Indian Journal of Science and Technology, *Vol 11(21), DOI: 10.17485/ijst/2018/v11i21/123113,* June *2018*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Global Mean Accessibility in Metropolitan Areas. Case Study: Chinchiná, Colombia

Diego Alexander Escobar[1], Santiago Cardona Urrea[1], and Carlos Alberto Moncada[2]

[1]Universidad Nacional de Colombia, Sede Manizales, Departamento de Ingeniería Civil, Colombia; daescobarga@unal.edu.co, scardonau@unal.edu.co
[2]Universidad Nacional de Colombia, Sede Bogotá, Departamento de Ingeniería Civil y Agrícola, Colombia; camoncadaa@unal.edu.co

Abstract

Objectives: To evaluate the alternatives of connection to the Metropolitan Area owned by the municipality of Chinchiná, Colombia: the Metropolitan Area of the Center-West (AMCO) and the Metropolitan Area of the Center-South Region (AMRCS). **Methods / Statistical Analysis:** A global mean accessibility analysis for different scenarios (Chinchiná as part of the AMCO and AMRCS, and a large region that sums both metropolitan areas) is used to determine which option generates greater benefits to the municipality of Chinchiná in terms of regional mobility. Besides, Kriging model is used to the geo-statiscal analysis and building the accessibility isochrones curves. **Findings:** The results showed that Chinchiná has the best geographical location in terms of global mean accessibility of the study area, corresponding to eight municipalities and two departments because it can be accessed in less than 60 min to all municipalities presents in AMRCS and less than 50 min to all municipalities presents in AMCO. **Application / Improvement:** The global mean accessibility as a tool to determinate the average travel time in Metropolitan Areas and the benefits fot new municipalities.

Keywords: Geo-statistics, Global Mean Accessibility, Gross Domestic Product, Metropolitan Area

1. Introduction

Metropolitan areas are fundamentally the result of economic growth and population processes that have led people to settle where there are more opportunities and where life expectancy is better[1]. They are a simplified market for land uses such as residential, commercial, and institutional, which is why they have become a mean to establish higher urban hierarchy worldwide, where public transport policies, land uses, urban environment management, housing, justice, etc. are studied at the scale of real impact[2]. Agglomerations in megalopolises or mega metropolitan areas around the world have existed since the 50s, with the formation of the New York metropolitan area. Over the years, 10 more were formed in cities such as Chicago, Los Angeles, Washington, Atlanta, among others. The metropolitan areas with the largest populations are located in Asia, such as Canton in China (49 million inhabitants) or Tokyo in Japan (40 million inhabitants). In Europe, given the proximity of countries and large cities, the urban system is made up of approximately 40 cities and a large number of intermediate cities. A few of the most important metropolitan areas in the continent are Moscow, London, Istanbul and Paris. In Latin America, metropolitan areas have been formed in countries such as Brazil (Sao Paulo, Rio de Janeiro and Belo Horizonte), Argentina (Buenos Aires), Venezuela (Caracas) and Colombia[1, 3].

In Colombia, metropolitan areas are regulated by Law 1625 (2013), where they are defined as: "*entidades administrativas de derecho público, formadas por un conjunto de dos o más municipios integrados alrededor de un municipio núcleo, vinculadas entre sí por dinámicas e interrelaciones territoriales, ambientales, económicas,*

**Author for correspondence*

sociales, demográficas, culturales y tecnológicas"[4]. Since 1968, they were incorporated into the constitutional reform and by December 15, 1981, the Metropolitan Area of the Western Center (AMCO) was formed by the municipalities of Pereira, Dosquebradas and La Virginia. In Colombia, there are 5 metropolitan areas legally constituted: Bucaramanga, Barranquilla, Centro Occidente, Cúcuta and Valle de Aburrá. Bogotá is considered a city-region constituted by 19 municipalities but it is not officially constituted[5, 6]. Chinchiná is a municipality in the Department of Caldas (Figure 1), located in the center west of Colombia 23 km south of the departmental capital, Manizales. It has an extension of 113 km2 out of which 2.3% (2.64 km2) corresponds to the urban area, and is located at 1,378 meters above sea level. Chinchiná is considered the national epicenter of the country's coffee industry since it is see to the National Center for Coffee Research "CENICAFE" and the Freeze-dried Coffee Factory, among others[7]. Chinchiná would have the possibility of linking to two metropolitan areas, one already existing and the other in the process of consolidation:

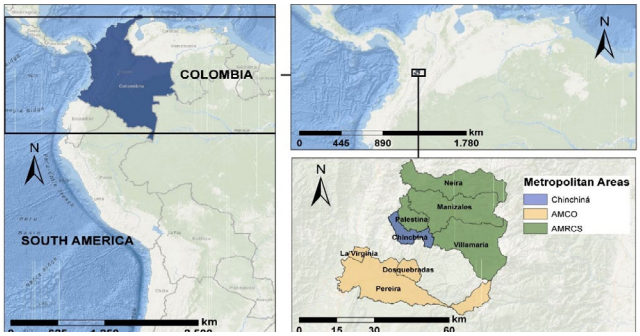

Figure 1. Geographic location of study area.

Firstly, AMCO (Figure 1) is made up of the municipalities Pereira (central core and department capital), Dosquebradas and La Virginia, the three from the department of Risaralda. The metropolis has continually supported the formulation of territorial planning for the municipalities that comprise it, as well as providing a framework for general policies on issues such as environmental order, land use regulations, public services and urban perimeters[8]. AMCO has made great progress in linking Chinchiná to its metropolitan area, considering they have been constituted since 1981 as an administrative entity and that they can generate great benefits for this municipality regarding transportation, multipurpose cadastre, and control model, among others[9]. Secondly, there is the desire to form a Metropolitan Area of the South Central Region (AMRCS) in the department of Caldas (Figure 1) due to the social, economic and physical links between the capital Manizales as a central nucleus and the municipalities of Neira, Villamaría, Palestina and Chinchiná[10]. The initiative to annex Chinchiná to AMCO has advanced in the last year[11]. In this research article, we study the two alternatives for linkage in the metropolitan area held by the municipality of Chinchiná in terms of global mean accessibility, emphasizing how current transportation infrastructure may envision a possible decision in the matter. Table 1 shows the population and GDP of AMCO and AMRSC municipalities, where the nuclei of each Metropolitan Area, Pereira and Manizales, concentrate the greater portion of the population. AMCO reaches a population of 709,323 inhabitants, while AMRSC reaches 522,830, 27% less. All municipalities have a higher population percentage in the urban area, except Neira and Palestine, indicating a greater rural vocation in these[12].

Accessibility is a concept used since the 50s in relation to land planning, transport, land use, etc. Hansen (1959) established its most classic definition, "potential

Table 1. Population

Municipality	Population Urban zone	Population Rural zone	Total	GDP (thousand millions)
Chinchiná	45,926	5,150	51,076	954,960
Manizales	371,307	27,523	398,830	5227,674
Villamaría	48,636	9,845	58,481	354,950
Neira	16,665	31,180	47,845	195,810
Palestina	6,848	10,826	17,674	191,237
Pereira	401,249	73,086	474,335	6306,103
Dosquebradas	194,374	8,421	202,796	1957,571
La Virginia	31,662	530	32,192	214,339

for interaction opportunities"[13], and laid the mathematical foundations of his calculation. In 1971, Ingram defines it as the inherent characteristic (or advantage) of a place with respect to overcoming some form of spatially operating source of friction (for example, time or distance). He proposed a subdivision of the concept: (a) relative accessibility that refers to the measure between two points of a city[14], and (b) integral accessibility that is the measure of a point with respect to the rest of them[15]. In the following years, Dalvi (1978) defined accessibility as the ease with which any land-use activity can be reached from a place using a particular mode of travel[16]. Geurs and Ritsema van Eck (2001) proposed four (4) different components for accessibility: land use, transport, time component and individual component[17]. They also defined four (4) different perspectives of analysis considering these components: measures based on place, person, utility and infrastructure[18]. It is precisely in this last perspective that the measures of global mean accessibility are coupled since an analysis is made between all the nodes of the road network through the average travel times obtained from the functional speeds of the road network[19].

Given the concept's multiple approaches[17], perspectives[18] and types of measurement[20], researchers have frequently used it in diverse topics such as land management[21,22], public transport planning[23,24], regional analysis[25,26], marketing[27], employment[28,29], social equity[30,31], study in metropolitan areas[32,33], among others. Following the introduction, the research method is explained, results are shown and discussed, and finally study conclusions are established.

2. Methodology

The research methodology addressed consists of four main and consecutive stages, which are presented in Figure 2.

2.1 Input Data

Two fundamental inputs were obtained from data entry: i) Territorial road network corresponding to the eight municipalities making up AMCO, AMRCS and Chinchiná. It is important to note that the territorial road network is composed only of the primary and secondary roads of the national network that connect these municipalities; ii) The polygon of municipality location and its urban area, as well as its population, in the urban and rural area, and its GDP, a macroeconomic term used to express the monetary value derived from the production of goods and services in a country or region, generally in an annual period[34].

2.2 Verification of Road Network

The topology and connectivity of the road network was verified[35]. Likewise, the lengths of the arches were calculated using a Geographic Information System (GIS) and their average travel time. Travel time was calculated by relating length and functional speed, obtained according to road category[36]. The road network had to be adjusted to calculate accessibility for each of studied scenarios: i) the region as a whole (AMCO and AMRCS), ii) AMCO including Chinchiná, and iii) AMRCS including Chinchiná.

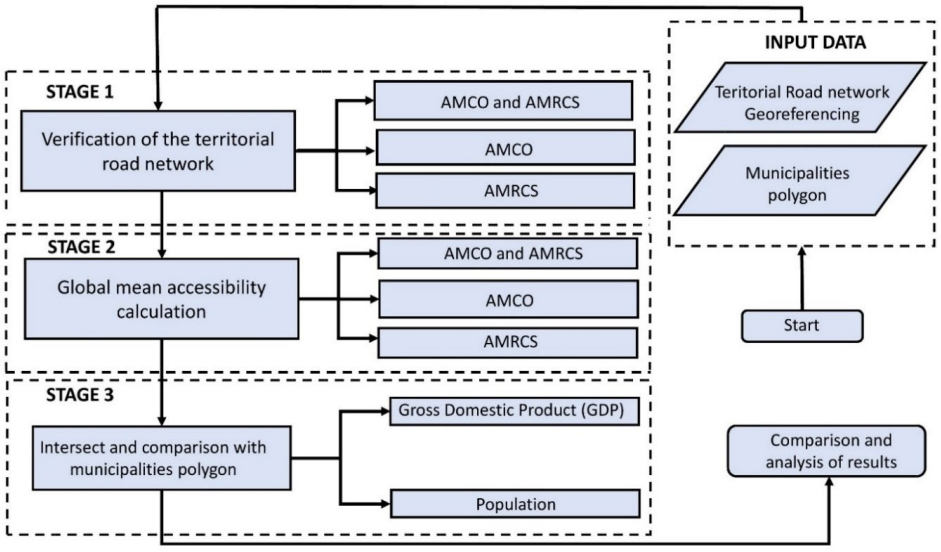

Figure 2. Research methodology.

2.3 Global Mean Accessibility Calculation

This measure was calculated for each scenario by isochronous travel curves. It was necessary to obtain the travel time matrix, which was the result of the calculation of the minimum path algorithm or Dijkstra algorithm through the tool "Multiple paths" of the GIS TransCad software[37, 38]. Then, the vector of mean travel times of the nodes was calculated $(\overline{Tv_i})$ (Equation 1), obtained from the division of the sum of travel times of each node and the remaining nodes $(\Sigma_{j=1}^{n} tv_{ij})$ between the number of nodes, except for the calculation node this does not travel towards itself (n-1).

$$\overline{Tv_i} = \frac{\sum_{j=1}^{n} tv_{ij}}{n-1} \qquad i = 1,2,3,\ldots,n \quad j = 1,2,3,\ldots,n \tag{1}$$

With the $(\overline{Tv_i})$ vector, the geo-statistical model was made in order to obtain the isochronous travel curves. The ordinary Kriging model was used, which approximates a projection space precisely[39]. It is dynamic since it can work with a wide range of spatial correlation functions, either linear or non-linear. In this case, the linear semivariogram function, initially defined by Matheron (1963), is used as a correlation function[40]. Likewise, this geo-statistical model and its correlation function have been used by several transport researchers in order to predict results in space where data are not available[41, 42].

2.4 Intersect and Comparison with Municipalities Polygon

This stage is fundamental for result analysis and discussion. It relates isochronous curves with municipality polygon that have socio-demographic data referring to population and GDP. The potential benefits to the Chinchiná municipality from joining AMCO or AMRCS are derived.

3. Results and Discussion

3.1 Global Mean Accessibility for both Metropolitan Areas

Figure 3 shows the isochrone curves of global mean accessibility for AMCO and AMRCS as a whole. Mean travel times of 49.27 min are found near Chinchiná's urban area, municipality with best global accessibility, and 158.27 min in the rural area of the Neira municipality. The urban areas of the municipalities of Palestina, Dosquebradas and Pereira are covered in between 50 and 60 min travel time. This allows people to access the entire region in average times of less than one hour. Manizales and Villamaría's urban areas are found in the isochronous time curve of 70 min. The most unfavorable accessibility conditions were registered in the municipalities of La Virginia and Neira, considering their location in the southern and northern part of the study area, reaching mean travel times of up to 90 and 100 min each.

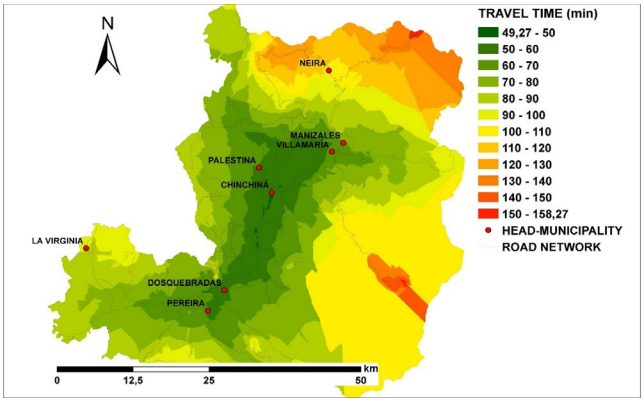

Figure 3. Isochrones curves for both metropolitan areas.

Figure 4 shows the cumulative percentage of population coverage for isochronous curves. 24% of the population is covered in an average time of one hour; 90% of the population is covered in 90 minutes mean travel time, in relation to both metropolitan areas studied.

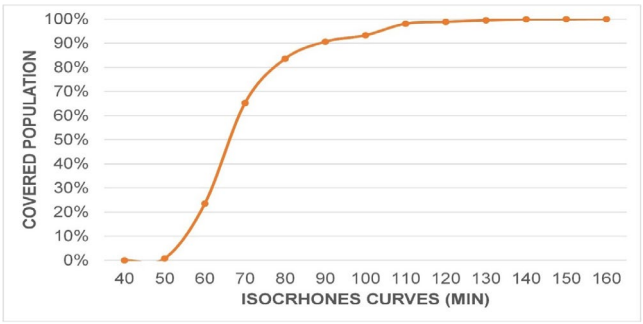

Figure 4. Covered population per isochrones curves, global situation.

Figure 5 shows each city's accumulated population coverage percentage. In 110 min, the maximum average travel time, 100% of Neira's urban population is covered. Travel time may reach up to 158 min, especially in rural areas in the northern part of AMRSC. Chinchiná is the municipality with the most accessible urban area: 22%

of the population is covered in average travel times of up to 50 min, and 100% of its population reaches averages of less than one hour. 94% of the population of the urban area of Palestine is represented by the isochronous curve of 60 min, reaching 100% coverage with the isochronous curve of 70 min. The population of the urban area of Dosquebradas reaches 84% coverage for an average travel time of 60 min and Pereira has 12% coverage for the 60-min isochronous curve, 96% coverage for the 70 min and 100% for 80 min isochronous curves. These municipalities have the best global mean accessibility conditions. 9% of the Manizales population have an average travel time of 60 minutes, and coverage percentage grows to 42% in 70 minutes and 100% of its population is covered by isochronous curves in 90 minutes.

Figure 6 shows each city's accumulated population coverage percentage in rural areas. Average travel times of up to 158 minutes are reached in the municipality of Neira. For the municipalities of Chinchiná, Palestina and Dosquebradas, 100% are covered in average travel times of less than 90 minutes, representing the best accessibility conditions at a rural level.

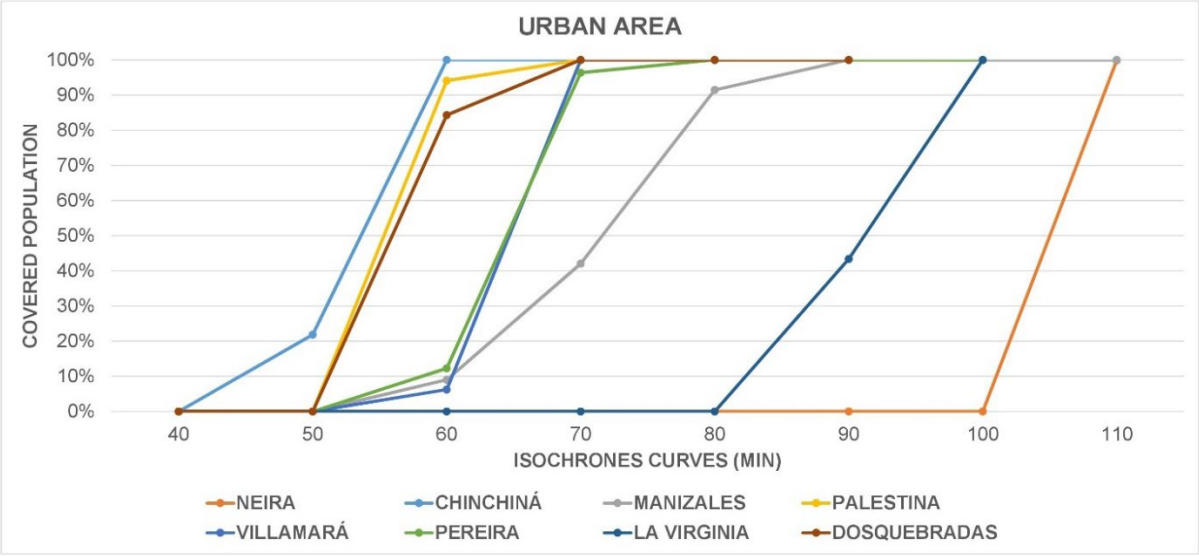

Figure 5. Covered population per isochrones curves at urban areas, global situation.

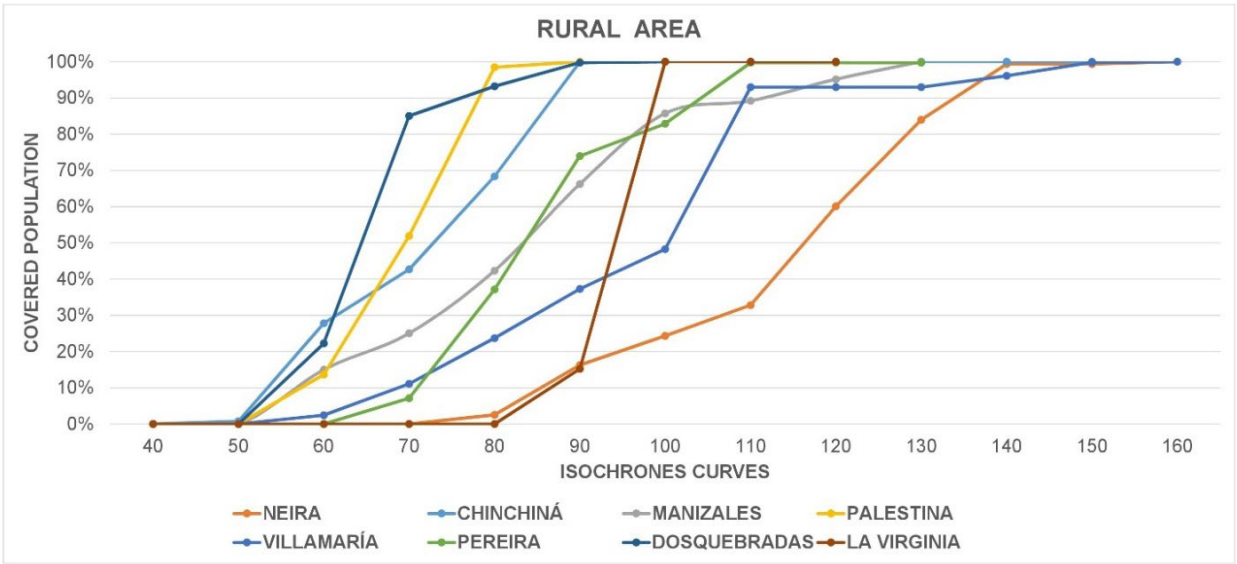

Figure 6. Covered population per isochrones curves at urban areas, global situation.

3.1 Global Mean Accessibility for the Metropolitan Area of the South Central Region

Figure 7 shows isochrone curves of global mean accessibility corresponding to AMRCS, including Chinchiná. There are average travel times of 40 min, including municipalities such as Manizales, Villamaria and Chinchiná, and up to 132 min in the rural area of Neira. Chinchiná and Manizales have trips ranging from 50 to 60 min. Palestine records average travel times of less than one hour while Neira is again the municipality with highest travel time average (90 min).

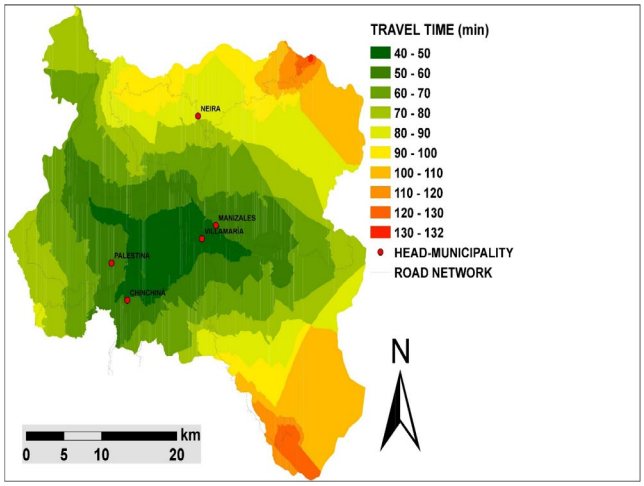

Figure 7. Global Mean Accessibility for AMRCS.

Figure 8 represents the percentage of population coverage for each isochrone curve in AMRCS, where 35% of the population has average travel times of up to 50 min., percentage that increases up to 85% in average times of less than 1 hour. Only a percentage less than 1% is in places accessible in times greater than 110 min.

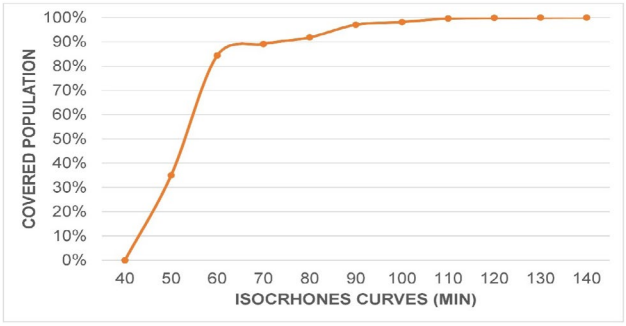

Figure 8. Average percentage coverage of Global Accessibility coverage for AMRCS.

Figure 9 shows each AMRCS city's accumulated population coverage percentage population coverage. The municipality of Villamaría has the best accessibility since the totality of its population is represented in the isochronous curve of up to 50 min, followed by the municipality of Chinchiná and Manizales with 43% and 34% of population coverage each. Chinchiná and Palestina reach 100% coverage for an average travel time of less than 60 min, while Manizales reaches it in 70 min. Neira reaches average travel times up to 90 min to cover the entire population. Once more, it is the municipality of the metropolitan area with higher average travel times.

Figure 10 shows the accumulated percentage of population covered of each city in rural areas. Times up to 132

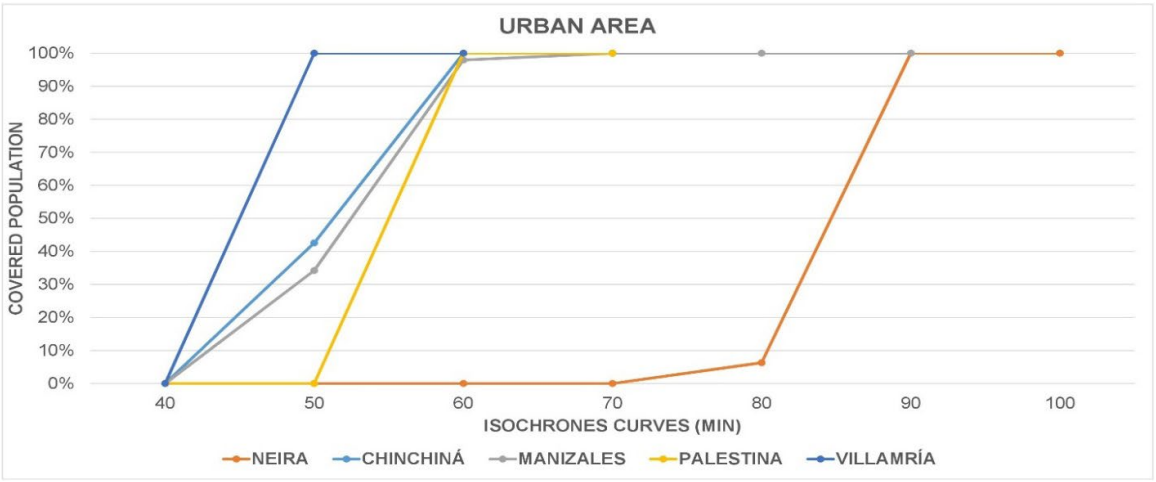

Figure 9. Average percentage of coverage of global average accessibility for urban area.

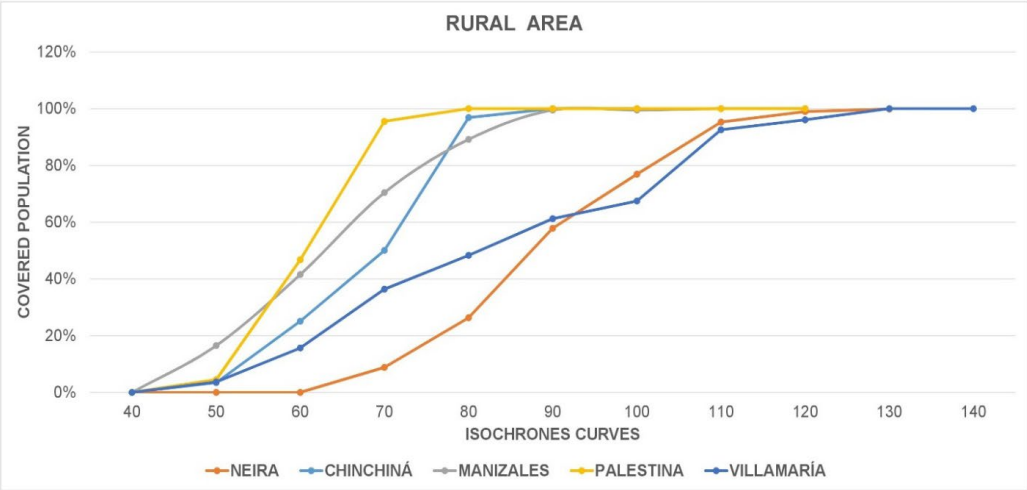

Figure 10. Average percentage of coverage of global mean accessibility for rural area.

min are reached in Villamaría and Neira. In Chinchiná and Manizales, 100% coverage of its population in the isochronous time curve of 90 min is reached, while Palestine is the municipality with the rural area that registers better global average accessibility conditions: its entire population is covered in average travel times less than 80 min.

3.2 Global Mean Accessibility for the Metropolitan Area of the West Center

Figure 11 shows the isochrone curves of global mean accessibility for AMCO, including Chinchiná. Isochronous curves of 27 min were obtained near the municipality of Dosquebradas, and 93 min in the rural area of the municipality of Chinchiná. The municipalities of Pereira and Dosquebradas have average travel times of between 30 and 40 minutes, while Chinchiná is in the isochronous time curve of up to 50 minutes. The municipality of La Virginia is in the time interval between 60 and 70 minutes.

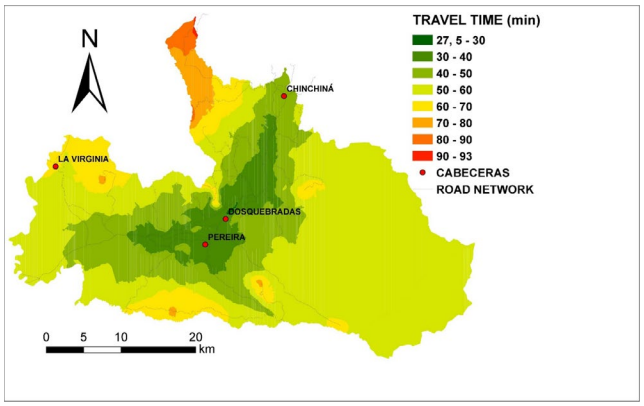

Figure 11. Global Mean Accessibility for AMCO.

Figure 12 shows the percentage of population coverage for each isochronous time curve for AMCO. 61% of the population averages less than 40 minutes in travel time. This percentage of the population grows up to 95% for average travel times of up to 1 hour. Less than 1% of the population perceives average times greater than 70 minutes.

The relationship between the covered population of the urban area and isochronous accessibility curves can be seen in Figure 13, where 80 min is the maximum time. In relation to urban areas, 89% and 80% of the population in the municipalities of Dosquebradas and Pereira have average times of up to 40 minutes. Their total population, as well as those from the municipality of Chinchiná, is under the isochronous time curve of 50 minutes. 25% of the population of La Virginia averages 60 minutes of travel, and their entire population is covered by the isochronous curve of 70 min.

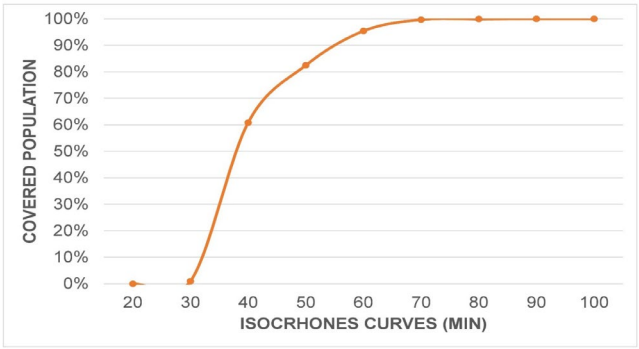

Figure 12. Average percentage of coverage of global average accessibility for AMCO.

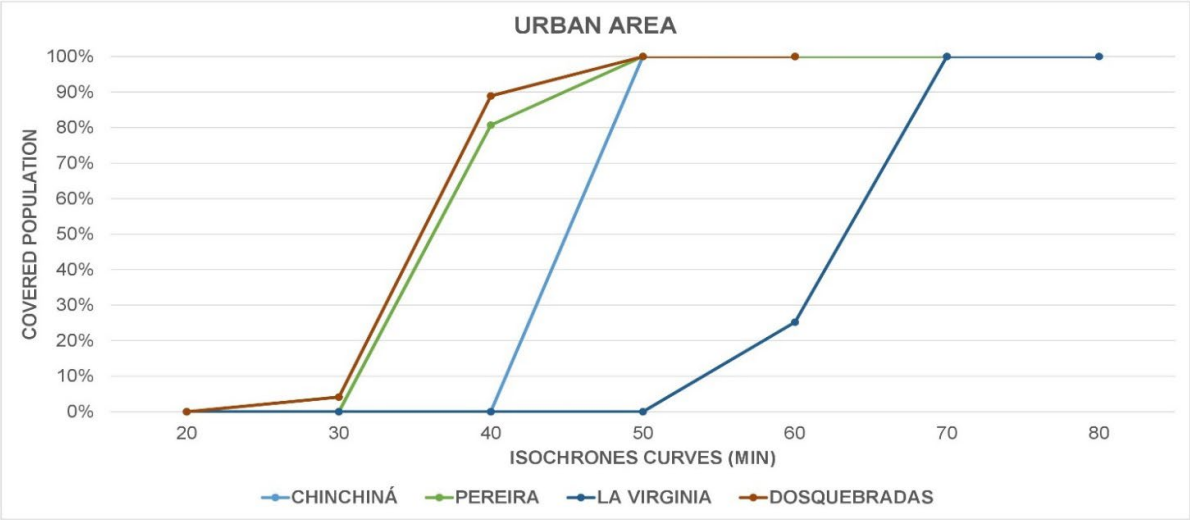

Figure 13. Average percentage of coverage of global average accessibility for urban areas.

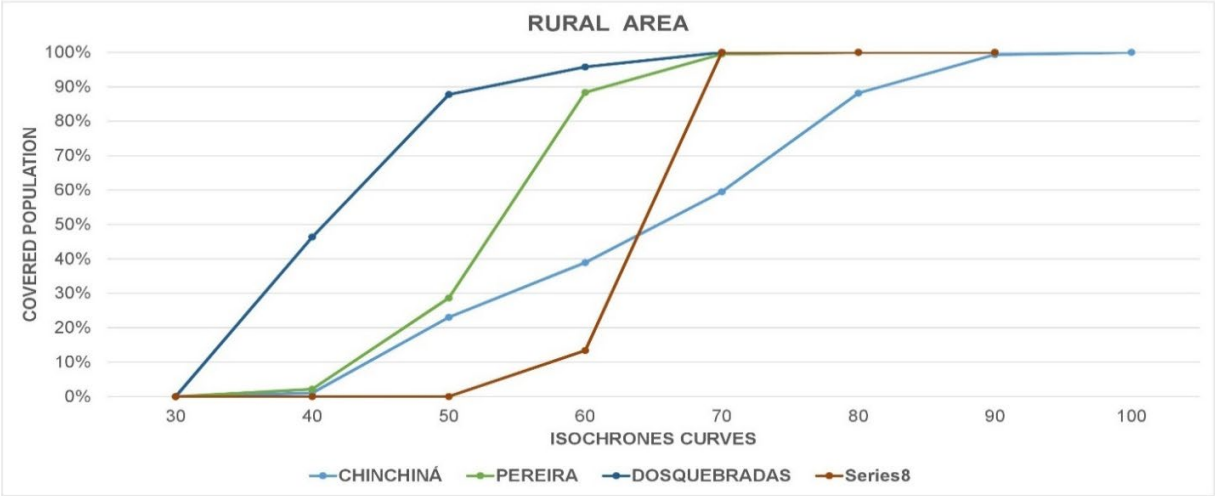

Figure 14. Ojiva percentage of global mean accessibility coverage for rural area.

Figure 14 shows the relation between population coverage and isochronous accessibility for rural AMCO. Average travel times of up to 93 minutes are reached in the Chinchiná rural area. The rural area of the municipality of Dosquebradas has the best accessibility with 96% of its population under the isochronous curve of 60 minutes, while this average travel time was only achieved by 88%, 39% and 13% of the population in the rural areas of Pereira, Chinchiná and La Virginia respectively.

4. Conclusions

Chinchiná has the best geographical location in terms of global mean accessibility of the study area, corresponding to eight municipalities and two departments. Chinchiná covers its entire urban population in less than 50 minutes, while in other municipalities people must invest a minimum of 60 min (Dosquebradas, Palestina and Villamaría) and a maximum of 110 min (Neira) in travel times. Regarding the two alternatives linking Chinchiná to metropolitan areas: AMCO has better conditions of global average accessibility for this municipality with its entire population covered in average travel times of up to 50 minutes, 10 minutes less than average travel time obtained in AMRCS. AMCO has better global mean accessibility results because its maximum average time, obtained in the rural area of Chinchiná, is 93 minutes, while in AMRCS the average

maximum time, obtained in the rural area of Villamaría and Neira, is 132 minutes.

This indicates that the access roads to these AMRCS municipalities should be improved in order to considerably reduce these travel times, and improve incoming and outgoing mobility conditions. In terms GDP, AMCO has a greater attraction for Chinchiná and its municipalities as a whole reached 3,050 million dollars compared to the 2,146 million dollars of production of AMRCS municipalities as a whole. In terms of global mean accessibility and GDP, Chinchiná would benefit most from joining AMCO. It would be important to analyze the potential of creating a large metropolitan area with these eight municipalities and Santa Rosa de Cabal, located between Dosquebradas and Chinchiná, where it would reach more than 1,356,064 inhabitants and a 5,800 million dollars GDP.

5. Aknowledgments

The authors express their sincere thanks to the students belonging to the research groups in Sustainable Mobility and Urban Planning of the National University of Colombia, Sede Manizales.

6. References

1. Borja J. Informe Sobre La Gobernabilidad De Las Áreas Metropolitanas En El Mundo. Urban Technology Consulting. 2004; p.1–150.
2. Feria-Torbio JM. La delimitación y organización espacial de las áreas metropolitanas espa-olas: una perspectiva desde la movilidad residencia-trabajo. Ciudad y Territorio. Estudios Territoriales. 2010, 164, pp. 189–210.
3. Lefèvre C. The improbable metropolis: Decentralization, local democracy and metropolitan areas in the Western world. Análise Social. 2010; 45(197):623–37.
4. Ley 1625. Diario oficial No. 48776 de la Republica de Colombia, Bogotá, Colombia. 2013 April 29. Available from: Crossref.
5. Cadena D. Conurbación y áreas metropolitanas en el derecho Colombiano. Derecho y Realidad. 2008; 2(11):49–62.
6. Preciado Beltrán J. Bogotá región: Crecimiento urbano en la consolidación del territorio metropolitano. Universidad Distrital Fransisco José de Caldas. 2005; p.1–18.
7. Alcaldía de Chinchiná. Información General. Chinchiná, Caldas. 2018 April 19. Available from: Crossref.
8. Arango O. El Área Metropolitana Centro-Occidente antecedentes y perspectivas. Revista de Ciencias Humanas. 2004; 10(33):119–36.
9. A Chinchiná le suena el área metropolitana del Centro-Occidente, Pereira, Risaralda. 2017 March 01. Available from: Crossref.
10. Jiménez LF. Motivación para la constitucion del area metropolitana de la region centro-sur de Caldas. Escuela Superior de Administración Pública. 2006; p.1–62. PMCid:PMC1343545
11. Chinchiná al AMCO, ya se habla de consulta popular. 2017 March 18. Available from: Retrieved from: Crossref.
12. Proyecciones de población total por sexo y grupos de edad de 0 hasta 80 y más a-os (2005 - 2020). 2018 April 27. Available from: Crossref.
13. Hansen WG. How Accessibility Shapes Land Use. Journal of the American Institute of Planners. 1959; 25(2):73–6. Crossref
14. Goodchild MF. Theoretical Geography. In: Bunge W, Human Geography. 1962.
15. Ingram DR. The Concept of Accessibility: A search for an operational form. Regional Studies. 1971; 5(2):101–7. Crossref
16. Dalvi MQ. Behavioural modelling accessibility, mobility and need: concepts and measurement. Behavioural travel modelling. 1978; p.639–53.
17. Geurs KT, Ritsema van Eck JR. Accessibility measures: review and applications. Evaluation of accessibility impacts of land-use transportation scenarios, and related social and economic impact. RIVM rapport 408505006. 2001; p.1–265.
18. Geurs KT, van Wee B. Accessibility evaluation of land-use and transport strategies: Review and research directions. Journal of Transport Geography. 2004; 12(2):127–40. Crossref
19. Escobar D, García F. Impacto regional: caso de aplicación de análisis de accesibilidad territorial. Revista Épsilon. 2012; 18(1988):71–86.
20. Pirie GH. Measuring Accessibility: A Review and Proposal. Environment and Planning A. 1979; 11(3):299–312. Crossref
21. Karou S, Hull A. Accessibility modelling: Predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK. Journal of Transport Geography. 2014; 35:1–11. Crossref
22. Akinbola KB, Md Yassin A, Olajide SE. Assessing the Strength of Sladecom as a Model for Improved Formal Accessibility of Urban Lands in Nigeria. Indian Journal of Science and Technology. 2016; 9(46):1–8. Crossref
23. Talavera-García R, Valenzuela-Montes LM. La accesibilidad peatonal en la integración espacial de las paradas

de transporte público. Bitacora Urbano Territorial. 2012; 21(2):97–109.
24. Gulhan G, Ceylan H, Özuysal M, Ceylan H. Impact of utility-based accessibility measures on urban public transportation planning: A case study of Denizli, Turkey. Cities. 2013; 32:102–12. Crossref
25. Escobar D, García F, Tolosa R. Análisis de accesibilidad territorial a nivel regional. Universidad Nacional de Colombia. Facultad de Ingeniería Y Arquitectura, Manizales. 2013.
26. Talpur MAH, Chandio IA, Memon IA, Napiah M. A Brief Review on the Role of Regional Transport Accessibility in the Development Process of Distant Sub-Regions. Indian Journal of Science and Technology. 2016; 9(13):1–9. Crossref
27. Montoya J, Escobar D, Sabogal O. Donde ubicar nuevos nodos comerciales en la ciudad de Manizales – Colombia ? Aplicación de un análisis geográfico. Revista Espacios. 2017; 38(53):7–18.
28. Cheng J, Bertolini L. Measuring urban job accessibility with distance decay, competition and diversity. Journal of Transport Geography. 2013; 30:100–9. Crossref
29. Sanchez TW, Shen Q, Peng ZR. Transit mobility, jobs access and low-income labour participation in US metropolitan areas. Urban Studies. 2004; 41(7):1313–31. Crossref
30. Foth N, Manaugh K, El-Geneidy AM. Towards equitable transit: Examining transit accessibility and social need in Toronto, Canada, 1996-2006. Journal of Transport Geography. 2013; 29:1–10. Crossref
31. Geurs KT, Boon W, Van Wee B. Social impacts of transport: literature review and the state of the practice of transport appraisal in the Netherlands and the United Kingdom. Transport Reviews. 2009; 29(1):69–90. Crossref
32. Allen WB, Liu D, Singer S. Accesibility measures of U.S. metropolitan areas. Transportation Research Part B. 1993; 27(6): 439–49. Crossref
33. Saghapour T, Moridpour S, Thompson RG. Public transport accessibility in metropolitan areas: A new approach incorporating population density. Journal of Transport Geography. 2016; 54:273–85. Crossref
34. Rajewski Z. Gross Domestic Product. Eastern European Economics. 1994; 32(4):71–80. Crossref
35. Perilla DJ, Escobar DA, Cardona S. New Transportation Infrastructure Impact in Terms of Global Average Access - Intersection "La Carola" Manizales (Colombia) Case Study. Contemporary Engineering Sciences. 2018; 11(5):215–27. Crossref
36. Loaiza CM, Holguín JM, Escobar D. Análisis comparativo de alternativas viales entre Manizales y Mariquita (Colombia) a través de un estudio de accesibilidad territorial. Informacion Tecnologica. 2016; 27(5):231–42. Crossref
37. Dijkstra EW. A note on two problems in connexion with graphs. Numerical Mathematics. 1959; 1(1):269–71. Crossref
38. Wu Q, Qin G, Li H. An Improved Dijkstra's algorithm application to multi-core processors, Metallurgical and Mining Industry. 2015; 9:76–81.
39. Simpson TW, Mauery TM, Korte J, Mistree F. Kriging models for global approximation in simulation-based multidisciplinary design optimization. AIAA Journal. 2001; 39(12):2233–41. Crossref Crossref
40. Matheron G. Principles of geostatistics. Economic geology. 1963; 58(8):1246–66. Crossref
41. Lindner A, Pitombo CS, Rocha SS, Quintanilha JA. Estimation of transit trip production using Factorial Kriging with External Drift: an aggregated data case study. Geo-Spatial Information Science. 2016; 19(4):245–54. Crossref
42. Prasetiyowati S. suryani, Imrona M, Ummah I, Sibaroni Y. Prediction of Public Transportation Occupation Based on Several Crowd Spots Using Ordinary Kriging Method. Journal of Innovative Technology and Education 2016; 3(1):93–104. Crossref