Transport models are used to evaluate how demand is performing and to define alternatives that are most appropriate for the reality under analysis. Generally speaking analysis makes use of statistical and mathematical models and can be used for short, medium or long term forecasting (Novaes, 1986).

One of the models currently used in transport planning is the Four Steps model shown in Figure 1, below. It makes it possible to estimate trips and translocations of people from one traffic zone to another and is based on four stages: trip generation, trip distribution, modal division and traffic allocation (Lopes, 2005).

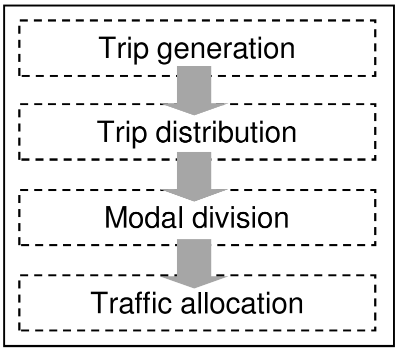

Figure 1 – Four steps planning

The first stage of the Four Steps Model, trip generation, is the focus of this study and Bruton (1979) defines it as determining the number of trips associated a certain traffic zone and it consists of the sum of the number of trips produced in the zone and those attracted to it. The trip generation stage investigates the relations between the characteristics of the movements involved and the population's socio-economic profile. Its main task is to relate the intensity of trips to and from a given area of land with the intensity and type of land use for the same area (Hutchinson, 1979).

In the case of the Trip Generation step it is presumed that the relations between the trip characteristics and the socio-economic conditions prevailing in the study area are stable for a given period of time. That makes it possible to estimate alterations to the demand that may occur resulting from any alterations to those conditions (Lopes and Pietrantonio, 2010). Ortúzar and Willumsen (2008) explain that there are various techniques for modeling this first stage (Trip Generation) of the Four Steps model and give examples of models based on growth factors, cross-referencing classifications, and regression models.

The growth factor-based model seeks to estimate variations in trips for a given traffic zone using a constant growth rate index obtained from average trip statistics obtained over a period of time. The cross-classification method, on the other hand separates the study area into different zones and the population into different categories. For each category the trip generating rate is determined and applied to each zone. The regression model is used to establish the statistical relations between the number of trips generated and the characteristics of the individuals in a given area (Lopes Filho, 2003; Ortúzar and Willumsen, 2008; Bruton, 1979).

Various authors have addressed the question of trip generation applied to urban transport as for example, Lemes (2005), who made a study of daily trip generation in the city of Uberlandia; Rodrigues, Cesar and Silva (2006), who examined trip generation associated to hyper-markets and supermarkets in various Brazilian cities; Rosa (2003) who investigated trip generation on the part of Shopping Malls in the Brazilian southeast; Flores and Alencar (2011) and Lopes and Pietrantonio (2010), who studied trip generation by the Metro system in the state of São Paulo; Lopes (2005), with the trips produced by households in the city and municipality of Porto Alegre; and Gontijo and Raia Junior (2009, 2010) who addressed the question of trips to public hospitals.

3. INFLUENCE OF SOCIO-ECONOMIC VARIABLES ON TRIP GENERATION

Selecting the variables to be used in forecasting trip generation rates is an important stage in transport system planning. As explained above, the number of translocations made by human beings and the variations in those numbers are related to factors such as personal and family group characteristics; the higher the income bracket the greater the number of translocations per person and the greater the number of destinations for their trips. Other highly influential factors are: age group, sex, schooling level and position in the labor market (ANTP, 1997).

Pitombo (2007), studying urban trip patterns proposes that because, generally speaking, they are strongly linked to human behavior the socio-economic characteristics of individuals and households offer a suitable basis for gaining an understanding of their behavior in relation to trips. Based on a review of the respective literature, that author states that the characteristics of people’s trips can be imposed by: (i) the economic power of transport users (individual and family income, type of occupation and possession of a vehicle); (ii) by the role of the household and its general characteristics (number of people in the household, presence of children, status of the individual in his or her household); (iii) by the sex of the transport user and others, including schooling level, age and the existence and use of transport voucher schemes.

In addition to personal and household characteristics, some authors underscore the important role played by the type of land use and settlement in generating trips. The form of land use influences the behavior of geographic areas in regard to their propensity for generating translocations (Bartoli, 2000). In that regard, Pitombo (2007) enumerates variables related to forms of land use such as: the presence of industrial activities, trade, services, schools and universities. One way of measuring those variables, according to that author, is to consider the accumulated numbers of jobs or matriculations registered or other similar data on those variables, within the given radius.

Another revealing group of variables that help to explain trip generation is related to activities. According to Pitombo (2007), individuals participate in a wide variety of activities and they can be grouped into three main categories: subsistence activities (work and study). household or family-related activities (meals, medical care, domestic obligations), and leisure (cultural activities, visits).

Lopes (2005) explains that variables, whether they be personal or household-related, land use-related or associated to activities, are related to trip generation in just two ways: they either originate (produce) trips or they attract them. Trip production refers to the number of trips that have their origin at a given point while trip attraction refers to the number of trips with the traffic zone or area in question as their destination

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Ortúzar and Willumsen (2008) point to other variables that affect trip production such as income bracket, vehicle ownership, household structure, the size of the family, the value of land, residential density and accessibility. Of those the most frequently used in studies of this kind are vehicle ownership, household structure and the size of the family (Rosa, 2003). In the aspect of attracting trips, important factors according to Lopes (2006) are available spaces for industry, trade and services and the number of jobs in the region under analysis.

4. CHARACTERIZATION OF THE STUDY AREA

The state of Goias is one of the 26 states that make up the Brazilian Federation along with the Federal District and it is situated in the geographic center of Brazil and Latin America. It has 246 municipalities and a total area of 304 thousand km², 4% of Brazil's total land surface. Figure 2 shows that the state has borders with five others: Tocantins to the north; Bahia and Minas Gerais to the east; Minas Gerais and Mato Grosso do Sul to the south and Mato Grosso to the west.

Figure 2 – States and Federal District (DF) of Brazil

According to data of the Brazilian Geography and Statistics Institute (IBGE, 2010), in 2010 the population of Goias surpassed the six million mark. In comparison with 2000 there was an increase of over one million inhabitants corresponding to an average annual geometric growth rate over the period of 1.84%, higher than the Brazilian national figure of 1.17%. That growth was partly due to increased migration which has given Goias the status of being the Brazilian state that most receives immigrants. In the period from 2004 to 2009, around 130 thousand people migrated to Goias.

Another vigorous process that has been taking place in the state in recent decades is urbanization (Figure 3). Up until 1970, 54% of the state's population, 1.13 million people, lived in rural areas but in that very decade a rural exodus began as a result of the so-called 'Green Revolution' embodying the technological advances that had been achieved in agriculture and livestock production.

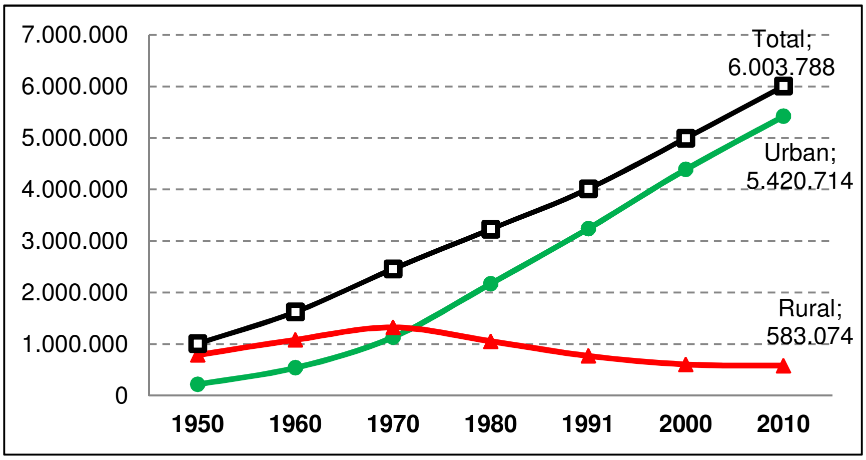


Figure 3 – Evolution of population figures for the state of Goias
Source: based on IBGE (2010) data

Of Goias's 246 municipalities, the capital Goiania is the most populated with 1.3 million inhabitants, 21.7% of the state's entire population. The 10 most populated municipalities together account for 50.5% of the state's population and their urbanization indexes are higher than 90%. Outstanding in that sense is the municipality of Valparaiso de Goias, which has no rural population at all.

While the population of the state continues to grow, it is doing so at a slower rate. In the period from 2000 to 2010 the population growth rate was 20.16% whereas in the period 1970 to 1980 it had been 31.3%. The estimated growth for 2011 compared to 2010 is 1.28% reaching a total number of 6.08 million inhabitants. Parallel to population growth there has been a population aging process in course. In 1980 just 4.5% of the population was 60 years old or more whereas by 2010 that percentage was up to 9.4%. In addition to that ageing of the profile there has also been a notable reduction in fertility rates in the state. In 2009 the average was 1.84 children per woman which happens to be the 5th lowest fertility rate in Brazil where the national average is 1.94 children per woman.

In the field of health, Figure 4 shows that only 12 municipalities in Goias have more than five hospitals. Goiania has the greatest number with 112, which corresponds to one hospital for every 11,625 inhabitants.

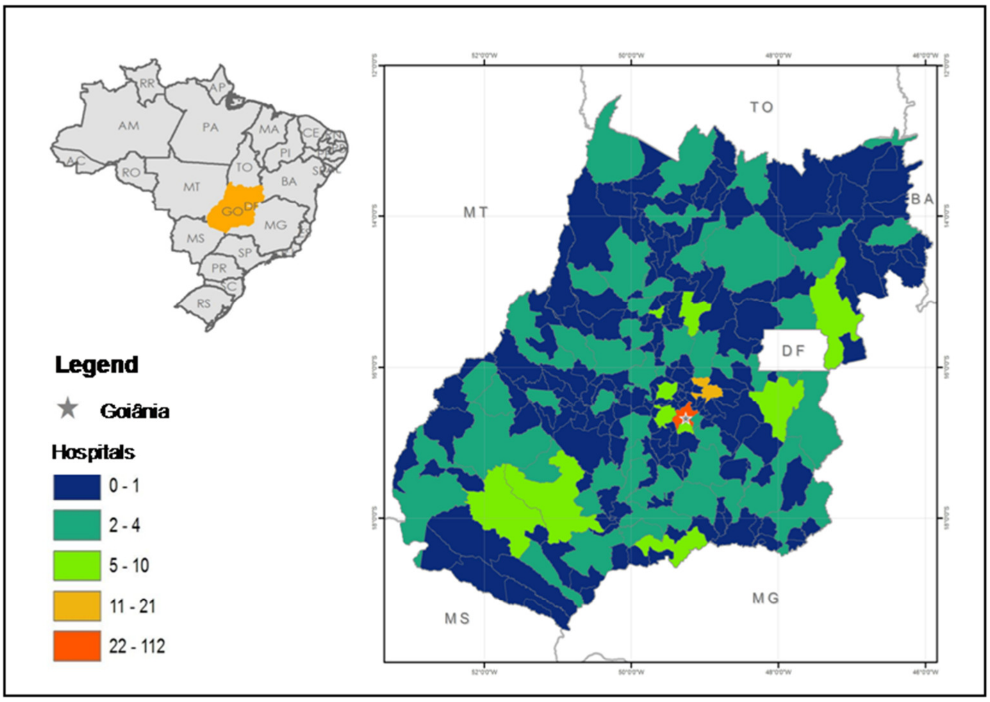


Figure 4 – Numbers of Hospitals in the State of Goias by Municipalities: Based on SEPIN (2011)

The situation regarding hospitals is most critical in the municipalities surrounding the Federal District and the state's metropolitan regions.

In the field of education, the illiteracy rate in Goias went down from 10.8% in 2000 to 7.32% in 2010; a reduction of 32%. However the total number of schooling establishments including pre-school, grade school and higher secondary school education also dropped by 13% over the same period.

In 2011, the ten municipalities with the highest number of schools were: Goiania, (744), Anapolis, (206), Aparecida de Goiania (190), Rio Verde (119), Luziania (107), Aguas Lindas de Goias (91), Formosa (79), Valparaíso de Goias (71), Jatai (69) and Catalao (64).

Figure 5 shows the relation between the number of schooling establishments and number of inhabitants and their distribution in the state. Among the ten municipalities in Goias with the highest population figures, Aparecida de Goiania and Valparaiso de Goias have the worst indexes with one teaching establishment for every 2,398 and 1,873 inhabitants respectively. Among the same ten municipalities, the one with best ratio of schools to inhabitants is Formosa, with one school for every 1,267 inhabitants.

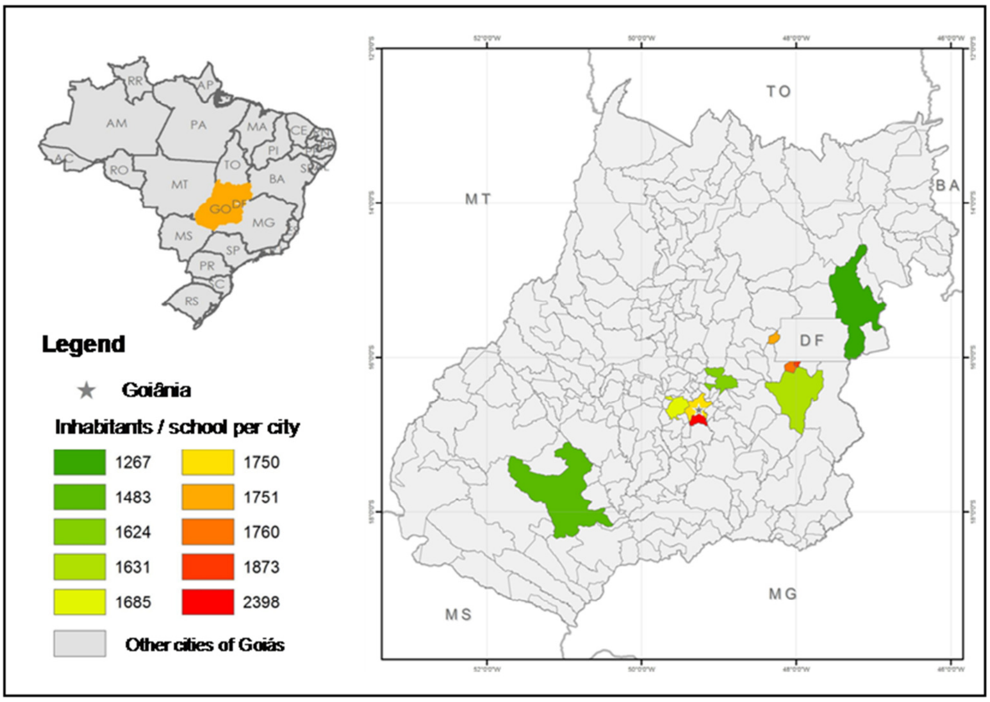


Figure 5 – Ratio of inhabitants to schools in the 10 most populated municipalities in Goias
Source: Based on SEPIN (2011)

5. DATABASE ANALYSIS AND SYSTEMATIZATION

A database was structured for the study proposed in this article based on the databases of the IBGE, the Goias Public Services Regulatory and Inspection Board (*Agência Goiana de Regulação e Fiscalização de Serviços Públicos* – AGR) and the Superintendence for Statistics, Research and Socio-economic Information (*Superintendência de Estatísticas, Pesquisa e Informações Socioeconômicas* – SEPIN) with information for the years 2008 and 2010. Their socio-economic variables were subjected to a preliminary analysis to eliminate any eventual inconsistencies such as municipalities with passenger flow figures that were incompatible with their population size or with the number of formal employment posts in their areas.

The initial database consisted of 246 registrations and 40 variables. Of the latter 14 were selected as being exogenous or independent and one as an endogenous or dependent variable, namely, the number of passengers with the municipalities as their trip destinations (attracted trips). The screening of the database was done by calibrating it first with a multiplicative model and then with an additive model as described below.

6. MODEL SPECIFICATION

The specification of the econometric models used to obtain forecasts for municipal passenger transport demand in the state of Goias made use of a set of variables available in the aforementioned databases. First the fit of a multiplicative model was tested taking into account all the following socio-economic variables:

$$Y_i = \alpha_0 X_1^{\alpha_1} X_2^{\alpha_2} X_3^{\alpha_3} X_4^{\alpha_4} X_5^{\alpha_5} X_6^{\alpha_6} X_7^{\alpha_7} X_8^{\alpha_8} X_9^{\alpha_9} X_1^{\alpha_1} X_{10}^{\alpha_{10}} X_{11}^{\alpha_{11}} X_{12}^{\alpha_{12}} X_{13}^{\alpha_{13}} X_{14}^{\alpha_{14}} \quad (1)$$

where: Y = passengers with the municipality as their destination
X_1 = industrial electricity consumption
X_2 = commercial electricity consumption,
X_3 = demographic density
X_4 = population
X_5 = number of schools
X_6 = economic development index
X_7 = vehicle fleet
X_8 = number of formal job positions
X_9 = gross domestic product
X_{10} = gross domestic product per capita
X_{11} = municipal revenues
X_{12} = average income
X_{13} = geometric growth index of population
X_{14} = number of hospitals,
α_0, α_1, α_2, α_3, α_4, α_5, α_6, α_7, α_8, α_9, α_{10}, α_{11}, α_{12}, α_{13}, α_{14} = coefficients to be estimated. All socio-economic data refer to the *i-th* municipality.

Subsequently the fit of the additive model was tested considering the same databases specified above:

$$Y_i = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \cdots + \alpha_{12} X_{12} + \alpha_{13} X_{13} + \alpha_{14} X_{14} \quad (2)$$

The selection of explanatory (predictor) for the proposed models was done using a stepwise procedure which tested the additional contribution each explanatory variable made to the prediction of the dependent variable. Within the selected models verification was made of to check that they met the requirements inherent to regression, namely: errors must average zero, they must have constant variance (homoscedasticity), they must not be correlated and they must be normally distributed.

6.1 Multiplicative Model

For the multiplicative model fit the first procedure was to make a logarithmic transformation of the variables to make the model linear. Then the stepwise procedure for selecting the exogenous variables was carried out which resulted in the selection of the variables X_7 e X_{13} (vehicle fleet and geometric growth rate if the population) to be used as explanatory variables for the demand.

Table 1 shows the initial results obtained from the multiple regression applied to the model in question.

Table 1 – Initial multiple regression results obtained for the multiplicative model

Variables	Estimated Coefficients	*P-value*
Intercept	$\hat{\alpha}_0$ = 4.36137	< 0.0001
X_7	$\hat{\alpha}_7$ = 0.73423	< 0.0001
X_{13}	$\hat{\alpha}_{13}$ = -0.25393	0.0039

This model resulted in a coefficient of determination of R^2_{Adj} = 0.4239 and did not fully meet all the presuppositions of regression in the aspects homoscedasticity and residual normality as can be seen in Table 2:

Table 2 – Presuppositions of the multiple regression applied to the multiplicative model

Presupposition	Test	Statistic	*P-value*
(i) $E(\varepsilon) = 0$	*t-Student*	$t = 0$	Pr > |t| 1.0000
(ii) $V(\varepsilon) = \sigma_\varepsilon^2$	*Chi-squared*	$\chi^2 = 17.32$	Pr > χ^2 0.0039
(iii) $Corr(\varepsilon_i. \varepsilon_j) = 0.\ i \neq j$	*Durbin-Watson*	$D = 1.833$	-
	t-Student	t = 0.844739	Pr > |t| 0.3990
(iv) Residual Normality	*Shapiro-Wilk*	W = 0.970775	Pr < |W| 0.0016
	Kolmogorov-Smirnov	D = 07085	Pr > D 0.0443

Figure 6 shows municipalities considered to exercise leverage in the overall set insofar as they cause significant alterations to some or all of the model's parameters if they are omitted from the overall data set. It also identifies other municipalities considered to be atypical or outliers insofar as they show values deviating by more than twice the standard deviation values beyond the average of the set of t-student residues (errors).

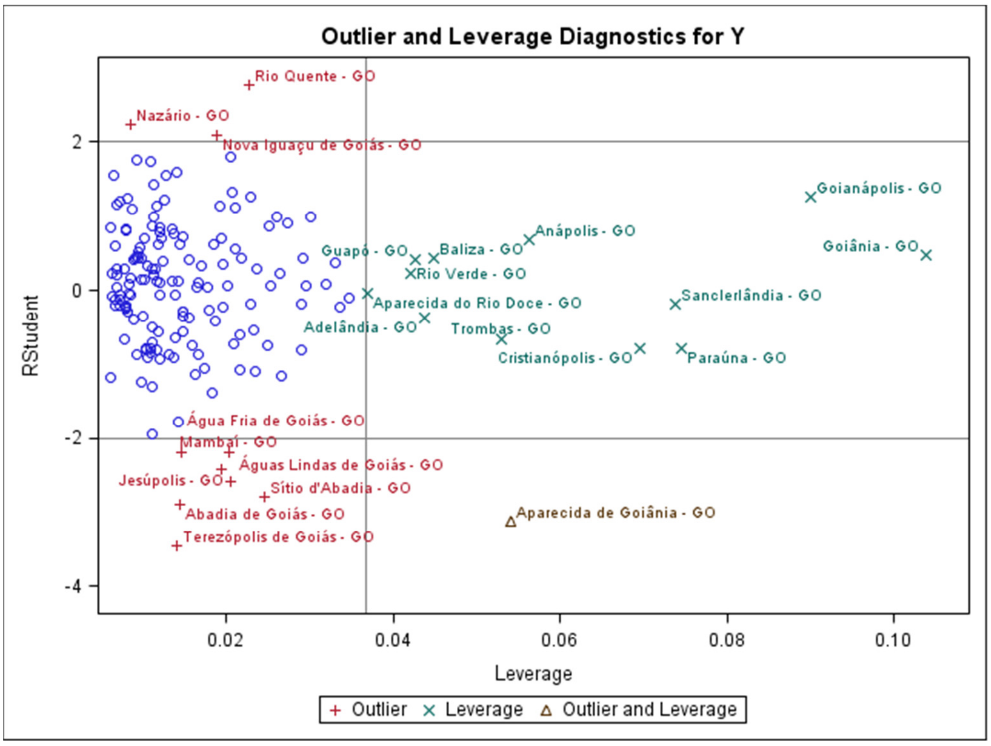


Figure 6 – Observed versus predicted values for Y

The presence of those 11 registrations affected the fit of the proposed model and so an analysis was made without their presence to verify their efficiency. The results are set out in Table 3.

Table 3 – Results of multiple regression applied to the multiplicative model

Variables	Estimated Coefficients	*P-value*
Intercept	$\hat{\alpha}_0$ = 4. 58968	< 0.0001
X_7	$\hat{\alpha}_7$ = 0. 71917	< 0.0001
X_{13}	$\hat{\alpha}_{13}$ = -0. 18008	0.0085

This model resulted in a coefficient of determination of R^2_{Adj} = 0.5414 and did not fully meet all the presuppositions of regression in the aspect of homoscedasticity as can be seen in in Table 4

Table 4 – Presuppositions fof the multiple regression applied to the multiplicative model

Presupposition	Test	Statistic	*P-value*
(i) E(ε) = 0	*t-Student*	*t* = 0	Pr > |t| 1.0000
(ii) $V(\varepsilon) = \sigma_\varepsilon^2$	*Chi-squared*	χ^2 = 13.79	Pr > χ^2 0.0170
(iii) $Corr(\varepsilon_i, \varepsilon_j) = 0, i \neq j$	*Durbin-Watson*	*D* = 1.849	
	t-Student	t = 0.948213	Pr > |t| 0.3440
(iv) Residual Normality	*Shapiro-Wilk*	W = 0.993678	Pr < W 0.7489
	Kolmogorov-Smirnov	D = 0. 040257	Pr > D 0.1500

Figure 7 displays the graphs related to the quality of the multiplicative model fit. In the graph showing t-student residues by predicted values and the Graph of Y values by predicted values. It can be seen that the variations on either side of the residues average and from the line of regression respectively seem to show a constant pattern.

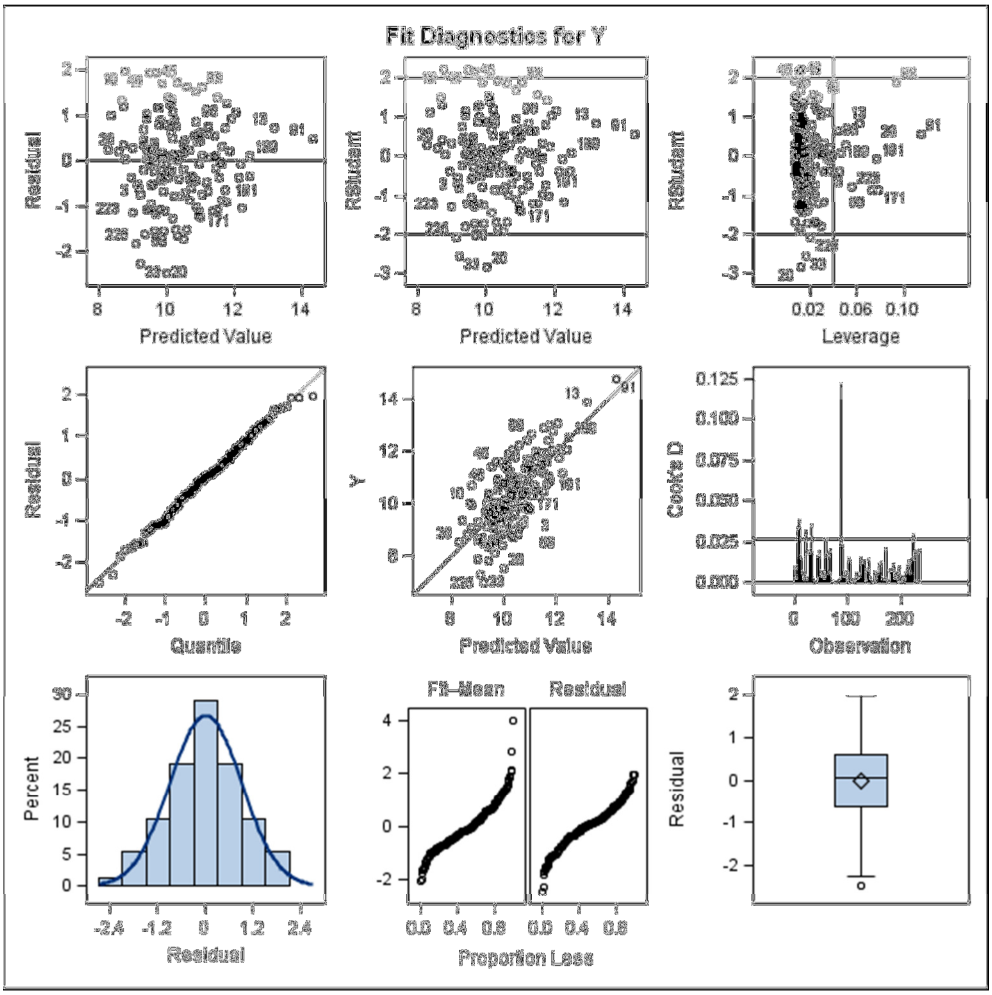


Figure 7 – Graphs showing fit diagnostics for Y

Another round without the presence of 12 registrations classified as outliers resulted in an efficient model as confirmed by the results set out in Table 5 and Table 6.

Table 5 – Final multiple regression results for the multiplicative model

Variables	Estimated Coefficients	*P-value*
Intercept	$\hat{\alpha}_0$ = 4. 63647	< 0.0001
X_7	$\hat{\alpha}_7$ = 0. 71410	< 0.0001
X_{13}	$\hat{\alpha}_{13}$ = -0. 14357	0.0158

This model resulted in a coefficient of determination of R^2_{Adj} = 0.6316 and fully met all the presuppositions of regression as can be seen in Table 6.

Table 6 – Multiple regression presuppositions for the multiplicative model

Presupposition	Test	Statistic	*P-value*
(i) E(ε) = 0	*t-Student*	*t* = 0	Pr > |t| 1.0000
(ii) V(ε) = σ_ε^2	*Chi-squared*	χ^2 = 5.34	Pr > χ^2 0.3761
(iii) Corr(ε_i. ε_j) = 0. i ≠ j	*Durbin-Watson*	*D* = 1.983	
	t-Student	t = -0.12923	Pr > |t| 0.897365
(iv) Residual Normality	*Shapiro-Wilk*	W = 0.98811	Pr < W 0.2743
	Kolmogorov-Smirnov	D = 0. 050355	Pr > D 0.1500

Considering that the adjusted multiplicative model only achieved a reasonable degree of explanation for the demand with the municipalities as the destination and considering that the functional expression was not one of direct understanding an additive model was tested based on the same database and accordingly, the same variables.

6.2 Additive Model

The calibration of the additive model began in the same way with the selection of the variables using stepwise regression. The results are set out in Table 7.

Table 7 – Initial Results of multiple regression applied to the additive model

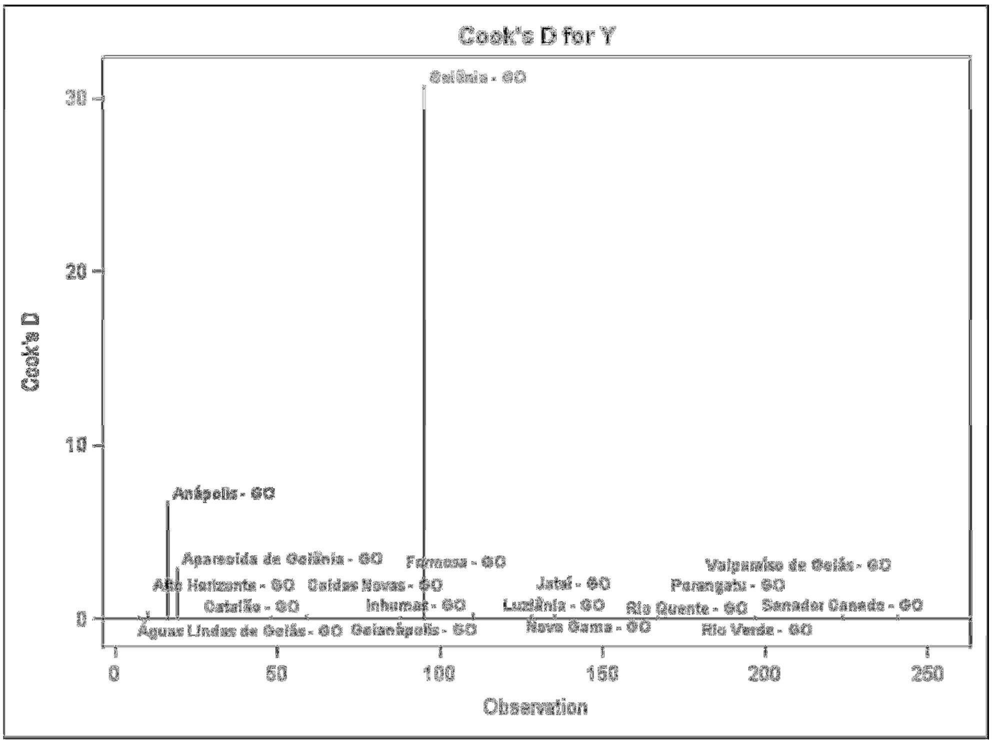
Variables	Estimated Coefficients	*P-value*
Intercept	$\hat{\alpha}_0$ = 1,618	0.1938
X_2	$\hat{\alpha}_2$ = 5.50563	< 0.0001
X_5	$\hat{\alpha}_5$ = 1,219.47324	0.0016
X_8	$\hat{\alpha}_8$ = -12.0000	< 0.0001
X_9	$\hat{\alpha}_9$ = 0,06780	< 0.0001
X_{10}	$\hat{\alpha}_{10}$ = -1.06428	0.0174
X_{14}	$\hat{\alpha}_{14}$ = 24,242	< 0.0001

It was found that the additive model could explain 89.30% (R^2_{Adj}) of the variation in passenger demand with the municipality as the destination (dependent variable) and that all parameters were statistically significant except for α_0. However the presuppositions of homoscedasticity and residual normality were not met as can be seen the results set out in Table 8.

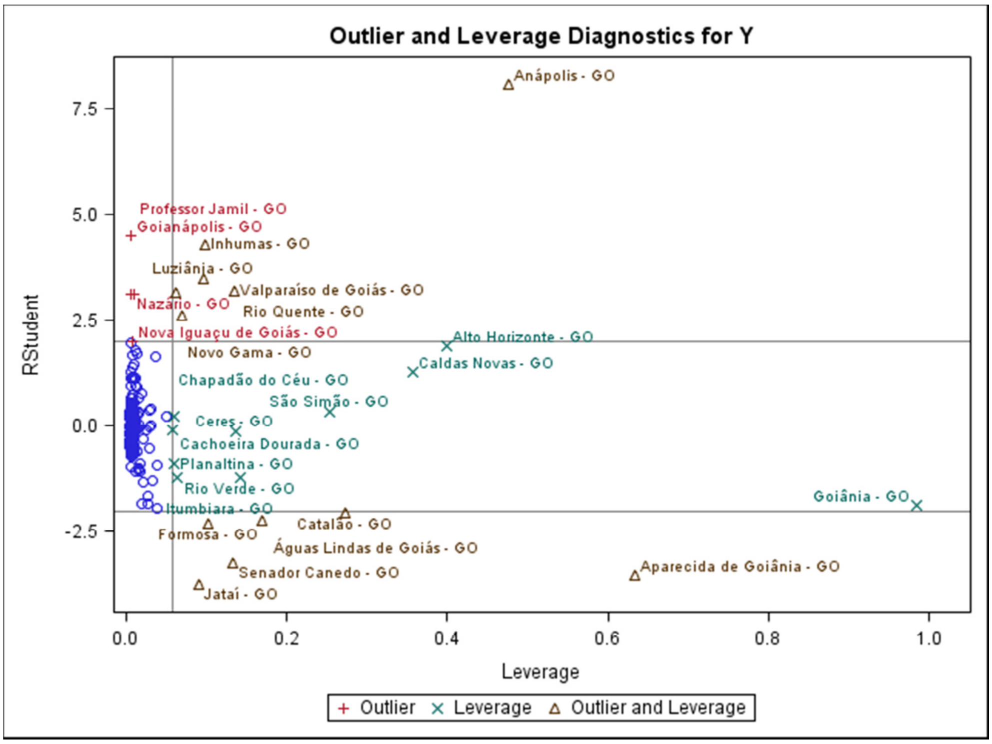
Table 8 – Multiple regression presuppositions for the additive model

Presupposition	Test	Statistic	*P-value*
(i) E(ε) = 0	*t-Student*	*t* = 0	Pr > |t| 1.0000
(ii) V(ε) = σ_ε^2	*Chi-squared*	χ^2 = 56.74	Pr > χ^2 0.0007
(iii) Corr(ε_i, ε_j) = 0, i ≠ j	*Durbin-Watson*	*D* = 1.962.	
	t-Student	t = 0.296843	Pr > |t| 0.866839
(iv) Residual normality	*Shapiro-Wilk*	W = 0.831818	Pr < W 0.0001
	Kolmogorov-Smirnov	D = 0.163453	Pr > D 0.0100

The reasons why those regression presuppositions were not satisfied can be identified in Figure 8, which clearly shows (a) the influence the city of Goiania has on the model estimates and consequently on the parameters, and in graph (b) the municipalities classified as outliers in the data set that was analyzed.



(a)



(b)

Figure 8 – (a) *D-Cook for Y*; (b) *RStudent* versus *Leverage*

Those results pointed to the need for another round of adjustment to and it was carried out this time without the presence of the 12 discrepant registrations. The results of this adjustment are set out in Table 9.

Table 9 – Partial multiple regression results for the additive model

Variables	Estimated Coefficients	*P-value*
Intercept	$\hat{\alpha}_0$ = -3,216.35299	0.1412
X_2	$\hat{\alpha}_2$ = 1.13333	0.2886
X_5	$\hat{\alpha}_5$ = 1,842.68574	< 0.0001
X_8	$\hat{\alpha}_8$ = - 0.90617	0.5583
X_9	$\hat{\alpha}_9$ = 0.00218	0.7197
X_{10}	$\hat{\alpha}_{10}$ = 0.08329	0.4237
X_{14}	$\hat{\alpha}_{14}$ = 7,623.27258	< 0.0001

With the removal of the *outliers,* the effects of variables X_2, X_8, X_9 e X_{10} were no longer significant and so another round was carried out including only variables X_5 and X_{14} (number of schools and number of hospitals) which continued to be significant in explaining the dependent variable. The new results set out in Table 10 below, confirmed the statistical significance of the proposed model.

Table 10 – Multiple regression results for the additive model

Variables	Estimated Coefficients	*P-value*
Intercept	$\hat{\alpha}_0$ = - 5,596.17337	< 0.0001
X_5	$\hat{\alpha}_5$ = 2,008.48749	< 0.0001
X_{14}	$\hat{\alpha}_{14}$ = 10,590	< 0.0001

With this model 99.54% (R^2_{Adj}) of the variation found in the passenger demand with a destination in the municipality (dependent variable) is explained. Furthermore the regression requirements were fully met as can be seen in the results set out in Table 11:

Table 11 – Multiple regression presuppositions for the additive model

Presupposition	Test	Statistic	*P-value*
(i) $E(\varepsilon) = 0$	*t-Student*	$t = 0$	Pr > |t| 1.0000
(ii) $V(\varepsilon) = \sigma_\varepsilon^2$	*Chi-squared*	$\chi^2 = 10.60$	Pr > χ^2 0.0600
(iii) $Corr(\varepsilon_i, \varepsilon_j) = 0, i \neq j$	*Durbin-Watson*	$D = 2.138$	
	t-Student	t = -0.96551	Pr > |t| 0.3356
(iv) Residual Normality	*Shapiro-Wilk*	W = 0.988742	Pr < W 0.1758
	Kolmogorov-Smirnov	D = 0.05935	Pr > D 0.1323

Figure 8 shows graphs related to the quality of the fit obtained by the additive model.

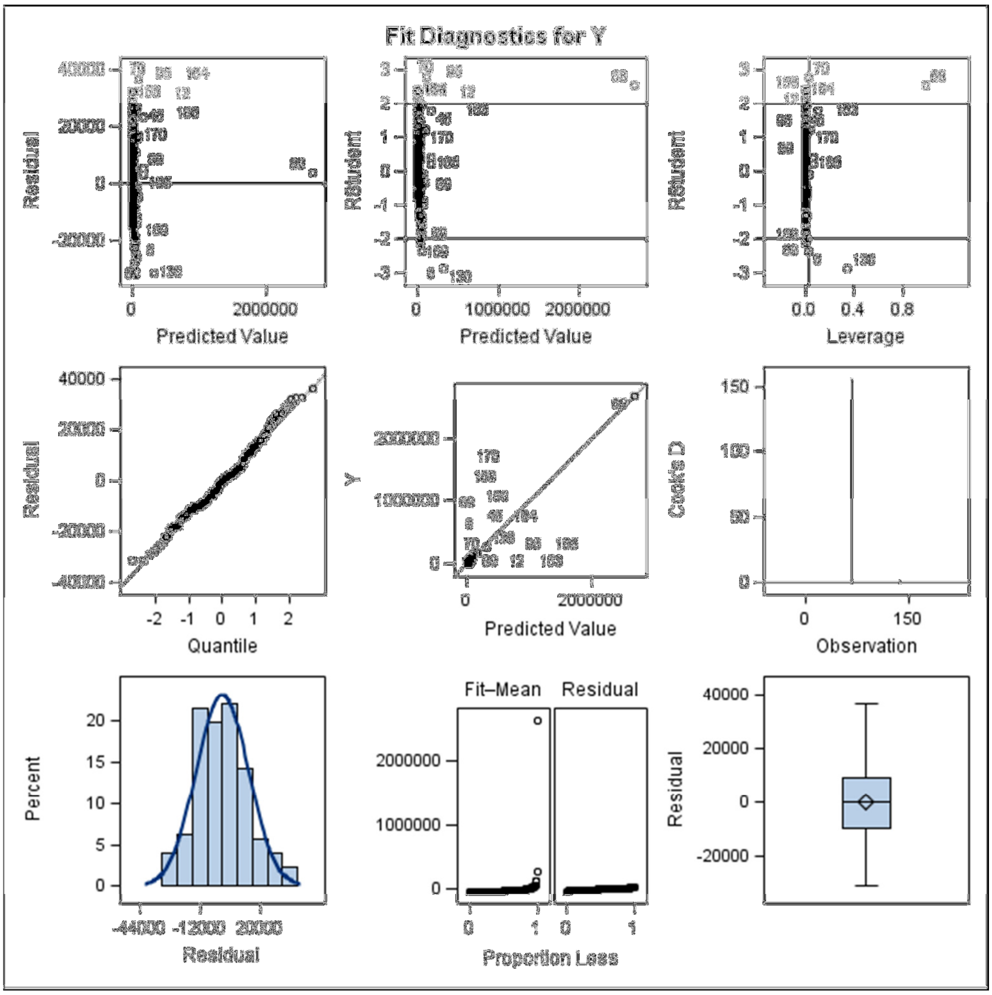


Figure 9 – Graphs of the Fit diagnostics for Y

The additive model is not only simpler but it makes it possible to gain an understanding of the direct relation between the explanatory variables and the variable of interest (*Y*). It must be underscored that the model that included all the observations showed a coefficient of determination (R^2_{Adj}) of 0.8691. Once the aberrant observations had been removed however, the model achieved a level of explanation of 0.9954.

FINAL REMARKS

Studies dealing with trip generation in urban environments normally consider the concentrations of employment and housing to construct trip generation models used in analyses to determine transport infrastructure allocation. Such models presume, correctly, that the place of residence and the place of work are the main trip generators when the transport in question is collective road passenger transport. Many models also include the location of schools but the latter are more commonly associated to trips on foot or made by private means of transport.

In the case of inter-municipal road transport, that is transport that links points in separate municipalities, the analyses presented in this study show that the variables most closely associated to the attraction of road transport trips were the number of hospitals and the number of schools and that suggests that in the case of the state of Goias these two variables are more important in determining demand for inter-municipal trips than those that art classically adopted in studies involving urban regions.

This can be explained by a dichotomy involving the number of hospitals and schools in the different municipalities of the state of Goiás, so that the relevance of these variables may be linked to the dependence of less developed municipalities in relation to the infrastructure of metropolitan regions.

Based on results obtained it is possible to establish public policies that take into account the numbers and locations of schools and health service establishments in such a way as to determine the sites for infrastructure improvements and orientate transport planning with a view to improving the transport supply side and the conditions in which the population makes its trips. Similar studies could be undertaken in other places to confirm the suitability of using these particular variables in planning inter-municipal transport or to identify others that reflect the dynamics that influence people's translocations in the state with greater precision and in closer alignment with the characteristics of the population.

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