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Proposal for greenhouse gas emissions reduction in public passenger transportation

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ABSTRACT

This article presents a proposal for the reduction of greenhouse gas emissions from public passenger transport using geographic information systems and spatial statistical analysis considering one-route demand through the creation of an alternative scenario to the actual one by stablishing bus stops according to its associated demand.

1. Introduction

Transport is an organizational process with very particular characteristics that allows the movement of the population and goods and products from one place to another, that is, it is an element that enables urban mobility and this in turn allows us to generate connection links; in such a way that urban transport is not an end in itself and its efficiency will depend on its contribution so that the relations of production and social reproduction are fulfilled (García, 2014).

The importance of public passenger transport for a city is that, through it, most of the social functions of transport should be fulfilled in a more efficient and city-friendly way (Urrutia, 1981).

In economic terms, it enables the reproduction of the labor force through the massive displacement of labor, because it increases the large economies of scale and the general productivity of the city (Henrry, 1985).

Urbanistically it has effects on the socio-spatial dimension and configuration of the city and on a cultural level, it enables different social relations from those strictly productive and generates spaces in which the citizen can represent and imagine the city (García, 1996).

As the developing world rapidly urbanizes, there is an opportunity to build safer, cleaner, more efficient, and more accessible transportation systems that reduce congestion and pollution, facilitate access to jobs, and reduce energy consumption in transportation. In emerging medium-sized cities, where the majority of new urban dwellers will live, urban planners have the opportunity to design inclusive and sustainable transportation systems from the start, bypassing the most polluting and costly modes (The World Bank, 2018).

Because of the aforementioned, it is essential for modern society, although it contributes in the same way with the negative effects such as congestion that makes cities less pleasant to live by reducing the efficiency of the transport system and increasing travel time, fuel consumption and stress of drivers, but one of the most negative effects can be measured through its contribution to air pollution.

This article was developed as follows: section one is an introduction that remarks the importance of public transport while section two explains the analysis considered in this research.

Section three explains the carried-out methodology, such as data treatment, data analysis and the proposal aroused and section four. gives the results obtained and the conclusions are presented in section five.

1.1. Transport and greenhouse gas emissions in the world

Carbon dioxide makes up 95% of all transportation-related greenhouse gas emissions. Cars, SUVs, and pickup trucks running on conventional gasoline, diesel, and other fuels emit carbon dioxide. Combined, these vehicles account for roughly two-thirds of transportation-related emissions (Federal Transit Administration, 2010).

GHG emissions have risen at a rate of 1.5 per cent per year in the last decade, stabilizing only briefly between 2014 and 2016. Total GHG emissions, including from land-use change, reached a record high of 55.3 $GtCO_2e$ in 2018. Fossil CO_2 emissions from energy use and industry, which dominate total GHG emissions, grew 2.0 per cent in 2018, reaching a record 37.5 $GtCO_2$ per year.

There is no sign of GHG emissions peaking in the next few years; every year of postponed peaking means that deeper and faster cuts will be required.

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By 2030, emissions would need to be 25 per cent and 55 per cent lower than in 2018 to put the world on the least-cost pathway to limiting global warming to below 2°C and 1.5°C respectively (United Nations Environment Programme, 2019).

Around 10% of the global population account for 80% of total motorized passenger-kilometers (p-km) with much of the world's population hardly travelling at all. OECD countries dominate GHG transport although most recent growth has taken place in Asia, including passenger kilometers travelled by low GHG emitting 2- to 3-wheelers that have more than doubled since 2000 (Sims and otros, 2014).

1.2. Transport and greenhouse gas emissions in Mexico

Mexico contributes 1.68% of global greenhouse gas (GHG) emissions, positioning it as one of the main emitters in the world. The main sources of emissions in our country are emissions produced by transport or mobile sources (26.2%), electricity generation (19%) and industry emissions (17.3%) (Secretaría del Medio Ambiente de la Ciudad México, 2018).

Transportation is the sector with the highest consumption of fossil fuels with more than 60% of the City's energy, and therefore is related to the highest emissions of particles (PM10 and PM2.5), nitrogen oxides and carbon dioxide.

In terms of emissions, there are indicators of the potential to generate pollutants, such as the age of the vehicles and the type of emission control technology; Normally, oldervehicles have higher emissions due to vehicle deterioration and less efficient technology (Secretaría del Medio Ambiente de la Ciudad México, 2018).

The use of high-capacity public transport is one of the options for reducing polluting emissions, Fig. 1 presents a comparison of carbon dioxide (CO2) emissions between different transport modes, where it is shown that the Bus rapid transit (Metrobus) system and the buses are those with the lowest emissions per passenger transported, which is why the increase in lines and high-capacity units is encouraged (Secretaría del Medio Ambiente de la Ciudad México, 2018).

1.3. Actions to improve public passenger transport in the world

Due to the importance and impact of public passenger transport in various cities of the world, policies have been implemented to improve and minimize impacts, of which the following can be highlighted (Rivas Tovar, 2006):

1. Hybrid transportation modes (join two or more types of transportation): planning for comprehensive public and private transportation is proposed, so intermodal systems are developed in which all the forms of transportation available can be combined in the city, so that the use of public transport is privileged.
2. Intelligent traffic management systems: it integrates different technologies such as cameras, sensors and radars to detect levels of fluidity or congestion in the main roads of a city and from the data obtained generate real-time solutions through which they can be Relieve congestion and take advantage of fast-flowing roads.
3. Effective signaling systems: preventive signaling that allows motorists to modify their routes before they find diversions due to demonstrations, repairs or for any reason that implies the closure of high-flow primary roads.
4. Integration of Bus Rapid Transit systems: which streamlines the urban road space by allocating reserved traffic lanes on the main axes to the transit of specially designed passenger buses, which has represented great advantages in terms of the costs of their implementation and operation over other options. Here it will be necessary, whenever a lane is restricted for the exclusive circulation of buses, to implement what is necessary so that there is continuity in the lanes for automobiles in the entire route of the road, avoiding bottlenecks since the bad planning or the current inefficient design of this system, cause unnecessary crowds.
5. Adequate parking policies: the use of private cars instead of public transport will be widely preferred if those can be parked for free or at very low cost in the destination places, so the creation of free or low-cost parking spaces promotes car use and urban sprawl, which has an impact on increased congestion. In this sense, efforts should be made to limit the supply of parking, so that in a certain way vehicle pressure can be controlled, while providing more spaces for public transport, making it possible to increase its coverage and frequency.
6. Authority for pedestrians and cyclists: authority in charge of the specific attention of users of non-motorized transport and pedestrians would help to better serve this specific sector of the population, ensuring that their rights are respected and comply with the obligations that correspond to them, and may even impose sanctions that go beyond verbal reprimand to those who violate the provisions on traffic, promoting a culture of traffic between pedestrians and cyclists (Rivas Tovar, 2006).
7. Promotion of a "charter of rights and obligations of users of public transport": the creation of a charter of rights and obligations of users of public transport would allow the population to expand their road culture by knowing in detail what the rights are They assist them by making use of the different forms of public transportation available to them, as well as the obligations they must fulfill for that use, which would help to improve mobility conditions in public transportation by having more and better informed users on the behavior expected of them when using this.
8. Adequate training of personnel who provide public transport services: the bases must be established so that the operators of the passenger transport units are trained for the best performance of their tasks, as well as in the care of the rights that users have. So that all the actors involved in public transport are fully aware of the rules that govern its use and operation, which would have an impact on improving the quality of the service.
9. Redistribution of motorized and non-motorized spaces: The proper development of mobility in the city requires that the movement of motorized and non-motorized transport be developed in coordination, providing security elements to its users, so a definition of the spaces is required. that correspond to each of these modalities and that at the points where they intersect, the preferences of each of the forms of transportation are respected, to which must be added the necessary road education for each of these elements (Rodriguez Arana, 2016).

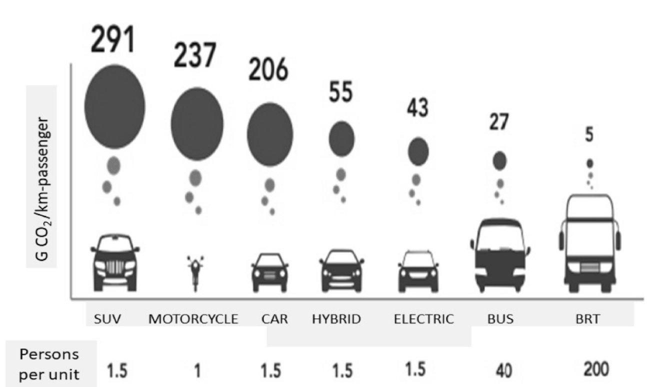

Fig. 1. Comparison of carbon dioxide (CO_2) emissions between different transport modes. Source: (Secretaría del Medio Ambiente de la Ciudad México, 2018).

2. Literature review

2.1. Spatial statistical analysis

Spatial analysis comprises the set of concepts and procedures used to approach the study of the structure and territorial relations based on knowledge of the position of geographic entities and the characteristics of the variables selected for study.

This analysis deals with the distinctive characteristics of geographic data, with special emphasis on the problems of spatial autocorrelation and spatial heterogeneity and can be defined as "a collection of techniques to describe and visualize spatial distributions, identify atypical spatial locations or spatial outliers, discover spatial association patterns, clusters or hot spots, and suggest spatial regimes or other forms of spatial heterogeneity " (Anselin, 1998)

An advantage of using spatial statistical analysis techniques is that they can summarize the complex spatial pattern, making this complexity digestible to the human mind and eyes, making decision-making and intervention more feasible (Madrid and Ortiz, 1999).

2.1.1. Technical tools for spatial análisis

A technical tool can be defined as a graphical, quantitative, qualitative and/or mixed type instrument, the use of which involves a series of procedures in which one or more variables are worked with the purpose of making a phenomenon more explicable and visible and they fulfill the two objectives of spatial analysis: to identify the components of space and in the processing or treatment of data (Fig. 2) (Madrid & Ortiz, 1999).

2.1.2. Main approaches for spatial analysis

For spatial analysis there are different approaches which are applied according to the purpose sought which are (De los Ángeles Mazo, 2016):

- Exploratory analysis of spatial data: it is used in spatial statistics, geostatistics and spatial econometrics, it is developed from the exploratory analysis of data.
- Spatial autocorrelation: the simplest definition of the concept of spatial autocorrelation is that it represents the relationship between the immediate spatial units, as seen in the maps, where each unit is coded with a single variable embodiment.
- Spatial autocorrelation measures and tests can be differentiated by scope or scale of analysis and are divided into global and local.
- Spatial clusters or Cluster: An implicit assumption in the analysis of spatial clusters is to determine the factors that influence the study variable. The techniques for this type of analysis can be divided into two categories: those that are used to determine if the grouping occur in the study region, and those trying to identify the location of the clusters.

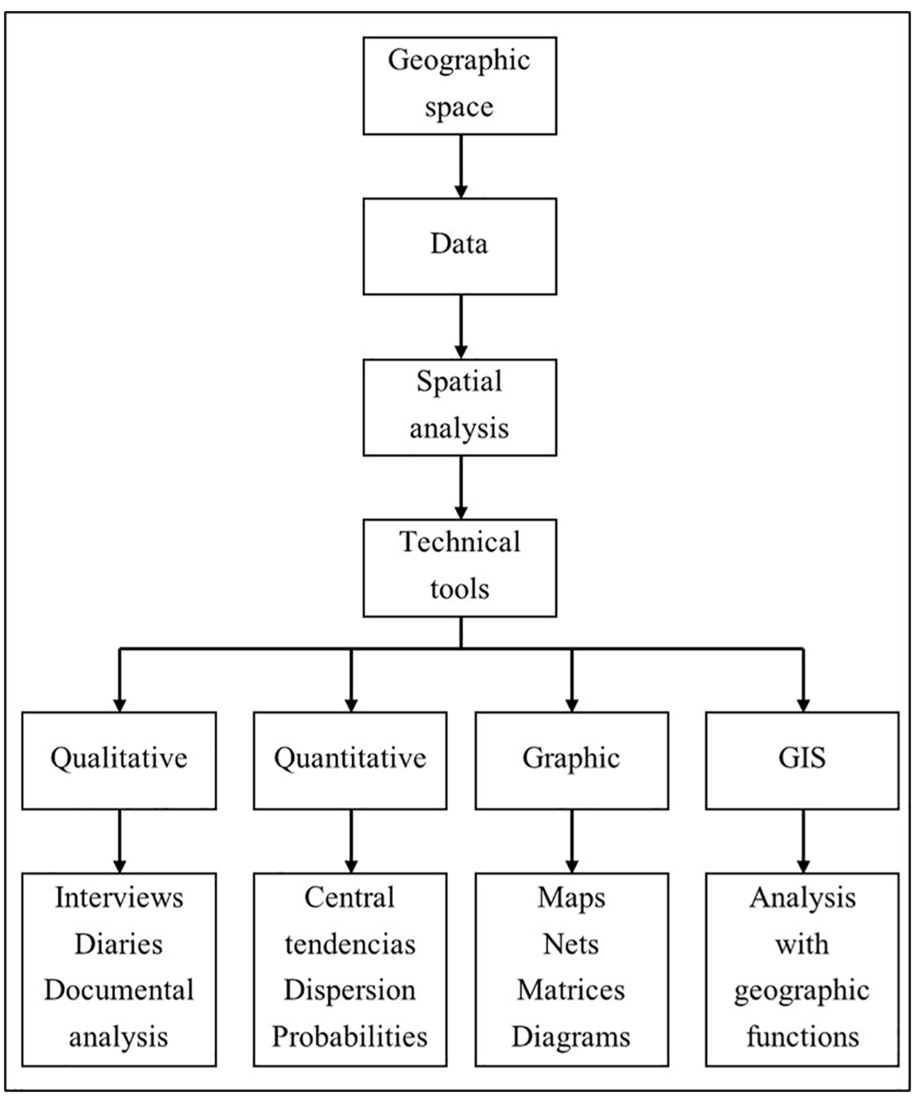

Fig. 2. Technical tools Source: (Madrid and Ortiz, 1999).

- Spatial Filters: aims to account for spatial autocorrelation in georeferenced data in a way that allows conventional statistical estimation techniques to be exploited.

In this work, the spatial autocorrelation approach with local grouping measures called Hot Spot Analysis will be applie (Getis-Ord Gi *).

2.1.3. Hot spot analysis (Getis-Ord Gi *)

Hot spot analysis calculates the Getis-Ord Gi * statistic for each entity in a dataset. The z-scores and resulting P-values indicate where entities with high or low values are spatially grouped (ESRI, 2020).

This analysis works by searching for entities within the context of neighboring or neighboring entities, in which an entity with a high value is interesting, but it is possible that it is not a statistically significant hot spot, in order to be one it must have a high value and also to be surrounded by others with high values and the cold points (cold spots) are points that around them have lower values. The local sum for an entity and its neighbors is compared proportionally with the sum of all entities; When the local sum is very different from the expected one, and that difference is too large to be the result of a random option, a statistically significant z-score is obtained as a consequence. Both z-scores (standard deviations) and p-values (significance level) are associated with the standard normal distribution.

By creating a new output feature class with a z-score, a P value, and a confidence level index (Gi_Bin) for each feature in the input class, the z-scores and p-values are measures of statistical significance that indicate whether will reject the null hypothesis; which indicates that the spatial distribution of the elements is given completely randomly, it postulates that the observed spatial pattern of the data represents one of the many possible spatial arrangements (n!), entity by entity. Indeed, they indicate whether the observed high or low value spatial clustering is more marked than expected in a random distribution of those same values (ESRI, 2020).

An entity with a high value is interesting, but it may not be a statistically significant hot spot. To be a statistically significant hot spot, an entity must have a high value and be surrounded by other entities with high values. The local sum for an entity and its neighbors is compared proportionally with the sum of all entities; When the local sum is very different from the expected one, and that difference is too large to be the result of a random option, a statistically significant z-score is obtained as a consequence.

A high z-score and a small P-value for an entity indicate high-value spatial clustering. A low negative z-score and a small P-value indicate low-value spatial clustering. The higher (or lower) the z-score, the more intense the clustering will be. A z-score close to zero indicates that there is no obvious spatial clustering, order, or random arrangement.

The calculations made are:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{x}\sum_{j=1}^{n} w_{i,j}}{s\sqrt{\frac{n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}}$$

Where:

x_j: attribute value for characteristic j determined

$w_{i,\,j}$: spatial weight between characteristics i and j.

n: is equal to the total number of characteristics

$$\overline{xx} = \frac{\sum_{j=1}^{n} xj}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\bar{x})^2}$$

Gi * is a z-score, so no further calculations are required, hot spots are defined as areas of high statistical occurrence and cold spots are areas of low occurrence.

2.2. Geographic information systems

A Geographic Information System is an organized integration of geographic hardware, software, and data designed to capture, store, manipulate, analyze, and display geographically referenced information in all its forms to solve complex planning and management problems (Anselin, 1998).

The GIS works as a database with geographic information (alphanumeric data) that is associated by a common identifier to the graphic objects on a digital map. In this way, by pointing to an object its attributes are known and, conversely, by asking for a record in the database, its location can be known in the cartography.

The fundamental reason for using a GIS is the management of spatial information, since it allows the information to be separated into different thematic layers and stores them independently, allowing working with them quickly and easily, and facilitating the possibility of relating existing information through of the topology of the objects, in order to generate a new one that we could not obtain otherwise.

The main questions that a Geographic Information System can solve, ordered from least to most complex, are:

- Location: characteristics of a specific place.
- Condition: the fulfillment or not of conditions imposed on the system.
- Trend: comparison between temporal or spatial situations other than some characteristic.
- Routes: calculation of optimal routes between two or more points.
- Patterns: detection of spatial patterns.
- Models: generation of models from simulated phenomena or actions.

Due to its versatility the field of application of Geographic Information Systems is very broad and can be used in most activities with a spatial component.

2.2.1. GIS components

A Geographic Information System is made up of the following elements (Madrid and Ortiz, 1999) (Fig. 3):

- Data: can come from different sources: remote sensors, GPS, aerial photographs, shapefile format files, CAD files, Excel files, etc.
- Software: for the correct analysis and interpretation of geographic information, the participation of a GIS software that has the power and functionality to work with information of this type is necessary.

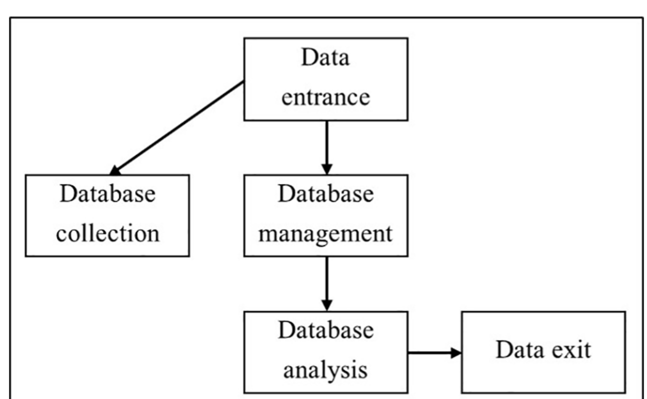

Fig. 3. Geographic Information System components. Source: (Madrid and Ortiz, 1999).

ArcGIS is currently the reference technology in Geographic Information Systems (GIS).

- Hardware: to use the software, a computer or hardware is required. Depending on the characteristics of this machine, we will obtain a greater or lesser performance when carrying out our analyzes.
- People: once we have the data and what to analyze it with, we need to know how.
- Processes: a successful GIS operates according to a good design of implementation rules.

2.2.2. Free and commercial GIS software

Geography information systems have various softwares which are divided into:

- Free software:

QGIS: With QGIS (formerly Quantum GIS) you can create, edit, visualize, analyze and publish geospatial information at no cost (SAGA, 2020).

GvSIG: manages, captures, and solves complex geographic problems. gvSIG emphasizes accessing all common vector and raster formats with an easy-to-use interface (gvSIG asossiation, 2020).

- Commercial:

Arcview: georeferenced data can be represented; the characteristics and distribution patterns of this data can be analyzed, and reports can be generated with the results of said analyzes (ESRI, 2020).

Arcgis:complete system that allows to collect, organize, manage, analyze, share and distribute geographic information (ESRI, 2020).

3. Methodology

The methodology used to delimit the proposed scenario is explained in this section:

3.1. Data organization

With the geographic and demand information collected for the route diagnosis presented in the article: Public transport case: route 36: diagnosis of Taxqueña modal transfer center-Puente de Vaquerito (García-Cerrud, 2019), layers were created for each of the routes (42 in total, 21 in the CETRAM Taxqueña-Glorieta de Vaqueritos trip and 21 in the Glorieta de Vaqueritos- CETRAM Taxqueña trip).

3.2. Data processing

To carry out a spatial statistical analysis that reflects the set of points (stops) and their associated demand, it is necessary to carry out the data treatment that allows visualizing the coincident points in the 42 routes.

3.3. Spatial statistical analysis

The analysis used for this work is called Hot Spot Analysis (Getis-Ord) which identifies statistically significant spatial clusters (spatial clusters) of high values (hot spots) and low values (cold spots).

3.4. Established stops proposal (proposed scenario)

Based on this analysis and the distances allowed in the stop design, the stops established for each run were determined.

3.5. Determination of direct emissions of gases and greenhouse compounds (CyGEI) based on the proposed established stops

When determining the established stops, it is possible to calculate the annual gasoline consumption of the route, taking as a basis for calculating the percentages of consumption reduction the information provided by the National Commission for the Efficient Use of Energy in its guides for the motorist and efficient operator. (Comisión Nacional para el uso Eficiente de Energía, 2018).

3.6. Comparison of the current scenario against the proposed scenario

Subsequently, the emissions are shared between the current scenario; which have already been calculated and presented in the article: Public transport case: route 36: diagnosis of Taxqueña modal transfer center -Puente de Vaqueritos (García-Cerrud, 2019) and the scenario proposed with the purpose of knowing if said proposal would help to reduce emissions.

4. Results

4.1. Data organization

In order to carry out an analysis of the data, it is necessary to organize them; in this case, layers were made for each of the routes taken (42), which are both geographical and demand representations for stops and their type. Figs. 4 and 5 show an example of the geographic positioning layer and the demand associated with these points, respectively.

4.2. Data processing

Once the information is organized, it is necessary to process the data so that the information of the 42 routes is unified in a single layer with which the spatial statistical analysis is performed. This treatment was carried out in the following way:

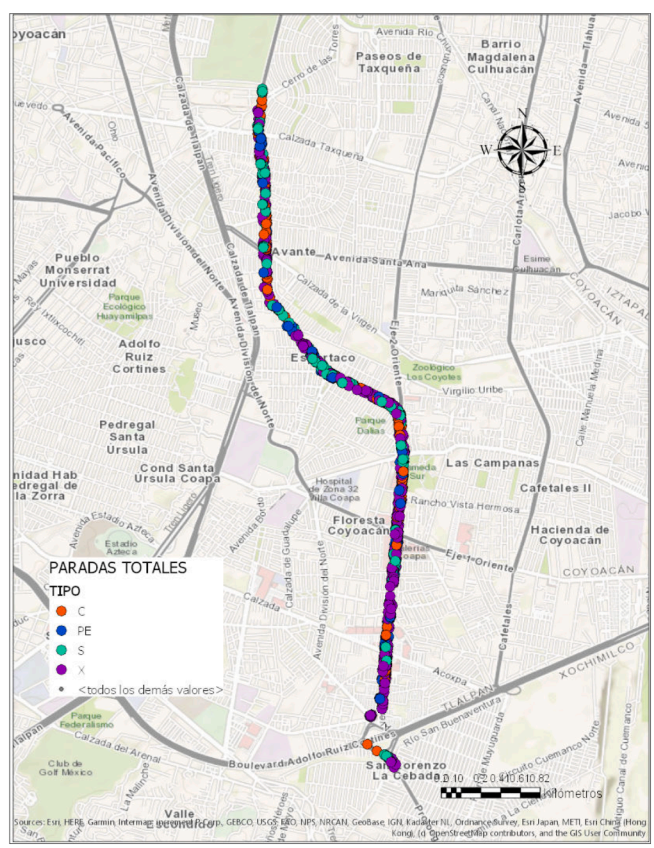

Fig. 4. Geographic stops position Source:Own data complied using Arcgis.

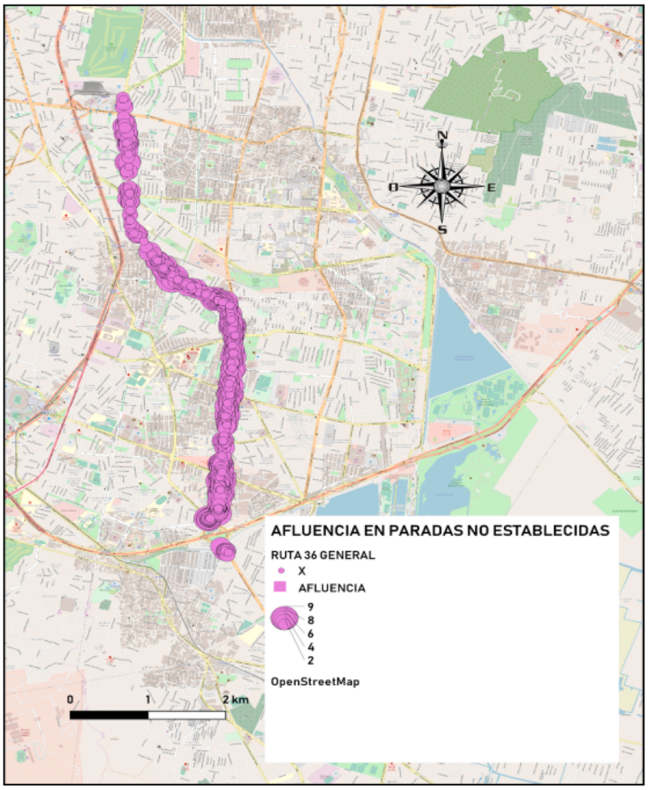

Fig. 5. Demand geographic representation. Source:Own data complied using Arcgis.

4.2.1. Layers intersection

Said intersection is made so that the entities or parts of entities (stops) overlap on all layers and are written to the output feature class, in which the attribute values of the input feature classes are will copy to the output feature class.

The example of the resulting attribute table is shown in Table 1.

4.2.2. Layers merge

Taking the resulting layers, we proceed to merge them creating a single layer which makes a relationship between the attribute tables by appending and adding the attributes of one to the other based on a field common to both; this tool accumulates numerical data.

For the purposes of this work, the fusion was performed using the geographic coordinates (latitude and longitude) and the accumulated data were those corresponding to the demand; resulting in a layer with the data of all the runs made.

The example of the resulting attribute table is shown in Table 2.

4.3. Spatial statistical analysis

Using the resulting layer of data processing, it is possible to carry out the analysis called Hot Spot Analysis (Getis-Ord).

With which we obtain a layer that shows the hot and cold geographical points with respect to the demand in the area as well as the resulting attributes in the analysis, which are shown in Table 3 and Fig. 6.

As observed in Fig. 6 regarding the influx of passengers, the analysis of the Getis-Ord spatial statistics shows concentrations of Hot Spots (red shades) in specific areas of the run: when crossing Calzada Taxqueña, near the streets Erasmo Castellanos Quito, Estrella Binaria, Lira and Astron, on Avenida Tizanas and finally when crossing the Glorieta de Vaqueritos.

From this analysis, we also present the concentration areas where the influx of passengers Cold spots (blue shades) is less likely to occur:

Table 1
Attributes table resulting of the intersection. Source:Own data complied using Arcgis.

FID_VT	LAT	LONG	TIPO	AFLU	DIA	FID_VN	LAT_1	LONG_1	TIPO_1	AFLU_1	DIA_1	FID_VM	LAT_12	LONG_2	TIPO_12	AFLU_12	DIA_12
5	19.290	−99.126	X	2	VT	5	19.291	−99.126	X	2	VN	6	19.289	−99.126	X	3	VM
5	19.290	−99.126	X	2	VT	5	19.291	−99.126	X	2	VN	7	19.291	−99.126	X	5	VM
5	19.290	−99.126	X	2	VT	5	19.291	−99.126	X	2	VN	8	19.292	−99.126	X	1	VM
5	19.290	−99.126	X	2	VT	6	19.291	−99.126	X	4	VN	6	19.289	−99.126	X	3	VM
5	19.290	−99.126	X	2	VT	6	19.291	−99.126	X	4	VN	7	19.291	−99.126	X	5	VM
5	19.290	−99.126	X	2	VT	6	19.291	−99.126	X	4	VN	8	19.292	−99.126	X	1	VM
5	19.290	−99.126	X	2	VT	7	19.293	−99.126	X	6	VN	6	19.289	−99.126	X	3	VM
5	19.290	−99.126	X	2	VT	7	19.293	−99.126	X	6	VN	7	19.291	−99.126	X	5	VM
5	19.290	−99.126	X	2	VT	7	19.293	−99.126	X	6	VN	8	19.292	−99.126	X	1	VM
5	19.290	−99.126	X	2	VT	8	19.294	−99.125	X	1	VN	6	19.289	−99.126	X	3	VM
5	19.290	−99.126	X	2	VT	8	19.294	−99.125	X	1	VN	7	19.291	−99.126	X	5	VM
5	19.290	−99.126	X	2	VT	8	19.294	−99.125	X	1	VN	8	19.292	−99.126	X	1	VM
6	19.291	−99.126	X	1	VT	5	19.291	−99.126	X	2	VN	6	19.289	−99.126	X	3	VM
6	19.291	−99.126	X	1	VT	5	19.291	−99.126	X	2	VN	7	19.291	−99.126	X	5	VM

Table 2
Attributes table resulting of the merge. Source:Own data complied using Arcgis.

LAT	LONG	TIPO	DIA	LAT_1	LONG_1	TIPO_1	DIA_1	LAT_12	LONG_2	TIPO_12	AFLU	DIA_12
19.302	−99.125	PE	DT	19.304	−99.125	X	DN	19.304	−99.125	X	8	DM
19.302	−99.125	PE	DT	19.304	−99.125	X	DN	19.304	−99.124	X	2	DM
19.302	−99.125	PE	DT	19.304	−99.124	X	DN	19.304	−99.125	X	8	DM
19.302	−99.125	PE	DT	19.304	−99.124	X	DN	19.304	−99.124	X	2	DM
19.308	−99.124	X	DT	19.307	−99.124	PE	DN	19.307	−99.124	PE	3	DM
19.314	−99.124	PE	DT	19.315	−99.124	X	DN	19.315	−99.124	X	1	DM
19.317	−99.126	PE	DT	19.316	−99.125	X	DN	19.316	−99.125	X	1	DM
19.341	−99.137	PE	DT	19.341	−99.137	PE	DN	19.341	−99.137	PE	3	DM
19.290	−99.126	X	VT	19.291	−99.126	X	VN	19.289	−99.126	X	3	VM
19.290	−99.126	X	VT	19.291	−99.126	X	VN	19.291	−99.126	X	5	VM

Table 3
Attributes table resulting of the hot spots analysis. Source:Own data complied using Arcgis.

SOURCE_ID	AFLUENCIA_	GiZScore	GiPValue	NNeighbors	Gi_Bin
1	6	2.59513597	0.00945535	258	3
2	6	2.59513597	0.00945535	258	3
3	6	2.59513597	0.00945535	258	3
4	6	2.59513597	0.00945535	258	3
5	1	−1.00068882	0.31697729	258	0
6	3	−0.35426549	0.72313993	258	0
7	3	−0.35426549	0.72313993	258	0
8	3	−0.35426549	0.72313993	258	0
9	3	−0.35426549	0.72313993	258	0
10	3	−0.35426549	0.72313993	258	0
11	3	−0.35426549	0.72313993	258	0
12	3	−0.35426549	0.72313993	258	0
13	3	−0.35426549	0.72313993	258	0
14	3	−0.35426549	0.72313993	258	0

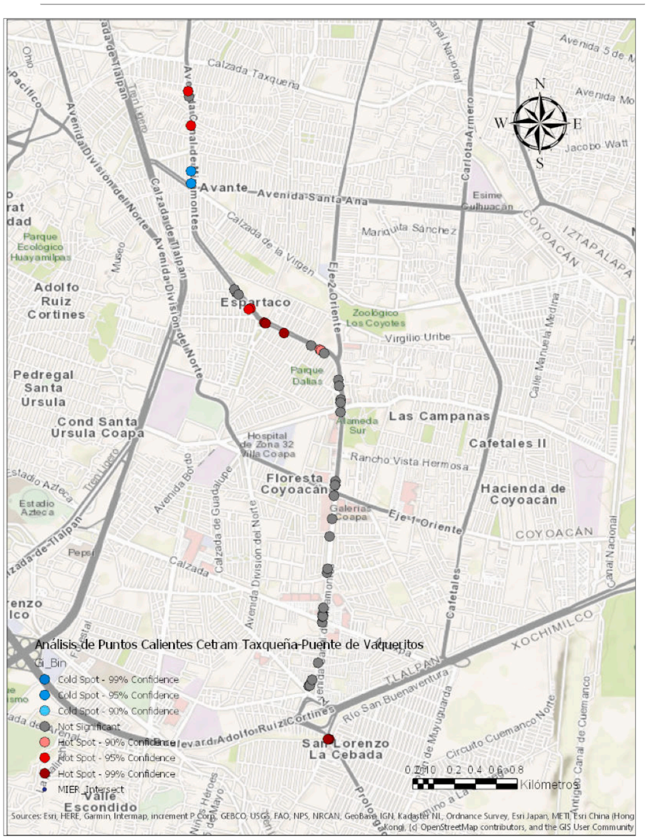

Fig. 6. Resulting map of the hot spot analysis. Source:Own data complied using Arcgis.

Calzada de la Virgen and its surroundings., Finally the rest of the stops carried out do not have statistical significance and are represented in gray.

This analysis provides us with a clear idea of the probability with which the stops are made with respect to the number of users that use them, which is why hot spots should be considered when establishing fixed stops.

4.4. Established stops proposal

With the information obtained from the analysis and the guidelines of stops for public passenger transport which indicates that in urban areas these stops must be in a distance interval that oscillates between 400 and 800 m, the pertinent measurements were made for their establishment taking the start of the tour as a starting point, the hot spots determined the location of specific stops based on the influx and the end point of the tour was established as the last stop on the tour. As for the distance measurements between the proposed established stops, this was done using the ArcGIS “measure” tool, which allows the geometry of the road to be followed, calculating the distances accurately.

From the analysis and measurement, 16 established stops were proposed for the run with direction CETRAM Taxqueña-Glorieta de Vaqueritos, which are shown graphically in Fig. 7 and Table 4 shows the distances and references associated with these.

The stops after the crossing were established in this way due to the influx of the streets with which they intersect and the vehicular flow of these, for the case of stop 13 it was determined that the location after the crossing was ideal due to the influx of users in said area; Finally, it is observable that the distance between stop 15 and the destination has a greater length, due to the geometry of the road (Glorieta de Vaqueritos), which, being elevated and not having sidewalks for the use of pedestrians or an area for ascent and descent, establishing a stop at any point of this is considered risky.

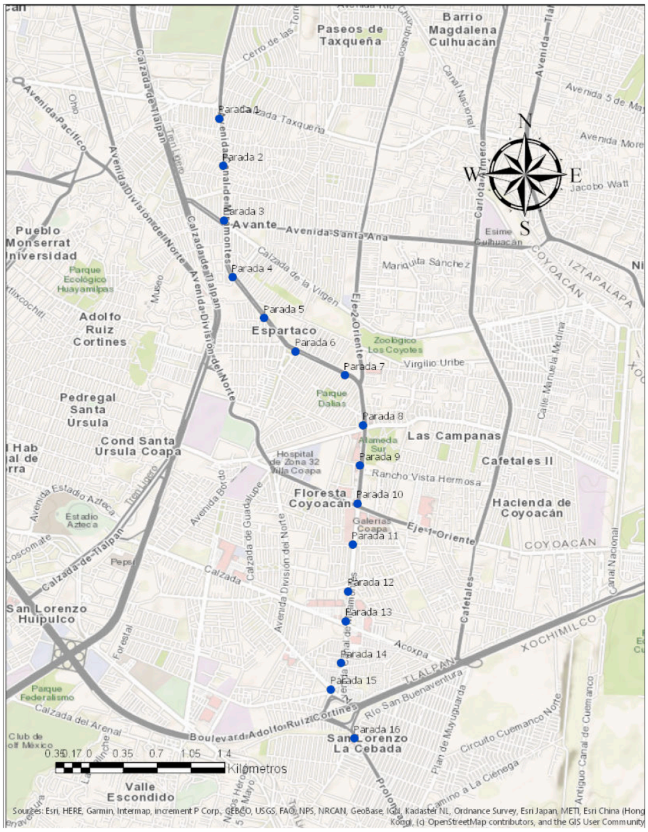

Fig. 7. Proposed established stops. Source: Own data complied using Arcgis.

Table 4
Distance and reference of the proposed established stops. Source: By authors.

STOP	DISTANCE (METERS)	REFERENCE
ORIGIN	0	CETRAM Taxqueña
STOP 1	575	After Taxqueña crossing
STOP 2	494.3	Álvaro Gálvez y Fuentes street
STOP 3	563.9	Calzada la Virgen
STOP 4	606.79	Retorno 49 street
STOP 5	524.96	Aldebarán street
STOP 6	466.39	Lira street
STOP 7	541.13	Parque Real street
STOP 8	589.22	Before Calzada de las Bombas crossing
STOP 9	420.73	Rancho Vista Hermosa street
STOP 10	400	Before Calzada del Hueso crossing
STOP 11	429.41	Monza street
STOP 12	484.87	After Calzada de las Brujas crossing
STOP 13	400	Before Calzada Acoxpa crossing
STOP 14	436.02	La Garita avenue
STOP 15	455.02	Cárcamo street
DESTINY	655.66	Rincón del Río street

4.5. Determination of direct emissions of gases and greenhouse compounds based on the proposed established stops

To determine the emissions, it is necessary to carry out a series of steps which are detailed below:

4.5.1. Percentages of reduction in energy consumption calculation

When determining the established stops it is possible to calculate the annual gasoline consumption of the route taking as a basis to calculate the percentages of consumption decrease the information provided by the National Commission for the Efficient Use of Energy in its guides for the motorist and efficient operator the which indicate that (Comisión Nacional para el uso Eficiente de Energía, 2018):

•Acceleration after reaching speed 0: + 50%.
• Heavy traffic: + 15%
• Speeds less than 40 km/h (times "0″): + 25%

Table 5 shows the associated percentages of decrease, the acceleration item after reaching zero speed and speeds less than 40 km/h was determined by calculating the variation with respect to the number of stops and in the dense traffic item; due to this being an uncontrollable variable, half the percentage was assigned.

Table 5 Percentages of reduction in energy consumption calculation. Source: By authors.

4.5.2. Energy consumption with reduction percentages calculation

In the current scenario, energy consumption, that is, gasoline, is 3,270,400 L per year (García, 2019), when calculating the reduction calculated in the previous point, the calculation of fuel in the scenario of established stops is equivalent to 2,001,888,125 L per year.

4.5.3. Emissions calculation

For the emissions calculations, the format provided by the Mexican Association of Automotive Distributors (AMDA) was used, which aims to guide the techniques and formulas for the application of methodologies for the calculation of emissions of greenhouse compounds, calculating the direct emissions of gases and greenhouse compounds derived from the consumption and oxidation of fuels in internal combustion engines in mobile sources stipulated in Article 5, Section II.

This calculation is shown in Table 6

4.6. Comparison of the current scenario against the proposed scenario

With the calculations made for the current scenario (García, 2019) and the proposed scenario in this work, it is possible to make a comparison of direct emissions of gases and greenhouse compounds.

When establishing specific stops, the zero travel times decreased by 46%, in terms of fuel consumption and emissions, the variation is shown in Table 7.

To show that there is not only an improvement in the environmental impact, but also in the operating costs of the service, the cost comparison shown in Table 8 is performed.

5. Conclusions

Public passenger transport is of great importance for the development of a country; therefore, it is necessary to ensure that it generates the least number of externalities, this is possible by optimizing energy consumption and consequent operational improvement.

For the case study, when establishing specific stops, the zero times in the route decreased by 46%, the associated polluting emissions and the operating cost associated with fuel consumption decreased by 58%, also it does not impact exclusively on these items, but also on the quality of service through shorter run times, eliminating risks associated with ascending and descending in dangerous areas.

With this premise in mind it is observable that when making small changes of low economic impact; since the stops do not require a specific infrastructure but signaling; the associated positive impact is highly relevant.

Table 5
Percentages of reduction in energy consumption calculation. Source: By authors.

CONCEPT	INCREMENT (%)	CORRESPONDING REDUCTION (%)
Acceleration after reaching speed 0	0.5	0.23
Heavy traffic	0.15	0.075
Speeds less than 40km/h (times "0")	0.25	0.115

Table 6
Direct emissions of gases and greenhouse compounds calculation. Source: By authors.

Fuel		Natural gas
Annual consumption		2,001,888.13
Emissions factors	CO2 (ton/M1)	0.0000693
	CH4 8kg/M1)	0.000025
	N2O (kg7M1)	0.000008
Caloric power (M1/bl)		5,122
Annual emissions	CO_2	4,469.41
	CH4	45.145
	N2O	136.726
Annual emissions		4,651.28

Table 7
Energy and emissions variation. Source: By authors.

Scenarios	Energy Consumption	Emissions (tCO2eq)
Actual Scenario	3,451,531.25	8,019.45
Proposed scenario	2,001,888.13	4,651.28
Variation (%)	58	58

Table 8
Energy saving cost comparison. Source: By authors.

CONCEPT	QUANTITY
Propose scenario associated costs ($)	16,612,250.00
Actual scenario associated costs ($)	27,612,250.00
Variation ($)	11,597,145.00
Variation (%)	-42

In the same way, it is pertinent to mention that the stops should not be established in an arbitrary way, but with a methodological support, since one of the components and in fact the purpose of the system is to provide users with a means of transport that provides a best service response to population demands taking into account location patterns, density of urban activities, attributes, conditions and location of infrastructure, road facilities, technological and operational characteristics, legal and institutional framework.

The quantitative diagnosis and the spatial statistical analysis or exploratory analysis of spatial data such as those presented in this work are recommended to be applied to all the routes that run through the roads in order to understand the existing interactions and to amplify the impact of this proposal.

In the same way, the delimitation of the confined lane is recommended (extreme right or left depending on the direction) since many of the risks that operators incur when changing lanes are associated with the lane occupation by third parties; this would speed up the routes impacting in the travel time, the congestion they face and, consequently, in the “0″ times and polluting emissions.

Another pertinent recommendation is the creation of policies by the route administration regarding the delimitation and use of stops for ascent and descent; possibly counting on a sanction system to the operators.

Due to the fact that public passenger transport system is governed and limited by state policies, it is considered necessary to propound the existing ones and/or create new ones based on an analysis of all the implications that may arise and, if possible, using a systemic approach in order to understand all externalities and how they will affect the system as a whole and its components individually.

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