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Counting Demand Of Vehicles To Be Parked By Mathematical Equation

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Abstract

The importance of the research lies in the need to give the problem of saturation and reduction of mobility an optimal solution that professionally guarantees positive results, to solve the crisis of vehicular demand during peak hours of tourism, in order to consult and analyze specific information of the sector of the urban area of the municipality of Chinácota, in which the procedure to formulate was developed and applied by performing traffic counts in that sector of the urban area of this municipality. The information that has been used to support the research is represented by physical and digital documents of inventory records of the road network, mapping of the place, surveys of parking areas usually used, observation and counting of vehicles in the field. Subsequently, the survey was divided into four parts equivalents to 25% each, taking as independent counting zones a 50% central sector and one in each corner of the block, which is complemented with the remaining portion of the contiguous block to result in another 50%. The counts were conducted on a deferred basis, during weekends, long weekends and holidays during the months of November 2019 to March 2020. Depending on the season and some uncontrollable causes such as the weather, the economy, and recently the coronavirus pandemic that significantly slowed trade and tourism in the municipality in recent weeks, the counts of the demand for vehicles to park may vary tending to increase.

Keywords: count; tourism; demand; vehicles; parking.

1. Introduction

Many municipalities, such as Chinácota, which is the focus of this project, are highly touristic or commercial, either permanently or at certain times during certain seasons of the year, which particularly makes it highly visited on weekends, especially holidays and vacation seasons. A constant problem has been observed with respect to congestion and high traffic due to the enormous volume of vehicles that

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circulate through the place and that generally go to commercial sites for tourism, stopping in the main and even secondary roads, obstructing the passage of other vehicles and in the best of cases reducing the effective width of the road to a single lane, which generates a slow flow given the high vehicular flow that is derived by the different bifurcations of the subsequent roads, which causes the speed of traffic to be reduced considerably.

This problem not only affects visiting drivers but also the drivers of cargo vehicles that generally carry agricultural and livestock products as well as other goods demanded by neighboring towns that must travel through the urban center of this municipality because there are no alternative routes that are similar in distance or time. Among others, passersby are also affected because it is difficult to move freely along the road, which generally leads to traffic jams during peak tourist hours, which are very common, preventing proper mobility, delaying the plans of many tourists and therefore the commercial demand of the area, which directly affects their income and indirectly affects the jobs and supplies of the population in question.

Vehicular congestion or vehicular overload refers to the condition of a vehicular flow that is saturated due to excess demand on the roads, producing increases in travel times and traffic jams. This phenomenon commonly occurs during peak hours or rush hours, and are frustrating for motorists, as they result in lost time and excessive fuel consumption (Wikipedia Organization 2019).

The consequences of traffic congestion result in accidents, despite the fact that cars cannot travel at high speed, since the motorist loses his calm when he is static for a long time in one place on the road. This also leads to road violence, on the other hand, it reduces the severity of accidents since vehicles do not travel at a high speed to be victims of damages or injuries of greater severity. Also, vehicles unnecessarily waste fuel due to being idle for a long time in the same place, without moving from one point to another.

Mathematically, the vector space R2 corresponds to what is called the real plane and has dimension 2. Traditionally, the set of vectors (i, j) is taken as the basis for this space, such that: i = (1; 0) and j = (0; 1). The set (i, j) is called the canonical basis. In the geometric representation of elements of this space, the vector i corresponds in the coordinate system to the x-axis, and the vector j corresponds to the y-axis; thus any vector u = (x; y) in the plane is usually written as u = (x; y) = xi + yj. The real numbers x, y are called the components of the vector u in the basis (i, j) (Monographs (2019).

Geometrically the maxima and minima of a function of two variables (Granville, W. A., Smith, P. F., Longley, W. R., & Byington, S. T. (1980) measure maximum and minimum altitudes on the surface that constitutes the graph of the function (they are like the coordinates of the highest point of a hill or the deepest point of a gully). However, just as the Weierstrass theorem guaranteed the existence of absolute maximum and minimum of a function y = f(x) continuous on $[a, b] \subset R$, it can be shown that z = continuous f(x, y) reaches its absolute maximum and minimum values in a closed (including the edge) and bounded region D of the plane (Universidad politécnica de Madrid (2019).

2. Method

2.1. Obtaining and analyzing sample information

The information that has been used to support the research is represented by the following physical and digital documents, which are not included in this report:

- Cartographic map of the sample area, which includes the road network of the sector.
- Inventory of public and private parking lots in the sample area.
- Surveys of road users who use the road for parking.
- Municipal land-use planning scheme to review the use of land in the area.
- use of land in the area.
- Count of parked vehicles.

The above, in their respective order, have been obtained from the following sources:

- Satellite geo-location software: Google Earth and Google Maps, both from the company Google LLC, main subsidiary of the U.S. multinational Alphabet Inc,
- Record taken in the field by the author of the project.
- Survey taken in the field by the author of the project.
- PANACEA S.A.S. consulting group, public forums held in the house of culture of the urban area of the municipality, between Saturday 14 and Sunday 15 March 2020 (PANACEA S.A.S. consulting group, 2020).
- Consulting contract No. 187 of 2019 with the purpose of consulting for the formulation, agreement and adoption of the land use planning scheme (EOT) of the municipality of Chinácota.
- Record taken in the field (Sepúlveda Celis, S. E., 2019).

The analysis of the information obtained is performed within the following sections, as required.

2.2. Sample transit counts.

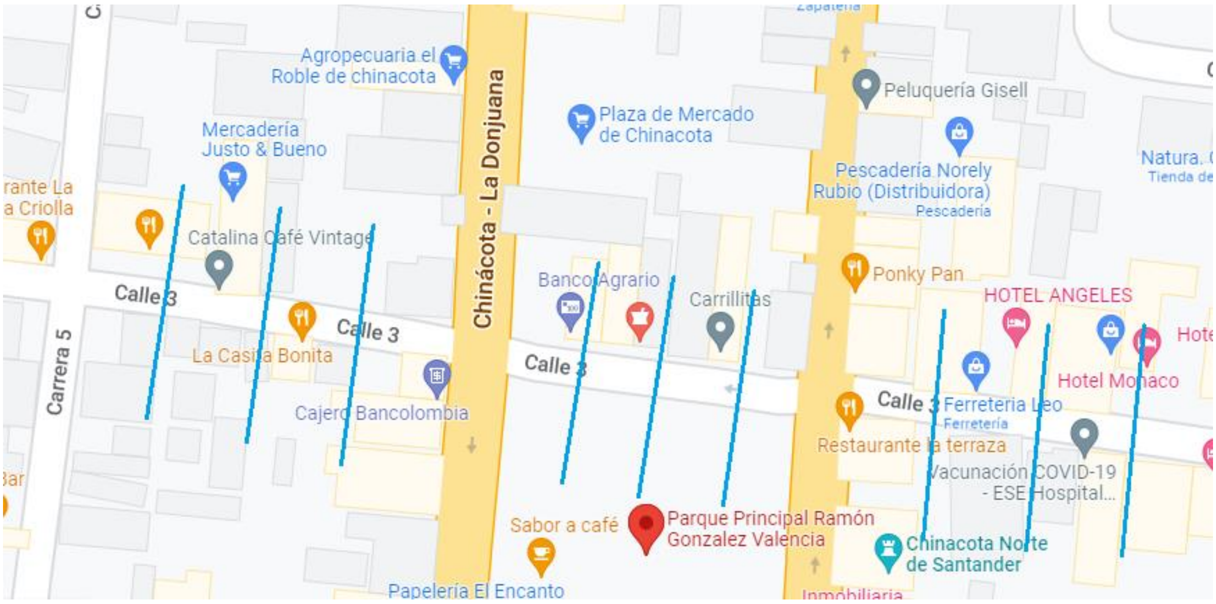
Since the main focus of the research is to count and determine the location and strategic capacity of parking lots, the magnitude of interest is not the vehicles that circulate but those that stop or park on the roads and in the parking lots of the sector, which are not included. Therefore, the vehicle counts carried out by the researchers have been based on parked vehicles, following the process described below (Japón, M. L. C. (2022).

3. Results and discussion

3.1. Procedure followed for counting parked vehicles

In the same way as for the traffic count (vehicles in transit) (Gambarte Zabala, C. A. (2022), the count was carried out every 15 minutes (Paez Ustariz, A. F., & Cuervo Niño, J. D.), noting the number of vehicles stopped for at least 5 min within 15 min intervals, continuously for 3 hours during peak tourism demand hours, and within a limited space equivalent to 50% of the block length, as shown in the figure.

Figure 1. Sectorization of blocks for vehicle counting by zones.



Source. Google Maps 2022.

As indicated in the image above, each block is partitioned into 4 parts equivalents to 25% each, taking as independent counting zones a 50% central sector and one in each corner of the block that is complemented with the remaining portion of the contiguous block to result in another 50% (National Traffic Code of Colombia CNT (2010).

- Thus, the algorithm of the counting process is as follows:
- In office, partition the blocks within the study area into fractions of 25% each.
- In the office, demarcate counting zones of 50% of the block length.
- In the field, count the number of vehicles parked in each zone for 15-minute periods within a total of 3 hours during peak demand hours.
- In the office, determine for each zone delimited within the study area, the maximum number of parked vehicles as the highest value among all those obtained for the different periods recorded.
- In the office, define the resulting grid of the study area with the maximum values recorded in each zone.

3.2. Resulting maximum registration

After applying the process of the previous section, the following scheme is obtained:

Table 1. Tabulation of the mesh of the study area, in it, the left numbering corresponds to the streets and their middle zones (X direction), and the upper numbering to the races and their middle zones (Y direction).

	2	2,5	3	3,5	4	4,5	5
7	1	1	1	0	2	1	1
6,5	1	0	3	0	1	0	3
6	2	0	2	2	3	1	1
5,5	3	0	0	0	5	0	2

5	3	2	4	9	4	4	8
4,5	1	0	4	0	8	0	4
4	3	2	8	4	5	0	1
3,5	1	0	8	0	5	0	0
3	1	5	4	3	4	2	2
2,5	2	0	3	0	3	0	3
2	0	0	1	3	1	2	0

Source: Own (2020)

In order to develop a simpler mathematical model, for the simulation of the same by means of interpolation functions (Arévalo-Ovalle, D., Bernal-Yermanos, M. Á., & Posada-Restrepo, J. A. (2021), as specified in the following section, the mesh is reduced to a system of road intersections (only considering streets and races and not the median strips), attributing this area to the corners by means of afferent areas, that is, loading the value of vehicles parked at the ends of the block for each section, as shown (Mujica Delgado, L. E., & Ruiz Ordóñez, M. 2022).

Table 2. Tabulation of the grid of the study area, where the left numbering corresponds to the streets (X direction), and the upper numbering corresponds to the races (Y direction).

	2	3	4	5
7	2,0	3,0	3,0	3,0
6	4,0	4,5	7,5	4,0
5	6,0	11,5	17,0	13,0
4	5,0	17,0	13,5	3,0
3	5,0	13,5	10,5	4,5
2	1,0	4,0	5,0	2,5

Source: Own (2020)

Equation 1. Distribution of vehicles parked at intersections loading by afferent lengths.

$$VP_{(X,Y)} = VP_{(i,j)} + \frac{VP_{(i+1/2,j)} + VP_{(i,j+1/2)} + VP_{(i-1/2,j)} + VP_{(i,j-1/2)}}{2}$$

Source: Own (2020)

Where:

VP(X,Y): parked vehicles attributed to an intersection (X,Y).

VP(i,j): Vehicles parked directly at an intersection (i,j) equivalent to Cartesian coordinates (X,Y).

i: Nodal position equivalent to Cartesian X

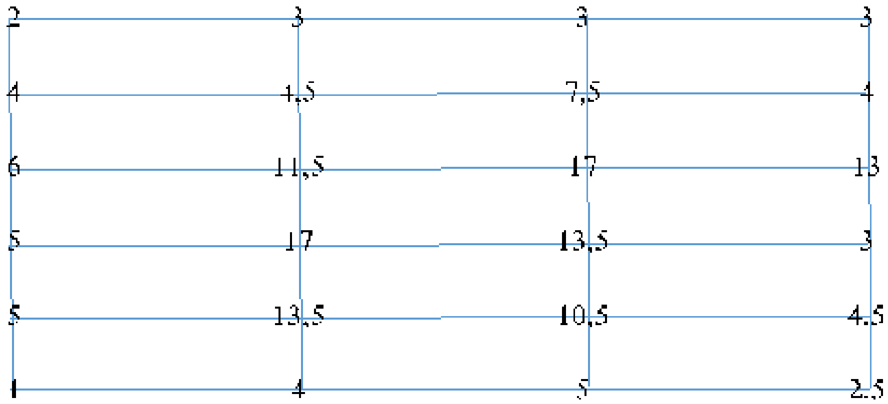
j: Nodal position equivalent to Cartesian Y

i±1/2: Nodal position equivalent to half a block in front (+) or behind (-) of the Cartesian coordinate intersection X

j±1/2: Nodal position equivalent to half a block in front (+) or behind (-) of the intersection of Cartesian Y coordinate.

In a more didactic way, the nodal grid looks like this:

Figure 2. Nodal mesh of the model, in blue: the idealized streets and races, the numbers in black at the nodes represent the theoretical amount of parked vehicles attributed to each intersection by afferent lengths.

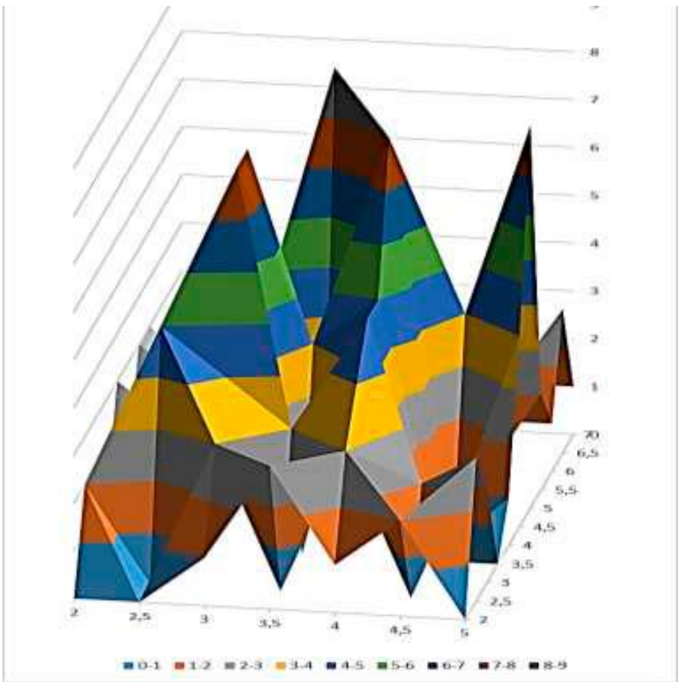


Source: Own (2020)

3.3. Surface graphic model

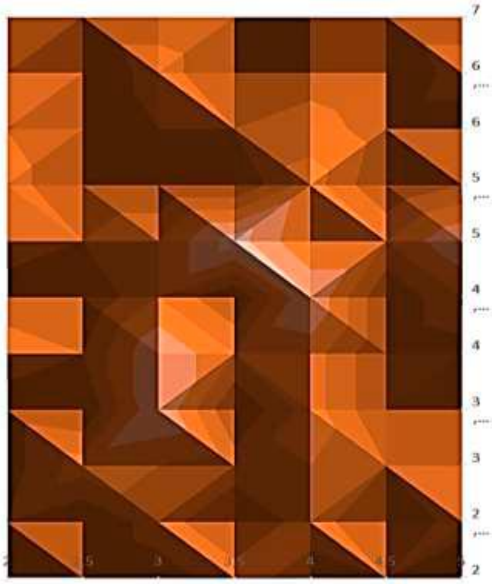
The models consigned (Torres Ordoñez, L. H., & Roa López, H. (2021) in the previous section of this paper capture the data record on a plane, i.e., they are represented in R2. By recreating the dependent variable (parked vehicles) as the third dimension in space, the nodal grid model becomes a surface function in R3 (Rebolledo-Gutiérrez, B. B. (2022)), as shown:

Figure 3. surface model of the nodal mesh.



In addition, the representation of the resulting nodal grid in intensity graphs is attached, in order to perceive the most critical areas of parking demand in the floor plan (Cadena Figueroa, W. P., & Savinovich Mejía, E. X. (2021).

Figure 4. Intensity map of the nodal grid.



Source: Own (2020)

3.4. Summary of the count

Finally, for the analyzed sector, the general data presented in the following table were found.

Table 3. General data of the count.

Total	163	Veh.
Blocks	38	quadra
Average	4,3	Veh/qua.

Source. Own 2020

5. Conclusions

The counts were conducted on a deferred basis, during weekends, long weekends and holidays during the months of November 2019 to March 2020 (inclusive). Depending on the season and some uncontrollable causes such as the weather, the economy, and recently the coronavirus pandemic that significantly slowed trade and tourism in the municipality in recent weeks, the counts of the demand for vehicles to park may vary tending to increase. A total of 163 vehicles were obtained, with an average of 4.3 vehicles per block, for subsequent construction (Gutiérrez, J. A. (2009).

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