TRIP GENERATION MODEL BASED ON HOUSEHOLD THROUGH CROSSED CLASSIFICATION TECHNIQUE IN THE MUNICIPALITY OF PALMIRA, COLOMBIA

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ABSTRACT

The process of transportation planning have to be understood as a collection of activities related one to another, that have the aim of optimize the conditions of mobility of people and in turn, to improving the life quality of citizens.

On this context, the trip generation forms part of this process of planning and it's essential to the model development called as sequential and its purpose is quantifying and qualifying the demand of trip of a city, with the objective of, on subsequent phases, it can to be contrasted with the transportation offer on different temporal horizons.

Thus, the present work proposes a trip generation model, for the municipality of Palmira, based on the Crossed Classification Technique, with a special interest put on the trip that are started or finished in household, or called as well as household based-trip.

The classification of the information for the definition of Transportation Analysis Zones -TAZ-, the characterization of the same according to the household survey and the trip generation model developed were spatially represented by the development of thematical maps as a analysis tool allowing quickly to understand the behavior of each zone on different temporal boundaries, recognizing trends, concentrations, variations, etc. This cartographical tool helps

the interpretation and explanation of behavior of variables that participate into building of model.

The work methodology was started with the zonification of areas relatively homogeneous called TAZ. Subsequently, with the collected data from the municipality through of Origin-Destination Household Survey, the average income for each TAZ and the percentage of household on each income range, on this stage were estimated, in the making of graph relating the average income by TAZ and the percentage of families by income range, the interpolation method of Cubical Tracer was used, the vehicle holding by family for each income range, the number of trip by household by day for each income range with vehicle holding, the number of total trip by day generated on each TAZ were calculated, and finally, the trp purpose categories: work, studies and others; were generated.

The technique of crossed classification is very useful for studying the quantity of generated trip on household for each trip purpose, with the exception of that for validate this technique is necessary rely on all the base information as historical data and other samples that allow to check the sound index of technique.

In conclusion, the technique of crossed classification shows some difficulty on the incorporation and interrelation of newly variables, limits the precision of estimation of future demands but the stability of supposed relations is acceptable.

Key words: Generation, trip, forecast, demand, transportation.

1. INTRODUCTION

The planning process of the transportation systems is a rational process that pursues to generate not biased information. This process is not addressed to generate a decision or solution that has to be taken, although that can be in this way on the relatively simple situations. Instead of that, the process pursues to give suitable information to those ones that will have the responsibility of decide if a transportation project has to go on.

The pursuit of this objective implies a group of processes characterized by the number of involved variables. Therefore, for estimating the impact of the different options is necessary to making models that allow to define the characteristics of system and to facilitate the decision making.

The most employed focus for the Transportation Planning is the “four steps process”: The Trip Generation, Trip Distribution, Mode Selection and Transit Assignment, see Figure 1. The generation - attraction of trip, is the process for determining the number of trip that are to be started or finished in each zone, into a study area.

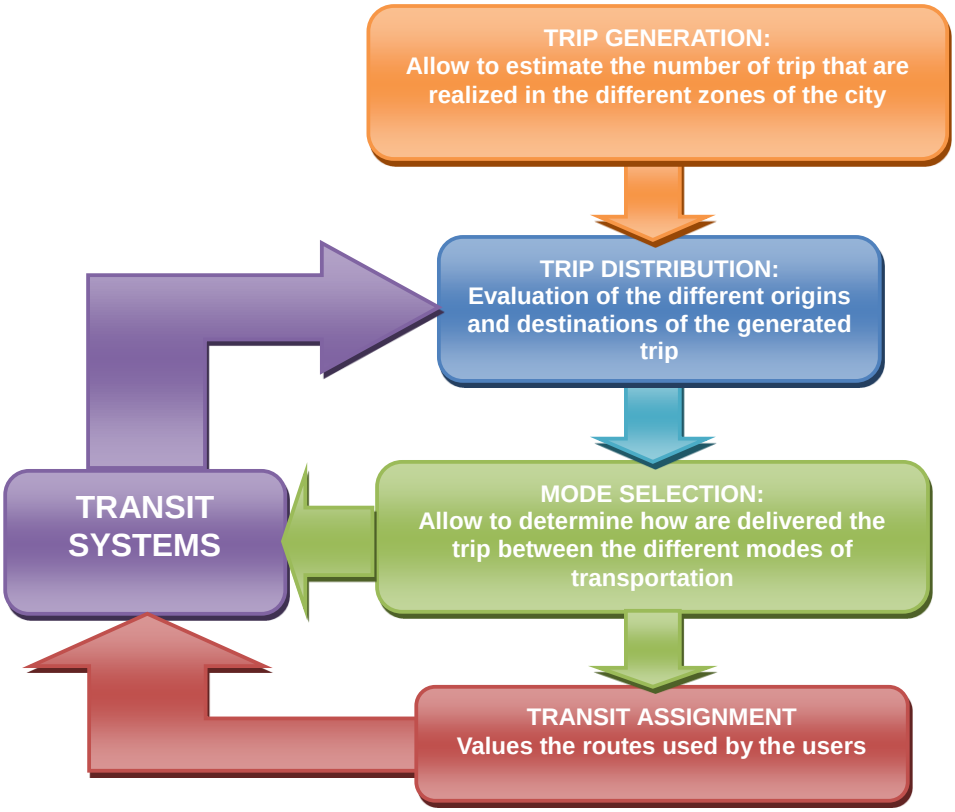

Figure 1 – Transportation Model of four stages or Conventional Model of transportation. Source: modified from the Methodological proposal for the elaboration of a transportation plan for La Ciudad Real, Spain, 2007.

For the municipality of Palmira is posed a model of analysis by crossed classification for determining the Trip Generation in the municipality of Palmira with a reliable forecast, from a sample of 2677 data, obtained from 421 Origin-Destination surveys to household realized in the urban zone on the year 2006.

The municipality of Palmira has a population of 223049 inhabitants in the urban zone and 55339 inhabitants in the rural zone. Its urban zone covers an area of 1123 Km^2. The economical institutions take up the territory on this way: 56.3% on the business and urban sector, 32.6% on services and the 9.6% on industry; its main economical activities are agriculture, livestock, trade, industrial and agricultural centers, business and mining.

2. METHODOLOGY

2.1 Information Collecting

Today we count on with an estimative growth technology for the Trip Generation. Such technology can to be improved for giving global projections that can be more in accord with reality and be suitable to be used as base information for the four staged model in future scenarios. From Road Plan of the municipality was taken as a base its classification of the TAZ's, which has as criterion that those household what constitute each TAZ have homogeneous socio-economical characteristics. See Figure 2.

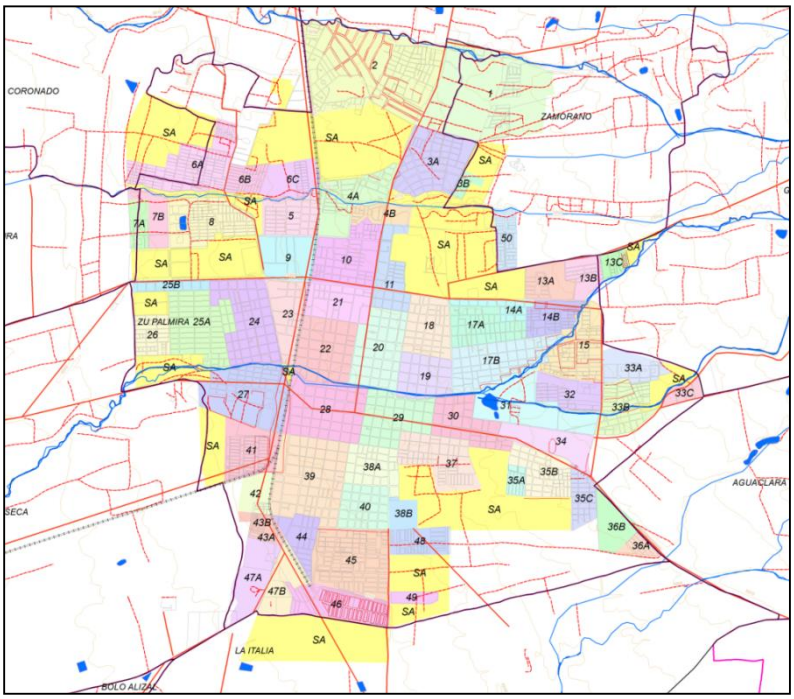

Figura 2 – Municipality of Palmira divided on the studied TAZ`s. Own elaboration.

2.2 Statistical analysis of variables

On this stage the existent information about origin and destination study carried out by the municipality on the year 2006, was checked and purged. Given that proposed models for the case on study estimate the number of generated trip at the level of household, all the variables that represent in a proportion the household socio-economical characteristics were included in them. In the Figure 3 is shown the flow of the variables in the development of the proposed methodologies.

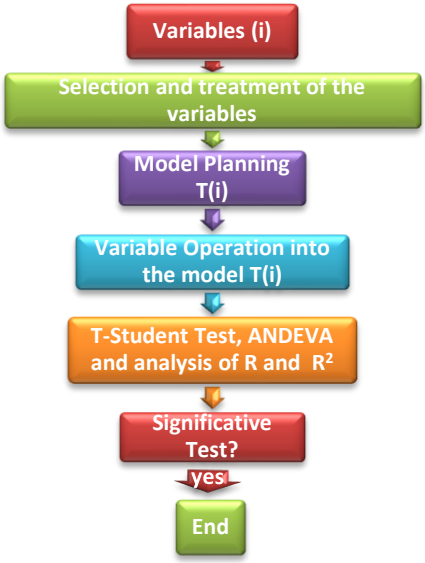

Figure 3 – Flow of variables in the development of the proposed methodologies. Own elaboration.

2.3 Calculation of Trip Generated by Each TAZ

2.3.1 Estimation of average income by each TAZ and the percentage of household in each income range

For obtaining the average income graph against the percentage of families by income range, an interpolation was realized using traditional polynomical methods. However, an irregular behavior of the curves that not represented a natural behavior of data was observed. For such a reason, it proceeded to using the interpolation method by Cubical Tracers (a polynomical function defined at parts with the second continuous derivative used for interpolation of point groups), which gives very much natural curves.

The function that represents the cubical tracers is:

$$S_j(x) = a_j + b_j(x - x_i) + c_j(x - x_i)^2 + d_j(x - x_i)^3$$

Where: $x_j \leq x \leq x_{j+1}$

Each is calculated between the average income ranges.

2.3.2. Vehicle holding by family for each income rage

The number of vehicles was classificated onto three categories thus: 0, 1, 2, or more vehicles. The number of trip by household by day was calculated for each income range with vehicle holding, and finally the total number of trip by day generated on each TAZ was calculated by the following equation:

$$P_{gh} = HH * I_g * A_{gh} * P_{H\ gh}$$

$$P_T = \sum_{g}^{5} \sum_{h}^{5} P_{gh}$$

Where:

= Number of families of TAZ
= Percentage of families in the TAZ with a range ***g*** of incomes (1, 2, 3, 4, 5)
= Percentage of families in the range ***g*** of incomes with ***h*** cars by family (*h* = 0, 1 o 2+)
= Number of trip generated by day in the TAZ by the members of the family with a range **g** of incomes and a car holding of **h**.
= Number of trip generated by day in a family with the range **g** of incomes and an **h** car holding.
= Total number of trip generated in the TAZ.

For the family number of each TAZ was relied on the household and inhabitants information in the municipal head. The average inhabitants/household value was calculated in the following way:

$$n = \frac{\text{inhabitants number}}{\text{household number}}$$

Obtained the n value, the household number by TAZ was calculated, thus:

$$\text{hogar}_{TAZ} = \frac{\text{inhabitant s}_{TAZ}}{n}$$

With the calculated values on each one of mentioned steps, the generated trip by day in each TAZ were calculated.

2.3.3. Categories calculation according to the trip purpose

As trp purposes were defined the following ones: Trip to the workplace based on household (***TBH*** *by its initials on Spanish*), Trip to the study place based on household (**EBH** *by its initials on Spanish*), Another trip based on household (**OVBH** *by its initials on Spanish*), and Trip no based on household (**VNBH** *by its initials on Spanish*). With this classification the trip percentage for each purpose into the income range was calculated, and based on these percentages the generated trip number in each TAZ by each trip purpose was calculated.

2.4. Cartographical visualization

The information classification for the definition of TAZ's, the characterization of the same ones according to the household survey and the trip generation model developed were spatially represented by means of development of thematical maps as a analysis tool that allows quickly understanding of the behavior of each zone in different temporal boundaries, recognizing trends, concentrations, variations, etc. This cartographical tool favors the interpretation and explanation of behavior of the variables that participate into the model making.

3. RESULTS

In the Table 1 the variables that were included on this analysis and the main statistics of them are presented.

Table 1 - Statistical data of the considered variables.

No. Variable	Mean	Median	Moda	Standard Deviation	Variance	Variation Coefficient	Minimum	Maximum
Status	2,846	3	3	0,748	0,559	0,263	1	5
Bicycle	1,268	1	1	1,133	1,283	0,893	0	6
Car	0,285	0	0	0,513	0,263	1,802	0	3
Motorcycle	0,457	0	0	0,597	0,356	1,307	0	3
Taxi	0,025	0	0	0,155	0,024	6,290	0	1
Motorcycle -taxi	0,018	0	0	0,163	0,027	9,035	0	3
Another vehicle	0,008	0	0	0,118	0,014	14,574	0	2
Age	34,635	35	40	17,288	298,868	0,499	2	100
Education	2,397	2	2	1,305	1,703	0,544	1	7
Activity	2,230	2	2	1,127	1,269	0,505	1	6
Trip purpose	2,571	2	2	1,541	2,375	0,599	0	7
Income	2,517	2	2	0,837	0,700	0,332	1	5
Sex	1,495	1	1	0,500	0,250	0,334	1	2
Innahibtants number	6,454	6	4	3,118	9,720	0,483	1	18

Below is showed the variation of average income by each TAZ for the different categories of income and vehicle holding (See Figure 4). On there is observed that for each average income there is a certain percental composition of families of each income range, where the total sum of any average income selected has to be equal to 100%.

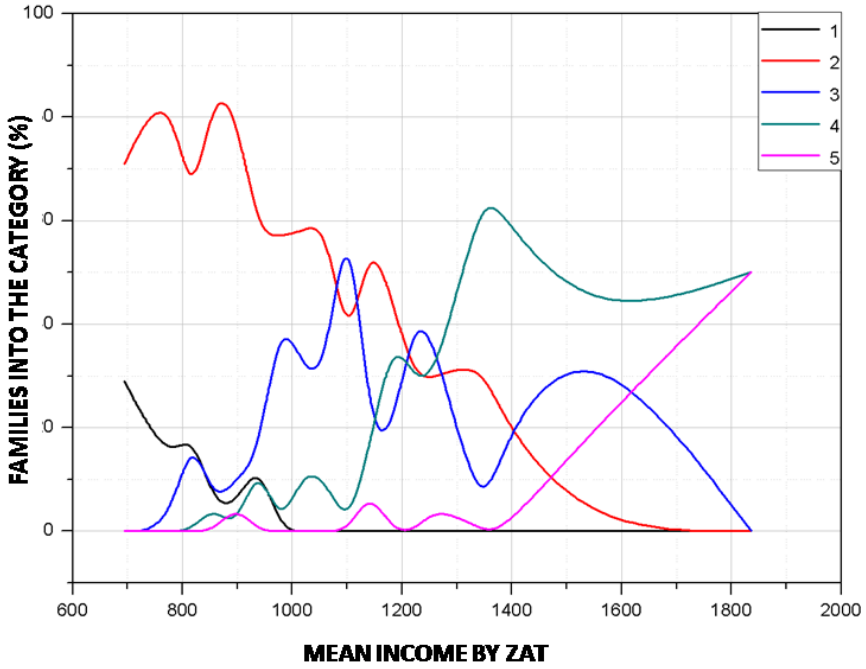

Figure 4-Average income by TAZ (in thousands of pesos) against the income category.

In the Figure 5 is observed the relation between the vehicle holding with the mean income ranges, where the families with vehicle present a continuous growth, occurring the opposite with the families that have not a vehicle where a decreasing is presented.

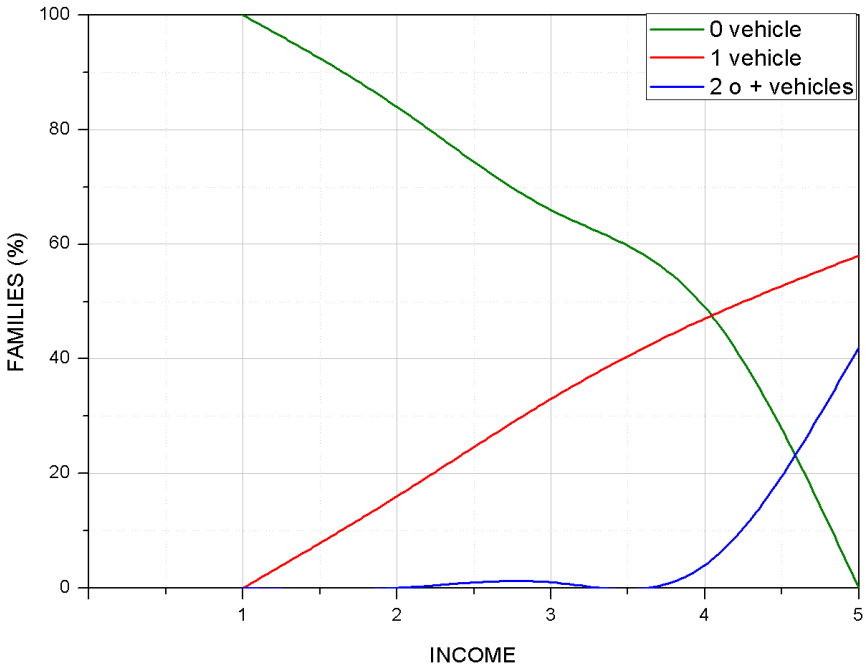

Figure 5 - Families by vehicle holding and income range.

For the trip number by family in function of the vehicle holding and income, you can to see in the Figure 6, in where is observed that up to the third mean income a growth of trip number/family is presented, which is only maintained for the families with vehicle holding.

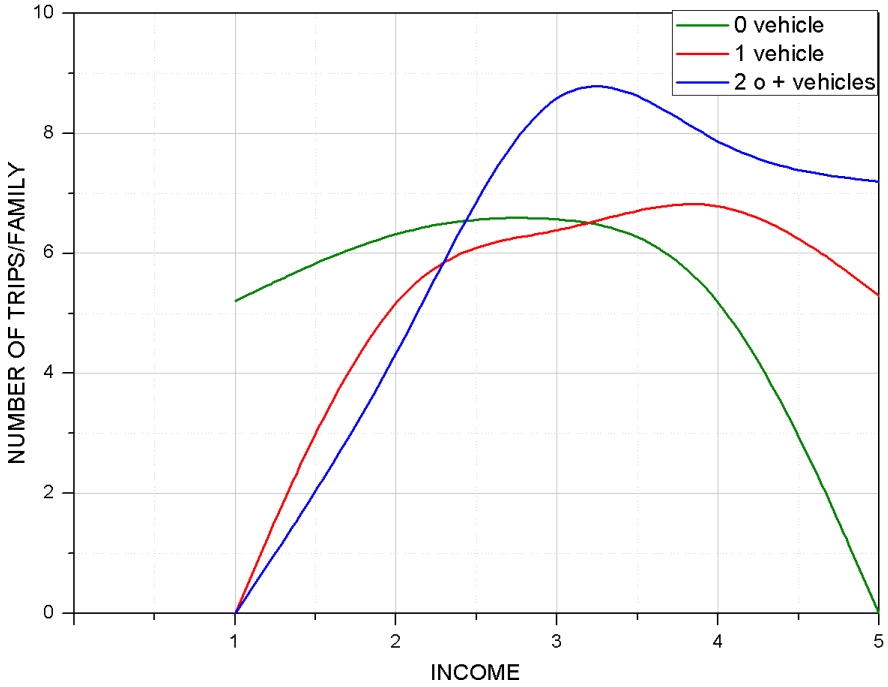

Figure 6 - Trip by family in function of vehicle holding and income ranges.

The calculation of mean number of inhabitants/household was realized thus:

Population of urban head: 223.049 inhabitants
Household number: 74.948

$$n=\frac{223.0499 \text{ inhabitants}}{74.948 \text{ household}}$$

n ≈ 3 mean number of inhabitants/household

By comparing this value with official data of DANE (2005 Census), which has for the municipal head a value of 3.6 persons by household, with the one calculated of 3 persons by household, is had an 83% of reliability.

In the Figure 7, is observed the trip percentage of each purpose in function of mean income. The not based on household trip along with other trip not based on household are the ones that represent the biggest proportion of the trip, approximately 80% and presenting a homogeneous behavior for all the categories.

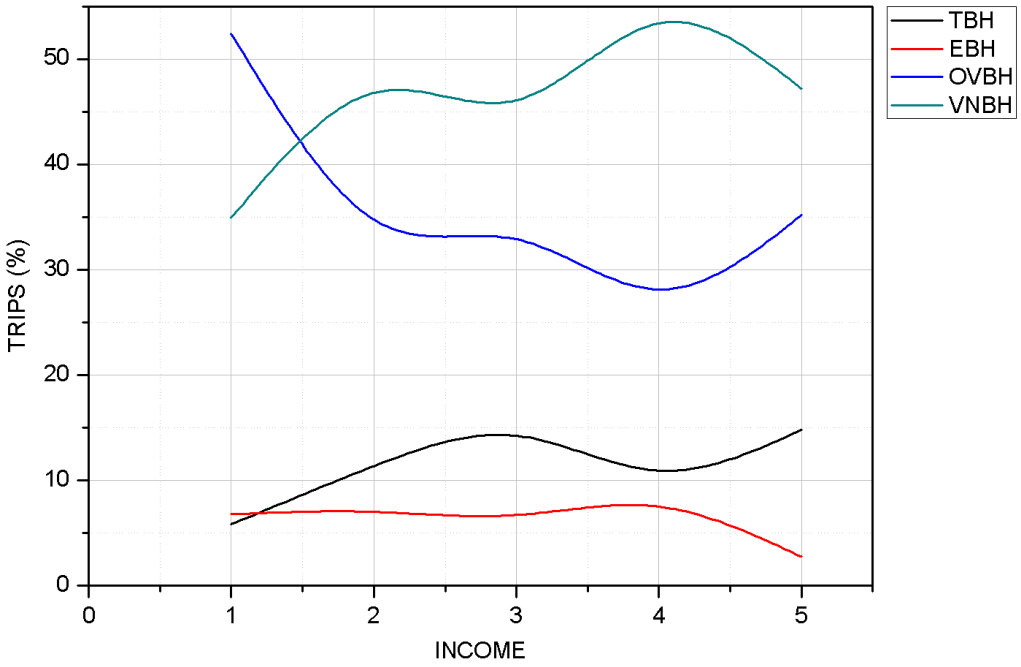

Figure 7-Trip by family en function of income and reason of the trip.

On the Table 2, are observed the household based-trip by each TAZ according to the Multiple Linear Regression models (RLM by its initials on Spanish), Analysis by Category, Crossed Classification and Total of trip by each model. The following equation obtained by means of the Multiple Linear Regression models, define the proposed model as characterization, operation and analysis of trip generation by household.

$$T = K + b_4 * x_4 + b_5 * x_5 + b_2 * x_2$$

Where:

b = coefficients
K = intercept
x_2 = total of people by household.
x_4 = Number of bicycles by household.
x_5 = Number of motorcycles by household.

This equation was the selected one owing to that it presented the biggest values of R^2 with respect to the other proposed RLM. Moreover, were obtained the values of t, *Prob.>|t|, R, R^2, F y Prob.>F* of this selected model for each one of TAZ of the study.

Table 2 - Household based-trip by each TAZ according to the Multiple Linear Models, Analysis by category, Crossed Classification and total of trip by each model.

TAZ	RLM Equation (14)	Crossed classification	Categories Analysis
	Population TAZ*(Trip/household)	Car	Car + Motorcycle + Bicycle
2	99.203	30.450	50.799
3A	25.176	8.881	31.726
4B	10.806	14.645	11.213
5	28.984	10.026	46.478
8	102.466	30.936	82.895
10	40.768	14.706	46.695
11	20.340	6.530	37.050
13A	2.800	801	3.440
13B	15.810	3.349	5.789
14A	19.420	70	13.911
14B	29.607	9.543	26.148
15	53.986	16.256	58.536
17A	24.732	13.258	56.109
17B	24.732	13.258	56.109
18	42.381	12.922	45.412
19	6.047	60.964	50.584
20	48.788	14.073	59.885
22	36.537	11.319	55.258
25A	56.642	20.096	93.454
26	27.221	8.237	32.622
27	32.890	10.959	49.055
28	18.867	9.548	16.084
29	33.407	14.105	25.050
32	25.954	8.780	32.190
33B	36.458	11.008	48.122
35B	39.867	10.513	38.898
35C	41.207	4.518	9.245
37	40.415	13.302	52.273
39	58.153	17.629	77.627
40	14.154	4.405	13.200
43A	5.808	1.947	4.200
45	44.620	13.616	65.885
46	47.257	14.439	66.226
TOTAL	**1.155.499**	**435.089**	**1.362.168**

The spatial distribution of calculated trip by the base year with the Crossed classification technique can to be observed in the Figure 8.

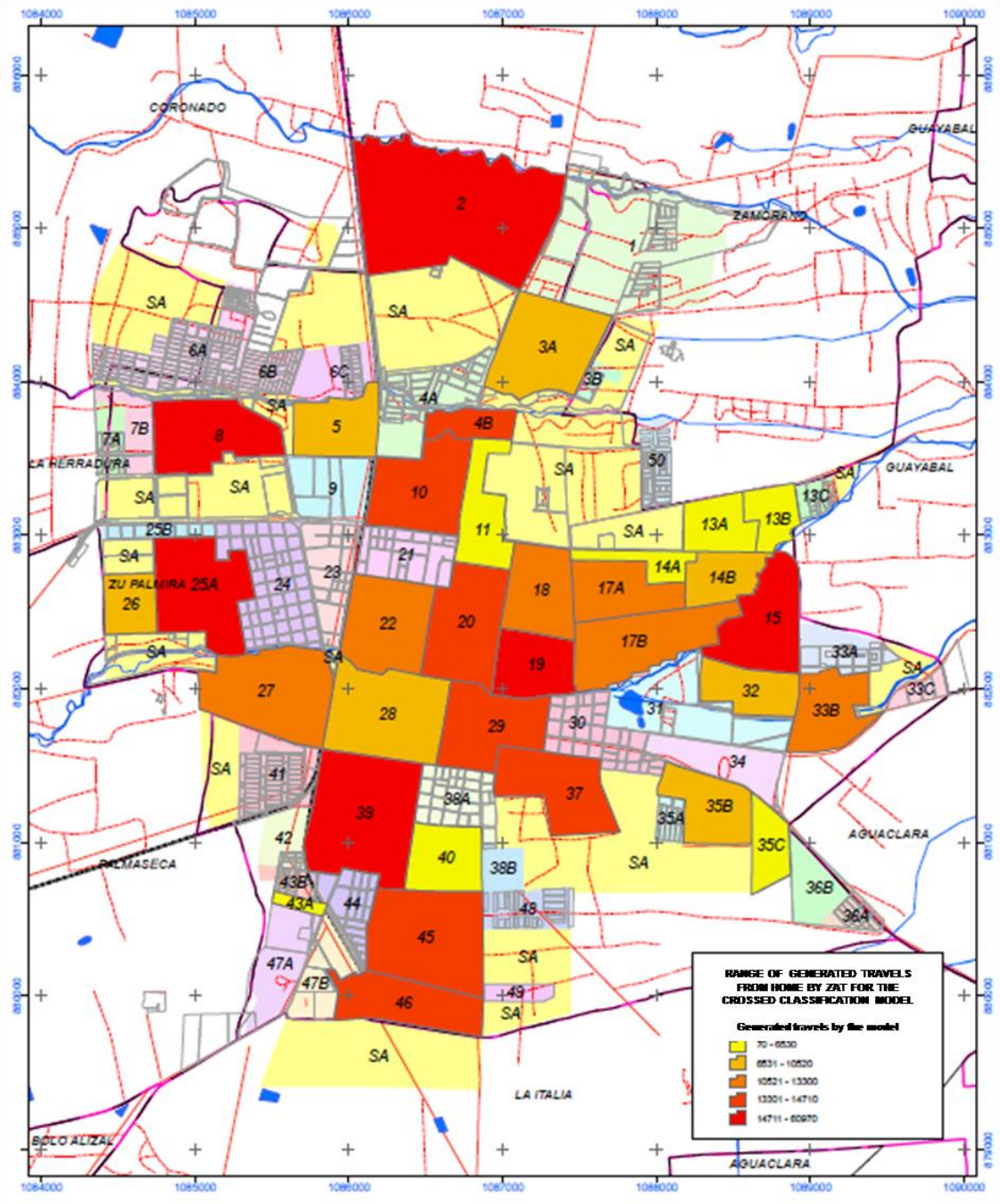

Figure 8 - Household based-trip by each TAZ.

In the Table 3 a summarized box of the main advantages and disadvantages that are presented by each one of the employed models for the estimation of trip in the municipality of Palmira is showed.

Table 3 - Summarized box of advantages and disadvantages of the different worked models for the determination of generated trip that are based on household.

Characteristic	RLM Analysis	Analysis by Categories	Crossed Classification
Conceptual Simplicity	Reasonable	Very simple and intuitive	
Size of the required sample	Reasonable	Very high	Very high
Stability of model	Good	Good	Good
Capacity of verifying the significance of the explanative variables	Good	It can not	It can not
Capacity of incorporate new variables	Very good	Very difficult	Very difficult
Problems of inter-correlation between variables	Considerable	Some, in particular if new variables are introduced	Very difficult
Software availability	Very good	Limited	Limited
Precision on the future estimations	Very good	Limited	Limited
Specialization of the estimations	Very good	good	It can not
Stability of supposed relations	Very good	Limited	Very good

4. CONCLUSION

The crossed classification model is a very simply method that works with relatively homogeneous groups, involving not complex mathematical relations, allowing to estimate the number of trip by household, on income classifications and determined trip purpose (TBH, OBH, etc.) for each one of the TAZ and total value, obtaining a value of 421830 trip by municipality.

Owing to the characteristics of crossed classification model is not possible to check the significance of chosen variables and a very big sampling is required, which in the case of Palmira it was very small, there was not similar historical data, and some of the used variables were estimated (number of households by TAZ, lacking income data), which would add an uncertainty even bigger.

The theoretical frame proposed by classical models has as main variables the car holding, the income and stratification. These models were developed in United States and England, in where the car holding are predominant and socio-economical variables that divide the TAZ are marked.

The base hypotheses of the classical methods are not applicable to the sample of the municipality of Palmira owing to by carrying out the analysis of calculated trip, was possible to observe that its behavior not followed the trend that is presented into the places of origin of these models. The calculated trip with the classical models only represent a portion of the whole of generated trip, leaving out the trip explained by variables as the bicycle or motorcycle holding, this transportation means being characteristically of the municipality.

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