Abstract: The supply of the country's road infrastructure and the demand of the vehicles that travel through it, must maintain a balance, which allows the trips generated by road users to be the shortest in distance and as soon as possible in time, also taking into account the comfort and safety of users. Achieving this goal is not an easy task, because there are many factors involved in the design and construction of this type of infrastructure project. One of the factors that must be taken into account to achieve infrastructure projects that respond to current and future needs, corresponds to the volumes of vehicles that will use the roads, for which it is of the utmost importance to know the past and current conditions of the vehicular flows that have occurred in the project areas or in sectors with similar conditions. The purpose of this work is to carry out a descriptive analysis of the distribution of vehicular traffic for road concessions Cartagena-Barranquilla and Santa Marta-Riohacha-Paraguachón, located on the roads of the Caribbean region of Colombia, during the period between the years 2010 - 2019. The information related to traffic was obtained from the website Datos Abiertos of the Gobierno Nacional de Colombia and was provided by the Agencia Nacional de Infraestructura (ANI). The data consulted contains information about the different types of vehicles (Cars, Buses and Trucks), as well as the different types of Trucks (C2P, C2G, C3-C4, C5 and C6) that transit through the two concessions that are made up of by six toll stations, three in each. With the information studied, a dataset was built, after carrying out the processing, ordering and cleaning of the data and with them different descriptive graphs were made that helped to draw the conclusions of the work. To carry out these tasks, tools such as Jupyter Notebooks and its data analysis libraries and Microsoft Excel were used. After this, an analysis of the main findings was carried out, among which a notable difference in the distribution of Cars, Buses and Trucks...
can be highlighted for the two road corridors studied, as well as the discrepancies between the vehicular flows of trucks, which supports the importance of carrying out this type of study to know the general conditions of a road section under study and determine what could be the possible demands of vehicles that may appear in them, to carry out road infrastructure designs according to the needs of each road section.

**Keywords:** Number of Vehicles, Vehicular Traffic, Type of Vehicle, Transportation, Vehicular Congestion, Highways

### 1. INTRODUCTION

World economic development and population growth in recent years have brought with it an increase in urbanization processes, and in turn, an increase in the vehicular flow, both at the urban level and on the highways, this as a consequence of the substantial increase in the new demands of the population and markets [1].

In recent years, with the processes of industrialization and globalization, a great benefit has been generated for the world population, both in developed and developing countries [2], managing to generate the production and distribution of many merchandise at lower costs, making many products more affordable for the final consumer [3]. In the case of the acquisition of vehicles, there has been a tendency to be able to obtain them at lower prices, with which, it is possible that these can be bought by more inhabitants of the planet, making notable increases in automotive fleets worldwide and producing consequently, the number of road users increases [4][5]. As evidenced in several major cities, the increase in road transport, both for people and goods, puts the performance of highways to the test, in terms of traffic congestion, especially on critical road sections or at peak hours, where traffic increases considerably, or in certain seasons of the year, where many vehicles are observed to converge in space and time on certain road sections [6].

The increase in vehicular demand leads to the fact that the roads must be prepared for these new requests [7]. For this reason, the road infrastructure of a country must be in accordance with the present and future conditions that may arise in terms of vehicular traffic and transport demands, in order to adequately respond to them. With this, it is possible to avoid mobility or co-management problems and prevent, as far as possible, the occurrence of traffic accidents on the roads, that is, well-designed roads based on future traffic conditions, can contribute to the comfort of users of roads, as well as reduce travel times, increase savings in fuel consumption, reduce environmental pollution and above all, most importantly, save many lives, preventing the occurrence of fatal traffic accidents [1] [6]. Hence the importance of carrying out good planning during the design phases of the roads, with accurate and updated information on their conditions, which help to make realistic and accurate predictions of possible future conditions, to avoid an increase in travel costs, which directly impact the economy of all the inhabitants of a region, either by passenger transport or by the transport of products, especially those of first necessity or basic needs, as well as to avoid the increase in travel times between the origin and destination sites or slow down the transport systems, which is directly related to the vehicular co-management of a vehicular section [8].
In the case of Colombia, several studies have been carried out on mobility and vehicular co-management and on repeated occasions, similar results have been reached, as is the case of a recent study carried out by the firm Moneybarn, which once again shows the situation of traffic in the country, resulting as relevant data, that of all the countries in the world, Colombia is the second slowest to drive. This conclusion was reached after analyzing different factors, such as: road conditions, highway speed limits and congestion, both in capital cities and in national highways [9]. Fortunately in Colombia, the National Government together with its government entities related to road matters, have been carrying out road infrastructure plans, to increase the offer in terms of road infrastructure, which are consistent with current and future traffic demands; it is from there that projects such as the so-called 4G or Fourth Generation (4G) roads of Concesiones Viales de Colombia have been born, which seek to create new strategic road corridors and increase the capacity of existing ones, in order to improve mobility in many regions of the country, thereby achieving a reduction in travel times, as well as an increase in road safety and a decrease in routes, which are reflected in a decrease in fuel consumption and operating costs, making cargo transportation in the country more competitive [10] [11] [12].

In order to achieve the objective of building and providing the country with infrastructure according to future vehicle demand, it is important to know that good planning must be started, making analysis of future traffic situations, based on the information that is currently known, as well as the use of existing information on vehicular traffic and similar cases that can be taken as a reference, both to avoid mistakes that have already been made, and to optimize the available resources. The purpose of this work is to show quantitatively the traffic volumes that circulate through two important corridors that are located in the north of Colombia in the Caribbean Region, for which use is made of the free access information published by the Agencia Nacional de Infraestructura (ANI), which has under its jurisdiction the administration and control of several major road concessions at the national level and in each one of them, presents toll sites where, in addition to making the collections for the maintenance of the roads, they also collects information on the number of vehicles that pass through its roads and their type. So, information from ten consecutive years between 2010 and 2019 will be used to carry out an analysis of vehicular behavior in these road sectors and see how their distribution is for Cars, Buses and Trucks and in the case of trucks, discriminate between them in the different categories that the entity has established in its databases. With this, the aim is to obtain a global overview of the traffic on these roads and to determine similarities and differences in these two sections, which are located in the route of several main cities in the country such as Cartagena, Barranquilla, Santa Marta and Río Hacha.

2. EXPERIMENTAL DESIGN, MATERIALS AND METHODS

2.1. Study area description

The Caribbean region is located in the northern part of Colombia and is one of the six natural regions of the country. It is currently made up of seven departments on the continental part that
correspond to Atlántico, Bolívar, Cesar, Córdoba, La Guajira, Magdalena and Sucre, which represent 11.6% of the 1,141,748 km² that comprise the total national territory [3]. It should be noted that for the present investigation, we worked with two road sections that are located in four of the seven aforementioned departments. In its physical aspect, the Caribbean region is constituted predominantly by low and flat lands, most of the territory is made up of low altitude lands (less than 130 masl), although part of the territory is framed by the foothills of the three mountain ranges [13]. Figure 1 presents the location and geographic distribution of this region.

![Figure 1](http://www.webology.org)

**Figure 1.** Location of the Caribbean region

*Source:* Región Caribe (Colombia) – Wikipedia (2022)

Modified by the authors

### 2.2. Material and Methods

The methodology followed in the development of this work was divided into two phases: the first phase consisted of obtaining information on collections and vehicular traffic administered by the
ANI and in the second phase, the information was organized by road concession, toll station, department of the station, type of vehicles, types of trucks and in the temporary variable, the frequency of the years was selected to observe the general behavior of the evolution of traffic in the selected road sections.

**Phase 1. Collection, Processing, Cleaning and Organization of Datasets**

The data was obtained from a single source of information, which corresponds to the Collection and Traffic data of the Agencia Nacional de Infraestructura (ANI), which were published on the website web Datos Abiertos of the national government [14], [15] and through the website of the Entity [16]. The files were in Excel and CSV format, and they were in different files organized by year, for which the first step consisted of unifying all the data with the relevant information for the study in a single file. For this task, the Excel spreadsheet tool was used. The format of the sheets was organized by the following columns: Concession, which corresponds to the concessioned road sector and which, in general, is made up of several road sections in the vicinity of different localities; Toll station, which corresponds to the physical collection site and where the counting and weighing functions of the vehicles are also carried out, according to the country's regulations; Department, which denotes the political and geographical division to which the Toll Station belongs; Municipality, which corresponds to the locality to which the Toll Station belongs. Collection Start Date and Collection End Date, as its name indicates, are the periods discriminated by day, month and year, in which the information was collected. In the present case, most of the toll booths give these reports on a fortnightly or monthly basis, which is what is observed in the data source; road traffic, discriminated by two criteria, as the first criterion is the type of vehicle whose classification can be consulted in Table 1 and as shown in Figure 2, being represented by the different types of Cars, Buses and Trucks that travel the most on the roads of Colombia and as a second factor, by the type of traffic, having Full Traffic, Special, Evader Traffic and Law 787 traffic. For this reason, for the present case, due to the particularities of the study, it is taken as a single category by adding the four different types of traffic for each category of trucks.

**Table 1. Categories of Toll Trucks of the Cartagena-Barranquilla and Santa Marta-Riohacha-Paraguachón concessions**

<table>
<thead>
<tr>
<th>Category</th>
<th>Type of Vehicle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Cars</td>
<td>Cars, campers, vans and minibuses with single-wheel axles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Buses, minibuses, minibuses with double-tire rear axle for roads</td>
</tr>
<tr>
<td>II</td>
<td>Buses</td>
<td>and/or mixed</td>
</tr>
<tr>
<td>III</td>
<td>C2P</td>
<td>Small trucks with two axles</td>
</tr>
<tr>
<td>IV</td>
<td>C2G</td>
<td>Large trucks with two axles</td>
</tr>
<tr>
<td>V</td>
<td>C3-C4</td>
<td>Passenger and cargo vehicles with three and four axles</td>
</tr>
<tr>
<td>VI</td>
<td>C5</td>
<td>Five-axle cargo vehicles</td>
</tr>
<tr>
<td>VII</td>
<td>C6</td>
<td>Six-axle cargo vehicles</td>
</tr>
</tbody>
</table>

Source: Agencia Nacional de Infraestructura - ANI
For the present work, in the case of the location of the Vehicle Collection sites, it was decided to work with only two concessions from the long list of concessions that the ANI has in its administration and these two concessions are located in two road sections of the Caribbean Coast, resulting in a total of six Toll Stations to study. Table 2 shows the information of the selected concessions. Additionally, it is worth mentioning that, although the information consulted was between the beginning of 2003 and the end of 2020, it was decided to work only with the period of years between 2010 and 2019, because it is considered a relevant period to look at the evolution of traffic in Colombia.

| Car | Bus | Truck | Tractor-trailer | Tractor-trailer |
| Van | Bus | Tractor-trailer | Tractor-trailer | Tractor-trailer |
| Pick Up | Small truck (C2P) | Big truck (C2G) | Tractor-trailer | Tractor-trailer |

2 Axles  | 2 Axles (Double Wheel)  | 3 or 4 Axles  | 5 Axles  | 6 Axles  |
| | | | | |

Figure 2. Graphic representation of the types of Vehicles
Source: Agencia Nacional de Infraestructura - ANI

For the present work, in the case of the location of the Vehicle Collection sites, it was decided to work with only two concessions from the long list of concessions that the ANI has in its administration and these two concessions are located in two road sections of the Caribbean Coast, resulting in a total of six Toll Stations to study. Table 2 shows the information of the selected concessions. Additionally, it is worth mentioning that, although the information consulted was between the beginning of 2003 and the end of 2020, it was decided to work only with the period of years between 2010 and 2019, because it is considered a relevant period to look at the evolution of traffic in Colombia.
Table 2. List of Toll Stations

<table>
<thead>
<tr>
<th>No.</th>
<th>Concession</th>
<th>Departmen t</th>
<th>Municipality</th>
<th>Toll Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cartagena-Barranquilla</td>
<td>Bolívar</td>
<td>Cartagena de Indias</td>
<td>Marahuaco</td>
</tr>
<tr>
<td></td>
<td>Cartagena-Barranquilla</td>
<td>Atlántico</td>
<td>Barranquilla</td>
<td>Papiros</td>
</tr>
<tr>
<td></td>
<td>Cartagena-Barranquilla</td>
<td>Atlántico</td>
<td>Barranquilla</td>
<td>Puerto Colombia</td>
</tr>
<tr>
<td>2</td>
<td>Santa Marta-Riohacha-Paraguachón</td>
<td>La Guajira</td>
<td>Manaure</td>
<td>Alto pino</td>
</tr>
<tr>
<td></td>
<td>Santa Marta-Riohacha-Paraguachón</td>
<td>La Guajira</td>
<td>Riocha</td>
<td>El Ebanal</td>
</tr>
<tr>
<td></td>
<td>Santa Marta-Riohacha-Paraguachón</td>
<td>Magdalena</td>
<td>Santa Marta</td>
<td>Neguanje</td>
</tr>
</tbody>
</table>

Phase 2. Organization of Information and Obtaining Results

After processing the information from the selected Toll Stations and the study periods, a DataFrame was created that was made up of the data of interest, for which the first step consisted of filtering the information obtained by dates, which were between January 2010 and December 2019, during which time, the six toll stations were in continuous operation. Then the concessions filter was carried out, for which, as presented in Table 2, we worked with the Cartagena-Barranquilla concession, which is located in the departments of Bolívar and Atlántico, and its toll stations are located one in the municipality of Cartagena de Indias and two in the city of Barranquilla. In the case of the second Concession, Santa Marta-Riohacha-Paraguachón, it is located in the departments of La Guajira and Magdalena, with its toll stations located in the municipalities of Manaure, Riochacha and Santa Marta. It is worth noting that for this last concession, the vehicular traffic of the Paraguachón Toll Station, located in Maicao (La Guajira), was not analyzed, because the way in which the traffic configuration is presented differs from the rest of the analyzed stations. Figure 3 shows the different stations located on the Caribbean Coast that are in charge of ANI. Of interest from said Figure are the stations assigned with numbers 35, 36, 37, 61, 62 and 63, which correspond to the Marahuaco, Papiros, Puerto Colombia, El Ebanal, Alto Pino and Neguanje Toll Stations, respectively.

The final step, in order to create a database with the information of interest, consisted in calculating the vehicular traffic based on the data from counts and collections, for which the values of net traffic, special traffic, evading traffic and traffic law 787, for each of the types of vehicles shown in Table 1.
3. RESULTS AND DISCUSSION

The Dataset built with the data from the concessions and toll stations, discriminated by department and municipality and between 2010 and 2019, with Monthly and annual vehicular traffic for the study period and for each type of vehicle discriminated by the ANI, was analyzed, so that from said information it was possible to build different Figures that show the behavior of Vehicular Traffic in the two road sectors in study.

To carry out the analysis, the information was grouped according to the type of Vehicle and two main categories were obtained, which were the ones that were of interest to analyze: on the one hand, there are vehicles categorized into Cars, Buses and Trucks and on the other hand, the information of the trucks discriminated in the categories C2P, C2G, C3-C4, C5 and C6, which correspond to the different types of trucks that the ANI considers in the consulted concessions. Additionally, the grouping of the data was carried out based on the existing geographic divisions in the country, in this case for the Departments, as well as for the Concessions and Toll Stations, in order to find similarities and differences in the observed vehicular flows. Finally, the annual traffic growth in both road corridors is presented, with which its behavior can be evidenced year by year during the study period. To carry out this phase, the Excel calculation tool and Jupyter Notebook were used, with its Data Science libraries, for the preliminary review and analysis of the Dataset, as well as the generation of data visualizations.

Figure 4 shows the distribution of vehicular traffic grouped by Concessions, during the ten years. The bar graph of Figure 4(a) shows the number of Cars, Buses, and Trucks that transited throughout
the study period through both concessions. On the other hand, Figure 4(b) presents the same total distribution, but discriminating the types of trucks according to the categories considered by the ANI.

![Figure 4](http://www.webology.org)

**Figure 4. Traffic Distribution of the Concessions**
(a) Types of Vehicles (b) Types of Trucks

Something to highlight from these graphs is that for the Cartagena - Barranquilla Concession, there is a greater number of vehicles of the Automobile type than for the other concession, which even, exceeds the number of total vehicles that transited in the other sector. But additionally, if only the number of commercial vehicles in both road sectors is analyzed, it is observed, on the contrary, that the number of commercial vehicles in the Cartagena-Barranquilla concession is much higher than those that transit in the Santa Marta-Riohacha-Paraguachón sector, being evident the large number of six-axle trucks in that sector.

![Vehicles by Concession](http://www.webology.org)
On the other hand, Figure 5 shows the relative distribution of vehicles for the concessions under study, being able to observe that for the Cartagena-Barranquilla concession, more than 85% of the vehicles that transit through its roads are automobiles and the most frequent types of trucks during the study period were C2P and C2G, together accounting for almost 80% of all trucks. In the case of the other concession, it is observed that a little less than 70% corresponds to Car-type vehicles, but there is a large number of trucks that is around 20%. Additionally, the two types of trucks that travel the most in this road corridor correspond to C2P and C6. Based on these findings, it could be concluded that the road sector that is in the Cartagena-Barranquilla concession has a greater number of cars because they are very tourist cities, while the other vehicular sector has a significant percentage of trucks and fewer cars, because it is more of an area where the transport of merchandise predominates, due to the same characteristics of that region, in addition to being a border area with Venezuela.

Figure 6 shows the distribution of traffic for each toll station, two graphs were also generated, one for the types of vehicles and another for the different truck types. Evaluating the types of vehicles, it can be noted that the toll station with the highest vehicular flow was that of Puerto Colombia, followed by that of Marahuaco and where it presented the least, and was Papiros, which is close to the city of Barranquilla. In contrast, in the case of trucks, the two tolls with the highest number of commercial vehicles correspond to El Ebanal and Neguanje, both located in the Santa Marta-Riohacha-Paraguachón concession, which is consistent with the information presented in Figure 4.
The information processed also allowed for a classification of traffic by department. This information is graphed in Figure 7, which shows the relative distribution of traffic for the four departments where the two concessions under study are located, discriminated again by types of vehicles and types of trucks. When analyzing the graphs in reference, it can be highlighted, what has already been commented previously: first, that the departments where more cars transit correspond to Atlántico and Bolívar and that for the departments of La Guajira and Magdalena, there is an important Truck component. On the other hand, when reviewing the distribution of commercial vehicles by departments, it is observed that the vehicle that predominates the most in the four departments corresponds to the C2P truck and in the case of the departments of Atlántico and Bolívar, the truck that follows in greater proportion is the C2G, while for the departments of La Guajira and Magdalena, the second most frequent commercial vehicle corresponds to the C6 type. This information is consistent with that found in Figure 5 and this relationship can be clearly seen, in this case, for each department.
Figure 7. Traffic Distributions by Departments
(a) Types of Vehicles (b) Types of Trucks

The distribution of traffic per year is another very important variable to evaluate, because it indicates the evolution of traffic over the years for the different types of vehicles. Figure 8 shows the total distribution over the 10-year study period, for both concessions. From Figure 8, it can be seen that, in the case of Cars, there has been a constant increase in the number of this type of vehicle, with a small decrease in 2019. It can also be observed, the evolution of buses and trucks, which at first glance seems to have remained almost constant, but the reality is different, only because of the scale of the graph it gives that impression, for which Figure 9 was built, with the aim of showing it on a larger scale adequate distribution of commercial vehicles, discriminating them by type of vehicle and making the graph for both concessions separately, because in these if notable differences were found.
When analyzing Figure 9, it can be noted that in the case of the Cartagena-Barranquilla concession, the type of vehicle that predominated in the roadways was the C2P during the entire study period,
although a decrease is observed over the years; the same happens for the second truck that registered the most on these highways, the C2G. Over the years, the number of vehicles of this type has decreased. On the other hand, it can be seen that C6 type trucks increase over the years. Meanwhile, if the Santa Marta-Riohacha-Paraguachón road sector is analyzed, it is observed that the two vehicles that predominated over the years are the C2P and the C6, with the C2P being the one that predominated for more years and it is also noticeable as its frequency increased over the years.

4. CONCLUSIONS

The information processed and analyzed about the distribution of traffic in two road corridors in the north of Colombia, between the years 2010 and 2019, give a vision of how traffic has behaved over the years and how they have been distributed by concession, by toll stations, by department and by year, discriminating by type of vehicle and by type of truck. From the analysis of this information, it has been possible to determine that the road sector that is located in the Cartagena-Barranquilla concession has presented automobiles as the most frequent type of vehicle, while in the case of the Santa Marta-Riohacha-Paraguachón concession, although the Car continues to predominate, there is a significant increase in the volume of trucks that transit through these roads. This data is very relevant, because plans can be generated that are aimed at implementing road projects more in line with the needs of each corridor, prioritizing in each case, the use that is being given, for example, in the case of the Cartagena – Barranquilla concession, vehicle congestion must be prioritized, due to the high number of light vehicles, while in the case of the Santa Marta-Riohacha-Paraguachón concession, special care must be taken in the capacity of the pavement structure, due to the fact that a type of vehicle that is very common on these roads presents higher load values compared to Cars. Additionally, looking at the annual distribution of vehicle types helps determine the trends that critical road vehicles have had over the years and helps make smarter decisions that favor future road projects in these road corridors or in corridors with similar characteristics.

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