A COMPARATIVE STUDY OF ANALYSIS UNITS USED FOR TRIP PRODUCTION QUANTIFICATION*

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1. Introduction

It is axiomatic that the development of travel-demand models requires data, typically from a household travel survey. In this case, the division of the study area into smaller regions with homogeneous patterns of land using and socio-economic characteristics is fundamental to the transportation planning process. By this procedure it will be possible to organize the amount of data needed for demand studies and then to collect and to analyse these information. However, it can be outlined that good household travel surveys are quite difficult and expensive to conduct, because of the required sample size. Therefore, small metropolitan planning organizations face difficulties to develop this kind of survey[11). According to Bruton[2)], household units, census sectors and traffic zones can be mentioned as the most common units used in the transportation planning area. On the other hand, the homogenous geographical area (HGA) and Photo Interpreted Class Pattern (PICP), developed by O'Neill[9)] and Taco *et al.* [10)], respectively, can be considered as new units in this process. The difference between analysis units usually causes variability in the demand data representativity[7)]. These patterns can be changed according to the available data in each study. Ding[4)] mentions the relationship between the analysis units and the kind of data used in the studies, who claims that it is possible to get more representative information if data are grouped in homogenous unit patterns.

Today increasing possible variations in these characteristics and patterns can be noted, mainly because of the development of new technologies. Among these there are the Geographical Information System and the Remote Sensing, which are largely applied in transportation demand studies. Then, the different characteristics of analysis units in the demand trip production quantification can be outlined. In this approach, these different patterns are named as analysis units typology. As a result, the typology is defined here as a group of different characteristics observed in the demand studies modeling, such as the units forms and sizes, and the methodology applied to the units definition process. The main objective of this study is to verify and compare the real influence of analysis units typology in the trip production stage of urban transportation planning process. It is also important to validate the results, using well-known performance coefficients.

2. The Concept

(1) Study Area Division: Traditional Vision

In transportation studies, the appropriate number of traffic zones to a study area must be initially determined. Some rules to zone definition can be seen in O'Neill [9)] and Ding *et al.*[5)], as well largely discussed in transportation literature.

(2) New Technologies Used in the Study Area Division

The existence of new tools that have been largely used in the travel-demand studies is another resource on which the present approach is based. For example, Remote Sensing and Geographic Information Systems have been increasingly used in those procedures. The GIS is recognized as useful for data interpretation and analysis, mainly those from RS. These data can be treated and changed to new information, and largely used by transportation decision makers[12)].

A new methodology is here outlined. This method is used to identify the Photo Interpreted Class Patterns (PICPs), which is one of two units used in this work. For more detailed information about PICPs, see Taco *et al*[10)]. According to this author, the PICPs are defined as small homogeneous units, which are determined from diverse urban portions. The trip production is obtained from the area of each homogenous pattern, multiplied by its own trip production index. This index

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is determined for each square meter of PICP. The homogenous patterns definition is based in characteristics such as land using, construction density, and other urban parameters. The first step is to evaluate the urban characteristics using aerial photographs, trying to identify macro region patterns. After that, the photo interpretation technique is used to define building characteristics. The USGS – *United States Geological Survey* concepts are used to define the PICPs.

After the identification of existent patterns, it is possible to calculate the value of trips per square meter in each pattern. Here, the analyzed data are from a sample of the study area. The sample trip production is related to its pattern area, and then the index of trips per m^2 of each sample area is obtained:

$$fa = Va/Aa \tag{1}$$

fa is the trip index for the $PICPa$, $\forall\ a \in \{1, 2, 3, ..., A\}$; Va is the number of sample trip production in the $PICPa$; Aa is the PICP sample area (m^2). This index is then considered as the index to the PICP total area. It is important to emphasize that this methodology agree with the trip pattern homogeneity throughout the PICP. Equation 2 shows the trip production for the study area, where V_i is the number of trips produced in the study area i; and TAa is the $PICP$a total area, $\forall\ a \in \{1, 2, 3, ... A\}$.

$$V_i = \sum_{a=1}^{A} fa \times TAa \tag{2}$$

3. A Survey for a Real City

The survey was conducted in Sobradinho, a small city located 22Km northeast of Brasilia, the capital of Brazil. Specifically, a portion of downtown was determined as the study area (124.000m^2). 124 households were sampled, which provided weekday travel information. It is necessary to highlight that one goal of this study is to compare the trip production results predicted here with the real data from study area. Consequently, a small area was admitted as the object of study.

(1) Household Survey

Traditional procedures to collect travel household information were applied here. In order to fulfill the objectives of the study, the survey was done considering all households located in the study area. Sociodemographic information are summarized in Table 1, and travel information obtained for the study area are presented in Table 2. These are separated by the purposes defined for this approach (home-work, home-school, and home-other). The region is characterized by medium/low residential and population density. This real data set provides a direct comparison with the travel data from the two methodologies (applied to TZ and PICP) being studied.

Table 1: Socio-Economic Characteristics of Study Area

	Population	Number of Business People	Number of Scholars	Number of Vehicles	Energy Consumption (R$)*
Total/Zone	547	257	176	193	8.921
Average/Domicile	4,41	2,07	1,42	1,55	71,95

* The currency used is Real (Brazilian currency: US$1 was similar to R$2.8 at the study time).

Table 2: Trip Producted in 24h

Purpose	Trip
home-work	473
home-school	331
home-other	385
Total	1189

(2) Other Sources of Data

Other two sources of information were used: first household construction patterns, land topography and topology, and aerial photograph were collected from Planalto Central Development Company[3]. The other one was the work by Taco *et al.* [10], which is the framework to the PICP modeling.

4. Trip Production Models

In this item the TZ and PICP units were used to simulate the trip production in the study area. In order to evaluate units typological characteristics, it must be reminded here that different methodologies were applied to each analyzed unit. The trip production estimation was then performed using household collected data. The sample set used for this part of the study was 50% of household data (sample of 62 out of 124 households). This considerable sample rate was resulted from the small universe of household used for this study. The sample size was determined using traditional methodology[8].

(1) Trip Production from TZ

Multiple Linear Regression model (MLR) was applied in this stage to simulate the number of movements produced in referred area. Since the area presents homogeneous patterns, required in transportation studies, the total study area was admitted as one TZ by CODEPLAN[3] previous study. The trip production estimated results are summarized in Table 3. In this table some multiple linear regression (MLR) model parameters are also presented.

Table 3: Trip Production Estimative from ZT

PURPOSE	VARIABLES	COEFICIENTS MODEL	TRIP PRODUCTION (TOTAL)	TRIP PRODUCTION (PURPOSE - %)
HOME-WORK	*EP* *EN*	$\beta_1 = 0{,}717$ $\beta_2 = 0{,}191$	304	33,1
HOME-SCHOOL	*ET* *EN*	$\delta_1 = 1{,}348$ $\delta_2 = 0{,}011$	335	36,5
HOME-OTHER	*RS* *EN*	$\gamma_1 = 0{,}217$ $\gamma_2 = 0{,}018$	279	30,4
TOTAL	—	—	918	100
EP = business people/domicile; *EN* = monthly energy consumption; *ET* = scholars/domicile; *RS* = people/domicile				

(2) Trip Production from PICP

Based in the methodology previously discussed, three different PICP were defined. Some parameters, such as household size, yard and garden existence and household building characteristics were analyzed here (Table 4). The trip production results from PICP are shown in Table 5. In order to perform the comparison evaluation proposed, the information resulted from the simulation of trip production were aggregated.

Table 4: PICP Characteristics

PICP	Household Size	Yard Existence	Garden Existence	Building Detaile
$PICP_1$	big	yes	yes	house
$PICP_2$	medium	yes	no	house
$PICP_3$	small	no	no	commerce

Table 5: Trip Production Estimative from PICP

PICP	fa (V/m^2)	*Area* (m^2)	$Vi_{estimated}$
$PICP_1$	0,015593646	22.809	355,67
$PICP_2$	0,024403233	25.254	616,27
PICP3	0,015794914	9.401	148,49
TOTAL	—	57.464	≅ 1121

4. Discussion of Results

(1) Trip Production Results

An index, the *precision index (Pi)*, was introduced to evaluate trip production results. This index was calculated for the two units using the relationship between estimated and observed trip production. Table 6 summarizes these results, and shows the *Pi* calculated for TZ and PICP. Comparing these results with actual trip production (1,189 movements, obtained from household survey), it can be noted that PICP estimation is an expressive representation of trip production, which can be also seen from *Pi* results. It is also shown that the trip production estimated for TZ presented an acceptable value.

Table 6: Trip results and Precision Index (*Pi*)

ANALYSIS UNIT (AU)	TRIP PRODUCTION (TP)	PRECISION INDEX (*Pi*)
TZ	918	0.7721
PICP	1120	0.9419

Table 7: R from TZ and PICP

MODEL		DETERMINATION COEFICIENT (R)
TZ	Home-Work	0.898
	Home-School	0.626
	Home-Other	0.550
PICP		0.901

(2) Models Representativity Analysis

In modeling works, one important question that arises is how well the model can represent the real world. Among large numbers of parameters used to evaluate the quality of models there is the Determination coefficient (R) – this represent relationship intensity between the estimated variable and other variables used during the modeling process and result data representativity[6)–8)]. In Table 7 the results for R can be seen, considering both analysis units. Statistics literature indicates results from 0.5 as admitted values to R coefficient, which makes all of the models used here acceptable for transport applications. However, it is known that the near the result is to 1, the better is the model reality representation. Thus, again the PICP showed better results as shown in Table 7. The results for TZ are acceptable although the models defined to home-school and home-other purposes (0,626 and 0,550 respectively) showed less representativity. It can be considered that maybe some variables used in this model do not represent properly the dependent variable (trip production). This situation highlights the need of using appropriate variables to represent the urban reality, in order to obtain good results to travel-demand models, such as trip production models, which deals with people movement desires.

(3) Topologic Characteristics Discussion

Some questions about the different characteristics of analysis units are here discussed. First of all, the unit definition is treated. As most of the traditional approaches, population socio-economic characteristics, as well as some other natural and/or artificial borders (for example, river course, railroad, and borders used in previous studies) were used here to define the traffic zone unit. However, some authors regard this kind of procedure as incomplete for transportation studies, as well as important parameters for travel decision action, like spatial characteristics, are not observed[1)]. Moreover, spatial characteristics were analyzed by the use of aerial photographs to define the PICPs. This point shows that urban characteristics must be verified in trip generation prediction studies. Another important aspect noted here is the unit size. Big size units can influence negatively the quality of model results, mainly if they are considered the question of aggregation (in terms of amount of information) and homogeneity (similarity of information in a same unit). These two parameters are directly related, that is, the bigger the amount of information aggregated in the same unit, the smaller the level of homogeneity. Hence, far from the reality will be the prediction results[1)]. In the presented situation, it can be clearly seen that PICP have shown better results for trip production estimation than TZ.

Described topics conduct this discussion to question about information quality applied in travel demand model studies. It could be seen here that different kinds of information probably conduct studies to different results. In this approach, described data were used to estimate trip production in the TZ unit, as occurs traditionally in transportation studies. Searching for the same objective, spatial information in the PICP based model was applied with very good results.

5. Conclusion

Some aspects, rarely addressed in transportation planning studies (mainly because of the traditional point of view, that usually do not deal with quality of information used in travel-demand modeling studies), were here discussed. It was possible by the use of a real data set (100% of trip production information in the study area). It must be pointed that the use of appropriate information is fundamental in transportation modeling studies. This can be seen in the TZ and PICP comparison. Consequently, it can be concluded that quality of information can never be separated from spatial characteristics analysis in trip production research. Thus, continuous searching for new and more appropriated methodologies is absolutely necessary.

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