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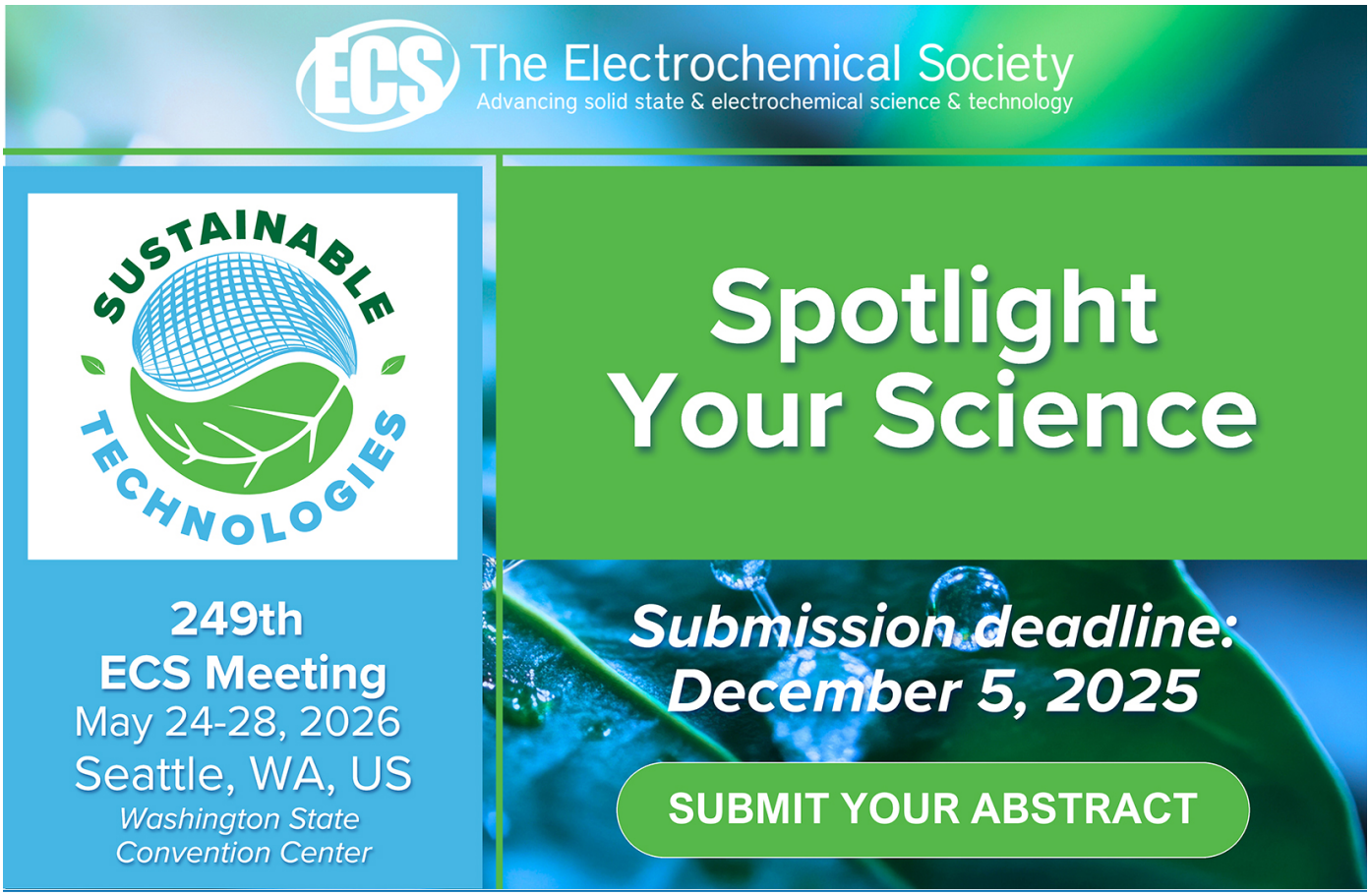
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Instantaneous speed as a tool for defining accessibility in the road network of Ocaña, Colombia

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Abstract. The application of the concept of instantaneous speed to the movement of vehicles on a city's road network made it possible to establish average operating speeds. With the help of software based on geographic information systems, it was possible to determine the minimum travel times required by vehicles to move between two points on the network. Through the above analysis of speeds and travel times, applied to the road network of the municipality Ocaña, Colombia, it was possible to establish the time required by various types of vehicles to travel between the different points of the road network, allowing to define the level of accessibility to move between different areas of the city. The analysis required the updating, characterization, georeferencing and determination of the instantaneous speeds for each trip in the different arcs of the network and the subsequent determination of the average travel time curves in the network. The urban area of the city is covered with an average travel time of 15 minutes and the operating speeds are between 5 km/h and 31 km/h, with variations depending on the type of vehicle (bus, taxi, motorcycle).

1. Introduction

Accessibility defined as the ease of communication that a network offers using a certain transport mode [1-3]; this is determined by the sum of the individual users' trips who use them. Accessibility allows measuring the ease or difficulty contributed by the infrastructures and transportation modes for a trip [1]. Furthermore, the impact of policies related to transport in each location can be measured using accessibility analysis, since users are responsible for determining which transport mode they use [4].

Accessibility and mobility are factors that are intrinsically determined by the city model; in this sense, the work developed by [5] compares displacements in urban areas of the Netherlands, seeking to establish the impact that the urban structure exerts on the mobility patterns, finding that travel times in polycentric areas are lower than in monocentric zones [6]. However, other investigations such as the one developed by [7] for the San Francisco Bay, United States of America, have shown that sometimes times and distances travel increase with the increase in the degree of polycentrism in the city.

In a monocentric city model, as mentioned by [8], urban development spins around a central nucleus, correlatively homogeneous, with a strong economic and functional centrality; this model arises associated with the center-periphery model in which there is a center with dynamic characteristics and a high concentration of the final productive procedures, instead, the peripheries are linked to procedures of transformation of local resources [9]. Instead, a polycentric city model, as expressed by [10], consists of a nuclear structure of the urban system with high concentrations of population and employment. In addition to concentrating the previous ones, it must be a space of influence and attract flows of workers and buyers [11].

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The current model of the municipality of Ocaña, Colombia, is characterized by concentrating the administrative area and basic economic activities, thus establishing a purely monocentric model. Bearing this in mind, a research project was proposed to define the operability of the road network of Ocaña, Colombia, for the different transport modes and to establish the accessibility that users must move from their homes to their destination within the urban perimeter.

2. Methodology

Considering that the accessibility analysis seeks to measure how adequate is the urban road infrastructure of a city to allow mobility using the different transport modes [12]. For this case study, the modes of transport selected were automobile, motorcycle, taxi, and bus.

The study was developed in 4 phases. In the first phase, the information collection, the updating, and georeferencing of the road network was carried out, as well as the definition of its operational characteristics. In the second phase, the calculation of the operating speeds for the different arcs of the network and the different transport modes was performed. In the third phase, the calculation of the global average accessibility offered by the network was carried out, considering its infrastructure and the transport modes that operate. In the fourth and last phase, the percentage of area, population, and number of households that are covered by average time travel curves obtained from the accessibility analysis are calculated.

2.1. Update and survey of the road network point to point

Initially, a recognition of the information on the road network was made, later it was validated and completed with the use of global positioning system (GPS) equipment Columbus V-900, these types of equipment were installed in two vehicles for each transport mode considered in this study. The records for each transport mode were made in a period of three weeks, obtaining records, in intervals of one second, of coordinates in the space in which it is located, as well as data and times of the data. The imprecise range of the record taken by the GPS was ± 3m. The coordinate systems which the information was georeferenced correspond to the official datum for Colombia.

2.2. Calculation of operating speeds

The American Association of State Highway and Transportation Officials (AASHTO) defines the operating speed as "the maximum average speed that a driver can travel on a given section of track under favorable meteorological conditions, predominant traffic conditions and without exceeding the safe speed at any time, determined by the speed of design based on an analysis by sections of the track" [13]. However, in the practical case, the 85th percentile of the distribution of speeds at which light vehicles operate under conditions of free flow and without restrictions is usually used to determine this parameter [14].

The speed of operation for each arc of the network was calculated from the data collected with the GPS equipment; in each case the following parameters were analyzed: (a) the vehicle speed of each data reading interval along i-th arcs, (b) the average speed of operation of i-th arc, (c) the speed of operation for each arc i of a certain route.

2.2.1. The instantaneous speed. This corresponds to the vehicle speed at each data reading interval along the different arcs of the road network. It is used to establish the variations of the speed on a particular arc between point 1 and point 2; it is obtained by using Equation (1).

$$\mathrm{vi} = (3.6/\mathrm{t})\sqrt{(\mathrm{y2}-\mathrm{y1})^2 + (\mathrm{x2}-\mathrm{x1})^2}, \quad (1)$$

where vi is the speed in Km/h, x1, y1 are the coordinates in meters of point 1, x2, y2 are the coordinates in meters of point 2 and t is the time interval in seconds between data.

2.2.2. Calculation of average speed. The average speed of arc travel is obtained with the relationship between the length of the arc and the difference of the times passages between the initial node and its end node, by applying Equation (2) [15].

$$v^a i = 3.6(l_a/(t_2 - t_1)), \quad (2)$$

where $v^a i$ is the speed in the arc a (Km/h), l_a is the arc length a in meters, t_1 is the transfer time in the initial node, and t_2 is the transfer time in the final node.

2.2.3. Calculation of the average speed for periods of time. The average speed in the arc for a period of time is calculated by applying Equation (3). This speed was calculated for each arc of the road network, and it was used to establish the impedances and for the development of the average travel time prediction model [15].

$$\overline{va} = (\sum_{i=1}^{n} v^a i)/n, \quad (3)$$

where $\overline{va}$ is the average speed of arc operation a, $v^a i$ is the speed i in the arc a (Km/h) and n is the number of speed data recorded in the arc a, for a period of time.

3. Results and discussion

The analysis for the different transport modes was carried out, mainly with respect to the average speed of operation on the different arcs of the network, obtaining graphics that represent the state of the city with respect to the average travel times comparing them with the different modes of transport. Based on the information provided by the transit office and the georeferencing of the city road network, the percentage of urban areas, population, and number of homes covered by different ranges of travel times were calculated. This was performed for each transport mode analyzed. In addition, with the application of the proposed methodology, the calculation of average travel times was made in terms of global average accessibility for the entire city, including the speeds of the different transport modes under study. The procedures and results obtained are indicated below.

3.1. Characterization based on secondary information of the road network

The categorization of the routes according to the use and importance was made by visual inspection, establishing road senses, restrictions, whether they are main road, secondary road, collector road, tertiary road, or pedestrian routes. Once all the information was obtained, the network was updated using the TransCad ™ software and with the superposition of the data collected by the GPS, errors were observed in the point cloud as shown in Figure 1, where the lack of an arc in the network can be observed; the route was made by bus on a seemingly non-existent arch, but with a field visit the existence of said arch was evidenced. Figure 2 shows the road network in its entirety, once the inconsistencies found have been corrected, indicating the degree of importance of road (Figure 2(a)) and sense (Figure 2(b)).

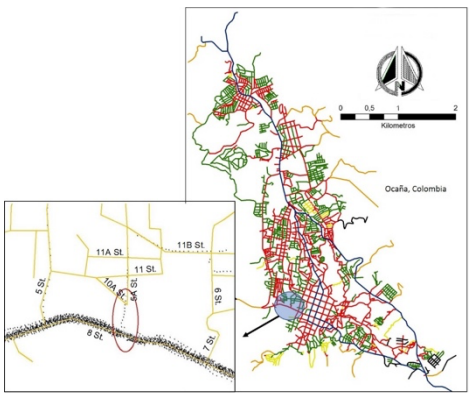
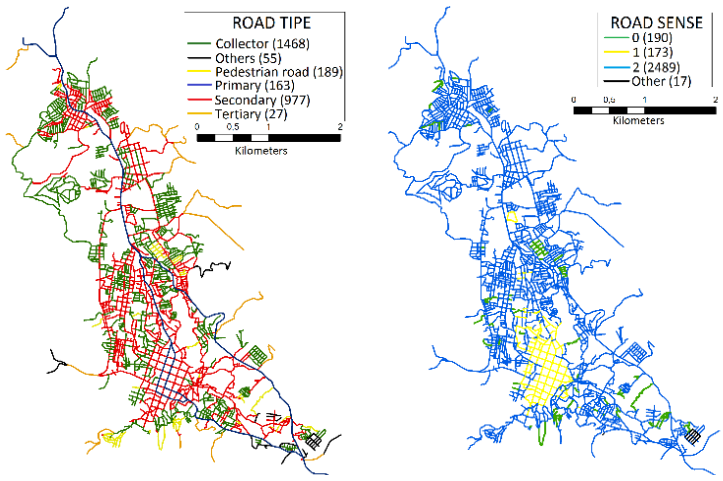


Figure 1. Floating arch in the road network.



(a) (b)

Figure 2. Characterization of the road network considering; (a) the degree of importance; (b) the sense.

3.2. Operating speeds of the different modes of transport in the road network

The different operating speeds for each transport mode were calculated based on Equation (1) and they were used to establish the impedances and the development of the prediction travel times model. Table 1 contains the average speeds calculated, according to the type of road and the mode of transport. The study established that of the different transport modes analyzed and, analyzing from the perspective of speed variable, in the case of the main road network, the motorcycle transport mode presents the best average speed to move around this network, with a speed between 2 Km/h and 3 Km/h higher to the car, taxi, and public transport (PT) modes, which have similar speeds in this network.

In the case of the secondary and collector road network, the motorcycle mode also maintains the highest speeds, with values above 7 Km/h to the average speeds of the car and taxi modes, and between 16 Km/h and 20 Km/h to the PT mode. In the case of the tertiary road network, the motorcycle transport mode has the highest speeds which are in the order of 4 Km/h above those of the car and taxi transport modes, and in the order of 24 Km/h above that of the PT mode. However, this mode of transport is the one with the highest accident rates in the city.

Table 1. Average speeds for each type of road depending on the mode of transport.

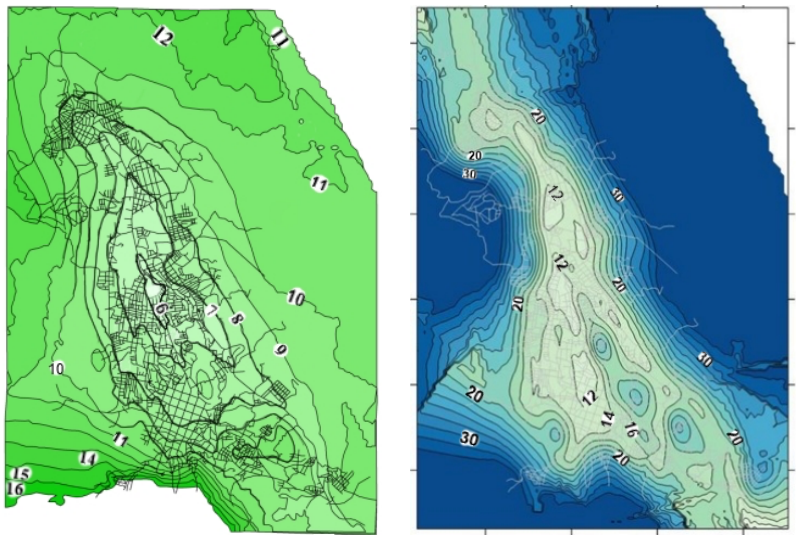
Type of route	Taxi speed (Km/h)	Automobile speed (Km/h)	Motorcycle speed (Km/h)	Bus speed (Km/h)
Main road	28.27	29.33	31.05	28.90
Secondary road	17.32	17.93	24.21	8.11
Collector road	15.54	13.14	22.96	2.77
Pedestrian road	2.00	2.00	2.00	2.00
Tertiary road	25.29	25.80	29.61	5.30

The operating speeds of sectors with the most traffic in Ocaña, Colombia, were analyzed such as “Avenida Francisco Fernández de Contreras”, “La Circunvalar” and the central and northern sector, where all transport modes circulate. The Center sector concentrates all trade and financial activities, defining a monocentric model, which causes people to constantly access this sector, generating great congestion. The street known as “El Dulce Nombre” located in the center sector, where there are many commercial stores and one of the access roads to “Parque 29 de Mayo” (main park of Ocaña, Colombia), where all the banking entities are, as well as public administration offices and clergy facilities. The speeds of operation registered in this street oscillate approximately between 11.83 Km/h and 22.79 Km/h, relatively low values.

3.3. Global average accessibility offered by the road network

The results of the TransCad® software indicate that the urban perimeter of Ocaña, Colombia, is covered by isochronous curves from 5 minutes to 36 minutes, which vary with respect to the selected transport mode. The expansions of the isochronous curves are highlighted more in the north-south direction than the east-west direction, analyzing the context of the city, the validity of these results is verified since most of the economic activities are developed in the central part of the city and the communication and displacement are carried out in the north-south direction, which corresponds to one of the main road axes of mobility. Likewise, the curves allow to identify the impact that is generated on the measured travel time, because the network offers specific vehicular corridors in Ocaña, Colombia, such as "Avenida Francisco Fernández de Contreras", "Las Llanadas", "Los Lagos", "La Circunvalar", and "El Marabel", which expands significantly in the sense.

Figure 3(a) shows the isochronous curves for the Automobile mode of transport; these curves represent the virtual space made up of the positions reached by a vehicle in time Ti starting from point i on the city's road network. It can be seen how the city of Ocaña, Colombia, is covered by travel time curves between 6 minutes and 12 minutes. Therefore, the sector covered by the lowest curve, that is, 6 minutes, is the one with the best accessibility, provided this means of transportation is used. Figure 3(b) shows that the city is covered by time curves between 12 minutes and 30 minutes for the bus transportation mode; a similar analysis was performed for the other modes of transportation studied.



(a) (b)

Figure 3. Global average accessibility curves of the mode of transport; (a) automobile; (b) bus.

3.4. Relationship between population, area, and global average accessibility curves

Using Surfer software for geostatistical analysis, the percentages of the area covered by each of the modes of transport were analyzed in each of the trips made by the vehicles analyzed. Figure 4 shows the percentage warhead about the area, population, and several households covered for the isochronous curves. It is also observed that 50% of the population of Ocaña, Colombia, is covered by the automobile transport mode in 8.2 minutes, and 100% of the population of Ocaña, Colombia, is covered in approximately 17 minutes (Figure 4(a)). Similarly, this analysis was carried out for the different transport modes, finding that in the case of the taxi transport mode (Figure 4(b)), 50% of the population is covered in 8.2 minutes and 100% in 18 min. For the motorcycle transport mode, 50% is covered in 6.8 minutes and 100% in 14 minutes (Figure 4(c)). Finally, for the bus transport mode, 50% is covered in 15 minutes and 100% in 36 minutes (Figure 4(d)).

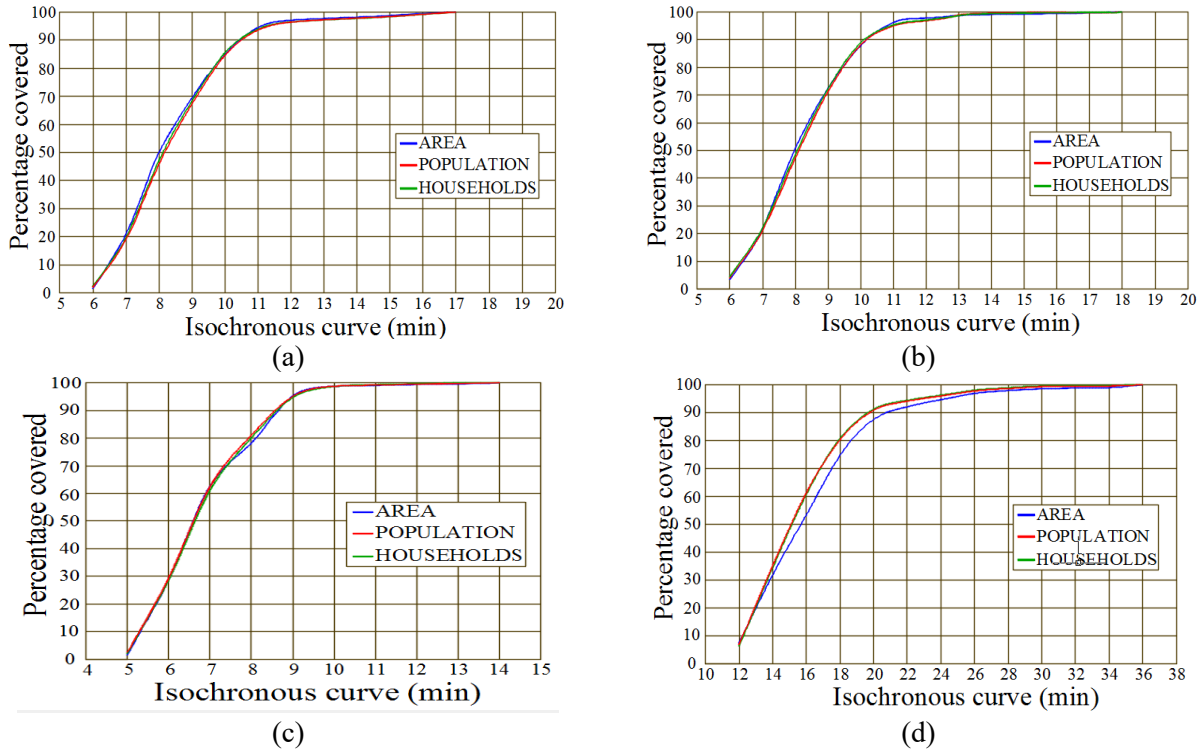


Figure 4. Percentage curve of area, population and number of houses covered by the isochronous curves for each transport mode: (a) automobile, (b) taxi, (c) motorcycle, (d) bus.

4. Conclusions

The accessibility analysis allowed establishing at which speeds the transport modes move in the road network. In the case of the public transport mode, the average speed in the primary network is about 29 Km/h, but in the secondary, collector, and tertiary road networks, it is about 8 Km/h, 3 Km/h, and 5 Km/h respectively. This indicates that it is necessary to design measures to improve the performance of this transport mode in the city's road network. Of course, this is from the perspective of the speed variable.

Also, it was established that the municipality of Ocaña, Colombia, is currently covered between isochronous curves from 5 minutes to 36 minutes, which is variable to the transport mode in which it is desired to move. For the transport modes studied in this research, the expansion of the isochronous curves is highlighted more in the north-south direction than in the east-west direction. This is valid because all economic activities are located in the central part of the municipality, and communication and movement are carried out vertically.

The curves expand along the north-south transport corridor, and the curves allow us to identify the impact they generate on average travel times. The network in Ocaña, Colombia, offers vehicle corridors such as “Avenida Francisco Fernández de Contreras”, “Las Llanadas”, “El Lago”, “La Circunvalar”, and “El Marabel”, which make the curves expand significantly in this direction.

Due to the monocentric model with which the municipality of Ocaña, Colombia, primarily works, the development of commercial activities and services is carried out mainly on a central road axis, which has generated a linear secondary structure, which has repercussions on a set of urban and environmental problems. This also causes mobility in a very sensitive area, due to its proximity to the service center, office areas, administrative area, and the historic center of the city.

References

[1] Escobar D, García F 2012 *Diagnóstico de la Movilidad Urbana de Manizales* (Manizales: Universidad Nacional de Colombia)
[2] Ng C P, Law T H, Jakarni F M, Kulanthayan S 2018 Relative improvements in road mobility as compared to improvements in road accessibility and urban growth: a panel data analysis *Transportation Research Part A: Policy and Practice* **117** 292
[3] Zhu X, Liu S 2004 Analysis of the impact of the MRT system on accessibility in Singapore using an integrated GIS tool *Journal of Transport Geography* **12(2)** 89
[4] Lopez C, Pueyo A 2018 Medida y valoración de la accesibilidad viaria en España: revisión de casos *Ciudad y Territorio: Estudios Territoriales* **L(197)** 473
[5] Schwanen T, Dieleman F M, Dijst M 2004 The impact of metropolitan structure on commute behavior in the Netherlands: a multilevel approach *Growth and Change* **35(3)** 304
[6] Leo A, Morillón D, Silva R 2017 Review and analysis of urban mobility strategies in Mexico *Case Studies on Transport Policy* **5(2)** 299
[7] Cervero R, Wu K L 1997 Polycentrism, commuting, and residential location in the San Francisco Bay area *Environment and Planning A* **29(5)** 865
[8] Gallo M T, Garrido R, Vivar M 2010 Territorial changes in the community of Madrid: polycentrism and dispersion *Revista Latinoamericana de Estudios Urbano Regionals EURE* **36(107)** 5
[9] Ascher F 2004 *Los Nuevos Principios del Urbanismo* (Madrid: Alianza Editorial)
[10] Boix R, Trullén J 2012 Policentrismo y estructuración del espacio: una revisión crítica desde la perspectiva de los programas de investigación *ACE: Architecture, City and Environment* **6(18)** 27
[11] Roca J, Marmolejo C, Moix M 2009 Urban structure and polycentrism: Towards a redefinition of the sub-centre concept *Urban Studies* **46(13)** 2841
[12] Geurs K, Ritsema van Eck J 2001 *Accessibility Measures: Review and Applications. Evaluation of Accessibility Impacts of Land-use Transport Scenarios, and Related Sodal and Economic Impact* (Bilthoven: Universiteit Utrecht)
[13] American Association of State Highway and Transportation Officials (AASHTO) 2011 *A Policy on Geometric of Design of Highways and Streets* (Washington: American Association of State Highway and Transportation Officials)
[14] Pérez A M, Camacho F J, García A 2011 La velocidad de operación y su aplicación en el análisis de la consistencia de carreteras para la mejora de la seguridad vial *Cuaderno Tecnológico de la Plataforma Tecnológica Española de la Carretera* (Madrid: Plataforma Tecnológica Española de la Carretera)
[15] Escobar García D A, Cadena Gaitán C, Salas Montoya A 2015 Cobertura geoespacial de nodos de actividad primaria. Análisis de los aportes a la sostenibilidad urbana mediante un estudio de accesibilidad territorial *Journal EIA* **12(23)** 14