

“TRIP GENERATION MODEL WITH THE APPLICATION OF REMOTE SENSING AND THE GEOGRAPHIC INFORMATION SYSTEMS”

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ABSTRACT

The main objective of the present research is to develop a methodology for the generation of trips using Geographic Information Systems and Remote Sensing. According to the new developments in this technology, it is now possible to sectorise an urban structure, through the analysis of the data obtained from aerial photographs. Furthermore, this sectorization allows the systematic identification of sectors with similar characteristics. These characteristics allow the definition of the geometric and photographic patterns in the urban structure, which can be grouped up to form “Homogeneous Aggregated Sectors” (HAS).

Based on the fundamentals from Geographic Information Systems (GIS) and Remote Sensing (RS), using the treatment of aerial photographs, a methodology was developed for the analysis and classification of the data from these images that results in of “Photo-Interpreted Classes” (PIC), which are grouped up to form “Homogeneous Aggregated Sectors” (HAS). With respect to the case study of the town of Sobradinho, 16 PICs and 15 HASs were identified. Furthermore, based on the relationship of these classes with the census data obtained from IBGE (Instituto Brasileiro de Geografia e Estatística), the formulation of a model for the generation of trips was developed. This model of trip generation factors for each class, in Sobradinho town was obtained. This results shows the relation between land use pattern and trip generation. In this study, the highest value was obtained in residential sectors with buildings with many floors while, mixed occupation patterns, such as residences and workshops or residences and comercial area, presented low value comparing with residencial patterns. It was also verified that the factor values of a class are influenced by the age of the area.

1 INTRODUCTION

In the Transportation Planning process one of the main activities is to estimate the trip demand. It aims to determine the amount of trips generated and attracted by a traffic zone, that will be essential to continue the process. In this sense, it is fundamental to determine the characteristics and patterns of trips (type, place of origin and destination, etc.).

In order to estimate the trip demand, the traditional methodologies require the attainment of a large number of information. These information are not only related to the system itself, but the socio-economic data of the population. Usually, it can be reached through extensive collection of data related to individual trips, that are called

origin - destination research. This collection phase consumes the most part of the time and demands the use of expressive human and financial resources, making the process sometimes invalid for most cities, principally the small and medium sized zones.

The trip generation / attraction variables are extremely dynamic in developing countries. Because of this rapid development, which has a narrow relationship with the transportation system and urban activities, it is necessary to obtain information about the trip characteristics. Then, this information has to be collected continuously for the analysis and the establishment of the future behaviour of the trips. This fact has as consequence the increase of the planning process costs and the necessity to develop alternative forms to collect, process and analyse the data for trip generation.

In this paper a trip generation model is presented, based on land-use patterns and land inhabitation, obtained through the association of Remote Sensing (RS) and Geographical Information System (GIS). In search of speed and effectiveness in the attainment of information for transportation planning.

This paper is structured in five sections. In the first section, the traditional trip generation models are discussed. The RS and GIS concepts are treated in the second section. In the third one, the formulation of the developed model is presented. A case study in the town of Sobradinho (District Federal - Brazil) and the viability of the model are described in the fourth section. Finally, the conclusions are presented in the fifth section.

2 EVALUATION OF THE TRIP GENERATION MODELS

The evaluation of the trip generation models shows a typically static level of analysis, since they don't possess resources which can enable them capture the urban changes related to land-use at a quick rate. Also, the large quantity of data needed to execute the modelling, impedes the updating of these data in a quick and continuous way, due to the high operational cost. These restrictions make the modelling, and evidently, the treatment of transportation problems complex. All these lead to the need to rely on tools which permit the treatment of large quantities of data, in a rapid and precise form, and at the same time facilitate the intervention of the modelling process in an interactive and dynamic way.

In this sense, some attempts can already be observed. Silva et al. (1995) developed a simplified model which facilitates the generation of trip rates, making use of GIS. Despite the effort involved in obtaining the additional data, one can still observe a strong dependence caused by lack of data, leading to the least exploration of the functional characteristics of GIS, together with other technologies.

3 GEOGRAPHIC INFORMATION SYSTEMS IN TRANSPORTATION (SIG-T) AND REMOTE SENSING (RS)

The Geographic Information Systems can be defined as a type of Information System which involves databases, technology and staff in a systematic and interactive way, in order to execute spatial analysis (Dantas et al., 1996). These analyses are defined by Goodchild (1988) *apud* (Gatrell, 1991) as a group of analytic methods which demand

access to the attributes (properties) of the study objects and information of their location (georeference). Spatial analysis plays a fundamental role in the treatment of graphic data (aerial photographs and satellite images) obtained from Remote Sensing, thereby permitting the attainment of essential information for the treatment of transportation problems, not simply as a viewing tool and data storage, but as a direct planning instrument.

The potential to be explored with the use of GIS and RS in transportation studies has presented considerable results. Recently, Bartoli et al. (1996), Taco et al. (1996) and Yamashita et al. (1997), obtained essential information to evaluate the accessibility of locations at bus stops; traffic zoning of the urban area through the definition of Aggregate Sectors, to analyse the intervening variables in attracted and produced trips, and the definition of bicycle routes, respectively.

4 TRIP GENERATION MODELLING WITH THE APPLICATION OF GIS AND RS

This model seeks to relate land-use patterns with the trip generation of a determined area. In other words, we intend to determine the rate of generated trips function in the inhabited area, for each type of urban construction. It is necessary to identify and characterise the different land-use patterns, in order to later correlate them mathematically with the trips. The modelling process is divided in five stages namely, identification and characterisation of photo-interpreted classes (PIC) and Homogeneous Aggregate Sectors (HAS); definition of involved variables; structuring and formulation of mathematical theory; and mathematical calculus of the factors of trips generated in the area.

In the modelling process, it is necessary to create data layers in the GIS software, which can relate transportation in terms of levels, types and location of the socio-economic activities within the urban context. In this model, the land-use layer maps, the "censitaire" sectors (CS), the traffic zones (TZ), and the photo-interpreted classes are assumed to be created in GIS. With respect to land use, the existent distribution and type of use must be defined. In the "censitaire" sectors and traffic zones, demographic and socio-economic data must be aggregated, together with the limits and location of their centroids. On the other hand, the location of the centroids and their areas within the CS and TZ are important for the PICs.

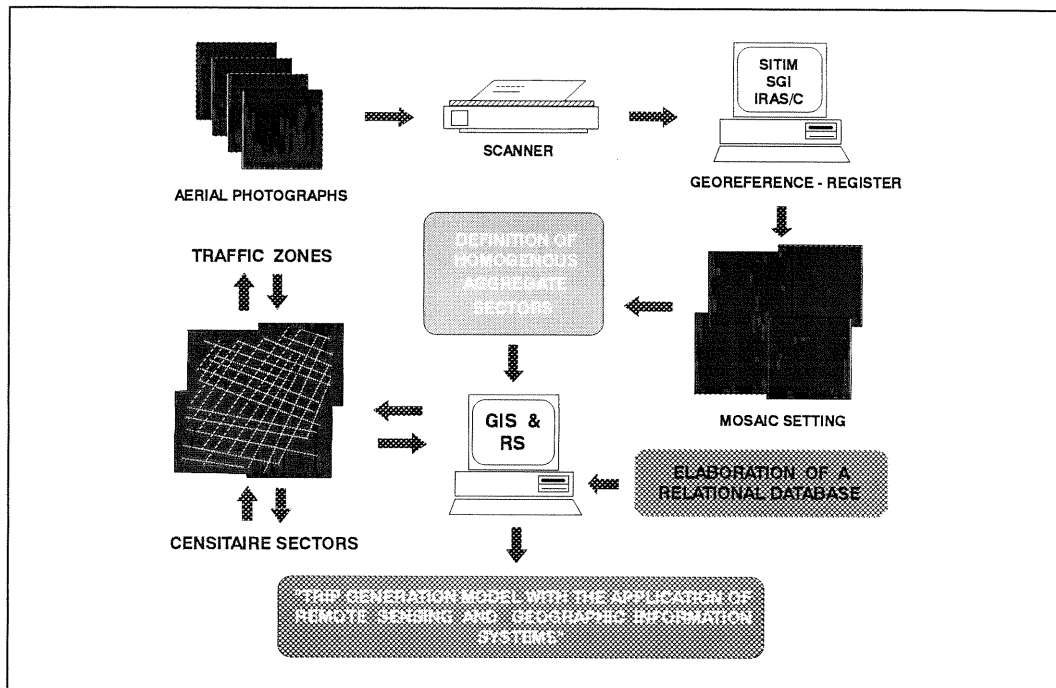


Figure 1: Methodological Diagram

4.1 Definition of the Photo-interpreted Classes and Homogeneous Aggregate Sectors

The principal objective of this phase of modelling, is the identification and characterisation of land-use and inhabitation, as well as the verification of how they interact in the urban areas. By this way, the aerial photographs are used to define the class sectors which will be based on modelling.

4.1.1 Definition of The Homogeneous Photo-Interpreted Classes (PIC)

Two levels of analysis for the attainment of PICs are established, based on the formulation theory developed by the U. S. Geological Survey (Abery & Berlin, 1990) and the practical verifications of Taco et al. (1996). In the first and more generic level, the homogeneous aggregate macro sectors will be limited, seeking a general understanding of the area and the separation of the residential areas from those constructed for other purposes. The macro sectors must be defined, seeking to characterize the different segments of the urban area in terms of their position in the local structure. This occurs, examining the aggregation of the individual objects of interest and defining the composition of each sector. The examination of the location of each object (habitation) or composition of objects (habitation sectors) in relation to their surroundings, is also done.

In the second level, which is more individual and acting on the identification of the macro sectors in the previous level, the PIC is defined in function with parameters such as, size of the parcel of land, construction of the parcel of land (lateral, frontal and backward setbacks); presence and treatment of gardens and backyards; land use, be it unique, residential, or mixed use; constructive density, presence and portions of green

areas; types of construction (ground, twin, isolated, in pavements, with tile roof, wooden huts, etc.), spontaneous or planned inhabitation; regular or irregular; age of sector, and topography.

The evaluation of the urban area in a general and individual level, in function with these parameters, make it possible to determine the kinds of patterns which differentiate one class from the other and which are grouped up according to the common attributes in each PIC, would also make it possible to determine the Homogenous Aggregate Sectors as elaborated by Taco (1997).

4.2 Definition of the Involved Variables

The model structuring process varies according to the reference of the data of trips, which can be obtained by “censitaire” sectors, traffic zones or any other type of specific division. Making necessary the definition of the variables involved in the modelling in aggregate (TZ) or desagregate (CS and PIC) levels, as specified as follows:

4.2.1 Censitary Sectors

The basic desagregation unit corresponding to the “censitaire” sector is characterized the same way as the corresponding “censitaire” variables by the following nomenclature:

- sc_id = “censitaire” sector identifier
- sc_area = area of “censitaire” sector (m^2)
- SC_i = “censitaire” sector i . Given $\forall i \in \{1 \dots m\}$, m the total number of CS
- $SC_i^{ZT_a}$ = “censitaire” sector i in traffic zone a . Given $\forall a \in \{1 \dots p\}$, p total number of TZ
- V^{SC_i} = generated trips in the “censitaire” sector i
- V^{SC} = total number of generated trips in the censitary sectors
- $V^{SC} = \sum_{i=1}^m V^{SC_i}$ (1)

4.2.2 Traffic Zones

The grouping of the “censitaire” sectors will constitute a traffic zone. By this way, each traffic zone will be characterized in a similar form in the “censitaire” sectors:

- z_id = traffic zone identifier
- z_area = area of traffic zone (m^2)
- ZT_a = traffic zone a . Given $\forall a \in \{1 \dots p\}$
- V^{ZT_a} = generated trips in traffic zone a
- $V^{ZT_a} = \sum_{i=1} V^{SC_i} . \forall i \in ZT_a$ (2)

- V^{ZT} = total number of generated trips in the traffic zones
- $V^{ZT} = \sum_{a=1}^p V^{ZT_a} . \forall a \in \{1 \dots p\}$ (3)

4.2.3 Photo-interpreted Classes

These will also be characterized in a similar way as the previous variables:

- pic_id = photo-interpreted class identifier
- pic_area = area of photo-interpreted class (m^2)
- f_k = photo-interpreted class factor k . Given $\forall k \in \{1 \dots n\}$, where n n^o of PICs
- $A_{f_k}^{SC_i}$ = total area of photo-interpreted class k in “censitaire” sector i
- A_{f_k} = total area of photo-interpreted class k
- $A_{f_k} = \sum_{i=1}^n A_{f_k}^{SC_i}$ (4)
- f_k^V = factor of trips generated by the photo-interpreted class k expressed in trips/ m^2

4.3 Formulation of the Mathematical Model

An area of study is considered for the formulation of the model, idealised in Figure 2, composed of p Traffic Zones, m “Censitaire” Sectors, and n Photo-interpreted Classes. As long as the limits of the traffic zones ZT_a , are clearly defined; and the limits of the “censitaire” sectors $SC_i^{ZT_a}$ don’t exceed the traffic zone limits, and the area of the photo-interpreted classes $A_{f_k}^{SC_i}$ are situated within the “censitaire” sector limits, there could be a factor f_k^V expressed in a number of generated and attracted trips by m^2 for each photo-interpreted class k , in each “censitaire” sector i or traffic zone a . Given that this factor should be the function of the number of generated trips for “censitaire sector V^{SC_i} or generated per traffic zone V^{ZT_a} , according to the aggregation or desegregation of the variables used.

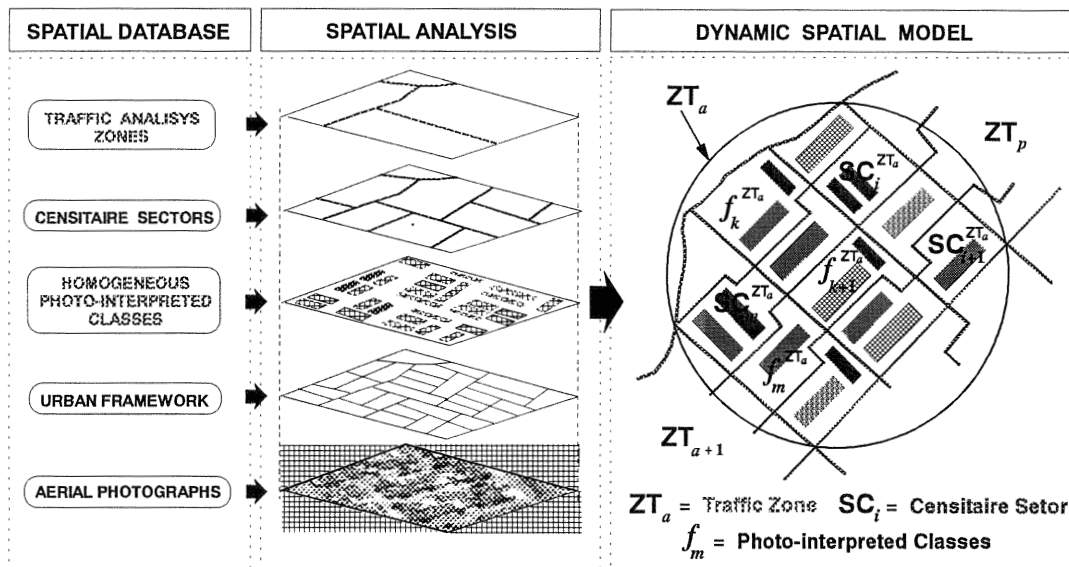


Figure 2: Formulation of the represented variables by the model.

4.3.1 Trips per "Censitaire" Sector

For one "censitaire" sector SC_i the number of generated trips V^{SC_i} will be equal to the product of the factor of the photo-interpreted class trips k (f_k^V) by its total area ($A_{fk}^{SC_i}$). For n photo-interpreted classes and m "censitaire" sectors, we will have the following equations:

$$\begin{aligned}
 V^{SC_i} &= w_i^{SC_i} + f_k^V A_{fk}^{SC_i} + f_{k+1}^V A_{fk+1}^{SC_i} + \dots + f_n^V A_{fn}^{SC_i} + U_i^{SC_i} \\
 V^{SC_{i+1}} &= w_{i+1}^{SC_{i+1}} + f_k^V A_{fk}^{SC_{i+1}} + f_{k+1}^V A_{fk+1}^{SC_{i+1}} + \dots + f_n^V A_{fn}^{SC_{i+1}} + U_{i+1}^{SC_{i+1}} \\
 &\quad \text{M} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{M} \\
 V^{SC_m} &= w_m^{SC_m} + f_k^V A_{fk}^{SC_m} + f_{k+1}^V A_{fk+1}^{SC_m} + \dots + f_n^V A_{fn}^{SC_m} + U_m^{SC_m}
 \end{aligned} \tag{5}$$

Assuming that the variable V^{SC_i} should depend on the values used by the independent variables $A_{fk}^{SC_i}, A_{fk+1}^{SC_i}, \dots, A_{fn}^{SC_i}, \forall i \in \{1, 2, 3, 4, \dots, m\}$ and $\forall k \in \{1, 2, 3, 4, \dots, n\}$, then the determination of f_k^V, f_{k+1}^V, f_n^V could be obtained through *multiple linear regression*, determining that this dependency be expressed by:

$$V^{SC} = w + f_1^V A_{f1} + f_2^V A_{f2} + \dots + f_n^V A_{fn} + U \tag{6}$$

where:

- V^{SC} = estimate for total number of generated trips in the "censitaire" sectors;
- w = regression constant;
- f_k^V = factor for photo-interpreted class trips $k, \forall k \in \{1, 2, 3, 4, \dots, n\}$;
- A_{fk} = total area for the photo-interpreted class $k, \forall k \in \{1, 2, 3, 4, \dots, n\}$;
- U = random component (error), which expresses the variations in measures, and the influences of the variables that were omitted in the model.

The adjustment of photo-interpreted class-factors values f_k^V will be made through the *multiple linear regression* between the variables observed and obtained through the minimum square methods. This method specifies that when a sample of x observations of variables $V^{SC_i}, A_{fk}^{SC_i} \forall SC_i$ with $i \in \{1, 2, 3, 4, \dots, m\}$ is given, the estimates w, f_1^V, \dots, f_n^V must be determined to obtain Eq. (6). By this way the calculation of these values will be such that, the squares of the deviations of the observed values in relation to those estimated for V^{SC} will be the minimum. Several actors have discussed the theoretic aspects of the minimum square techniques (Costa Neto, 1977), in the same way as several informative programs have been developed to solve these problems, therefore, this topic will not be discussed in this item of modelling.

4.3.2 Trips per Traffic Zone

For one traffic zone ZT_a the total number of generated trips V^{ZT_a} will be equal to the product of the photo-interpreted class factor (f_k^V) by the total area of the photo-interpreted class k situated in this zone ($A_{fk}^{ZT_a}$). For n photo-interpreted classes and p traffic zones, here are the following equations:

$$\begin{aligned}
 V^{ZT_a} &= u_a^{ZT_a} + f_k^V A_{fk}^{ZT_a} + f_{k+1}^V A_{f_{k+1}}^{ZT_a} + \dots + f_n^V A_{f_n}^{ZT_a} + U_a^{ZT_a} \\
 V^{ZT_{a+1}} &= u_{a+1}^{ZT_{a+1}} + f_k^V A_{fk}^{ZT_{a+1}} + f_{k+1}^V A_{f_{k+1}}^{ZT_{a+1}} + \dots + f_n^V A_{f_n}^{ZT_{a+1}} + U_{a+1}^{ZT_{a+1}} \\
 &\text{M} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \text{M} \\
 V^{ZT_p} &= u_p^{ZT_p} + f_k^V A_{fk}^{ZT_p} + f_{k+1}^V A_{f_{k+1}}^{ZT_p} + \dots + f_n^V A_{f_n}^{ZT_p} + U_p^{ZT_p}
 \end{aligned} \tag{7}$$

A similar process to the development for the “censitaire” sectors is followed by the analysis of the traffic zones, obtaining:

$$V^{ZT} = u + f_1^V A_{f_1} + f_2^V A_{f_2} + \dots + f_n^V A_{f_n} + U \tag{8}$$

where:

- u = regression constant;
- U = random component (error), which expresses variations in measures and the influences of the variables which were omitted in the model.

5 APPLICATION OF THE MODEL IN THE URBAN AREA OF SOBRADINHO - DF

The main objective of this item is to verify the applicability of the proposed model. Trip values for each Homogeneous Aggregate Sector (HAS) photo-interpreted in the function of the trips generated in each Traffic Zone and the desagregate data at the “Censitaire” Sector levels are calculated for the urban area of Sobradinho.

Sobradinho is situated about 23,5 km, north-east of Brasília DF, on the margins of the BR - 020 highway, with a population of 93,160 inhabitants, registered in 1996, in the administrative region (CODEPLAN - IBGE - IDHAB/DF, 1996), which in the majority developed activities linked with the Plano Piloto. The knowledge of some of the characteristics of the study area are important for the modelling process, with emphasis on the following:

- *Urban land-use*, according to concepts of the urbanistic project, the town was divided into sectors (CODEPLAN, 1984), giving the residential and or commercial sector, a unique cell of the town. In the laterals of each square, areas are reserved for local commerce whose extremities are in special, reserved areas. Areas for educational and leisure purposes were also planned. The commercial squares, situated in the center of the town, made up of squares and sectors, such as administrative and hotel sectors. The industrial sector, garages in general, small-sized factories and warehouses are situated in the isolated and special areas.

- *Data of the Origin - Destination matrix of the domestic research* - executed by the Development Company of the Central Plateau (CODEPLAN, 1990) for the administrative region of Sobradinho. Given that the internal trips are related to the 14 traffic zones, numbered from 236 to 249, they correspond to the trips executed by all the modes and motives in a period of 24 hours.
- *Demographic "Censitaire" data executed by the IBGE Foundation*, are obtained in the month of September, 1991, from which information based on the total number of residences, houses, population per residence, minimum salary wage, and the average nominal bread winner's wage (RMN) were selected.

5.1 Definition of the Photo-interpreted Classes of the Study Area

In the present item, the methodology for the acquisition of the PICs is practically applied, showing the following procedures for the georeference of aerial photographs in GIS. In addition, the spatial disposition of the classes in the traffic zones determined for Sobradinho by CODEPLAN is discussed.

5.1.1 Georeference of Aerial Photographs

In order to carry out the identification of the photo-interpreted classes, the elaboration of project in GIS must be executed through the elaboration of a database with socio-economic and trip information. These information should be related to categories, features and tables of the traffic zones, "censitaire" sectors and photo interpreted classes. After this the next step is the construction of the maps for each created feature.

The aerial photographs in a 1:8.000 scale, acquired from CODEPLAN, were transformed to a raster format with a 300 *dpi* resolution, being georeferenced through the I/RAS C -Image Rastering software - (1993) module of Mapping/Modular GIS Environment -MGE- (1994), through a process called Geometric Correction (Crósta, 1993). The first one permits a quick integration of the aerial photographs in a vectorial base, facilitating the vectorization of the areas of the PICs, which have the digital image as the background. At the end of this stage, it will have been possible to analyse the aerial photographs for the identification of homogenous unit patterns, and consequently the determination of the PICs.

5.1.2 Determination of the Photo-interpreted Classes

Initially, the general process of the analysis of the urban fabric has involved the delimitation of the homogenous macro-sectors in the function of the land use, seeking a general understanding of the area and the separation of the residential areas from those constructed for other uses. These macro-sectors were defined as a function of the proposed methodology, grouped up in residential, commercial and service, transportation, communication, public service and mixed urban use levels. Concerning the identification of these macro-sectors, the classes were defined through the analysis of the standard characteristics of each segment of the sector, as specified as follows:

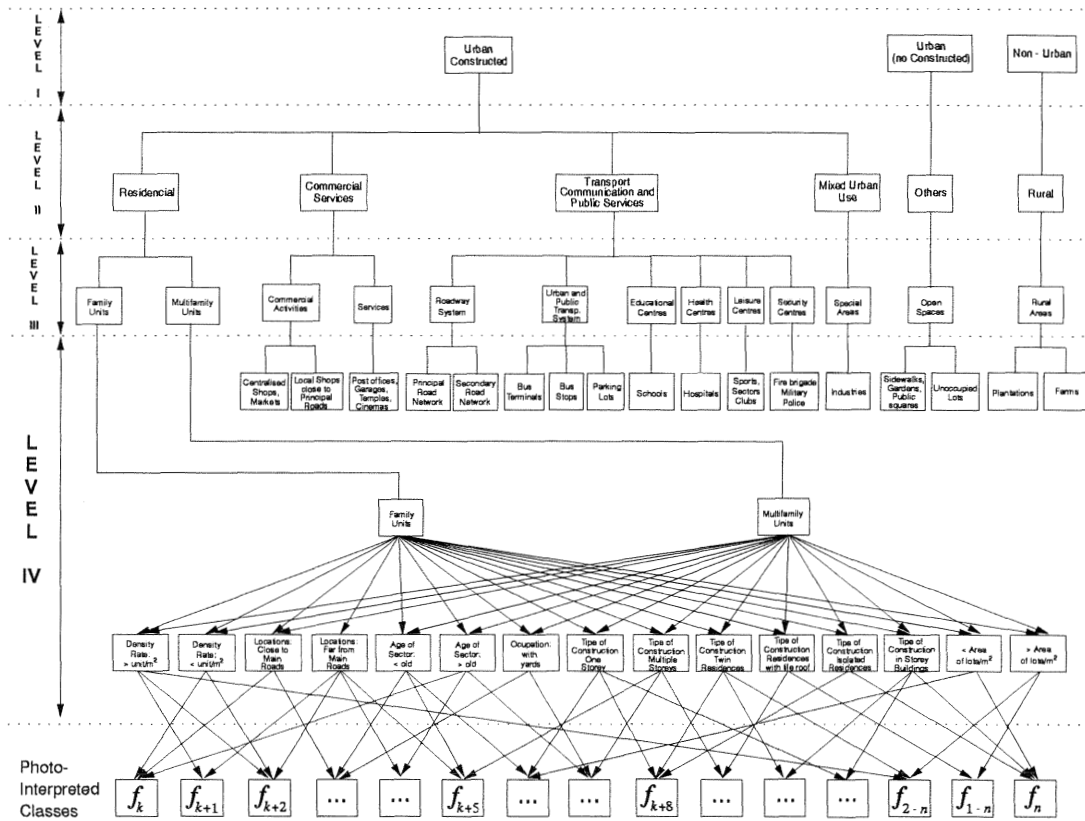


Figure 3: Levels of Aggregation of the Urban Areas for the definition of Photo-Interpreted Classes $f_k \rightarrow f_n$

In those traffic zones that make up the urban area of the town of Sobradinho, 16 photo-interpreted classes were identified, whose location characteristics in relation to the street, geometric and photographic patterns are presented with Characteristics of the Photo-interpreted Classes per Traffic Zone following, respectively:

- **236:** Two photo-interpreted classes are identified in this TZ. The f_{10} class is formed as the commercial sector between street blocks, distributed throughout the whole study area. The f_{16} class made up of a large area with a few constructions of non-residential characteristics, symbolising an occupation of different activities such as garages.
- **237-238:** Four types of homogenous units were identified, which when grouped up, form photo-interpreted classes f_1 , f_2 , f_3 , and f_4 . The f_1 class presents a greater reflection, when compared with the other units of this zone. This can be explained by the scarcity in green surfaces, indicating a lesser occupation period than the previous ones. The f_2 type presents yards in the frontal area of the house, providing access to the street, and a similar geometry between the parcels of land. On the other hand, the areas occupied by classes f_3 , and f_4 present low spectral answers, due to the presence of green surfaces. Some similarity is observed in certain aspects, among these classes, but the density factor is divergent. In class f_3 , the

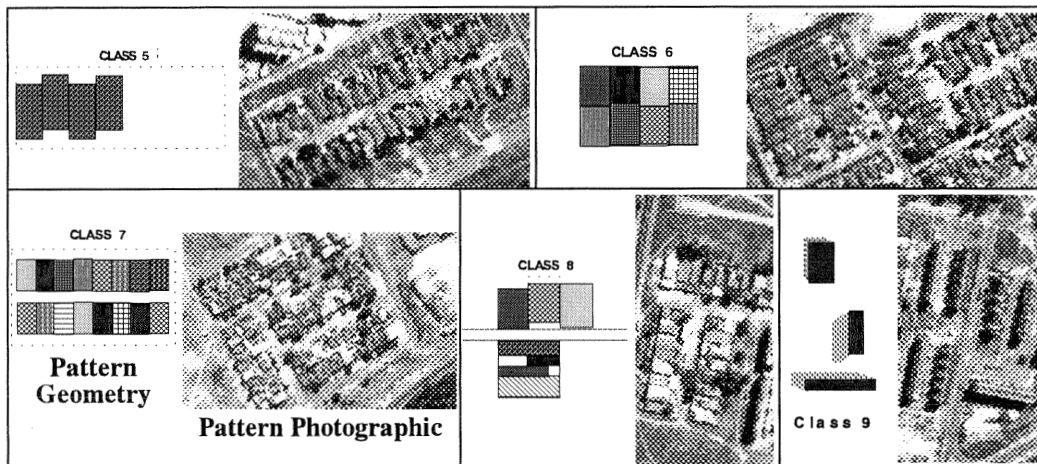


Figure 5: Standardisation of the photo-interpreted classes f_5 , f_6 , f_7 , f_8 and f_9

- **243:** Classes f_2 , f_3 , f_4 and, f_{10} , are repeated, with f_3 occupying a larger area in this zone, and distinguishing classes f_{12} and f_{13} . Class f_{12} has a pattern characterized by the habitation of half of the lot, and a uniform geometry. Even so, the dimension of the parcel of land in class f_{13} is larger and the geometry of the building, disperse.
- **247:** Classes f_9 , f_{10} , f_{13} previously described, were identified as well as class f_{14} , which presents a geometry of a dispersally occupied area with the density of its constructed area, above half of the lot.
- **249:** In this zone, the area occupied per lot presents a specific characteristic due to their recent implantation, with two distinguished classes. In class f_{15} , the area of the lots have lesser dimensions, when compared to the other classes, with a strong density. Class f_{16} is made up of pre-fabric houses, whose geometry is completely uniform and distributed in well delimited street blocks.

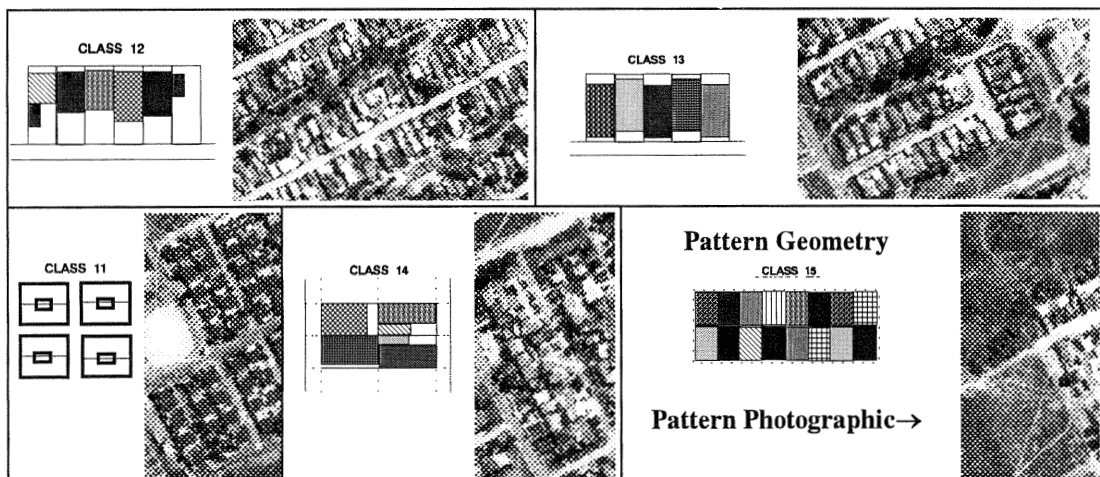


Figure 6: Standardisation of the photo-interpreted classes f_{12} , f_{13} , f_{14} , and f_{15}

parcels of land have a larger dimension and a lesser number of parcels of land per area. In class f_4 , a larger number of houses per square meter was observed (Fig. 4).

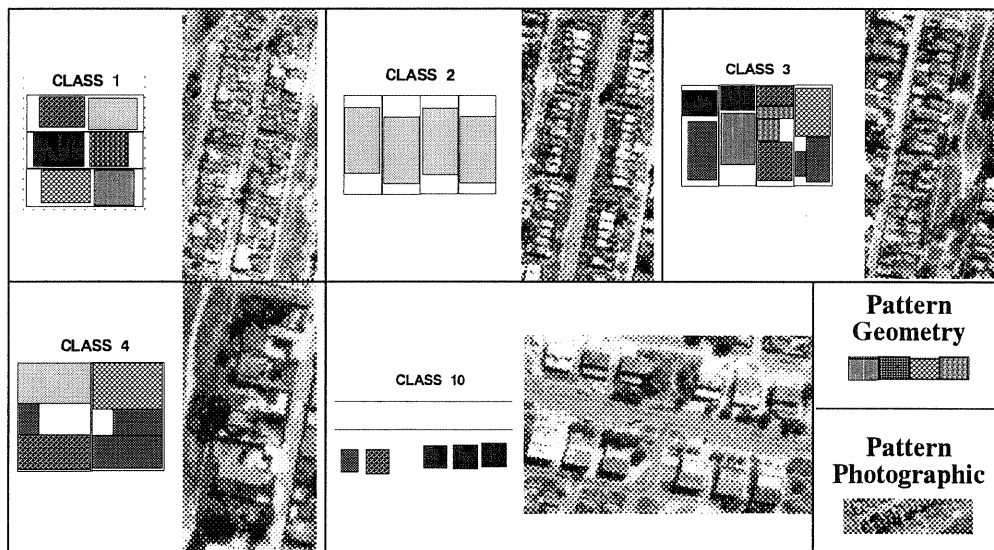


Figure 4: Standardisation of the photo-interpreted classes f_1 , f_2 , f_3 , f_4 and f_{10}

- **240-246:** Five classes: f_5 , f_6 , f_7 , f_8 and f_9 were identified. Class f_5 is characterised for being made up of a group of twin houses, in isolated groups without neighbors in the front or back area, and with tile roof types. Class f_6 , also has twin houses, but with a difference in the way it is connected with its next neighbors. Class f_7 , with a larger occupation per area in relation to the other previous classes, presented an answer to the average spectral, characterized by the distribution of the group of symmetric parcels of land with the mediation of a common free area for both. Class f_8 is identified as close to the habitation groups, with indications of non-projected habitation, of disperse geometry and with lesser density and the others, presenting little inhabited area per parcel of land. Class f_9 is made up of construction buildings, which can be easily observed through the projected shadow and their homogenous geometry. The areas of these zones denote characteristics of recent habitation, with signs of lesser urban development with relation to the other areas being studied (Fig. 5).

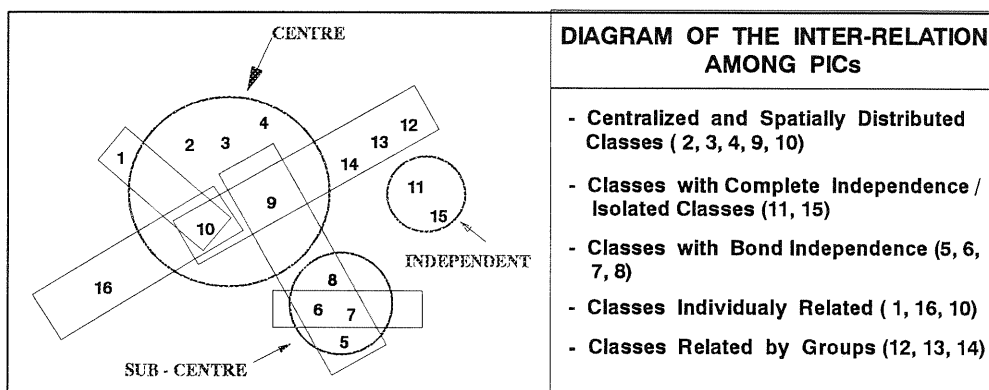


Figure 8: Diagram of the inter-relation among photo-interpreted classes in urban area of Sobradinho.

5.2 Calculation of the Generated Trip Factor per Photo-Interpreted Class

With the aggregation of generated trips per “censitaire” sector and the vectorization of each of the 16 photo-interpreted class areas, a matrix of correlation $M_{m \times n}$ of 64 “censitaire” sectors (sc_id) by 16 columns of the PIC areas (A_i) was created. Using these variables, the correlation for the equation of the matrix was determined, followed by the value of each of the factors for the generated trips for each class. Statistically, this correlation was solved through the Multiple Linear Regression method, attaining an average value and standard deviation for each one of the factors. Several simulations were carried out, presenting the solution attained from Eq. (11) which resulted in a better correlation (93%). In Table 1, the coefficient values for the PICs and the different land use patterns are shown.

$$\text{LOG}(V^{SC}) = \sum_{k=1}^{16} f_k A_k \quad (9)$$

$$\sum_{k=1}^{16} f_k A_k = f_1 A_1 + f_2 A_2 + f_3 A_3 + \Lambda + f_{14} A_{14} + f_{15} A_{15} + f_{16} A_{16} \quad (10)$$

$$\text{given } \varphi = \sum_{k=1}^{16} f_k A_k \quad \text{therefore } V^{SC} = e^{\varphi} \quad (11)$$

Table 1: Adjusted results for $\text{LOG}(V^{SC})$ model per PIC

Land use pattern	Photo-interpreted Class	Coefficient x 10^{-6} trips/m ²	Land-use pattern	Photo-interpreted Class	Coefficient x 10^{-6} trips/m ²
R. Buildings	f_9	1054,0	R. Houses	f_4	85,0
R. Houses	f_{15}	216,0		f_{14}	77,0
	f_6	201,0		f_{13}	54,0
	f_{12}	162,0	Mixed use	f_{16}	51,0
	f_1	143,0		f_2	45,0
	f_3	122,0	R. Houses	f_5	34,0
	f_{11}	106,0	Commercial	f_{10}	27,0
	f_7	94,0	R. Houses	f_8	-94,0

R = Residential

Mixed Use = Commercial, Residential and Garages

6 STATISTIC ANALYSIS OF RESULTS

With respect to the values attained, the variables to be considered in the quantitative and qualitative analysis process of the photo-interpreted class factors, were determined in function of the socio-economic data per "censitaire" sector, expressed in function of the family minimum salary wage, the patterns of habitation and land use, be it residential, commercial and mixed use (shops + residential, residential + garages), and of geometric patterns and resulting photographs from photo-interpretation.

By this way, it is noted that for a house pattern residential group, a sum of 12 houses is grouped. As was expected, it is in the building type of residential land use pattern, that the major trip generation factor is found in the function of the number of domiciles per square meter, also presenting one of the highest family wage rates. The least trip generation factor was also verified in the residential group in f_8 , with a negative value.

The existence of a negative factor in the grouping of the residential factors motivated the execution of a specific analysis of this class in the "censitaire" sectors where they occur, seeking to determine a relationship with the other factors exhibited in this residential group. Class f_8 was verified to exclusively belong to "censitaire" sector 20C together with classes f_5 and f_9 , thereby correlating with other factors. This fact shows that class f_9 influences f_8 , due to the building character of the first class, with a high rate of domiciles per square meter, when compared with f_8 of the house kind of residences. Therefore, the following hypothesis can explain this fact: the first one would be the necessity to verify the number of trips per square meter *in loco*; the second one, a new grouping of the photo-interpreted patterns to sector 20C; and the final one, the desegregation of the data from trips and traffic zones for the "censitaire" sectors which should be verified.

With respect to the mixed land-use and commercial pattern, the presence of classes f_2 , f_{10} and f_{16} was verified. Note that in these patterns, a reduced number of domiciles are presented, leading to small generated trip factors per square meter.

Finally, in the statistics analysis, certify that the probability level of the relation between the photo-interpreted class factors present satisfying results, since these values could be very different from the unit, showing a non dependent characteristic which is the basic condition of the multiple linear regression models. On the other hand, it could be observed that the "t" test values for classes f_2 , f_5 , f_8 , f_{12} and f_{13} are situated outside the probability curve, considering 95% of the representation. This means that these classes have some similar characteristics, with which a re-grouping process may become necessary. However, the model can be considered acceptable, based on the values from the probability level.

7 CONCLUSION

The model for the generation of trips which is established, making use of the potentials of GIS and RS, scene to be able to function as part of the urban transportation planning process. Through the use of aerial photographs, the model correlates land use and

transportation, which apart from being vital to the planning process, turns out as an assignment which requires the little data attained from land surveys, since it explores the resources in the spatial analysis of GIS.

Despite the advances reached in this study, the perspectives for the future show that there is still much to be done, both in the improvement of the model and in the possible future similar works for other transportation planning steps. Concerning the improvement of the model, its application can be seen in other urban realities, where the potential of GIS is each time more explored, thereby showing its first strides as a fundamental element in the transportation analysis. With reference to the future studies, there is an intention to work with refined formulations, so that the attained results may become even closer to ideal.

The Brazilian cities present similar urban structures, which can lead one to the definition of common photo-interpreted class patterns. It is believed that within the execution of some studies to elaborate a photo-interpreted class database, it could be possible to process the modelling developed only with the aid of aerial photographs. Such a fact, would certainly mean a reduction in the actual costs of attaining of the necessary information for transportation planning.

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